Instream flow assessment for the Otukura Stream

Stage 2: Instream flow requirements

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Executive summary

This report assesses the instream flow requirements of the Otukura Stream with the objective being to manage water quantity in the Otukura Stream and its major tributary, Battersea Drain, so that the ecological values of the waterways are improved. The information gathered in this instream flow assessment will be used by Greater Wellington when proposing a minimum flow for the Otukura Stream.

Critical factors for improving ecological values of the streams were chosen for investigating instream flow requirements; these were water temperature and dissolved oxygen concentration. Investigation of relationships between flow and these factors in the critical reach of the Otukura Stream, using the model WAIORA, found that:

- High water temperatures (in excess of 25°C) may occur during low flow and extreme climatic conditions;
- High instream temperatures are unlikely to be avoided through flow management in the Otukura Stream, at least in the stream's current hydraulic and riparian condition;
- Dissolved oxygen is a potentially critical issue for the Otukura Stream during times of low flow, and daily minimum dissolved oxygen concentrations are predicted to decline rapidly at flows less than 40 L/s;
- A flow of 95 L/s in the critical reach of the Otukura Stream (at the Greater Wellington flow monitoring site) is predicted to maintain daily minimum dissolved oxygen above the 6 mg/L threshold for long-term protection of aquatic life.

It is recommended that:

1. A minimum flow of 95 L/s for the Otukura Stream be considered for the Regional Freshwater Plan.
2. Policies for reducing stock access and restoring riparian vegetation are considered when the Regional Freshwater Plan is reviewed. In addition, Greater Wellington should consider promoting or requiring riparian restoration through the resource consent process.

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1. Introduction

The values relating to the environment of a stream are called instream values, and these include ecological, recreational, landscape and Maori cultural values. Instream values can be adversely affected by activities such as damming, abstracting water, and discharging contaminants.

The purpose of this report is to provide information and recommendations on the flows required to sustain the instream values of Otukura Stream. The report is the second stage of the instream flow assessment. The first stage report – Instream flow assessment for Otukura Stream and Battersea Drain Stage 1: Instream Flow Issues Report (Watts 2007) – identified instream values and the current condition of the Otukura Stream and one of its main tributaries (Battersea Drain), and proposed an instream flow objective. That report is referred to throughout this document as the *Issues Report*. This second stage report presents the results of scientific investigations into the flow requirements for achieving the instream flow objective.

1.1 Why is an instream flow assessment needed?

The water resources of the Otukura catchment are used extensively, particularly for stock water and irrigation. The catchment has historically experienced water allocation difficulties and during severe low flows the streams are unable to sustain demand in some places. Knowledge of the flow requirements to protect or enhance the instream values of the Otukura Stream is needed before appropriate water allocation policies (in particular those relating to minimum flows) can be developed.

Greater Wellington Regional Council's (Greater Wellington) existing policies relating to the Otukura Stream are outlined in Appendix 1.

1.2 Instream flow assessment framework

Greater Wellington's approach to assessing instream flow requirements is set out in the *Framework for Instream Flow Assessment in the Wellington Region - Working Version* ('The Framework') (Greater Wellington 2006). The steps in an instream flow assessment according to The Framework are:

1. Collate and review all existing hydrological, ecological, and water quality data for the stream or river.

2. Carry out a field assessment to identify stream values and gain an impression of flow-related issues in the catchment.

3. Propose an instream management objective. The objective includes the key value(s) to be protected by the management regime.

4. Plan scientific investigations. These are the investigations to determine what flows are required to achieve the instream management objective.

5. Prepare an Instream Flow Issues Report, and send this report to key stakeholders for consultation.

6. Review the planned investigations in light of stakeholder feedback and carry out scientific investigations.

7. Recommend a (minimum) flow that will achieve the instream flow objective and prepare a supporting Instream Flow Assessment technical report.

This report completes Step 7 of the Framework by reporting on the consultation in Step 5 (Section 2) and investigations carried out under Step 6 (Sections 4-6).

1.3 Focus of the instream flow assessment

Otukura Stream is a small lowland Wairarapa stream that rises from springs in the Fabians Road area south of Kemptons Line, and discharges to Lake Wairarapa. The catchment lies between the Tauherenikau and Ruamahanga rivers, to the south of Greytown and west of Bidwill Hill (Figure 1). Major tributaries of the Otukura Stream are Battersea Drain, Stonestead Creek (also known as Dock Creek), and tail races of the Moroa water race. The instream flow assessment and water allocation policy development is concerned with Otukura Stream and Battersea Drain. As discussed in the Issues Report, Stonestead Creek has distinctly different flow characteristics to Otukura Stream. Therefore, instream flow requirements of that waterway will be considered separately at a later date.

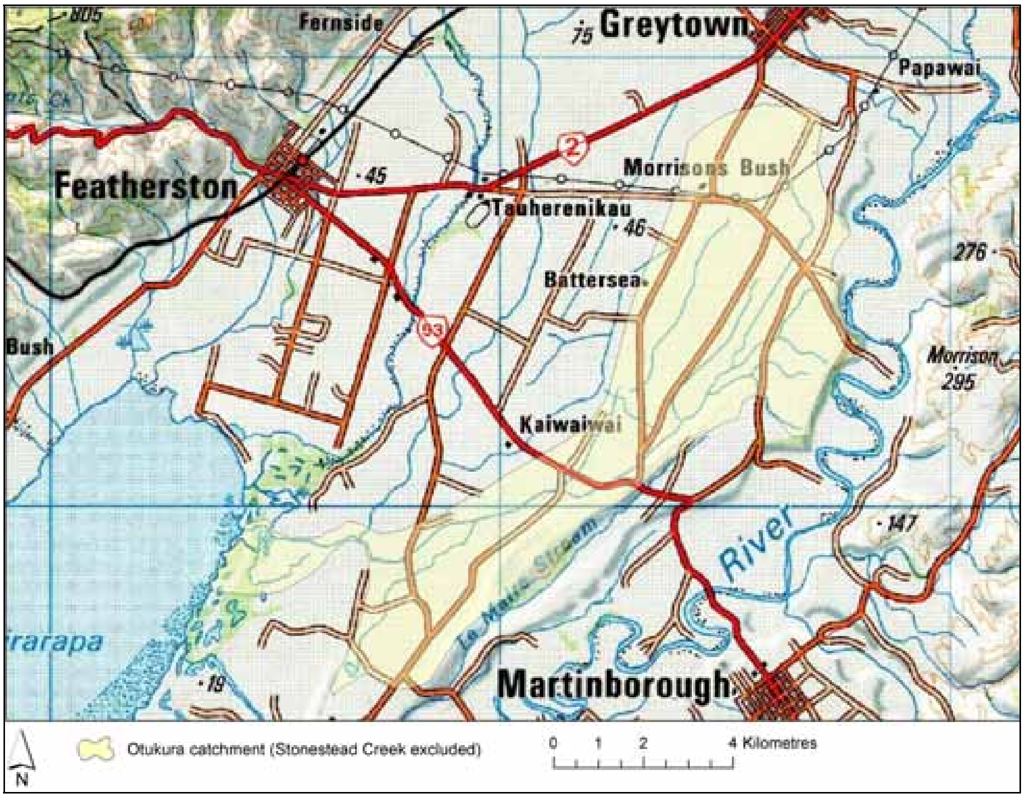

Figure 1: Boundaries of the Otukura catchment for assessment of instream flow requirements

2. Consultation on the Issues Report

Following completion of the Issues Report, Greater Wellington staff discussed Maori cultural and traditional values with iwi representatives. Copies of the Issues Report were distributed to the iwi (Rangitaane o Wairarapa and Ngati Kahungunu ki Wairarapa) and it was acknowledged that the report was lacking inclusion of the values that Maori associate with the Otukura Stream. Following a workshop to discuss iwi input into the instream flow assessment process, a representative from Ngati Kahungunu ki Wairarapa prepared a report on instream values of the Otukura Stream and Lower Ruamahanga River (Te Whaiti 2007). The findings of the report relevant to the Otukura Stream are described in Section 3.

The Issues Report was sent to the Department of Conservation and Fish & Game New Zealand in March 2007. The Department of Conservation responded with the following comments (paraphrased from Ericksen 2007 pers. comm.):

- They were happy with the description of instream values and the proposed instream flow objective;
- Permitted activity water takes need to be identified, and the flow record should be naturalised;
- Water takes from the streams should be restricted during times of low flow;
- A better means of managing sub-surface irrigation weirs should be developed so that the take can be measured more accurately;
- The report is weak on affirmative action, including the exclusion of stock from waterways and appropriate revegetation to address the water quality issues.

