COVER NOTE

Greater Wellington has undertaken this work as part of information gathering leading up to the Whaitua Kāpiti process. This is only part of the information base that the Whaitua Kāpiti Committee may draw from and is not considered to be definitive.

Awanui Science

Memorandum

To:	Helli Ward (Greater Wellington)
Copies:	Mike Harkness, Penny Fairbrother (Greater Wellington); Robin Holmes (Cawthron)
From:	Laura Keenan
Date:	14 June 2022
Subject:	**Kāpiti streams: hydrological statistics and impacts of water allocation**

Greater Wellington Regional Council require hydrological information for small streams on the Kāpiti Coast. This information will support ecological investigations and minimum flow recommendations being carried out by Cawthron and will contribute to background information for the Kāpiti Coast whaitua process.

This memo gives a brief description of the hydrological characteristics of the main streams (excluding Waikanae and Ōtaki rivers) and presents selected hydrological statistics for each stream, with a focus on low flow characteristics.

Method

For most small Kāpiti streams, hydrological data are fairly limited and key statistics (7-day mean annual low flow (MALF), median flow and mean flow) are estimated in this memo based on relatively few gaugings and thus may contain considerable uncertainty. In some cases, statistics are taken from the *NZ River Maps* tool (Whitehead and Booker, 2020). For the streams with continuous flow records some more in-depth statistics are presented. In all cases, the continuous flow recorders are located in the upper reaches of the streams and are unimpacted by any major abstraction.

A brief assessment is given of likely low flow depletion resulting from consented abstractions in the middle/lower reaches of the streams. This assessment assumes full utilisation of surface water takes, because flow and water use data are not detailed enough for these streams to determine actual (measured) depletion. However, for most streams there is very little consented surface water abstraction.

In addition to the surface water takes, which occur directly from the streams, there is likely to be some flow depletion as a result of groundwater use. The Proposed Natural Resources Plan (PNRP) requires this depletion to be calculated for each consent using the criteria in Table 4.1 of the PNRP (whereby only takes with greater than 60% seasonal surface depletion are counted). However, this approach effectively misses a portion of depletion associated with groundwater takes that individually deplete less than 60% at the surface but cumulatively may result in more significant depletions. Therefore, the approach taken in this memo is to consider

depletions as calculated under the PNRP but also depletions estimated from zone-scale (i.e., cumulative) modelling of existing abstractions. Thus, the depletions presented should not be assessed against the allocation limits in the PNRP.

While groundwater depletions are difficult to accurately quantify, an estimate for each stream is given here based on the zone-scale Kāpiti groundwater modelling carried out by Mzila et al. (2015) and recently converted into files suitable for use by Tonkin & Taylor (2022). The streamflows were modelled based on an estimate of actual groundwater use (rather than fully consented or full allocation) for the period 1992–2011, and depletions calculated by comparing 'no abstraction' and 'with abstraction' modelled streamflow scenarios. Therefore, the estimated depletion varied from year to year depending on estimated actual use; for the purpose of this analysis the depletion reported is the average annual peak depletion for the period 2001–11.

The categories describing the degree of depletion are those used by Keenan (2020) in other rivers of the Wellington region (Table 1) and are intended to be interpreted alongside ecological assessments (e.g., a potential streamflow depletion of 70% of MALF is classed as 'very high' hydrological change but will not necessarily result in 'very high' ecological change). Note that the abstraction and flow data are not detailed enough to allow an assessment of abstractive impact on low flow duration and frequency.

Table 1: Categories of hydrological change applied to results of low flow depletion in this memo

Depletion of MALF by consented abstraction	Hydrological change category
< 10%	Low
10–25%	Moderate
26–50%	High
> 50%	Very high

There is little available information quantifying permitted water abstraction from the streams. Nation (2020) provided estimates of maximum permitted use from each Kāpiti catchment, assuming full utilisation of the relevant allowances under PNRP and the Resource Management Act and these estimates are reproduced in this memo (converted to L/s). However, it is important to note that (1) some permitted abstraction will be 'accounted for' in the measurement of downstream flows, and (2) the estimates of Nation (2020) are based on maximum allowable use and therefore represent a 'worst-case' scenario.

At the end of the memo, some brief comments are made regarding hydrological trends and climate change effects in the Kāpiti small stream catchments.

The small streams of the Kāpiti Coast are grouped into three types based on their predominant source of flow:

- hill-country catchment streams, with flow largely influenced by rainfall in the coastal hills / Tararua foothills (although hydrological characteristics may alter as the streams cross the coastal plains)

- lowland streams, which may flow from the western hills faces but receive their main flow from lowland runoff

- spring-fed streams.

Hill-country streams

1. Waitohu Stream

1.1 Hydrological setting

Waitohu Stream (catchment area 54 km^2) is a small, gravel-bed stream with headwaters in the Tararua foothills to the east of Ōtaki. As the stream emerges from the foothills and flows westward across the coastal plain towards the sea it initially has a steep gradient which flattens out downstream of about State Highway 1.

