IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of Proposed Plan Change 9 to the Bay of Plenty Regional Natural Resources Plan
AND	submissions and further submissions by Trustpower Limited

STATEMENT OF EVIDENCE OF PETER LILLEY

1. Introduction

1.1. My name is Peter Bryan Lilley. I am an independent consultant providing services in water planning, management and optimisation.

1.2. Prior to April 2017 I was Trustpower Limited's ("**Trustpower**") Acting Generation Manager, a position that had overall responsivity for the organisations generation assets, including their performance and safe operation. Prior to this position, I was employed as the Generation Strategy Manager, for the optimisation and enhancement of Trustpower's existing hydro-electric generation assets and the development of new schemes.

1.3. I hold the qualification of Bachelor of Engineering (Civil) from the University of Auckland (1989) specialising in the areas of catchment hydrology, river hydraulics and water resource engineering. I am a member of the International Water Resources Associate (IWRA) and New Zealand Society of Large Dams of which I am the immediate past chair.

1.4. Prior to joining TrustPower in June 2000, I was an Associate of Riley Consultants Ltd, a firm comprising specialist Water Resources and Geotechnical engineering consultants.

My experience over this time consisted of safety evaluations of dam and associated structures, hydrological analysis and scheme optimisation and enhancement investigations.

1.5. I have prepared the following statement of evidence in support of the submission and further submissions made by Trustpower on Plan Change 9 (PC9) to the Bay of Plenty Regional Natural Resources Water Plan.

1.6. While this hearing is not before the Environment Court, I have read the Code of Conduct provided within the Environment Court's Practice Notes for Expert Witnesses and agree to comply with it.

2. Scope of Evidence

2.1. The submission and further submissions by Trustpower on PC9 raises concerns around the potential impact of new water takes on other authorised users. In particular, I understand that the submission seeks to ensure that PC9 establishes an appropriate framework for the protection of the existing allocations for hydro-electricity generation schemes and ensure the potential for cumulative effects is considered in decision-making on water takes and allocation frameworks. I also understand that other submitters are seeking that PC9 reduce the level of protection afforded to the existing hydro-electricity generation schemes.

2.2. As such, in this brief of evidence I discuss:

(a) The hydrology of the Rangitaiki and Wairoa Catchments.

(b) The operation of Trustpower's hydro-electricity generation schemes within these catchments.

(c) How these hydro-electricity schemes integrate within the hydrology of the river systems.

(d) The impact upstream use and storage has on hydro-electric operations,

(e) The use of transfer mechanisms in facilitating improved water management.

3. Hydrology

Rangitaiki Catchment

3.1. The Rangitaiki River has a total catchment area of 3,005 km^2. The catchment land use is approximately 21% pasture, 50% exotic forest and 29% native forest or scrub.[1] The main features relevant to hydrology are presented on **Figure 1**.

3.2. The catchment is dominated by two distinct geological zones, which influence catchment hydrology. Greywacke to the east is poor at absorbing rainfall resulting in more rapid and direct response to rainfall but with correspondingly low base flow. The largest catchment to the east is the Whirinaki River, which covers a catchment area of approximately 530 km^2 (18% of total catchment area). The ash and pumice geology in the larger western portion of the catchment is better at absorbing rainfall. This yields a lower and slower direct response to rainfall but a more sustained base flow to the Rangitaiki River.

3.3. The key hydrological statistics for the catchment are provided in **Table 1** below. The different catchment geology is highlighted by the flow statistics. The Seven Day Mean Annual Low Flow (7DMALF) and the 1 in 5 Seven Day Mean Annual Low Flow (Q5 7DMALF) in the Whirinaki River are much lower relative to mean flow, than for the Rangitaiki River at Murupara. The Rangitaiki River at Te Teko amalgamates these geological influences on hydrology.

[1] Beca 2009.