The Department of Conservation's comments are addressed where appropriate in this report.

The report was sent to holders of resource consents to take water from the Otukura Stream and Battersea Drain, in May 2007. Although no comments were received, the resource consent holders were informed that they would have an opportunity to make a formal submission if any relevant changes are proposed to Greater Wellington's Regional Freshwater Plan (Wellington Regional Council 1999).

3. Instream values

3.1 Findings of the Issues Report

The instream values, threats to those values, and current condition of the Otukura Stream and Battersea Drain were outlined in the Issues Report. Some of the key findings were:

- The ecological values of the streams are considered to be low in the current condition. There is low observed fish abundance and species diversity, and a lack of habitat diversity.
- The ecological values of the streams have been adversely affected by extreme low flows, poor water quality (as a result of the agricultural land use and stock access), a high degree of stream modification including loss of riparian vegetation, and barriers to fish passage.
- The streams have very low natural character and amenity value in their current condition, mainly due to a high degree of channel modification.

3.2 Maori customary and traditional values

It was acknowledged in the Issues Report that Maori customary and traditional values had yet to be assessed. As noted in Section 2, since the Issues Report was completed Greater Wellington staff have been meeting with Wairarapa iwi representatives to discuss iwi input to the instream flow assessment process. In December 2007, Ngati Kahungunu ki Wairarapa prepared a report that included comment on values that they associate with the Otukura Stream (Te Whaiti 2007). The report states:

“The Otukura Stream is significant to hapu of Ngati Kahungunu ki Wairarapa. The Otukura Stream comprises part of the original Tauherenikau River bed and water from the Tauherenikau still flows into the Otukura Stream via the original bed renamed Dock (Stonestead) Creek. JK Donalds wildlife reserve which takes water from the Otukura through a weir was originally called the Roto Lagoon. The Otukura (and its tributary, Dock Creek) flow directly into Lake Wairarapa, which has enormous value to Ngati Kahungunu ki Wairarapa, and during low flows the water body must have high significance for the lake” (Te Whaiti 2007).

The key values identified in the report are summarised below. It is important to note that considering Otukura Stream and Battersea Drain in isolation is to some extent a foreign concept to tangata whenua. Therefore the values described are not necessarily specific or unique to the Otukura Stream.

3.2.1 Mauri

‘Mauri’ refers to the ‘essence’ or the ‘life-force’ of the waterbody. Important indicators of mauri that Ngati Kahungunu ki Wairarapa have identified are:

- The capacity to renew groundwater flow and surface water stocks. The Otukura Stream has important connections with groundwater and also with Lake Wairarapa.

- Maintaining mahinga kai species and freshwater habitats, including passage for migratory fish species.

- Flow variability including floods so that the river "cleanses" itself.

- Continuity of flow from the source to the sea.

- Naturalness of water quality. The Otukura Stream has degraded water quality, as described in Section 4.

Although it is not commented on in the Ngati Kahungunu ki Wairarapa report, the mauri of Otukura Stream and Battersea Drain is likely to have been adversely affected by the high degree of channel modification, extreme low flows and water abstraction, and poor water quality at times.

3.2.2 Waahi tapu

Waahi tapu sites (sites of special spiritual significance) in the Otukura catchment have not been specifically identified.

3.2.3 Mahinga kai

The Otukura Stream and Battersea Drain have been important to Ngati Kahungunu ki Wairarapa in the past as a source of food, particularly tuna (eels) and watercress, but also including flounder, inanga and kökopu. However, in recent years the mahinga kai value of these streams has declined due to low eel numbers and poor water quality. The iwi would particularly like to see the restoration of the Wairarapa eel fishery (Te Whaiti 2007 pers. comm.).

Wairarapa Moana (Lake Wairarapa) is used extensively by tangata whenua for food gathering. As previously mentioned, the Otukura Stream and its tributary Dock (Stonestead) Creek are important for providing water to Wairarapa Moana.

The Otukura catchment was historically an important area for growing harakeke (flax), but this is no longer the case. Relatively high groundwater levels are required for growing strong harakeke.

3.2.4 Summary

The values that tangata whenua associate with the Otukura Stream and Battersea Drain relate to mauri, waahi tapu and mahinga kai. The mauri is likely to have been affected by channel modification, poor water quality at times, and extreme low flows. The traditional mahinga kai values – in particular the use of these streams for gathering harakeke, watercress and eels – have also been adversely affected due to these factors.

4. Environmental characteristics: additional information

The characteristics of the Otukura Stream and Battersea Drain were described in the Issues Report. Some additional information has since been collected to fill knowledge gaps identified in that report. This section updates the information presented in the Issues Report.

4.1 Water use

The consented water use from Otukura Stream and Battersea Drain has not changed since the completion of the Issues Report. There are six consented takes, all located upstream of the Greater Wellington flow monitoring station, with a total instantaneous take of 56 L/s (Table 1).

Table 1: Consented water use from the Otukura Stream and Battersea Drain

Consent	Name	Source	Rate of take (L/s)	Expiry date
WAR010115	Mensen	Battersea Drain*	3	30/09/2009
WAR010240	Svensen	Battersea Drain*	2	30/09/2009
WAR060114	O'Neale	Battersea Drain*	2	30/09/2009
WAR020179	O'Neale	Battersea Drain	9	Expired
WAR020124	D B Osborne Trust	Otukura Stream	30	Expired
WAR020123	Doherty	Otukura Stream	10	Expired

*Subsurface irrigation, so also includes consent to install a weir

In addition to this abstraction, Fish & Game NZ hold a resource consent to divert water from the Otukura Stream. The diversion of 100 L/s into the J K Donald Reserve (to maintain water level in a wetland) occurs downstream of the Stonestead Creek confluence.

Since completing the Issues Report, Greater Wellington has conducted a permitted activity water use survey in the Otukura catchment. The survey sought to find out more about the uses people are making of water taken under the existing permitted activity rule[1], how much water is abstracted, and whether people in the area use stream water, groundwater or rainwater.

A total of 49 survey forms were posted out. Twenty three landowners were then visited over a two day period in November 2007 and an additional 5 survey forms were returned by post, making a total of 27 survey respondents.

Lifestyle blocks (16) were the most frequently occurring property type surveyed followed by dairying (6), sheep and beef (2), residential (2) and horticulture (1). Most properties used a combination of one or more water sources, including bores, rainwater, water races or streams/drains. Of the 27 landowners surveyed, 22 obtained water from bores, 14 used rainwater, 14 took

[1] Rule 7 of the Regional Freshwater Plan allows the taking or use of up to 20,000 litres per day of freshwater, at a maximum abstraction rate of 2.5 L/s.

water from water races and on two properties water came from a stream or drain.

Water was used for domestic purposes, gardening and stock watering. One landowner did some small scale irrigation but others irrigating on a larger scale required resource consents.

The amount of water taken and used on individual properties was not able to be precisely calculated. People are not required to meter their permitted activity water takes. In situations where water was only used for domestic use, it was estimated by a few people to be in the order of 500 litres per day. Other users estimated that the water they take is well below the amount for a permitted activity.

In general, it seems that very little water is taken out of the Otukura Stream or Battersea Drain under the permitted activity rule.

4.2 Hydrology

4.2.1 Mean annual low flow

In the Issues Report, estimates were made of 1-day and 7-day mean annual low flow at the Greater Wellington flow recording site (upstream of the confluence with Stonestead Creek). As part of the consultation on the Issues Report, the Department of Conservation suggested that the flow record be naturalised. It is not possible to naturalise the entire record, because no historic abstraction data are available[2]. In addition the meaning of a 'naturalised' flow record for the Otukura Stream is questionable, given the high degree of modification that affects flow in the stream (in particular the water race contributions that may vary significantly over time).

However, it is possible to remove the impact of consented water abstraction from the low flow statistics for each year of record. This was done by graphing the period of lowest flows for each year of record and then adding on consented abstraction by removing any pump cycles (the site is downstream of all consented abstraction) and checking irrigation restriction notices to determine which takes were likely to be occurring at the time. Permitted activity abstractions were not taken into account because these are considered as part of the permitted baseline in the Regional Freshwater Plan; in addition, the magnitude of these at certain times in the past is difficult to determine.