During low to moderate flow conditions, within its upper coastal plain reach (i.e., from where it emerges from the foothills and downstream to about Taylors Road) the stream loses a considerable proportion of its flow to the shallow gravel aquifer. In its middle reach – from about Taylors Road downstream to about Convent Road / Ōtaki Golf Club – the stream gradient reduces significantly and flow gains/losses during low to moderate flows are generally neutral, with a small input from the tributary Ngātotara Drain. Parts of this reach may run dry during extreme low flow conditions. In its lower reach, from Convent Road to the sea, the stream meanders across what was once swampy land and gains flow from groundwater.

1.2 Key flow statistics

Greater Wellington operates a continuous flow monitoring site in the Waitohu Stream at Water Supply Intake, at the start of the upper reach. The site has been operating since the mid-1990s and is unimpacted by water abstraction. The flow record shows mean monthly flows are lowest in late summer / early autumn and highest in spring (Figure 1); this is typical of west coast catchments, which tend to have their highest flows in October or November, reflecting the increased westerly airflow (and hence, rainfall events) that occur over New Zealand at this time of the year. Some key flow statistics for the site are shown in Table 2.

Table 2: Selected hydrological statistics for Waitohu Stream at Water Supply Intake, 1996–2021 (flows rounded to nearest 5 L/s)

Median flow	470 L/s	Summer median flow	370 L/s
Mean flow	890 L/s	1-day MALF	135 L/s
Mean annual flood	46 m^3/s	7-day MALF	145 L/s
Average annual maximum accrual period*	40 days	Average annual maximum low flow period#	12 days

*Accrual period taken to be duration between freshes greater than three times median flow

#Low flow period calculated as continuous time with flow less than the 90th percentile low flow

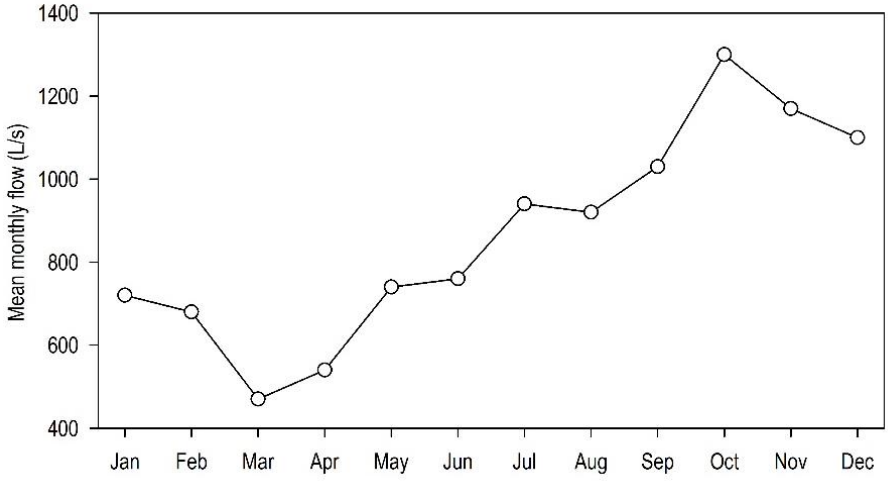

Figure 1: Mean monthly flows – Waitohu Stream at Water Supply Intake, 1996–2021

However, as is evident from the hydrological setting description, the statistics are not representative of the stream as it crosses the coastal plain. Estimated flow statistics, derived using concurrent gauging data, for the middle reach mid-point are[1]:

- Mean flow: ~700–800 L/s
- Median flow: ~300–400 L/s
- 7-day MALF: 50 L/s.

Estimated flow statistics from NIWA's *NZ River Maps* tool (Whitehead and Booker, 2020), corroborated using gauging results, for Waitohu Stream at its mouth are:

- Mean flow: 1050 L/s
- Median flow: 600 L/s
- 7-day MALF: 200 L/s.

1.3 Water allocation and abstraction

The allocation limit for Waitohu Stream specified in the PNRP is 45 L/s[2], which includes depletion associated with takes from Waitohu Category A groundwater and Ōtaki Category B groundwater. The minimum flow is 140 L/s at the Water Supply Intake monitoring site (at the top of the upper reach).

Historically, Kāpiti Coast District Council abstracted water from Waitohu Stream for Ōtaki's municipal water supply. However, this take ceased in the early 2000s, with the water now sourced from groundwater. Current consented abstraction consists of one consent for 15 L/s from Category A groundwater and several Ōtaki (Waitohu sub-zone) Category B groundwater takes. The estimated peak depletion associated with the Category B groundwater takes is ~14 L/s. The total estimated depletion of MALF falls

[1] Mean and median flow estimates have low confidence, hence marked with '~' and presented as a range, because concurrent gaugings have focused on low flows. *NZ River Maps* estimates for this reach do not appear accurate.

[2] This is based on a default maximum allocation rule of 30% of estimated natural 7-day MALF, as described by Thompson and Mzila (2014). Naturalised 7-day MALF was estimated to be 150 L/sec, based on the average of three sites from the foothills to the stream mouth.

into the hydrological change category of moderate for both the middle and lower reaches (Table 3).