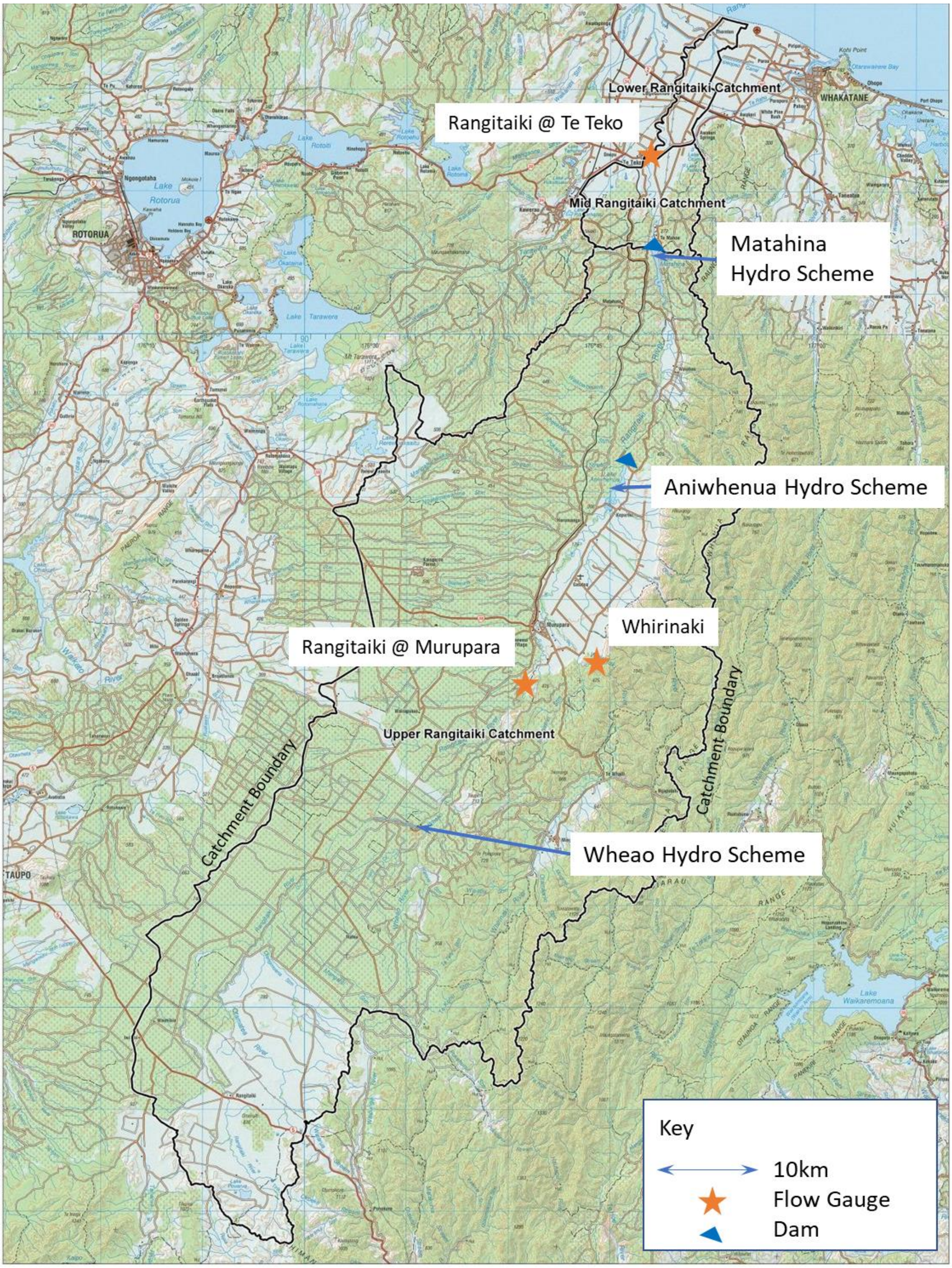


Figure 1: Rangitaiki Catchment

Site ***(Ref Figure 1)***	**Catchment Area** km^2 & % of total area		**Mean flow** m^3/s	**7DMALF** m^3/s	**Q5 7DMALF** m^3/s
Whirinaki	530	18%	14.9	4.8	4.1
Rangitaiki @ Murupara	1180	39%	21.4	14.6	12.9
Rangitaiki @ Te Teko	2890	96%	70.5	41.9	38.4

Table 1: Key hydrological statistics for the Rangitaiki River catchment

3.4. There are three hydro-electric schemes on the Rangitaiki River. The Wheao Hydro Scheme is the most upstream scheme, located approximately 125km from the river mouth. It is a run-of-river scheme that has minimal effect on downstream flows beyond some daily regulation. It is a “diversion” scheme, that draws on a combined catchment area of approximately 775 km^2 (26% of total catchment). It takes water from the Wheao and Rangitaiki Rivers via intake and diversion systems to supply the two stations within the scheme. The Rangitaiki River @ Murupara river flow site is the most representative site for this station with the catchment feeding the station being 65% of that of the gauge.

3.5. The Aniwhenua Hydro Scheme, owned by Southern Generation Limited Partnership, is approximately 65 km upstream from the river mouth, with approximately 75% of the total catchment area upstream. Aniwhenua has a small reservoir in terms of river flow and operates as a run of river scheme with some daily regulation of flows. The scheme is a “diversion” scheme with flow conveyed via canal to the station approximately 4km downstream from the point it was diverted. The combined flow at the Whirinaki and Rangitaiki River @ Murupara represents 70% of the catchment area feeding the Aniwhenua Scheme.

3.6. The Matahina Hydro Scheme is the lower most scheme, located approximately 37km from the river mouth and has 2,844 km^2 (95%) of the catchment upstream. The station is an “in-river” scheme with flow drawn from the reservoir for generation purposes and returned to the river immediately downstream. The catchment area feeding the station is over 98% of that recorded at the Rangitaiki River @ Te Teko river flow site. This site is therefore representative of flow volumes entering, and leaving, the Matahina Dam.

3.7. The Te Teko site, being representative of the majority of the catchment, is useful in assessing long term hydrological change in the Rangitaiki River catchment. An examination of the time the river spends in low flow is important in understanding the potential impact over time of water use, particularly consumptive use. The portion of time the river flow is below the Q5 7DMALF (being 38.4m^3/s) is provided in **Figure 2** below, presented as a rolling average over the preceding 10 years.

3.8. While the Te Teko site is below the Matahina Dam, and as such subject to alterations in flow induced by the scheme, conditions of consent imposed on the scheme during low flow mean the scheme will not influence these figures (i.e. there is a requirement to match outflows with inflows).

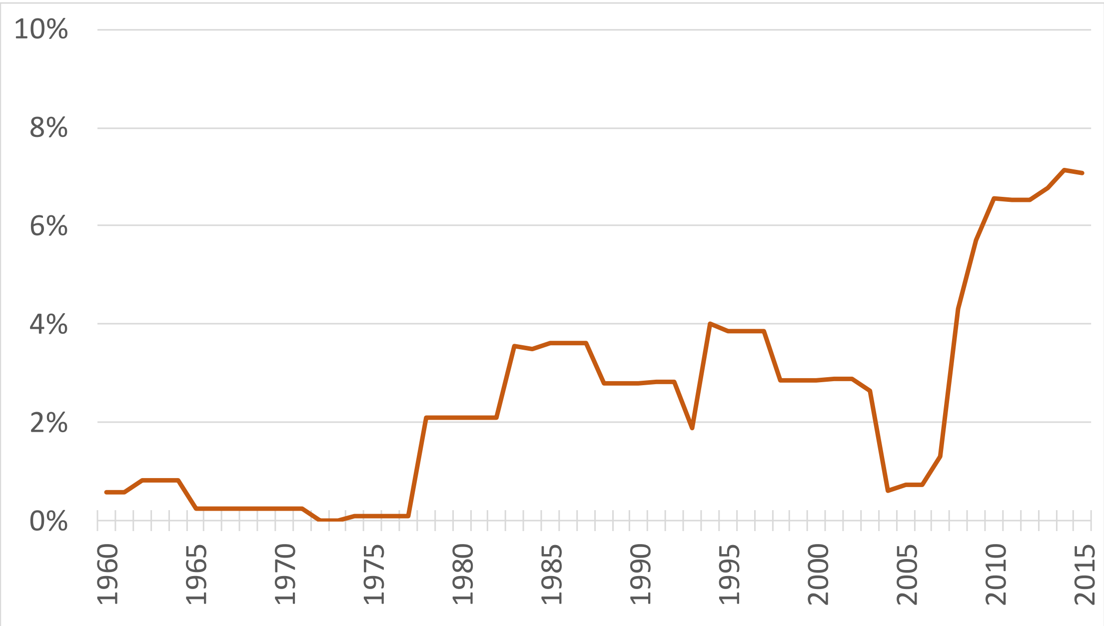


Figure 2: Proportion of time Te Teko flows is below the Q5 7DMALF

3.9. This analysis shows that low flow conditions have become more prevalent over recent times. While this may not indicate a definitive change or trend in catchment yield, it does highlight the need for careful consideration of the impacts of additional water use over time, particularly in the context of natural variability within the catchment.

3.10. The reservoir formed by the Matahina Dam has a normal operating storage of 6.6 million m^3 of storage, a little over one day of storage at the mean inflow rate of 70.5 m^3/s. This provides daily and some weekly regulation of inflows to match energy demand. In addition, there is further storage outside of the normal operating range, utilised during flood conditions.