The statistics for each low flow season are shown in Table 2. The final estimates of 97 L/s and 107 L/s for the 1-day and 7-day mean annual low flow respectively are similar to those estimated in the Issues Report.

[2] During consultation on the Issues Report, Department of Conservation suggested that the subsurface irrigation weirs be modified so that the take can be measured. The need for a measuring device on these consents will be considered when replacement applications are made following resource consent expiry in 2009, and may depend on the requirements of the new National Environmental Standard for Measurement of Water Takes. Similarly the need for water meters on the three other takes in the catchment will be assessed when the renewal consent applications are processed.

Table 2: Low flow statistics for Otukura Stream at Weir

Year	1-day flow (L/s)		7-day flow (L/s)	
	Recorded	Estimated unimpacted	Recorded	Estimated unimpacted
1997/98	30	53	37	64
1998/99	35	65	52	74
1999/2000	121	174	138	185
2000/01	18	40	28	53
2001/02	175	178	180	185
2002/03	21	38	25	42
2003/04	181	185	202	205
2004/05	102	120	109	125
2005/06	4	30	17	40
2006/07	44	89	60	97
Mean	73	97	85	107

Due to the proportionally large input from Stonestead Creek, the mean annual low flow of Otukura Stream at its mouth is likely to be in the range 550-700 L/s.

4.2.2 Flow patterns and groundwater interactions

As recommended in the Issues Report, an additional concurrent gauging run was performed, during low flow conditions in March 2007 (Figure 2). The gaugings showed a similar pattern to previous gauging runs. That is, the stream gains some flow between Moroa Road and Wards Line, but downstream of the Battersea Drain confluence there are no other major flow gains until the Stonestead Creek confluence. Stonestead Creek contributes a significant flow: about a seven-fold increase on the day of gauging. The water race contributions did not appear to be significant at the time (for example, a water race contribution at Wards Line was estimated to be 2-3 L/s), although it is assumed that a proportion of flow entering the Otukura Stream upstream of Moroa Road is derived from the Moroa water race.

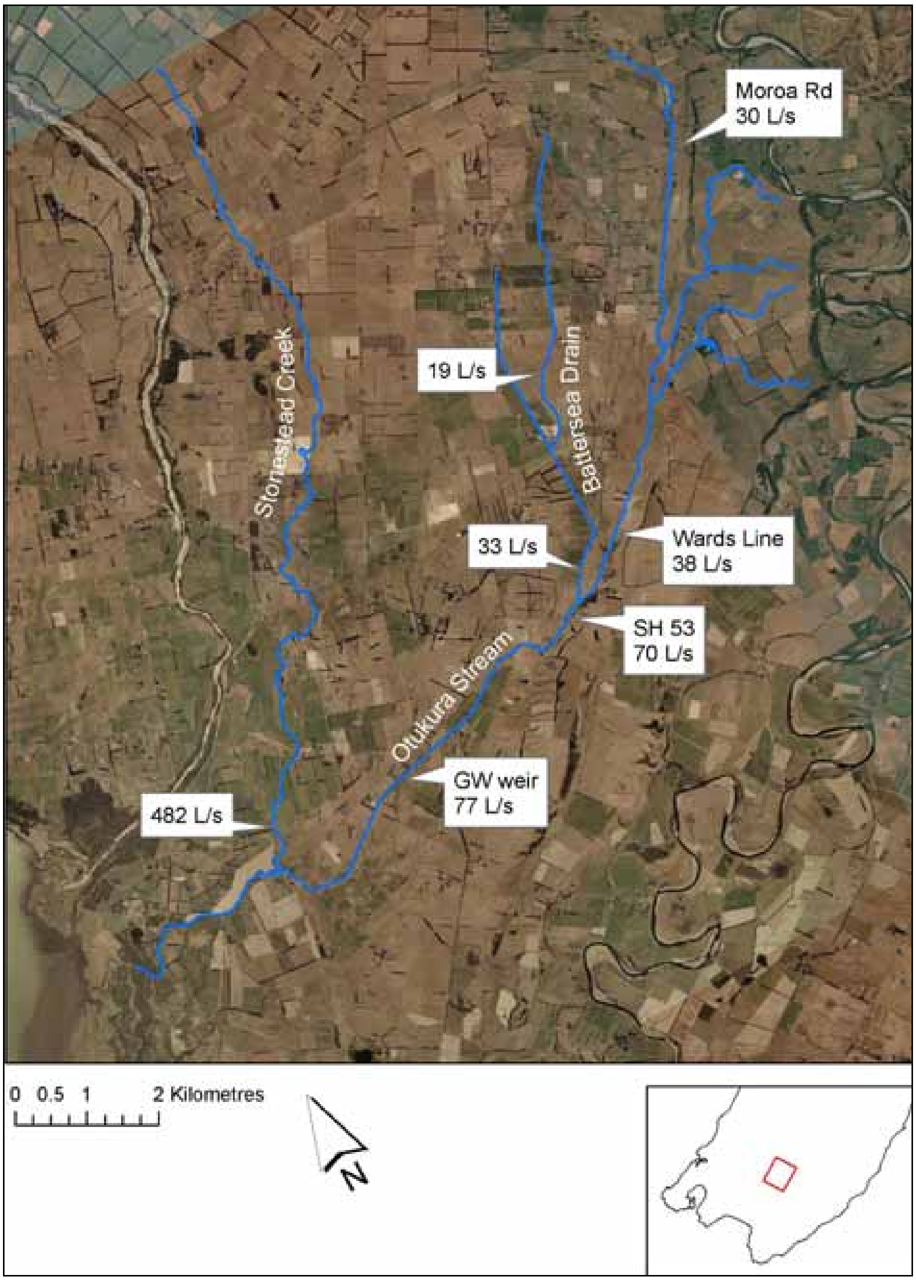

Figure 2: Results of flow gauging in the Otukura catchment, March 2007

The stream flow patterns are a reflection of the hydrogeology and human modification of the area. The stream rises from springs in a depression west of Te Maire Ridge, and runs along the base of the ridge gaining a small amount of flow from farm drainage and discharge from the shallow Battersea aquifer. Downstream of the Battersea Drain confluence the groundwater system is deeper and confined, therefore the stream does not gain a significant amount of flow until the Stonestead Creek confluence.

It was a recommendation of the Issues Report to investigate how resource consents to abstract groundwater could be managed to avoid depletion of flow in the Otukura Stream. The discharge from the Battersea shallow groundwater system is being investigated as part of Stage 2 of the Wairarapa Groundwater Model, due for completion in June 2009. Following the model completion Greater Wellington will have a better understanding of how groundwater interacts with streams in the area and this will aid in the review of the groundwater safe yields in the Regional Freshwater Plan. In addition to this, any resource consent application to take groundwater should consider potential effects on nearby streams.

4.3 Water quality and ecology

The general findings of the Issues Report in relation to water quality were:

- Water quality tends to get poorer with distance downstream between Fabians Road and the confluence with Stonestead Creek. Downstream of the confluence, water quality is likely to improve due to the influence of Stonestead Creek.

- At times during low flows the streams experience high instream temperatures and low dissolved oxygen.

- There is a lack of information about water quality in the streams and the effects of low flows on water quality.

To supplement the existing data, further water quality investigations have been carried out since the Issues Report was prepared. These investigations were: additional continuous temperature monitoring, measurement of nitrogen and phosphorus concentrations, and an aquatic macroinvertebrate survey.

Instream temperature was monitored continuously over the 2006/07 low flow season at the Greater Wellington flow monitoring site, Otukura Stream at Weir. This reach of the stream is likely to have some of the highest water temperatures in the catchment. The temperature data collected over 2006/07 showed very similar results to the monitoring performed in 2004/05. Instream temperatures regularly exceeded 20°C, the temperature above which sensitive macroinvertebrates may be adversely affected (Quinn & Hickey 1990) (Figure 3). Temperatures in excess of 25°C were recorded on eight days during January-February; temperatures above this threshold may adversely affect fish spawning (see Section 5).

To further define the water quality status of the stream, one-off samples were taken from two locations in the Otukura Stream in March 2007. These samples were analysed for total nitrogen and total phosphorus concentrations. The results showed that nutrient concentrations increased in the Otukura Stream between Moroa Road and SH53 (downstream of the Battersea Drain confluence) (Table 3). At both sites, the total nitrogen concentration complied with the maximum guideline value for lowland streams (ANZECC 2000). However, the total phosphorus concentration at both sites exceeded the guideline value, and was particularly high at SH53. The results are similar to those collected at Greater Wellington's long-term water quality monitoring sites on other Wairarapa lowland streams, such as the Parkvale Stream.