Table 3: Estimated depletion of Waitohu Stream flow due to consented takes

	Middle reach	Lower reach
Estimated 7-day MALF (L/s)	50	200
Depletion associated with surface takes (L/s)	0	15
Estimated maximum depletion from consented groundwater abstraction (L/s)	7*	14*
Total estimated depletion (L/s)	7	29
Hydrological change category	Moderate (~15%)	Moderate (~15%)

*Total depletion from groundwater takes is assumed to accumulate downstream; i.e. half the estimated depletion is apportioned to the middle reach and 100% to the lower reach.

Estimated maximum permitted activity water abstraction from the Waitohu catchment, excluding that from groundwater, is ~30–35 L/s (adapted from Nation, 2020).

2. Mangaone Stream

2.1 Hydrological setting

Mangaone Stream (catchment area 53 km^2) originates in the foothills of the Tararua Range to the east of Te Horo. As the gravel-bed stream emerges from the foothills and crosses the alluvial coastal plain it loses flow to the underlying unconfined aquifer. In its lower reach – approximately from State Highway 1 downstream – it gains flow from the unconfined sand aquifer (Mzila et al., 2015) as well as several farm drain tributaries and changes to a soft sediment bottomed, sluggish stream dominated by macrophytes. There are therefore two coastal plain stream reaches referred to in this assessment: an upper (losing) reach, from the top of the coastal plain to approximately State Highway 1, and a lower (gaining) reach, from approximately State Highway 1 to the sea.

2.2 Flow statistics

Greater Wellington operates a continuous flow monitoring site in the Mangaone Stream at Ratanui, at the top end of the upper reach. The site has been operating since the mid-1990s and is unimpacted by water abstraction. Mean monthly flows are lowest in late summer / early autumn and highest in spring (Figure 2); this is typical of west coast catchments, which tend to have their highest flows in October or November, reflecting the increased westerly airflow (and hence, rainfall events) that occur over New Zealand at this time of the year. The average annual maximum low flow duration and accrual period (Table 4) are similar to those of Waitohu Stream in its upper reach, reflecting the influence of generally frequent rainfall events in the Tararua foothills.

Table 4: Selected hydrological statistics for Mangaone Stream at Ratanui, 1996–2021 (flows rounded to nearest 5 L/s)

Median flow	200 L/s	Summer median flow	165 L/s
Mean flow	325 L/s	1-day MALF	70 L/s
Mean annual flood	14 m^3/s	7-day MALF	75 L/s
Average annual maximum accrual period*	48 days	Average annual maximum low flow period#	12 days

*Accrual period taken to be duration between freshes greater than three times median flow

#Low flow period calculated as continuous time with flow less than the 90th percentile low flow

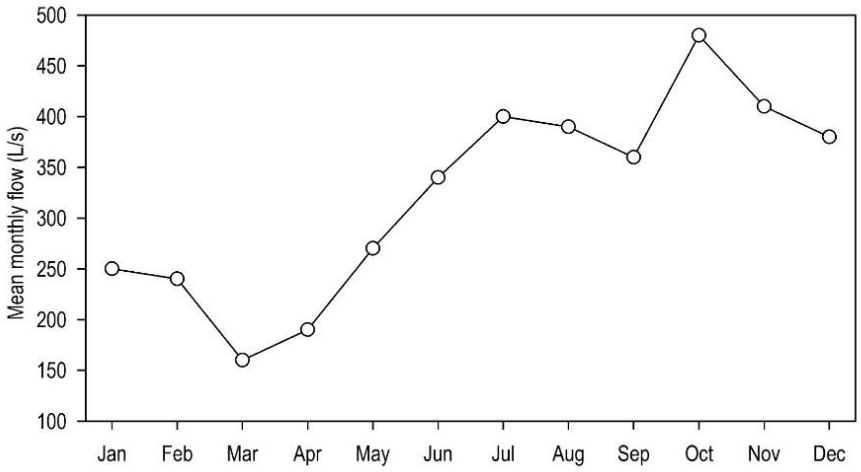

Figure 2: Mean monthly flows – Mangaone Stream at Ratanui, 1996–2021

However, as is evident from the hydrological setting description, the median, mean and MALF statistics are not representative of stream as it crosses the coastal plain. Estimated flow statistics, derived using concurrent gauging data, for the transitional point between the upper and lower reaches are[3]:

- Mean flow: ~250–300 L/s
- Median flow: ~180 L/s
- 7-day MALF: 55 L/s.

Estimated flow statistics for Mangaone Stream at its mouth are[3]:

- Mean flow: ~500–750 L/s
- Median flow: 400–600 L/s
- 7-day MALF: 230 L/s.

[3] Mean and median flow estimates have low confidence, hence marked with '~' and presented as a range, because concurrent gaugings have focused on low flows. *NZ River Maps* estimates for this stream do not appear accurate.

2.3 Water allocation and abstraction

The allocation limit for Mangaone Stream specified in the PNRP is 24 L/s[4], which includes depletion associated with takes from Te Horo Category B groundwater. The minimum flow is 22 L/s at the Ratanui monitoring site (at the top of the upper reach).