3.11. Flow downstream of Matahina Dam is influenced by the scheme operating in response to energy demand with this influence attenuating somewhat with distance below the dam. At the river mouth, tidal level dominates the water level in the river, with this extending upstream as far as the fault line, about 4 km upstream of Edgecumbe.

Wairoa Catchment

3.12. The Kaimai Hydro Scheme is located within the Wairoa River catchment. The catchment has a total area of approximately 425 km^2. The catchment predominantly drains toward the north from the Mamaku Ignimbrite plateau to the south which was formed from eruptions of Lake Rotorua some 140,000 years ago. This geology influences hydrology as it absorbs significant portions of rainfall that falls on the catchment, in turn producing strong and sustained base flows. The main catchment features relevant to hydrology are provided on **Figure 3**.

3.13. A portion of the catchment (approximately 25%) drains from the Kaimai Ranges to the west and lies on Minden Rhyolites. These exhibit higher direct flow response to rainfall and hence flood response, and in turn less absorption with corresponding lower base flows. The lower most portion of the catchment (approximately 15%) lies on a mixture of Rhyolite and estuarine deposits.

3.14. Defining the key hydrological statistics for the Wairoa Catchment is complex. The catchment consists of numerous sub catchments most of which have no recorded flow data. Where data does exist the length of record available is modest (typically < 25 years). The hydro-electric scheme consists of many diversion, dams and generation facilities. This means flow in most parts of the catchment are modified by station operations.

3.15. Where they can be defined, the key hydrological statistics for the catchment are provided in **Table 2** below. The catchment areas shown include the areas diverted by the Kaimai Hydro Scheme, rather than the natural catchment area upstream of each location. This will reduce the mean flow derived as the flood portion of the flow is not included due to the capacity constraint of the diversions. This impacts the figures for the Mangapapa River @ Dam location most as 75% of the catchment supplying this site is diverted. For the Wairoa River @ Ruahihi, 90% of the catchment would naturally flow past this point anyway. The low flow figures are not impacted in the same way as the exclusion of flood flows do not influence the low flows.

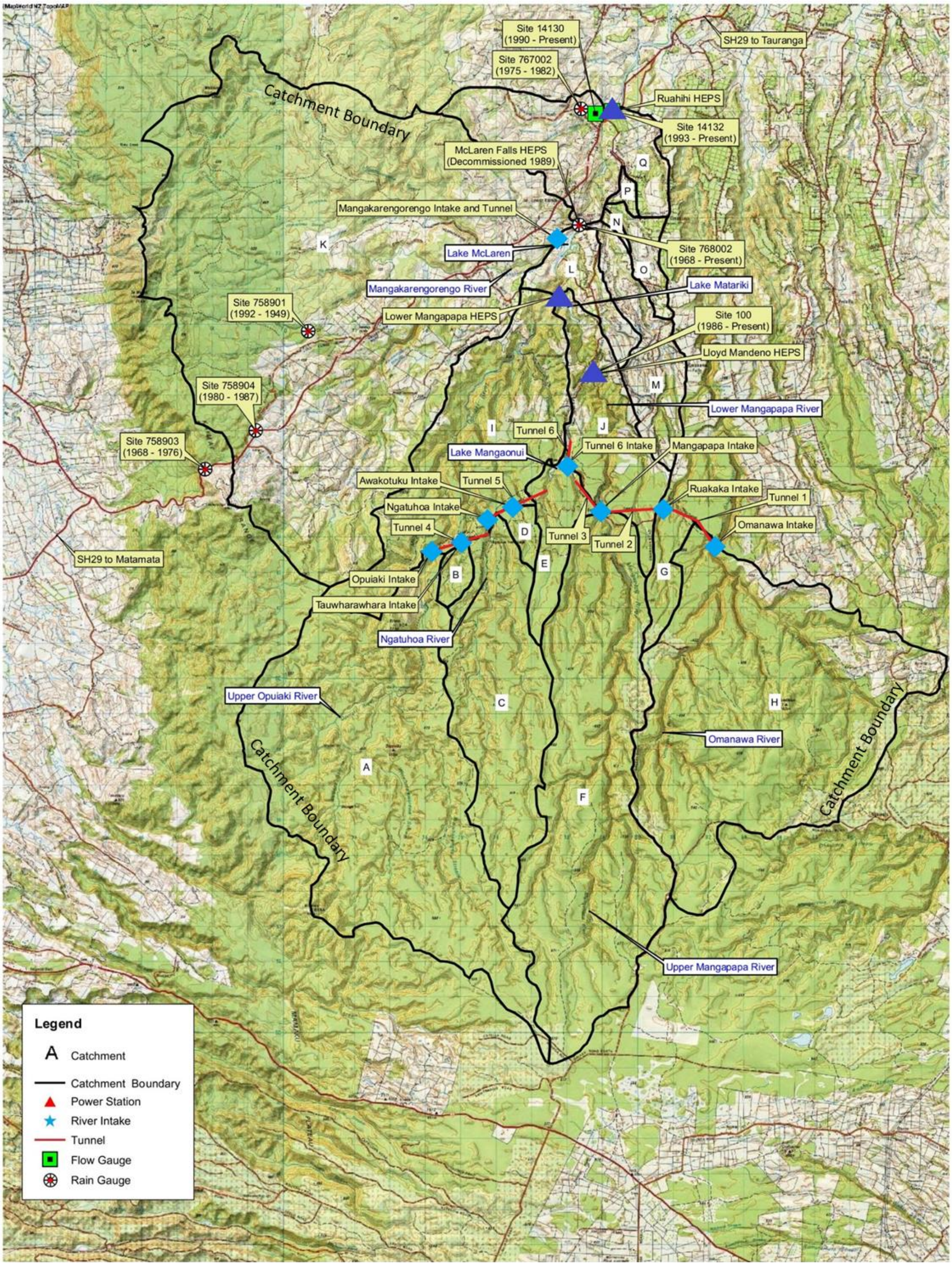


Figure 3: Wairoa Catchment

Site *(Ref Figure 3)*	**Catchment Area** km^2 & % of total area		**Mean flow** m^3/s	**7DMALF** m^3/s	**Q5 7DMALF** m^3/s
Mangapapa @ Dam[(i)]	218	51%	7.4	4.8	4.2
Wairoa below Ruahihi[(ii)]	347	82%	16.5	7.6	6.1

(i) Derived from Lower Mangapapa Power Station Flow.

(ii) Derived by adding gauged river flow above Ruahihi Power Station to Station discharge

Table 2: Key hydrological statistics for the Wairoa River catchment

3.16. The figures highlight the comparatively high low flows, compared to the mean flow, reflecting the geology of the catchment.