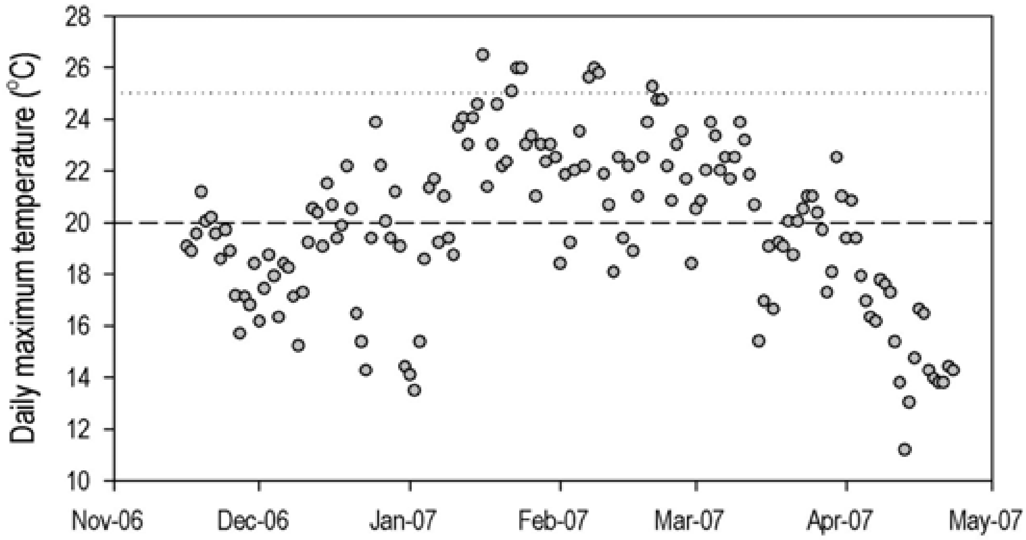

Figure 3: Daily maximum water temperature recorded in the Otukura Stream at Weir, November 2006 – April 2007. Threshold lines are the 20°C and 25°C thresholds referred to in the text.

Table 3: Results of nutrient sampling in the Otukura Stream, 8 March 2007

	Otukura Stream at Moroa Road	Otukura Stream at SH53	ANZECC 2000 guideline
Total nitrogen (g/m^3)	0.46	0.56	<0.614
Total phosphorus (g/m^3)	0.077	0.124	<0.033

Stream macroinvertebrate community structure is a product of both the physical habitat and water quality over time (Milne & Perrie 2005). Macroinvertebrate sampling was carried out in the Otukura Stream at Weir (identified as Reach 2 in the Issues Report) in April 2007. The invertebrate community was dominated by pollution tolerant taxa such as the snail *Potamoprygus antipodarum* and Oligochaetes (worms). The percentage of pollution-sensitive taxa (mayflies, stoneflies and caddisflies) was 15.3%, which indicates 'moderate' water quality. However, the Macroinvertebrate Community Index (MCI) result of 71 falls into the 'probable severe pollution' category of Stark (1985, 1993). Once again, this is similar to results of long-term monitoring of another Wairarapa lowland stream, the Parkvale Stream (Perrie 2007).

5. How will instream flow requirements be assessed?

5.1 Instream flow objective

The instream flow objective (proposed in the Issues Report) is:

To manage water quantity in the Otukura Stream and Battersea Drain so that the ecological values of the waterways are improved.

It is recognised that the ecological, mauri and mahinga kai values of the streams are degraded and this is, at least in part, due to low flows and flow-related declines in water quality. However, some of the degradation is due to non-flow related issues, such as channel modification, agricultural run off and stock access. Thus management of flows alone will not restore the instream values of Otukura Stream and Battersea Drain.

During consultation on the Issues Report, the Department of Conservation indicated that they agreed with the proposed instream flow objective. The objective is consistent with the wish that Ngati Kahungunu ki Wairarapa have expressed for the Wairarapa eel fishery to be restored because improving the ecological values encompasses improving the condition of the streams for eels. The objective is also consistent with the identified mauri indicator of maintaining mahinga kai species and freshwater habitats.

In addition to the instream flow objective, the Regional Freshwater Plan contains a water quality objective for the Otukura Stream:

To manage water quality for trout fishery and fish spawning purposes.

Although the Issues Report found that the Otukura Stream does not (at least in its present state) have significant value as a trout fishery, this objective is considered in the instream flow assessment because of its status in the Regional Freshwater Plan.

5.2 Critical factors

Critical factors are the parameters that are critical for achieving the instream flow objective. In this case, the objective relates to improving ecological values. Based on the findings of the Issues Report and Section 3 of this report, the possible flow-related critical factors for the Otukura Stream and Battersea Drain are considered to be **water temperature** and **dissolved oxygen**. The instream flow investigations will therefore focus on determining instream flow requirements to avoid high water temperatures and low dissolved oxygen.

High water temperatures can affect the aquatic ecology of a stream by having adverse impacts on behavioural responses and growth of fish, and excessively high temperatures can be lethal to aquatic organisms. Trout deaths have been reported in New Zealand when water temperatures have equalled or exceeded 26°C, although the thermal tolerance of native New Zealand fishes is generally higher than that of trout (Hay 2008). Prolonged temperatures above 20°C are detrimental to some stream macroinvertebrates (such as mayflies and stoneflies) (Quinn & Hickey 1990). For this assessment, two temperature thresholds are used: a **20°C** threshold to indicate conditions detrimental to aquatic life (MfE 2001) and a **25°C** threshold (based on the Third Schedule of the Resource Management Act 1991, for streams managed for trout fishery and spawning values).

Low dissolved oxygen concentrations are stressful to aquatic life, and low flows may exacerbate this by reducing the reaeration rate (Wilding 2007). Low dissolved oxygen can also affect water quality by increasing the toxicity of contaminants, and by causing nutrients (notably phosphorus) to be released from sediment. Salmonids (trout) are more sensitive to low dissolved oxygen than most other freshwater fish (Hay 2008), and therefore setting a guideline value for trout is likely to protect conditions for other fish (such as eels) and aquatic invertebrates (Hay 2008, ANZECC 2000). Although some aquatic life may be able to withstand dissolved oxygen concentrations as low as 3 or 4 mg/L (and eels may withstand concentrations as low as 2 mg/L), a higher concentration is appropriate for long-term protection of aquatic ecosystems; ANZECC (1992) recommend a guideline of **6 mg/L**.

A third flow-related critical factor is habitat availability. However, in this case it was decided that water quality (in particular temperature and dissolved oxygen) is likely to be more of a limiting factor to the recovery of ecological values of the Otukura Stream and Battersea Drain. Critical factors that are not flow-related include nutrient concentrations[3], habitat diversity, and fish passage[4].

5.3 Critical reach

The Issues Report divided the Otukura Stream and Battersea Drain into four reaches:

1. Otukura Stream from its headwaters near Fabians Road to the Battersea Drain confluence.

2. Otukura Stream from Battersea Drain confluence to Stonestead Creek confluence.

3. Otukura Stream from Stonestead Creek to Lake Wairarapa.

4. Battersea Drain.

Greater Wellington’s *Framework for Instream Flow Assessment* recommends identifying a reach of primary interest (or a ‘critical’ reach) for focusing the scientific investigations. Although all reaches are of interest, the second reach of the Otukura Stream is considered to be the critical reach for the purposes of this study. This is the reach in which the cumulative impact of upstream activities (such as abstraction and agricultural run off) is likely to be greatest and therefore the flow requirements will be the highest. It is also the reach of the Otukura Stream in which the highest temperatures occur (Watts 2007). The

[3] It is recognised that all aspects of water quality may be affected by low flows. However, nutrient concentrations are primarily related to discharges, diffuse source run-off and stock access.

[4] Although fish passage is linked to flows, in this case fish passage is classed as a non-flow related issue. The barriers to fish passage in the Otukura Stream will exist during most flow conditions, and are therefore not considered in the assessment of instream flow requirements.

Issues Report found that ecological values of the Otukura Stream improve significantly downstream of the Stonestead Creek confluence.