Current consented surface water abstraction consists of one consent for 24 L/s, taken from the stream in its lower reach, just 1 km upstream of the stream mouth. The modelled peak depletion associated with the Category B groundwater takes from the Te Horo groundwater zone is ~6 L/s for 2001–11. However, given that there has been some increase in allocation compared to that used in the groundwater model, and modelled streamflows for the Mangaone catchment appear too low, actual depletion is likely to be higher. Based on Mzila *et al*.'s (2015) recommendations for calculating depletion in the groundwater zone, the streamflow depletion estimate adopted for this assessment is 20 L/s([5]). The estimated depletion of MALF falls into the category of 'moderate' (Table 5).

Table 5: Estimated depletion of Mangaone Stream due to consented takes

	Transitional point (between upper/lower reaches)	Stream mouth
Estimated 7-day MALF (L/s)	55	230
Depletion associated with surface takes (L/s)	0	24
Estimated maximum depletion from consented groundwater abstraction (L/s)	10*	20*
Total estimated depletion (L/s)	10 (~18%)	44 (~20%)
Hydrological change category	Moderate	Moderate

*Total depletion from groundwater takes is assumed to accumulate downstream; i.e. half the estimated depletion is apportioned to the middle reach and 100% to the lower reach. The consented surface take (24 L/s) occurs in the lower reach.

Estimated maximum permitted activity water abstraction from the Mangaone catchment, excluding groundwater use, is ~75–80 L/s (adapted from Nation, 2020). However, this estimate is 'skewed' by the PNRP Rule 136, which allows up to 20,000 L/day on properties greater than 20 hectares – of which there many within this catchment – and is therefore likely to be a considerable overestimate.

3. Wharemauku Stream

3.1 Hydrological setting

Wharemauku Stream originates in the low hills behind Paraparaumu and flows through a mixture of rural land, forestry, native bush and low-density urban areas before emerging from the hills near the Paraparaumu commercial town centre. It then crosses the coastal plain through the urban area before discharging to the sea at Raumati beach. Within the

[4] This is based on a default maximum allocation rule of 30% of estimated natural 7-day MALF, as described by Thompson and Mzila (2014). Naturalised 7-day MALF was estimated to be 155 L/sec near the stream mouth based on data available in 2009

[5] Calculated by assuming 80% utilisation rate of consented daily take from Te Horo groundwater zone (5265 m3/d), multiplied by streamflow depletion factor of 0.4 (from Mzila et al., 2015).

urban area, the stream has a highly modified, uniform, trapezoidal channel, and has been engineered and maintained to optimise flood conveyance (Beca, 2012).

As it crosses the coastal plain the stream gains flow from the unconfined Holocene sand aquifer (Mzila et al., 2015). It also receives significant stormwater discharge following rainfall events from the urban areas of Paraparaumu and Raumati.

3.2 Flow statistics

Greater Wellington operates a continuous flow monitoring station on the Wharemauku Stream at Coastlands, a short distance downstream of where it emerges from the foothills. While some data was collected in the early 1980s, the record is very patchy until the late 1990s. Data from 1998 onwards show the stream experiences more prolonged low flows than streams with headwaters stretching further into the Tararua foothills (i.e., Mangaone and Waitohu) (Table 6). The stream experiences its lowest mean monthly flows in February/March and highest monthly flows in the winter months (Figure 3).

Table 6: Selected hydrological statistics for Wharemauku Stream at Coastlands, 1998–2021 (flows for some statistics rounded to nearest 5 L/s)

Median flow	40 L/s	Summer median flow	26 L/s
Mean flow	90 L/s	1-day MALF	18 L/s
Mean annual flood	7 m^3/s	7-day MALF	20 L/s
Average annual maximum accrual period*	70 days	Average annual maximum low flow period#	26 days

*Accrual period taken to be duration between freshes greater than three times median flow

#Low flow period calculated as continuous time with flow less than the 90th percentile low flow

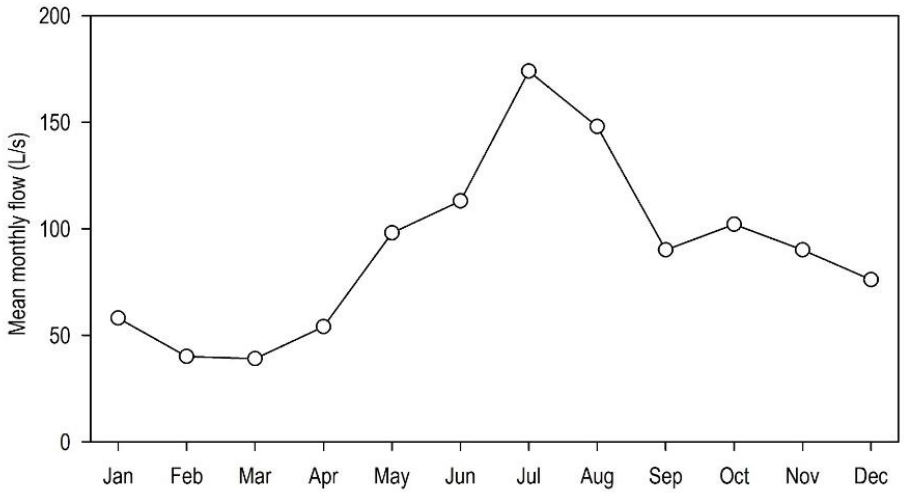

Figure 3: Mean monthly flows – Wharemauku Stream at Coastlands, 1998–2021

Gauging data indicate that during normal (stable) flow conditions the stream gains 30–50 L/s over its lower reach. Estimated hydrological statistics for Wharemauku Stream at its mouth are[6]:

- Mean flow: 200–250 L/s
- Median flow: 100–150 L/s
- MALF: 50 L/s.