3.17. The Kaimai Hydro Scheme is located within the catchment and consists of a cascade of generation stations. The scheme progressively combines, through a series of intake works and diversion systems, several of the upper tributaries of the Wairoa River. Along the way the flow passes through three modest sized storage reservoirs. These modify flows within the river system both through diversion of flows and regulation of flow releases for generation. The use of the storages to regulate flow for generation is primarily within the day. All the storages are small with little capacity to store and release water beyond a day.

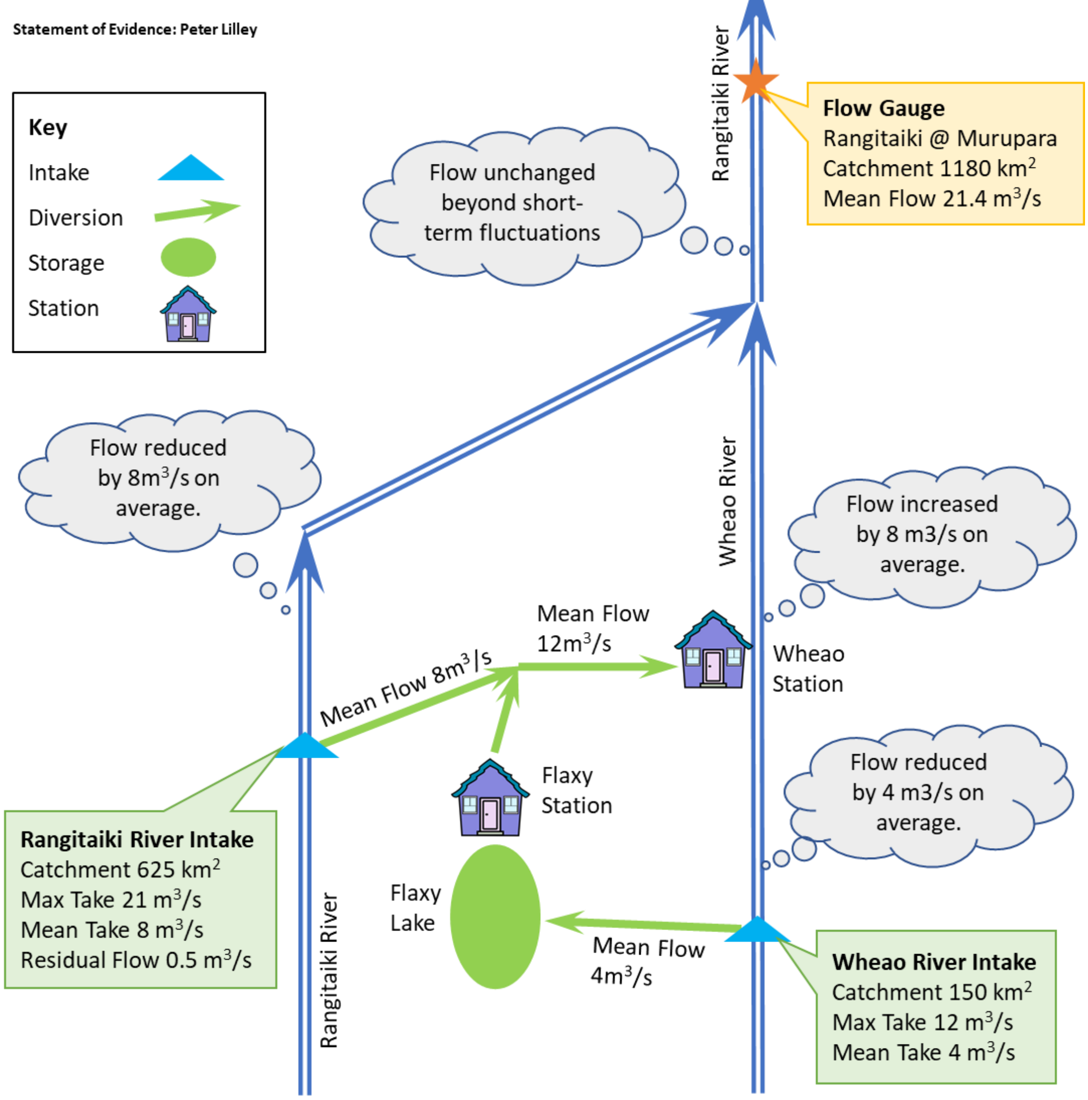
3.18. Flow in the Wairoa River downstream of the scheme is influenced by generation discharges which varies to meet energy demand. This typically means rise and falls in flow on a twice daily basis but flow changes can occur at any time. There are also flow releases from Lake McLaren for recreational purpose. These occur on 26 days per year, predominantly over the summer season.

4. Scheme Operation

Wheao Hydro Scheme

4.1. The operation of the Wheao Scheme is primarily defined through its resource consents, particularly those related to the maximum rate of abstraction from the river, and, minimum and maximum discharge rates from the Wheao Power Station. A schematic of the scheme is provided in Figure 4.

Figure 4: Schematic, Wheao Hydro Scheme



4.2. Water is supplied to the Wheao Hydro Scheme via two river intakes. The Wheao River intake supplies on average approximately $4m^3/s$ (one third of the scheme inflow) from a catchment area of approximately 150 km^2. The maximum rate of diversion, permitted by the resource consents is $12m^3/s$, which is only exceeded by river flow approximately 2% of the time. The Rangitaiki River intake provides the larger portion of scheme inflow at approximately $8m^3/s$, (two thirds of scheme inflow) from a catchment area of 625 km^2. The maximum rate of diversion, permitted by resource consent is $21m^3/s$ which is only exceeded by river flow less than 1% of the time. The Rangitaiki River intake has residual flow requirement of 0.5 m^3/s.

4.3. Because river flow seldom exceeds the capacity of the intakes, apart from residual flow, the scheme utilises the vast majority of yield from the catchments. Any consumptive use upstream of the intakes, except during high flow events, will directly impact on the volume of energy produced by the scheme.

4.4. Flow diverted from the Wheao River is conveyed in to a small Flaxy Storage reservoir which provides a modest level of daily regulation for the smaller portion of scheme inflow. Flow diverted from the Rangitaiki River enters the 4.7km long Rangitaiki Canal and has no measurable storage capacity or corresponding flow regulation.

4.5. Water drawn from the Flaxy Storage passes through the small Flaxy Power Station (2.1MW), before discharging in to the Rangitaiki Canal to combine with the flow diverted from the Rangitaiki River. The combined flow then feeds the larger Wheao Power Station (24MW), before discharging to the Wheao River. Flow, and hence generation, from the Wheao Power Station is only regulated using the Flaxy Storage as the flow from the Rangitaiki diversion is unregulated.