5.4 Method for assessing instream flow requirements

Investigations are required to determine stream flows that will achieve the instream flow objective. More specifically, the investigations will focus on linkages between flows and water temperature and dissolved oxygen concentrations in the critical reach of the Otukura Stream.

The model WAIORA version 2 (NIWA 2004) was selected to model the effects of flow on water temperature and dissolved oxygen in the Otukura Stream. WAIORA (Water Allocation Impacts on River Attributes) uses information on stream morphology to predict how stream hydraulic properties and water quality will change with flow. A description of how the WAIORA model was calibrated is given in Appendix 2.

6. Instream flow requirements: results and discussion

6.1 WAIORA temperature model verification

The WAIORA water temperature model was calibrated as described in Appendix 2, using hydraulic data collected during very low flow conditions (36 – 66 L/s) in the critical reach of the Otukura Stream. The model was verified by randomly selecting 10 days within the period November to March in 2004/05, 2006/07 and 2007/08 (when continuous water temperature monitoring data were available) and comparing predicted and observed water temperatures for those days. The WAIORA model performed well, particularly for predicting daily maximum water temperatures (Figure 4)[5]. The mean error for the validation events was 4.6% in predicting daily mean water temperature and 2.4% in predicting daily maximum water temperature.

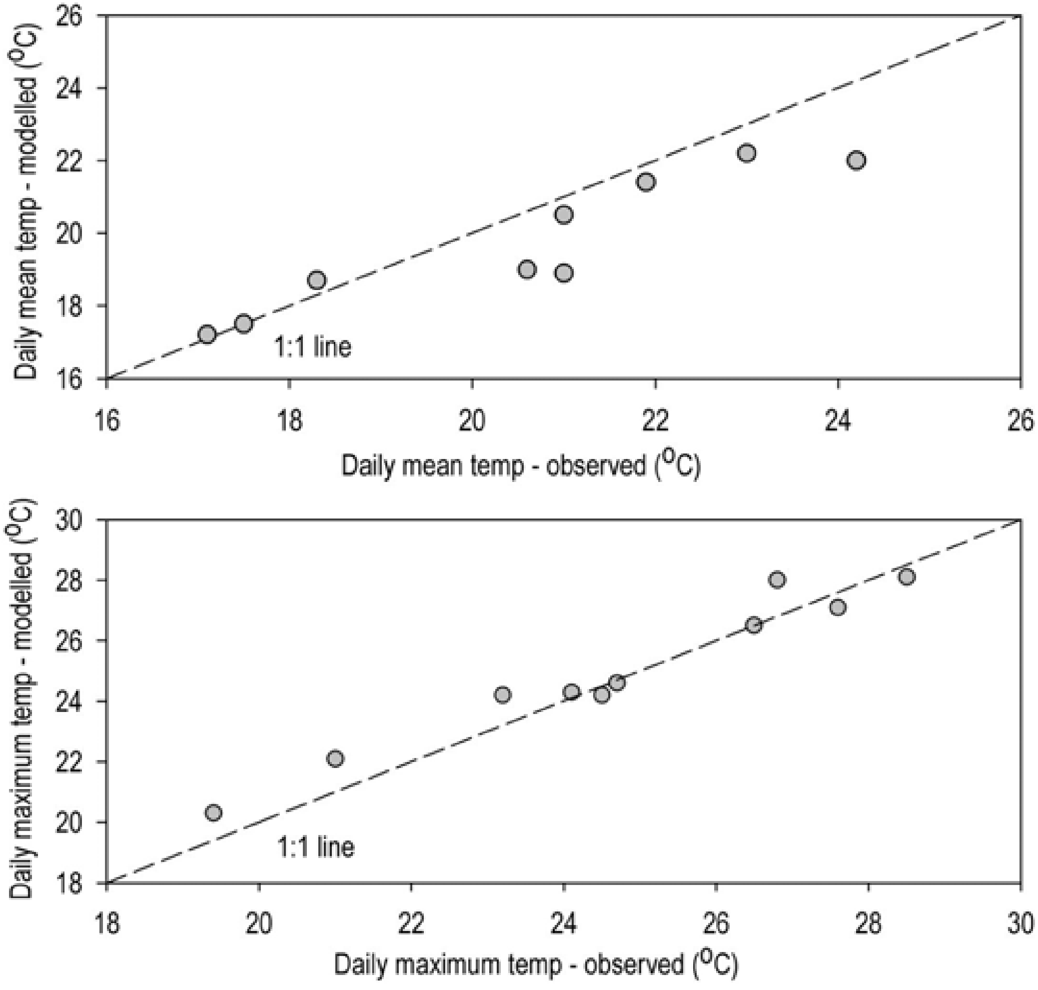

Figure 4: Otukura Stream WAIORA temperature model verification results

[5] The best calibration results were obtained when the daily mean relative humidity reading (required for the instream temperature model) was substituted with midday relative humidity. The WAIORA model was developed in Auckland, where humidity tends to be high. In the Wairarapa, during the hottest part of the day the humidity is generally low. Using the midday relative humidity reading – which is usually lower than the daily mean relative humidity – provides a more accurate representation of the effect of humidity on stream water temperature in the Wairarapa.

The verification events were for a range of temperature and flow conditions – with flow ranging from 44 to 550 L/s. Because the model adequately reproduced the observed water temperatures for the verification dates, the model can be used with confidence to investigate flow/temperature relationships in the critical reach of the Otukura Stream.

6.2 Water temperature results

The calibrated WAIORA temperature model was used to predict how water temperature during average flow conditions varies over the warmest months of the year (November to April). To represent 'average' flow conditions, the estimated (unimpacted) 1-day mean annual low flow of 97 L/s was used, although mean annual low flow generally occurs between January and March. Average climate parameters for each month were taken from the nearby climate station 'Alloa' (Appendix 3).

The model predicts that, at mean annual low flow and during average climate conditions, daily mean water temperatures in the critical reach of the Otukura Stream remain below the threshold of 20°C (Figure 5). However, during such flow conditions daily maximum water temperatures are predicted to exceed 20°C at times, and peak at around 24°C during average conditions of January.

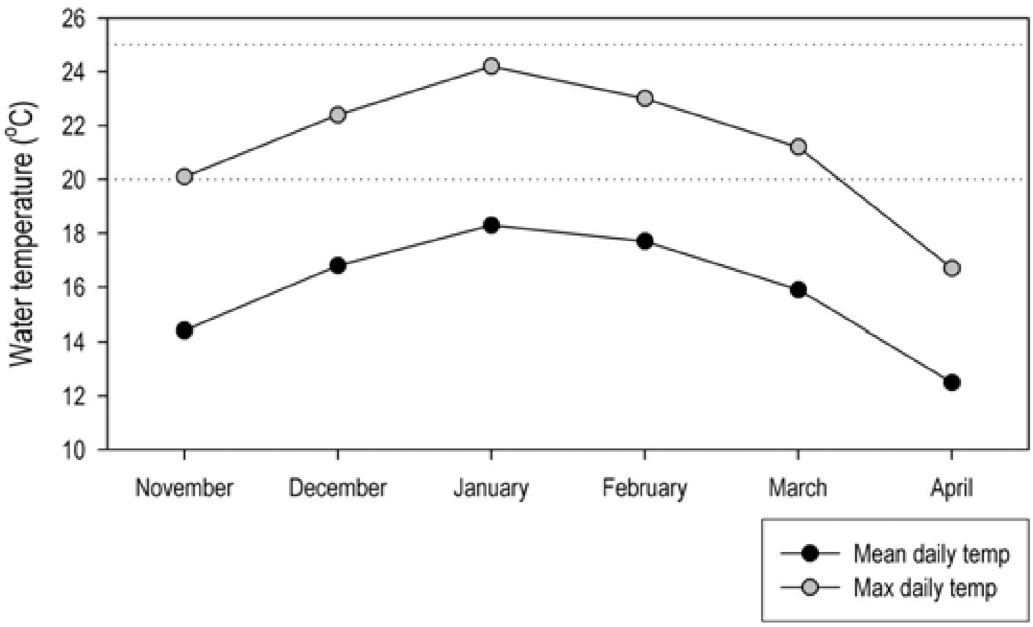

Figure 5: Predicted mean and maximum daily water temperatures in the Otukura Stream (critical reach) at 1-day mean annual low flow (97 L/s) during average monthly climate conditions. The dotted lines indicate the critical thresholds of 20°C and 25°C.