3.3 Water allocation and abstraction

There is no specific allocation listed for Wharemauku Stream in the PNRP, and hence the 'default' rule of 30% of 7-day MALF applies. Currently, there are no consented water takes directly from the stream. The estimated peak depletion associated with the Category B groundwater takes is ~4 L/s. Thus, flow depletion resulting from abstraction is less than 10% of 7-day MALF, equating to a low degree of hydrological alteration.

Estimated maximum permitted activity water abstraction from the Wharemauku catchment is ~15 L/s (adapted from Nation, 2020).

4. Whareroa Stream

4.1 Hydrological setting

The Whareroa Stream catchment is located in foothills to the east of McKays Crossing, north of Paekakariki. The stream has two main branches that come together in Queen Elizabeth Park: one from a northern subcatchment in the vicinity of Waterfall Road, and one from a southern subcatchment within which Whareroa Farm regional park is located. The stream then traverses the coastal dune system within Queen Elizabeth Park to the sea. In its lower reach the stream gains flow from the unconfined sand aquifer.

4.2 Flow statistics

There are no continuous flow records for Whareroa Stream. Flow gauging has tended to focus on times of low flow and suggest a typical low flow of the southern (main) branch as it emerges from the foothills is around 10–20 L/s, increasing to 30–60 L/s at the stream mouth.

Estimated flow statistics from NIWA's *NZ River Maps* tool (Whitehead and Booker, 2020) for Whareroa Stream at its mouth are:

- Mean flow: 275 L/s
- Median flow: 150 L/s
- MALF: 55 L/s.

[6] Mean and median flow ranges are based on *NZ River Map* estimates presented within a 50 L/s range. MALF was estimated based on low flow gaugings but concurs with the MALF estimate in the *NZ River Map* tool.

4.3 Water allocation and abstraction

There is no specific allocation listed for Whareroa Stream in the PNRP, and hence the 'default' rule of 30% of 7-day MALF applies. Currently, there are no consented water takes directly from the stream. It is likely that groundwater abstraction from the Raumati groundwater zone results in some depletion of Whareroa Stream; however, the model provided does not give flow output for this stream. A similar magnitude of depletion estimated from Wharemauku Stream (4 L/s) is asssumed to occur from Whareroa Stream. Thus, estimated flow depletion resulting from abstraction is less than 10% of 7-day MALF, equating to a low degree of hydrological alteration.

Estimated maximum permitted activity water abstraction from the Whareroa catchment is ~8 L/s (adapted from Nation, 2020).

5. Wainui Stream

5.1 Hydrological setting

Wainui Stream rises on the western side of Mt Wainui and flows west to the coast at the northern end of Paekakariki. In its steep, upper reaches the stream is within regenerating native forest and exotic forestry. As the stream emerges from the hills it flows across the alluvial outwash fans and sand dunes to the sea; within this reach the land use is predominantly farmland and recreational park (Queen Elizabeth Park). A major tributary, Te Puka Stream, joins Wainui Stream on the coastal plain, at approximately the location where the stream crosses under the railway (downstream of State Highway 1).

Gauging data and anecdotal evidence suggest the stream loses considerable flow as it emerges from the hills, and upstream of State Highway 1 the streambed is often dry. While flow loss to groundwater is a natural occurrence in this catchment, there have been discussions in the past (and concerns from community groups) regarding the effect of a perched culvert at State Highway 1 on the ability of the stream to down-cut through the alluvial fan (Thompson, 2019). In its lower reach the stream gains flow from the unconfined sand aquifer.

5.2 Flow statistics

A continuous flow monitoring site was operated in Wainui Stream for a short period during 1998/99. However, there have been relatively few gaugings conducted in the Wainui catchment in recent years. Several concurrent gauging runs were carried out during 1998–2001, although interpretation of the results is complicated by operation of the KCDC water supply take for Paekakariki. The results suggest MALF is around 15 L/s at the site 'above KCDC intake' and 0 L/s at State Highway 1. Downstream of State Highway 1 the results are variable, with a large flow gain observed on some occasions and not on others.

Estimated flow statistics from NIWA's *NZ River Maps* tool (Whitehead and Booker, 2020), for Wainui Stream at its mouth are:

- Mean flow: 250 L/s
- Median flow: 140 L/s
- MALF: 40 L/s.

However, gauging data suggest these estimates may be slightly high.

5.3 Water allocation and abstraction

There is no specific allocation listed for Wainui Stream in the PNRP, and hence the 'default' rule of 30% of 7-day MALF applies.