4.6. Below the Wheao River intake the flow is reduced for approximately 6.9km, by the amount diverted, before the discharge from the Wheao Power Station re-joins the river. Below the Wheao Power Station the river is increased, by the amount diverted at the Rangitaiki intake, until the Wheao River joins the Rangitaiki River approx. 12.3km downstream of the Wheao Power Station. Similarly, the Rangitaiki River flows are reduced below the Rangitaiki River intake for approximately 17.8km, by the same amount, before reaching the confluence with the Wheao River.

4.7. Discharge from the Wheao Station, back to the Wheao River, is controlled by resource consent with a minimum discharge of 6 m^3/s unless flow naturally falls below or a fault occurs at the station, and a maximum of $24m^3/s$.

Matahina Hydro Scheme

4.8. The Matahina Scheme (80MW) is the largest hydro-electric power scheme in the Bay of Plenty Region. The scheme is operated within limits imposed by many resource consent conditions. These determine, amongst other things, how quickly the station can respond to changes in energy demand (ramping), limits on maximum and minimum generation and use of the reservoir. These form the primary controls within which the scheme operates.

4.9. The maximum take for generation defined by resource consent is $160m^3/s$, approximately 2 ½ times the median flow in the river. While there are additional consent conditions applying constraints during periods of low flow, the limit of 160m $^3/s$ effectively defines the portion of river flow that can be utilised by the scheme. When inflow exceeds $160m^3/s$ the portion above $160m^3/s$ cannot be directly used for generation, although at times it may still be able to be captured by the reservoir for later use.

4.10. Inflow to Lake Matahina only exceeds $160m^3/s$ 1.5% of the time. This means for over 98% of the time any consumptive use of surface water upstream of the scheme will directly reduce the useable flow entering the lake and hence impact the volume of energy produced by the scheme. Approximately 1% of the annual volumetric yield for the river is from flow above 160 m^3/s, however this will vary significantly from year to year due to the size and frequency of flood events.

4.11. Within the limits imposed by resource consent conditions the scheme operates to match energy production to electricity market demand. The scheme was built as a peaking station, providing an important role in balancing local energy production against demand. The storage within the reservoir is the storage “battery” that facilitates generation flexibility. When demand for energy is less, within resource consent limits, inflow can be stored for periods of higher energy demand.

4.12. While the make-up of energy production in New Zealand has evolved over time, the need for peaking capacity remains. In recent years the progressive increase in wind and solar generation introduces greater volatility in energy supply as these are uncontrolled forms of energy production. This needs to be balanced by flexible and controllable generation. This is primarily provided in New Zealand through hydro-electricity.

4.13. As noted earlier the storage available in the reservoir provides daily and some weekly regulation of inflows to match energy demand. When inflows are low use of the storage is constrained by resource consent conditions to match outflow equal to inflow. Under these conditions no peaking is available.

Kaimai Hydro Scheme

4.14. The Kaimai Hydro Scheme operates under resource consents that are the primary controls on how the scheme operates. While consisting of three large and one small station, the scheme is operated as an integrated peaking generation facility feeding directly in to the Tauranga electricity supply. The flexibility provided by multiple stations and storage reservoirs, combined with the strong base flows produced by the majority of the catchment, makes the scheme very reliable at meeting energy demand. A schematic for the scheme is provided in Figure 5.

Figure 5: Schematic, Kaimai Hydro Scheme

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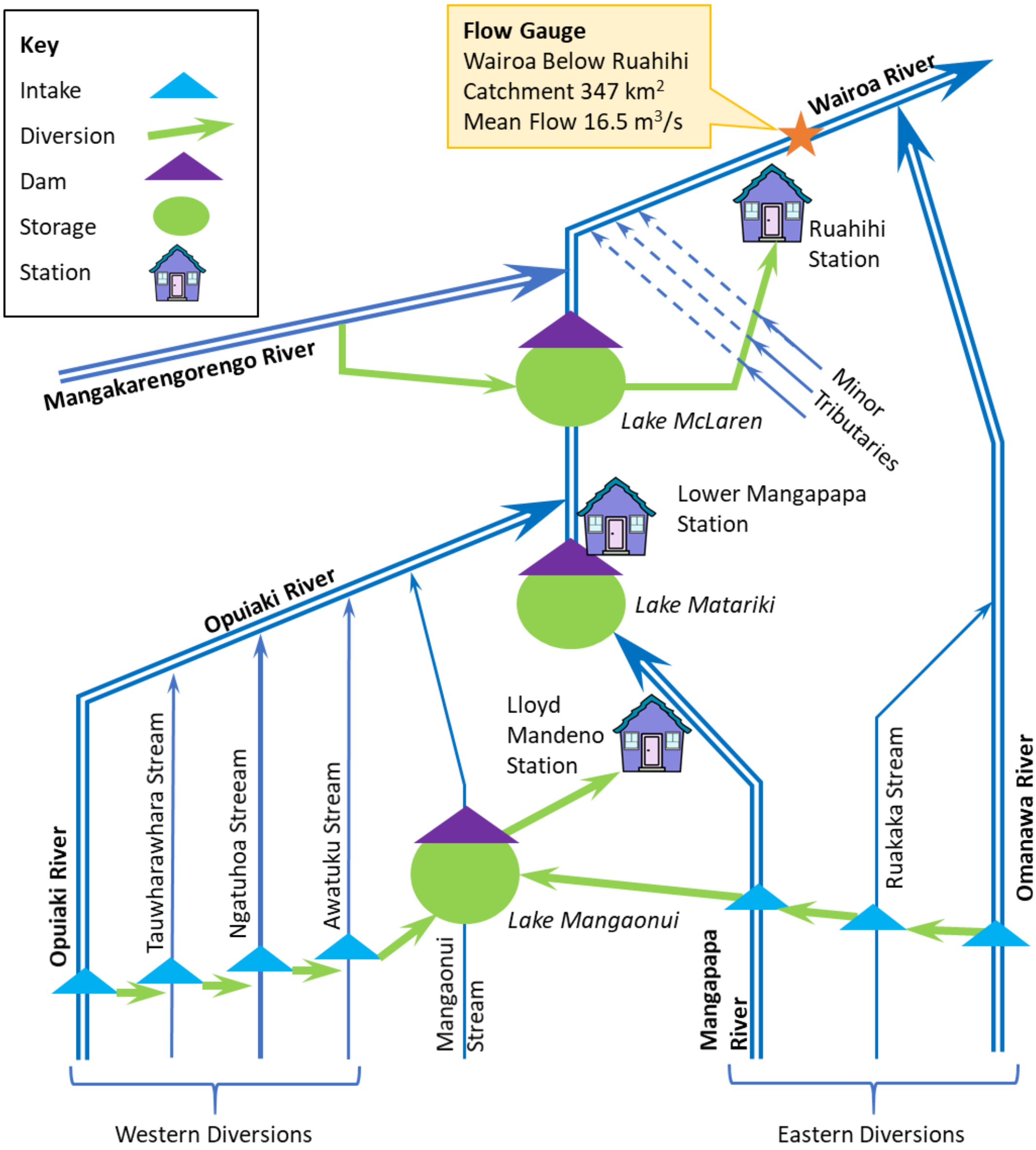