As an indication of possible temperatures during more extreme climate conditions (rather than average conditions), water temperature at mean annual low flow was modelled using climate data from the 10 hottest days on record at Alloa (see the 'January / February high' data in Appendix 3). Under the more extreme climate scenario, maximum daily water temperatures of up to 26.4°C are predicted to occur at mean annual low flow in the critical reach.

To predict how water temperatures may be affected by flow in the critical reach of the Otukura Stream, the average January and February and the ‘high January / February’ climate conditions were modelled with varying flow conditions. As expected, predicted daily maximum water temperatures for the ‘high January/February’ scenario exceed 25°C. However, for all climate scenarios, water temperatures are relatively insensitive to changes in flow; i.e., increasing the flow has only a minor effect on reducing predicted maximum daily temperatures (Figure 6). The model predicts that flows in excess of 1000 L/s are required before daily maximum water temperature drops below 25°C in the critical reach during the extreme January/February climate scenario, although it should be kept in mind that the WAIORA model was calibrated to low flow conditions (i.e., the model may not accurately predict water temperatures during high flow conditions).

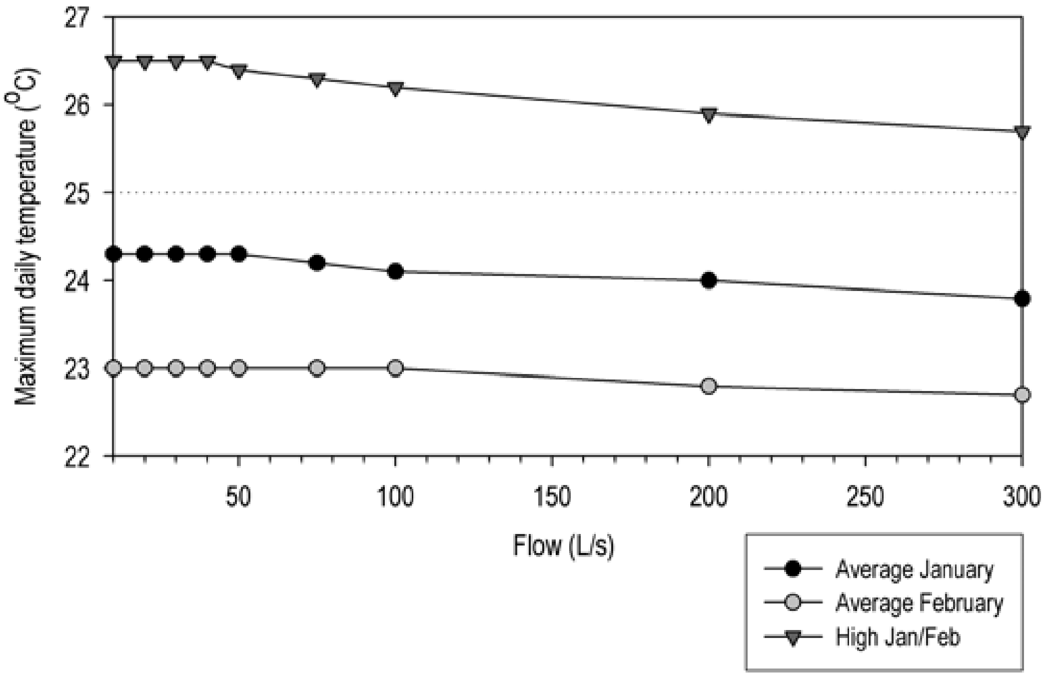

Figure 6: Predicted daily maximum water temperature with increasing flow in the critical reach of the Otukura Stream

6.3 Dissolved oxygen results

The WAIORA model was deemed to be appropriate for modelling dissolved oxygen concentrations in the Otukura Stream because the monitoring showed large diurnal fluctuations in dissolved oxygen. Such fluctuations indicate there is considerable oxygen production and consumption by aquatic plants. Following inspection of the critical reach of the Otukura Stream (upstream of the Greater Wellington flow recorder weir) it was determined that dissolved oxygen variations were primarily driven by benthic algae[6]. Although macrophytes are present they are generally emergent species and not dominant throughout the reach.

[6] The WAIORA model requires the user to specify whether macrophytes or benthic algae are dominant and this affects the predicted dissolved oxygen levels.

The WAIORA model was calibrated using dissolved oxygen data collected during January 2005 at the Greater Wellington flow monitoring weir (Appendix 2). Due to the short period of record available, the model was calibrated but was not able to be validated for a range of temperature and flow conditions. Although flow was higher than mean annual low flow at the time the dissolved oxygen data were collected, high air temperatures (up to 31°C) occurred during the period of monitoring and therefore the record should represent dissolved oxygen concentrations during typical Wairarapa summer conditions.

The WAIORA model predicts that daily minimum dissolved oxygen concentrations decline sharply toward zero as flow in the Otukura Stream falls below about 40 L/s (Figure 7). The predicted flow to a maintain dissolved oxygen concentration above 6 mg/L is 95 L/s, which is about equal to the 1-day mean annual low flow.

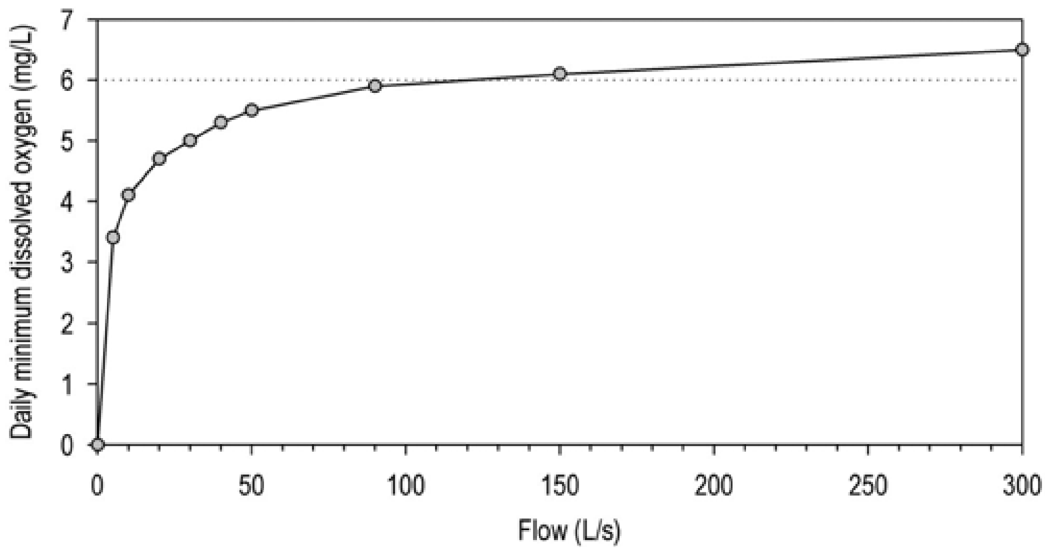

Figure 7: Relationship between daily minimum dissolved oxygen and flow in the critical reach of the Otukura Stream, predicted using WAIORA. The dotted line indicates the dissolved oxygen threshold of 6 mg/L.

6.4 Discussion: temperature and dissolved oxygen in the critical reach

This assessment was carried out with the purpose of determining instream flow requirements, bearing in mind the instream flow objective of improving ecological values of the Otukura Stream and Battersea Drain. The investigations focused on flows in the critical reach of the Otukura Stream, between the Battersea Drain and Stonestead Creek confluences. It is therefore assumed that setting a minimum flow at the Greater Wellington flow monitoring site ‘Otukura Stream at Weir’ will protect values in other reaches of the streams, because flow requirements are generally highest in the critical reach.

The critical factors that were assessed were water temperature and dissolved oxygen. The WAIORA modelling found that during November to March instream temperatures are likely to exceed 20°C (the critical threshold for protection of aquatic macroinvertebrates), and during extreme climatic conditions in January and February water temperature may exceed 25°C (the critical threshold for trout fishery and fish spawning) at low flows. This is consistent with results of temperature monitoring and confirms that water temperature of the Otukura Stream is likely to be a critical factor for the aquatic ecology of the stream.

However, modelling showed that water temperature and flow are not strongly related. The lack of correlation is likely to be due to the very low amount of shading throughout much of the stream length, and shallow water depths at low to moderate flows. Therefore, increasing the flows within the low to moderate flow range will not have a discernable affect on temperatures. This suggests that, although water temperature is considered to be a parameter that is critical to sustaining ecology of the Otukura Stream, it is not feasible to set a minimum flow to avoid high water temperatures.