While in the past KCDC sourced water for Paekākāriki town supply directly from the stream, the water supply take is now almost exclusively from two groundwater bores, with the surface take only used in emergency situations (and it is assumed that it is generally not utilised). The groundwater takes are not restricted according to low flows in Wainui Stream. Opus (2013) predicted that, with continuous year-round pumping (at an abstraction rate of 20 L/s), the groundwater take would result in > 99% of the pumping rate as streamflow depletion (i.e., depletion of 19.9 L/s). Although it is unlikely that continuous pumping would occur for this long, even with pumping reduced to 14 hours/day the depletion was predicted to be in the order of 12 L/s. Similarly, Thompson (2019) analysed of groundwater level data from the monitoring bore and concluded that the rapid response of water levels to rainfall events suggested a direct hydraulic connection between the supply aquifer and the surface. However, actual depletion effects of the groundwater take have not been confirmed. This should be further assessed, as the outcome could have a significant bearing on how the impact of the KCDC take on the stream values is viewed.

In addition to the town supply take, other groundwater abstraction from the Raumati groundwater zone will result in some depletion of Wainui Stream flow. A similar magnitude of depletion estimated from Wharemauku and Whareroa streams (4 L/s) is asssumed to occur from Wainui Stream.

The combined depletion from the water supply take and general consented groundwater use is therefore likely to be in the order of 15–20 L/s (perhaps as a worst-case scenario) and MALF at the stream mouth may be depleted by around 50%. This falls into the hydrological alteration category of 'high'.

Estimated maximum permitted activity water abstraction from the Wainui catchment is ~3 L/s (adapted from Nation, 2020).

Lowland streams

6. Te Kowhai Stream

6.1 Hydrological setting

Te Kowhai Stream (also known as Hadfield's Stream) flows from the steep hillsides inland from Peka Peka and heads westward across pastoral land to enter the sea through a small estuary, north of Peka Peka. The main source of flow to the stream is likely to be from highly modified drainage systems that were put in place to make the previously swampy land suitable for farming.

6.2 Flow statistics

There are no flow gaugings in Greater Wellington's database for Te Kowhai Stream. Estimated flow statistics from *NZ River Maps* for Te Kowhai Stream at its mouth are:

- Mean flow: 200 L/s
- Median flow: 130 L/s
- MALF: 40 L/s.

6.3 Water allocation and abstraction

There is no specific allocation listed for Wainui Stream in the PNRP, and hence the 'default' rule of 30% of 7-day MALF applies.

There are currently no consented surface water takes from the stream or its tributaries. Abstraction from the Te Horo groundwater zone (Category B) is modelled to result in a minor streamflow depletion (average annual peak depletion of ~2 L/s). Thus, hydrological alteration of Te Kowhai Stream as a result of consented abstraction falls into the category of 'low'.

Estimated maximum permitted activity water abstraction from the Peka Peka area – assumed to roughly equate to Te Kowhai Stream catchment – excluding groundwater use is ~25–30 L/s (adapted from Nation, 2020). However, given that many of the properties in this catchment are large the estimate is 'skewed' by the allowance under the pNRP Rule 136, and is likely to be higher than actual use at this time.

7. Mazengarb Stream

7.1 Hydrological setting

Mazengarb Stream flows from the steep, west-facing hills to the north of Paraparaumu and traverses Paraparaumu residential area before discharging to Waikanae River estuary. While receiving flow from the hillsides (in its upper reaches) and groundwater (in its lower reaches), the hydrological characteristics of the stream are dominated by the influence of residential stormwater – including direct stormwater discharges and those from stormwater attenuation ponds associated with subdivisions. The stream also receives treated wastewater from the Paraparaumu wastewater treatment plant, which comprises a significant portion of the flow in the stream in its lower reaches. The stream has a highly modified channel in its middle and lower reaches.

7.2 Flow statistics

Greater Wellington operated a continuous flow monitoring site on Mazengarb Stream from 1995 to 2015, at Scaife Drive (in its mid-reaches). Flows at the site were influenced by discharge from the upstream wastewater treatment plant discharge. If wastewater discharge records were to be obtained from Kāpiti Coast District Council the flow record could be naturalised to obtain detailed flow statistics; however, given the likely low need for hydrological data for the stream the exercise is probably not warranted.

Assuming a wastewater discharge in the order of 75–100 L/s during average to wet conditions and 30–40 L/s during dry periods, and some gain from groundwater in the lower reaches, estimated statistics for Mazengarb Stream at its mouth are[7]:

- Mean flow: 150 L/s
- Median flow: 100 L/s
- MALF: 30–40 L/s.

7.3 Water allocation and abstraction

There is no specific allocation listed for Mazengarb Stream in the PNRP, and hence the 'default' rule of 30% of 7-day MALF applies.

Currently, there are no consented water takes directly from the stream. However, it is likely that groundwater abstraction from the Waikanae groundwater zone results in some depletion of Mazengarb Stream in its lower reaches. Mazengarb Stream was not included as a stream output node in the groundwater modelling results provided but is assumed to be similar to that estimated for Waimeha Stream (Section 9.3), in the order of ~5% of naturalised MALF. However, the hydrological alteration resulting from other activities (i.e. wastewater discharge, stormwater discharge, artificial channelisation and catchment urbanisation) is extremely significant.

Maximum permitted activity use from the stream is estimated to be less than 5 L/s (Nation, 2020, based on estimate for 'Paraparaumu Beach').

[7] These estimates were derived by rough adjustment of the Scaife Road flow record and are similar to the *NZ River Maps* estimates for Mazengarb Stream.