Lloyd Mandeno Power Station

4.15. The upper most main station, Lloyd Mandeno (16MW) is a "diversion" scheme and includes eight of the nine river intakes and associated diversion systems utilised by the overall Kaimai Scheme. The diversions are provided in the **Table 3** below. These diversions supply; via a combination of canals, pipelines and tunnels, Lake Mangaonui the largest and uppermost storage in the scheme.

	Diversion (West to East)	Contributing Area (km^2)(i)	Tributary of;	Max Diversion (m^3/s)(ii)
Western Diversions	Opuiaki River	54.7		8.50
	Tauwharawhara Stream	1.3	Opuiaki	0.283
	Ngatuhoa Stream	21.0	Opuiaki	14.2(ii)
	Awatuku Stream	1.3	Opuiaki	0.425
Lake Catchment	Mangaonui Stream	4.7	Opuiaki	
Eastern Diversions	Mangapapa River	44.5		14.2(iv)
	Ruakaka Stream	3.3	Omanawa	0.283
	Omanawa River	51.1		7.79

Table Notes

(i) Kaimai HEPS Flood Review, OPUS, 2016.

(ii) Max Diversion at each intake as defined by resource consent.

(iii) The max consent limit on diversion of $14.2m^3/s$ from the Ngatuhoa Stream includes the combined diversions from the Opuiaki River and Tauwharawhara Stream. This implies a limit of $5.42m^3/s$ from Ngatuhoa Stream.

(iv) The max consent limit on diversion of $14.2m^3/s$ from the Mangapapa River includes the combined diversions from the Omanawa River and Ruakaka Stream. This implies a limit of $5.42m^3/s$ from Mangapapa.

Table 3: Diversions to Lloyd Mandeno Power Station

4.16. Also provided in Table 3 is the maximum diversion permitted at each intake as defined be resource consent. As noted in the table footnotes the max diversion defined by the source consents are not simply cumulative as the Western and Eastern diversion operate in sequence.

4.17. Lake Mangaonui has a total contributing catchment of 182 km2, (43% of the Wairoa Catchment) of which only 4.7 km2 is from its natural catchment, the rest being derived from the diversions. The small micro-hydro “K5” (0.3MW) is installed on the combined outlet from the four western most diversions.

4.18. Because nearly all of inflow to Lake Mangaonui is derived from diversions, inflow is largely truncated by the capacity of the diversion. Flow exceeding the diversion capacity (e.g. during flood events) spills past the intake weirs and remains in the rivers. Apart from the Omanawa River and Ruakaka Stream intakes, any spill past the intakes will, while bypassing the Lloyd Mandeno scheme, will still contribute to flow in to one or both of the lower stations.

4.19. Lake Mangaonui is utilised to provide daily and some weekly regulation of flow through the three stations downstream to match energy production against demand. Lake Mangaonui, via tunnel and canal, directly feeds the Lloyd Mandeno Hydro Electric Power Station which in turn discharges to the Mangapapa River and the downstream Lake Matariki.

Lower Mangapapa Power Station

4.20. Lake Matariki, is formed within the Mangapapa River behind the Lower Mangapapa Dam located 0.8km upstream of the confluence with the Opuiaki River. Inflow to Lake Matariki is derived from;

a) discharge from the Lloyd Mandeno Station, plus

b) flow from the 10.8 km^2 of catchment located downstream of the Mangapapa River intake that diverts flow to Lake Mangaonui , plus

c) flow not diverted at the Mangapapa River intake which includes;

   I. residual flow provisions at the Mangapapa River intake, and

   II. any flood flow that exceeds the diversion capacity of the Mangapapa River intake.

4.21. Lake Matariki supplies the smallest of the three main stations, the Lower Mangapapa Hydro-electric Power Station (5.6MW). The power station is located only a short distance downstream (approximately 0.6km) of the dam and hence is considered an “in river” scheme. Lake Matariki receives, and spills, flood flows derived from the Mangapapa River, including from the 44.5 km^2 upstream of the diversion.

4.22. Immediately downstream of the Lower Mangapapa Power Station the Opuiaki River joins the Mangapapa River. The flow from the Opuiaki River at this confluence consists of;

a) flow from the 25.8km^2 of additional catchment downstream of the 5 diversion intakes (four western plus Lake Mangaonui) located within its upper Opuiaki River catchment plus,

b) flow not diverted at the four western intakes (Opuiaki River, Tauwharawhara Stream, Ngatuhoa Stream & Awatuku Stream) including from;

I. residual flow provisions at these diversions, and

II. any flood flow that exceeds the diversion capacities of the four western diversions.

4.23. Theses flows join discharge from the Lower Mangapapa Hydro-electric Power Station (including spill) before entering Lake McLaren.

Ruahihi Power Station

4.24. Lake McLaren, formed behind the McLarens Falls dam, is the lowest storage in the scheme and is located 0.3km upstream of the Mangakarengorengo River confluence. The combined flow described above enters Lake McLaren and is augmented by the ninth and final diversion within the scheme, from the adjacent Mangakarengorengo River.

4.25. Water is drawn from Lake McLaren in to the Ruahihi Canal that in turn feeds the final, and largest station in the scheme, the Ruahihi Power Station (20MW). Lake McLaren provides only modest daily regulation of flow for generation purposes but is utilised in conjunction with the other two lakes to provided daily regulation of generation flow.

4.26. Inflow to Lake McLaren that exceeds the capacity of the Ruahihi Canal spills over the McLarens Falls dam back in to the river. This combines with residual flow provisions and any flood flow that exceeds the diversion capacity at the Mangakarengorengo

River diversion to form the flow in the Wairoa River below the Mangakarengorengo confluence.

4.27. The flow in the Wairoa River is augmented by inflow from an additional 15 km^2 of catchment downstream of the Mangakarengorengo confluence and above the Ruahihi Power Station located approximately 4km downstream. Three small tributaries of the Wairoa River that join the Wairoa river over this reach are truncated by the Ruahihi Canal with their flow joining the canal flow. These comprise a total area of 10.3 km^2. Any spill flow from the Ruahihi Canal, typically derived from these small tributaries, is returned to the Wairoa River within this reach.