Conversely, instream dissolved oxygen was found to be linked to low flows. Predicted daily minimum dissolved oxygen concentrations decline rapidly at flows less than 40 L/s, and the flow for sustaining 6 mg/L (for long-term protection of aquatic life) was predicted to be 95 L/s. Therefore, a minimum flow of 95 L/s is recommended for achieving the dissolved oxygen threshold for the Otukura Stream. This is about equal to the estimated unimpacted 1-day mean annual low flow, and is about 89% of the estimated 7-day mean annual low flow (107 L/s).

The dissolved oxygen modelling was based on monitoring carried out during moderate flow conditions in January. However, it is expected that dissolved oxygen is a critical factor during extreme low flows in the Otukura Stream, and abstraction during such conditions (without the provision of a minimum flow) will exacerbate low dissolved oxygen conditions. Greater Wellington has a duty to monitor the effectiveness of its plans. Hence ongoing monitoring of the Otukura Stream – particularly for dissolved oxygen concentrations – should occur following the addition of a minimum flow for the stream into the Regional Freshwater Plan.

6.5 Other considerations

When setting minimum flows to protect instream values, habitat availability is often considered because it is assumed that the amount of habitat available to aquatic life is a critical factor at low flows. To assess habitat availability at low flows, hydraulic methods such as RHYHABSIM – which is a fairly data intensive method – can be used. It is common practice for habitat availability at a proposed minimum flow to be compared to habitat availability at mean annual low flow, to determine the amount of ‘loss’ in habitat that will occur at the minimum flow. The mean annual low flow has been described as an ecologically relevant statistic because many fish species – such as trout – respond to annual limiting events because their cohorts are annual (Hay 2008).

The relationship between habitat availability and flow in the Otukura Stream cannot be modelled, because a RHYHABSIM survey was not carried out[7]. However, the WAIORA model predicted how changes in flow affect hydraulic variables (stream width, depth and velocity) (see Appendix 2). The WAIORA hydraulic model predicts that at a flow of 95 L/s in the study reach of the Otukura Stream, stream width, depth and velocity will be reduced by less than 10% compared to width, depth and velocity at the estimated 7-day mean annual low flow (Table 4). It is assumed that these relatively small changes in hydraulic properties mean that the habitat availability at 95 L/s is not significantly reduced compared to the habitat at mean annual low flow.

Table 4: Predicted difference in hydraulic properties of the Otukura Stream (critical reach) between the estimated 7-day mean annual low flow (107 L/s) and 95 L/s

	Mean stream width	Mean stream depth	Mean velocity
Predicted change	-1.2%	-6%	-7%

The Ministry for the Environment has recently proposed a default method for setting minimum flows that sustain ecological values of waterways, as part of a proposed National Environmental Standard (NES) (Ministry for the Environment 2008). The suggested 'interim' minimum flow for small streams is 90% of the 7-day mean annual low flow. The flow of 95 L/s that is estimated to achieve dissolved oxygen standards is about 89% of the 7-day mean annual low flow, which suggests that it is in line with the proposed NES for setting ecological flows[8].

Setting a minimum flow with the aim of maintaining dissolved oxygen concentrations above that required for long-term protection of aquatic life is an important step in achieving the instream flow objective and for other objectives such as restoring the Wairarapa eel fishery. However, there are other mechanisms for working towards improving the ecological values of the Otukura Stream and Battersea Drain. The investigations carried out by Greater Wellington suggest that reducing stock access to the Otukura Stream and its tributaries and increasing riparian vegetation could have huge benefits for improving water quality and ecological values of the streams. Such actions are supported by the comments on the Issues Report by Department of Conservation. The report from Ngati Kahungunu ki Wairarapa recommended stock exclusion and encouragement of riparian restoration as a means of improving the condition of the waterbody (Te Whaiti 2007).

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7 It is questionable whether the RHYHABSIM method is applicable for small streams because the habitat suitability curves were generally developed using data collected from large rivers.

8 Ecological flows are flows required in a water body to provide for the ecological function of the flora and fauna present within the water body and its margin (Ministry for the Environment 2008).

7. Conclusions and recommendations

Investigation of the relationship between flow and water temperature and dissolved oxygen in the critical reach of the Otukura Stream, using WAIORA, found that:

- High water temperatures (in excess of 25°C) may occur during low flow in the Otukura Stream and extreme climatic conditions;
- High water temperatures are unlikely to be avoided through flow management in the Otukura Stream, at least in the stream's current hydraulic and riparian condition;
- Dissolved oxygen is a potentially critical issue for the Otukura Stream during times of low flow, and daily minimum dissolved oxygen concentrations are predicted to decline rapidly at flows less than 40 L/s;
- A flow of 95 L/s in the critical reach is predicted to maintain daily minimum dissolved oxygen concentrations above the 6 mg/L threshold for long-term protection of aquatic life.

The modelling suggested that a minimum flow of 95 L/s (89% of the estimated 7-day mean annual low flow) would result in relatively minor changes in mean stream width, depth and velocity compared to those at 7-day mean annual low flow, and is consistent with the proposed NES for ecological flows.

The study assumes that the instream flow requirements are greatest in the critical reach (in this case, from the Battersea Drain to the Stonestead Creek confluence). Therefore setting a minimum flow in the critical reach should also mean the instream flow requirements of the other reaches are maintained. However, the effect of individual water abstractions on flow in the reach of abstraction should be considered during the resource consent assessment process.

7.1 Recommendations

1. It is recommended that a minimum flow of 95 L/s for the Otukura Stream is considered for the Regional Freshwater Plan.
2. Policies for reducing stock access and restoring riparian vegetation should be considered when the Regional Freshwater Plan is reviewed. In addition, Greater Wellington should consider promoting or requiring riparian restoration through the resource consent process.

Acknowledgements

Haami Te Whaiti (Ngati Kahungunu ki Wairarapa) provided a report on the cultural values associated with the Otukura Stream, the findings from which have been incorporated into this report. Also included in this report was feedback on the Issues Report from Nadine Gibbs and Phil Brady (Department of Conservation).

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Appendix 1: Policy framework

Under the Resource Management Act 1991, Greater Wellington has a responsibility to manage the region's water resources in a sustainable manner. The Regional Freshwater Plan (Wellington Regional Council, 1999) sets out policies and recommendations to help Greater Wellington meet this responsibility. The parts of the Regional Freshwater Plan that are pertinent to the management of Otukura Stream are:

Policy 4.2.14: *To avoid, remedy or mitigate any adverse effects on important trout habitat in the Region, identified in Appendix 4, by:*

- *Managing water quality so that Policy 5.2.3 is satisfied; and*
- *Managing the flows and levels of water bodies so that [Policy 6.2.2 is] satisfied; and*
- *Having particular regard to offsetting adverse effects on trout habitat; and*
- *Having particular regard to maintaining the same, or similar, river bed configuration in the rivers identified.*

Policy 5.2.3: *To manage water quality for trout fishery and fish spawning purposes in those rivers, or parts of rivers, identified in Appendix 4 (subject to Policy 5.2.10). Appendix 4 includes Otakura (sic) Stream upstream of its confluence with Lake Wairarapa.*

Policy 6.2.2: *To manage the flows in rivers and streams not identified in Policy 6.2.1 by having regard to:*

- *The significance of natural, amenity, and tangata whenua values; and*
- *The scale/magnitude of any adverse effects on natural, amenity and tangata whenua values; and*
- *The reversibility of any adverse effects on natural, amenity and tangata whenua values.*

Method 8.5.5*: Where practicable, obtain more information to establish desirable minimum flows and approaches to water allocation… for the following water bodies where there is potential for water shortages to occur (includes the Moroa/Battersea/Otakura (sic) Stream system).*

An instream flow assessment for Otukura Stream is therefore strongly supported by the Regional Freshwater Plan, in particular by Method 8.5.5.

In addition to the aforementioned policies, proposed Plan Change 3 to the Regional Freshwater Plan was notified in May 2007. This proposed plan change affects the Otukura Stream and Battersea Drain by proposing a capped allocation limit of 60 l/s. Submissions on the proposed Plan Change 3 closed on 29 June 2007.

The following submissions on Plan Change 3 relate to the Otukura Stream and Battersea Drain:

- Wellington Fish & Game Council submitted that the capped allocation limit does not apply to the Otukura Stream downstream of the confluence with Stonestead Creek.