8. Waimanu Stream

8.1 Hydrological setting

Waimanu Stream (sometimes known as Rahui Stream) is a small tributary of Ōtaki River. The stream is sourced from spring flow, supplemented by runoff from the foothills of the Tararua Range. The springs that feed the stream rise in a forested area toward the end of Rahui Road and are fed from a shallow groundwater system that receives inflow from Ōtaki River. Waimanu Stream is thus intricately connected with the river.

The stream flows for about 4 km across farmed river terraces and enters Ōtaki River via a small, man-made lagoon at Chrystalls Bend. The lagoon was formed during construction of flood protection works in the mid-1990s (Tonkin & Taylor, 2016).

8.2 Flow statistics

Greater Wellington do not operate a continuous flow recorder on Waimanu Stream. However, spot gaugings have been undertaken at several locations along the stream.

Available data indicate the stream tends to maintain a relatively consistent flow year-round and along its length, with no significant losses. The mean flow is estimated to be ~180 L/s; median flow is likely to be approximately equal.

Because continuous flow data have not been collected for the stream, detailed flow statistics cannot be presented. However, some work was recently done to estimate MALF based on a correlation with the Ōtaki River (Keenan, 2022). This resulted in a 7-day MALF estimate of 140 L/s for Waimanu Stream at the Ōtaki River confluence. This estimate assumes that the lagoon at Chrystalls Bend does not affect flow in the stream, i.e., outflow is approximately equal to the inflow.

8.3 Water allocation and abstraction

As a tributary of Ōtaki River, Waimanu Stream falls under allocation policies for the Ōtaki catchment in the PNRP.

There are currently five irrigation takes that source water directly from Waimanu Stream, with a combined take of 110 L/s. In addition, all groundwater in this area is classed as Ōtaki Category A groundwater and therefore all groundwater abstraction is assumed to have a direct impact on streamflows. There are two consented groundwater abstractions for stock water, with a combined take of 8 L/s. The total take (118 L/s) obviously represents a very high proportion of the estimated 7-day MALF (~85%) and falls into the category of ‘very high’ hydrological change. While it is possible that not all takes have operated concurrently, it is likely that a fair proportion of the streamflow has been taken in the past; gauging by Greater Wellington during very dry conditions in February 2015 measured a flow reduction of ~40% as a result of irrigation abstraction.

It should be noted that the irrigation consents have now expired and renewal applications are currently being considered by Greater Wellington, with options for take reductions

and appropriate minimum flow conditions being discussed with the applicants. The stock water takes may be classed as permitted activity usage in future.

The assessment of permitted water takes (Nation, 2020) did not differentiate Waimanu Stream from Ōtaki River. However, from a scan of GIS information showing well locations and property boundaries, it is likely that the two takes referred to above are the main stock/domestic takes; total permitted abstraction is therefore unlikely to exceed about 10 L/s.

9. Waimeha Stream

9.1 Hydrological setting

Historically, the Waikanae River split into two branches at the present-day Edgewater Reserve. The northern branch followed the present alignment of the Waimeha Stream and rejoined the southern branch at the Waimeha Lagoon. However, the northern branch is noted to have dried up sometime between the 1870s and 1890s (Easther, 1991). Nowadays, the Waimeha Stream rises from springs fed from the Q1 alluvial aquifer system of the Waikanae groundwater zone in the vicinity of Park Ave (Mzila et al., 2015) and also receives stormwater from parts of Waikanae urban area. While it once followed the course of the historic northern Waikanae River branch, in the 1920s it was diverted directly to the sea at Huiawa Street to allow urban development (Easther, 1991). The stream has one major tributary, Ngārara Stream, which flows out of Te Harakeke wetland and joins Waimeha Stream a short distance before it enters the sea.

9.2 Flow statistics

Hydrological data for Waimeha Stream consist of a short period of continuous flow record (2003–07) and relatively few ‘spot’ gaugings at several locations. The short flow record indicates that a fairly consistent flow occurs in Waimeha Stream – typical of spring-fed streams – with annual mean and median flows approximately equal. The lowest flows occur in March/April, reflecting the annual low in groundwater levels (Figure 4). While stormwater discharges can cause high peak flows following rainfall events, at other times the flow upstream of Ngārara Stream confluence is generally within the range 120–180 L/s. The record is not long enough to derive duration-based statistics, such as low flow duration and accrual periods. However, due to the spring-fed nature of the stream it is likely that the stream does not experience extended durations of extreme low flows. Estimated hydrological statistics for Waimeha catchment are:

- Mean flow: 160 L/s (Waimeha Stream upstream of Ngārara confluence)
- Median flow: 160 L/s (Waimeha Stream upstream of Ngārara confluence)
- MALF:
    - 120 L/s (Waimeha Stream upstream of Ngārara confluence)
    - ~30–50 L/s (Ngārara Stream at Waimeha confluence)
    - 150–170 L/s (Waimeha Stream at mouth).