4.28. Below the Ruahihi Power Station, discharge the river flow is largely reflective of the natural upstream catchment apart from the flow diverted from the Omanawa River and Ruakaka Stream. These flows would not naturally be within the Wairoa River reach downstream of the station until the Omanawa River confluence approximately 2.9km further downstream.

4.29. Because of the complexity of the scheme it is difficult to accurately define how much catchment yield is effectively captured by each intake and conversely how much is spilled. Examination of the storages within the catchment, and in particular the storage levels, do indicate how effective the scheme is at capturing flow. Lake McLaren, the lowermost lake only spills a little over 2% of the time. Similarly, Lake Matariki spills less than 2% of the time. Finally, Lake Mangaonui at the top of the scheme almost never spills although this is largely due to it being supplied almost entirely by diverted flows that do not contain flood flows.

4.30. The storage level data confirms that the scheme is very effective at capturing and utilising the vast majority of catchment yield. Any consumptive use upstream of one or more of the stations, unless only occurring at times of flood, will therefore reduce the energy generated from the scheme.

5. Impact of New Upstream Use

5.1. I understand that some submitters oppose the provisions in PC9 (particularly WQ O2 and WQ P19) that are designed to maintain the renewable energy derived from hydro-electricity schemes within the region. However, I note that any flow utilised upstream of a hydro-electricity facility has the potential to impact on that facilities operation. There are three main considerations in how significant this impact may be.

a) Is the upstream use consumptive or non-consumptive?

b) Is it continuous, or variable over time?

c) Is there a resulting temporal change in flow patterns downstream?

5.2. These considerations are discussed below. It is important to note that the impacts from each can be cumulative. This is particularly relevant where numerous individual takes are for the same or similar use (for example water use in dairy shed operations). While individually these takes may be small, in a temporal sense they will all largely operate at the same or similar times. In terms of hydrological impact on a downstream hydro-electric station therefore, they can be considered as one large use.

5.3. While it is understood that different magnitudes of water take are assigned different activity status, again from a hydrological view point this is irrelevant. It is the cumulative impact of all takes and whether they are consumptive or not, that defines the impact on downstream users.

Consumptive vs Non-Consumptive Use

5.4. Consumptive use reduces the flow in the river and hence will almost certainly impact on a hydro scheme downstream. The most common examples of consumptive use in the catchments in which Trustpower operates assets are associated with agricultural and horticultural operations, including irrigation use.

5.5. Consumptive uses will reduce energy production largely on a pro-rated basis (e.g. if 10% of flow is consumed then generation will reduce by 10%). It has been highlighted in the previous section that the three hydro schemes operated by Trustpower in the region all utilise very high portions of the available yield in their respective catchments. River flows seldom exceed the station capacities and as such little spill occurs. Unless any upstream consumptive uses are limited to only operating during infrequent and unpredictable flood events, they will impact on the energy produced by the downstream hydro-electric scheme.

5.6. In addition, consumptive uses will influence how the generation facility can operate to meet its resource consents obligations. Where a hydro scheme has residual or minimum flow criteria these must be met first before flow is utilised for flexible generation. For example, at the Matahina Hydro Scheme over 50% of catchment yield passes directly through the station to satisfy residual flow requirements leaving less than half the catchment yield available for flexible generation. Any flow consumed upstream therefore can reduce this flexible portion compromising the ability for the station to match energy supply to demand. Further, if the upstream use is not subjected to similar minimum flow constraints there is an increase probability that the generation facility is unable to meet its own minimum flow obligations.

5.7. For example, upstream of the Matahina Dam there is approximately $2m^3/s$ of consumptive use associated with irrigation, predominantly of pasture. The Matahina Hydro Scheme is required to maintain a flow at Te Teko greater than $35m^3/s$ unless, inflow falls below $35m^3/s$. I understand that few, if any, of the upstream irrigation takes have minimum flow cut-offs and given that demand for irrigation typically coincides with lower river flow, these will impact on the portion of time river flow approaches the $35m^3/s$ trigger at Te Teko. Examination of the flow data at Te Teko indicates that $2m^3/s$ of consumptive take upstream, unless controlled by appropriate low flow constraints, more than doubles the time that the river could be anticipated to fall below $35m^3/s$ at Te Teko from 3 days per annum on average to over 6 days per annum.

5.8. In comparison, non-consumptive use is unlikely to measurably impact on the volume of flow available for generation unless, as discussed below, variability or temporal aspects make flow less available for use at a downstream facility.

Continuous vs Variable Use

5.9. For a given volume of use, whether abstracted at a continuous and constant or variable rate, will influence the impact it has on hydro-electric operations downstream. A constant and continuous use, if consumptive, will impact the entire flow range utilised for generation operations, including the potential to impact on low flow constraints. However, if non-consumptive, the impact of a constant take is unlikely to be measurable. There are few examples of continuous and constant takes in any of the catchments in which Trustpower operates assets. The closest example is probably the small town-water supply from Lake Matahina for the Te Mahoe village below the dam.

5.10. A variable rate of use will have lesser or greater impact depending on how it occurs within the hydrological regime of the river. Beyond the direct impact of the reduced flow volume available that arises from consumptive use, variability in the timing of use will have a similar potential impact if consumptive or non-consumptive.

5.11. If the variability in use arises from it being a function of the natural river flow, then the impact is likely to be more subdued as abstraction will reduce as river flow reduces. For example; irrigation takes are inherently variable over any given year and between years. If a given irrigation take is controlled through criteria relating to the flow of the river, and not just a maximum limit, then the take should have a lesser impact on other users.

5.12. If however, as is more typical, variability is simply a function of irrigation demand, and that demand is not transparent to a downstream hydro-electric facility, managing generation is more challenging as the inflow to the hydro station becomes less predictable. To ensure compliance with resource consents, the station is likely to need to be operated more conservatively to mitigate the increased uncertainty in inflow. This in turn reduces the ability to match energy supply to demand.

5.13. For example, the Aniwhenua Hydro Scheme influences inflow to Lake Matahina increasing short-term (typically intra-day) variability but does not impact on total volume or the way river flow natural falls away over time in the absence of rain. In comparison irrigation abstractions can induce unpredictable step changes in the river flow for periods of days to several weeks depending on irrigation demand.

Temporal Changes

5.14. Temporal changes predominantly arise from non-consumptive use that involves storage. Hydro-electric schemes often have this impact as noted about the Aniwhenua Hydro Scheme in the previous example. Temporal changes in flow can be relatively short term (e.g. hourly to daily) to long term (e.g. weekly, seasonal). If operated as an integrated system, as a general rule, additional storage should have a beneficial impact on both direct and indirect downstream uses including hydro-electric power stations.