- Department of Conservation submitted that a default minimum flow as well as capped allocation limits apply, with a default minimum flow equal to 7-day mean annual low flow.

A decision on Plan Change 3 was released to submitters on 29 April 2008, but at the time of writing this report the decision was still within the timeframe for appeal.

Appendix 2: WAIORA model calibration

To calibrate the WAIORA model's hydraulic component, measurements of stream width and depth were made at five cross-sections in run (four cross-sections) and riffle (one cross-section) habitat in reach 2 of the Otukura Stream at two different flows. The measurements were taken during very low flow conditions in January 2008, and manual flow gaugings were performed at the time of survey. The hydraulic survey results are shown in Table A1. The cross-sections were located in the vicinity of the Greater Wellington flow recorder. The model then uses this information to predict how mean width, depth and velocity will vary with flow (Figure A1).

Table A1: Otukura Stream flow, width and depth measurements used for WAIORA model calibration

	Stream flow (L/s)	Mean channel width (m)	Mean depth (m)
18 January 2008	66	4.8	0.14
24 January 2008	36	4.5	0.12

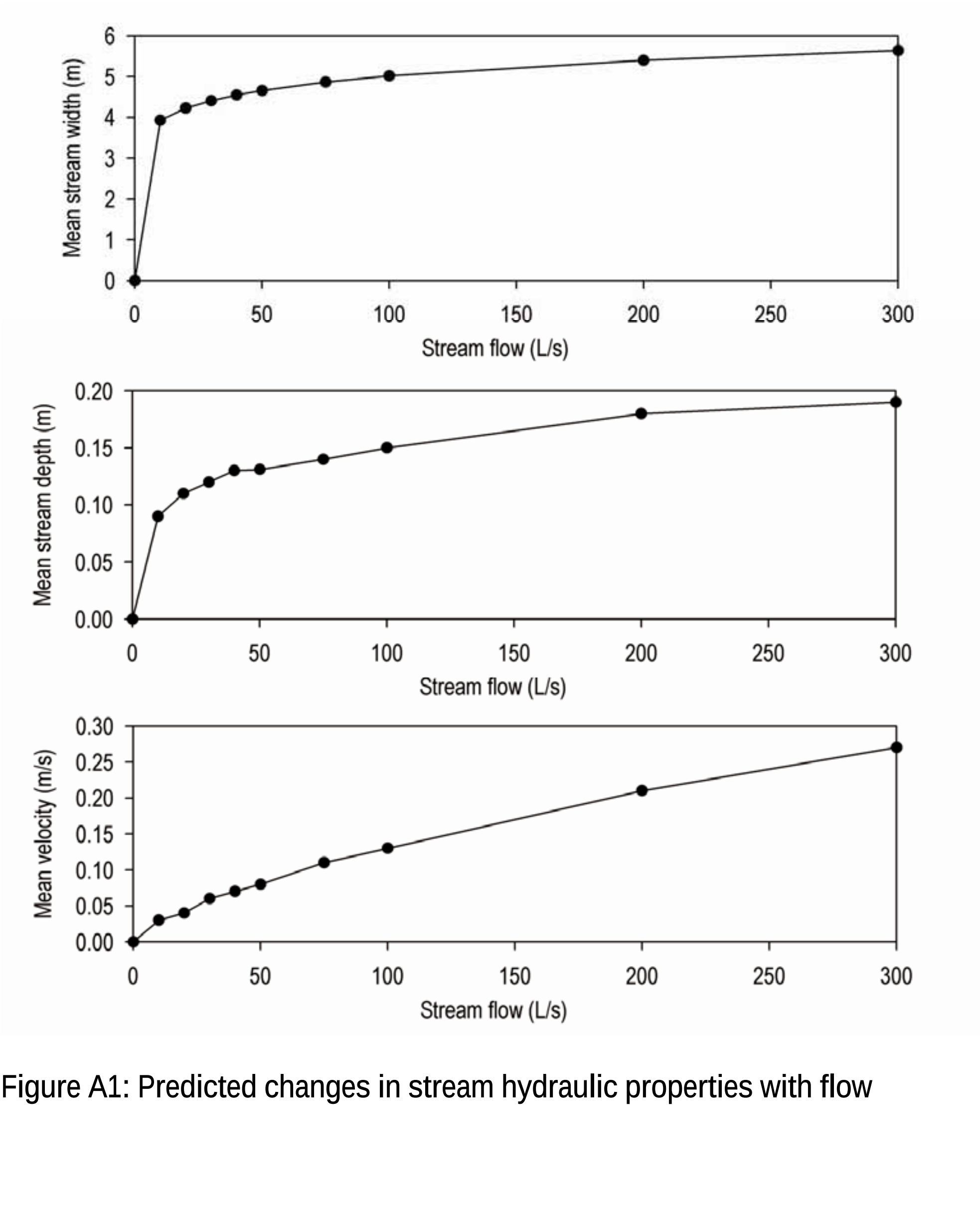

Figure A1: Predicted changes in stream hydraulic properties with flow

The WAIORA instream temperature model requires water temperature and meteorological data for its calibration. Continuous (15 minute) temperature monitoring was conducted over the 2007/08 summer at Greater Wellington's flow site Otukura Stream at Weir (close to where the WAIORA cross-sections were located). This supplemented continuous water temperature data collected during the 2004/05 and 2006/07 summers. All water temperature monitoring was carried out using StowAway Tidbit temperature loggers. Meteorological data were obtained from the nearby climate station *Alloa*, and estimates were made in the field of Otukura Stream shading in the study reach (1000 metres from the temperature logger upstream).

To calibrate the WAIORA temperature model, the unknown parameters (stream bed conductivity, thickness and temperature) were varied so that predicted mean daily water temperature and maximum daily water temperature matched measured temperatures for 3 randomly selected days for which temperature and flow data were available. The calibration of the WAIORA temperature model determined the best-fit parameter values as shown in Table A2. The shading-related parameter values shown in the table were estimated in the field. The derived parameters were within the range of those recommended in the WAIORA user manual. Following the calibration, the model was verified by comparing predicted and observed mean and maximum water temperatures on 10 randomly selected days. Results of the verification are described in Section 6.1.

Table A2: Otukura Stream WAIORA temperature model – derived parameters

	Calibrated / estimated value	Recommended in user manual
Stream bed conductivity (J/m/sec/°C)	45	10-50
Bed thickness (m)	0.6	Around 1, but can vary depending on stream type
Bed temperature (°C)	Equal to monthly mean air temperature minus 0.5°C, but not less than 18°C	Approximately equal to monthly mean water temperature
Stream shade topographic angle (°)	35	Measure in field
Canopy angle (°)	40	Measure in field
Fraction through canopy	0.95	Measure in field

The WAIORA dissolved oxygen model was calibrated using continuous dissolved oxygen data collected during January 2005. The model automatically calculates the required parameters based on dissolved oxygen measurements, as shown in Table A3. Unfortunately, due to the short nature of the continuous dissolved oxygen record, there was insufficient data available to verify the model results.

Table A3: Otukura Stream WAIORA dissolved oxygen model – derived parameters

	Calibrated / estimated value	Comment
Time lag between maximum DO and solar noon	0.89 hours	Estimated from average time of DO maximum during calibration period
Average daily DO	8.5 mg/L	
DO range	4.25 mg/L	Average range during calibration period
Daily mean water temperature	20.2 °C	Derived from WAIORA instream temperature model
Daily community respiration	69 $g/m^3/day$	Calculated by WAIORA
Daily production/respiration ratio	0.77	Calculated by WAIORA
Reaeration coefficient	30.7	Calculated by WAIORA

Appendix 3: Climate data used for instream temperature modelling

Data from Greater Wellington's monitoring site *Alloa* (near Featherston)

	November	December	January	February	March	April	Jan/Feb high
Mean daily air temperature (°C)	14.1	16.3	17.8	17.6	16.1	13.0	17.8
Maximum daily air temperature (°C)	25.4	27.8	30.7	29.1	27.7	23.9	32.9
Mean daily total solar radiation (MJ/m^2)	21.4	22.9	23.1	19.2	15.6	10.5	31.8
Wind velocity (m/s)	2.8	2.6	2.3	2.2	2.2	1.7	1.4
Midday relative humidity (%)	59.2	59.7	26.4	57.4	58.9	65.1	40.4

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Otukura Stream downstream of
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