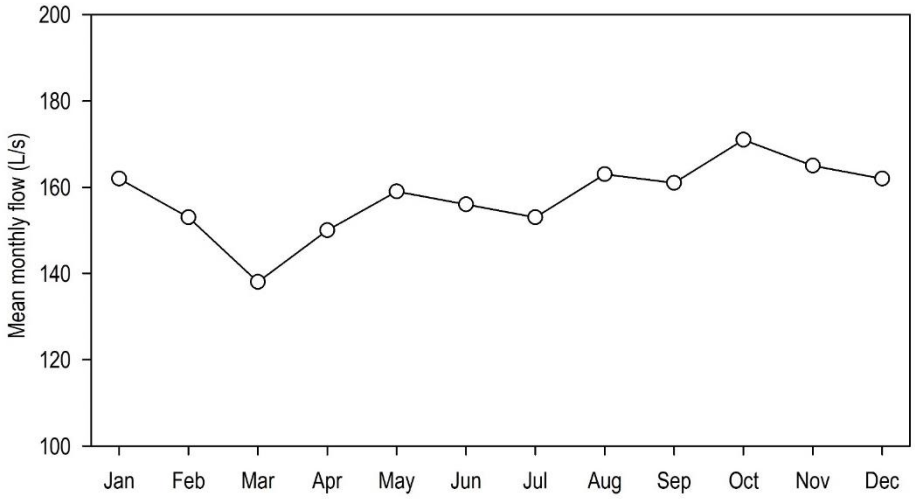

Figure 4 – Mean monthly flows – Waimeha Stream at Te Moana Rd upstream of Ngārara Stream confluence), 2003–2007

9.3 Water allocation and abstraction

There is no specific allocation listed for Waimeha Stream in the PNRP, and hence the 'default' rule of 30% of 7-day MALF applies.

There is one direct surface take from the stream, consisting of 15 L/s for golf club irrigation. Consented use of category B groundwater in the Waikanae groundwater zone is likely to result in some flow depletion of Waimeha Stream. The raw groundwater model output is of limited use for this stream, because modelled streamflow appears to be too low; however, assuming the modelled percentage reductions are realistic gives annual maximum depletions of typically ~4%. However, when the Waikanae borefield is in operation – which occurs over short durations – depletion of Waimeha Stream is likely to be higher: the groundwater model output suggests a reduction in flow of ~10% using pre-2011 abstraction, but borefield operation is likely to have increased over the last decade due to use of groundwater for Waikanae River recharge.

Based on the above findings, the depletion of Waimeha Stream resulting from consented abstraction (surface take plus cumulative groundwater depletion) is likely to be in the order of 20 L/s (borefield not in operation), which falls into the hydrological alteration category of 'moderate'. When the borefield is in operation the depletion will be highly dependent on pumping rate and duration and may require further assessment.

There is unlikely to be significant permitted activity abstraction from Waimeha Stream due to the highly urbanised catchment. However, estimated maximum permitted use from Ngārara Stream is 30–35 L/s. This includes the catchment area of the streams that feed into Te Harakeke wetland.

10. Stream flow trends and climate change

Trends and patterns in Kāpiti stream flows reflect sub-decadal scale climate modes (e.g., El Nino Southern Oscillation, Southern Annular Mode), longer term climate cycles (e.g., Interdecadal Pacific Oscillation) and human-induced climate change. Differentiating the effects of individual influences is thus very complicated.

For this memo, basic analysis of long-term trends in low flows and floods in Kāpiti streams was conducted using flow data for Waitohu Stream at Water Supply Intake and Mangaone Stream at Ratanui. However, it must be noted that these records are relatively short, both beginning in the mid- 1990s. More reliable and informative analysis of long-term hydrological trends should use some of the sites with longer records, e.g., Waikanae River at Water Treatment Plant or Tararua rainfall gauges.

The trend analysis conducted did not detect any significant trends in low flows – that is, magnitude of the annual 7-day flow minima and duration of the annual maxima low flow period – in the Waitohu and Mangaone catchments since records began the 1990s. However, at both sites, there was a 'cluster' of particularly low flows in the first decade of this century. This has also been noted in other parts of the Wellington region (e.g., Ruamahanga River; Keenan, 2021). Given the records for Waitohu and Mangaone streams only began in the late 1990s it is difficult to place the low flows of the early 2000s in the context of long-term variability without more detailed analysis of records for nearby rivers.

Similarly, no significant trends in annual flood magnitude or frequency were detected at the two sites; once again, the short nature of the record precludes any meaningful interpretations.

Current projections of climate change, using RCP 8.5, predict that the Kāpiti Coast will have up to a 10% increase in annual rainfall by the end of this century, with an increase occurring across all seasons (NIWA, 2017). However, the increase in rainfall largely reflects an increase in high intensity rainfall events. Thus, despite the overall increase in seasonal rainfall, mean annual low flow is projected to decrease in streams of the Kāpiti coast, in the order of 40% by the end of the century. Within the same time frame, an increase in the mean annual flood magnitude of 20–60% is expected for Kāpiti streams (Greater Wellington, 2020). A hotter climate – particularly with higher temperatures in autumn (when average temperature is projected to increase by up to 3.25°) – will no doubt lead to an increase in demand for water from Kāpiti streams and groundwater systems. The information presented in this memo regarding interactions between streams flows and groundwater systems, and impacts of groundwater abstraction on stream flows, highlights the importance of conjunctive water management.

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