5.15. Negative impacts can however still arise. For example, an upstream storage utilised for irrigation may store winter flows for release during the summer to users downstream of the generation station. In this situation there is no direct change in the overall volume of water received by the station over the year. This may even have the positive impact of regulating flows, particularly flood flows, so the generation stations produce more energy over the year. It may also have a negative impact in terms of energy value by moving flow from the higher energy demand winter period to the lower demand summer period.

5.16. At a scheme like Matahina for example, temporal changes could also have the impact of inducing constrained low flow operation during the high value peak winter demand months as water, diverted to upstream storage, reduces downstream availability.

Storage Use and Impacts

5.17. Storage is a mechanism to both, provide increased resource availability, and to potentially manage some of the direct impacts one use may have on another within a river. Primarily it enhances the amount of water available for use by storing water in times of low demand and lesser environmental impact, for use at times of high demand. Storage decouples the link between river flow and use. Apart from the direct impact from a consumptive use, impacts of an upstream use on a downstream user can be at least partially mitigated through storage.

5.18. Storage within an existing hydro-electric scheme could be utilised to reduce the impact from variability and temporal aspects of upstream use. This would however be at the cost of using that same storage to provide generation flexibility.

5.19. Any storage used within the hydro-electric power scheme, to manage inflow variability induced through upstream use is then however less available for optimising generation. For example, the hydro-electric storage reservoir may have to be operated at a lower than optimum level to provide a buffer against inflow variability, derived from storage operation, to mitigate the risk of spilling water. Similarly, the reservoir may not be able to be operated to its lower limit as sudden increases in use upstream might otherwise cause the reservoir to fall below permitted levels.

5.20. Upstream storage, not associated with a hydro-electric facility can reduce the impact of upstream use on the generation facility. In practical terms, the impact of any consumptive use largely remains irrespective of storage however it may be lessened by the storage being filled at times when the flow is less valuable for energy production. Similarly impacts from variability and temporal use can be better managed.

5.21. It is often presumed that, if a storage is only filled when available river flow exceeds the capacity of a downstream hydro-electric facility, there will be no impact. Care must be taken in making this presumption for several reasons.

5.22. Firstly, if the hydro-electric facility has its own storage this will almost certainly be used to capture flows exceeding the maximum generating capacity of the station. Ahead of flood events the reservoir will be drawn down to capture flood inflows. For example, Matahina can capture up to 6.6Mil m^3 of flood volume within the full normal operating range is used. Over a typical small flood event this would equate to approximately 24 hours at 75 m^3/s of inflow over and above the maximum station capacity of 160 m^3/s. As 75m^3/s is a little over the mean flow for the scheme, which effectively equates to an extra days generation per flood event, that would not be possible without storage.

5.23. Secondly, a storage that only relies on high flows for filling may have unacceptable reliability for any users. Floods are unpredictable and may not even occur at all in some years. Users may therefore not have the certainty of supply needed for their operation or even to warrant investment. Pressure will therefore be on filling the storage from more predictable flows that would correspond to flow used by the hydro-electric station. As noted there is minimal time where flow exceeds the capacity of any of the three Trustpower assets discussed above. Any storage designed to only access water that would not be available for use by these schemes would have very low reliability of filling.

5.24. Another consideration is cost. If the storage is not located within the river it needs to be filled via a river intake and conveyance system. If this is only used during occasional flood events it must be sized to achieve storage filling during a limit time and number of events. This could for example mean an intake and conveyance system 100 times larger, and costlier, than for a storage that can be filled throughout the year.

6. Transfer Mechanisms

6.1. Use of allocation or consent transfers, either temporary or permanent, is often raised as a mechanism for enabling more efficient use of water and alleviating some of the non-resource related reasons for over-allocation. However, I understand that the transfer policies and rules in PC9 are opposed by some submitters, notwithstanding that they are also seeking access to water for abstractive use purposes.

6.2. The use of transfer mechanisms can place a resource under increased pressure if not properly managed. However, if done well, it is my opinion that transfer mechanisms can increase the value derived from the resource used and reduce impacts on the river system - particularly during stress periods.

6.3. Permanent transfers are potentially simpler than temporary transfers, as they do not need to consider real time transient need and hydrological conditions. They are likely to arise where a given user does not need their allocation for an extended period and is willing to transfer to a user that does have a sustained need (and presumably they have not had their allocation reviewed by the regional council). Care does always have to be exercised when a transfer shifts the location of a use relevant to other users – as is recognised in the matters of discretion in Rule WQ R9 of PC9.

6.4. With respect to temporary transfers, it is often asserted that different types of use are, by default, in direct competition for the available resource. As discussed above, it is not the use, but how a use impacts on resource availability for others that is of relevance. When there are many users with the same type of use occurring, peak in demand is likely to broadly coincide across all users - which dictates the available capacity within the resource. This is sometimes known as the "rush hour effect". Much of the time however there is unused allocation.

6.5. Where there is a diversity of use, there is more potential for peak periods of demand, or value derived from the use, to differ between each type of use. Different types of use either have a variable demand for the water and/or derive different value from the water at different times. For example, a hydro-electric facility will be able to use the same rate of flow at any time, subject to the river supply. However, the value derived from that flow varies from hour to hour, day to day and beyond. The value, derived from the same amount of flow, can fluctuate by more than an order of magnitude. Similarly, for a crop farmer, irrigation water may only be required at specific times, and have differing value depending on the stage of the crops production.

6.6. The ability to transfer portions of allocation between users, as per Rule WQ R9, is one potential mechanism to assist in achieving improved use efficiency and the value derived from that use. To be effective, a transfer mechanism needs to primarily address the conditions under which a transfer may occur and not focus on constraining when it will occur. This is because demand peaks are inherently unpredictable and may occur with little warning.

6.7. Any transfer mechanism therefore should define the conditions under which transfer occurs to provide both the flexibility and certainty to users required to enable investment and value production. For example, an irrigator can invest in new more efficient equipment that uses less water in the knowledge that there is a transfer mechanism that allows access to additional water in stress (e.g. drought) periods. In simplistic terms an effective transfer system should allow a portion of the allocation to move in real time, to areas of highest current need, based on the value derived from that use.

6.8. Consideration of how transfers will occur, the assessment of value associated, and mechanisms to deal with extreme events, needs to be undertaken on a case by case basis. Due to the unique combination of catchment characteristics, hydrology, infrastructure, nature of use, environment and community drivers it is unlikely that a mechanism that works in one situation would be able to be directly fitted to another. The broad principles and process is however similar.

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