Memorandum

To:	Paul Barrett	**Of:**	Hawke's Bay Regional Council
From:	Julian Weir	**Date:**	30/10/2021
Reviewed by:	Ross Hector	**Job no:**	WL18045-14
Subject:	**Ruataniwha Tranche 2 Groundwater Modelling – Response to PDP's 3rd Review**		

Dear Paul,

This memorandum presents our response to Pattle Delamore Partners Ltd (PDP)'s 3rd review of the Ruataniwha Tranche 2 modelling (PDP, 2021)[1]. In summary, key areas of concern raised by PDP relating to modelling are:

1. Effects on smaller streams and rivers;
2. Comparisons of gaining and losing reaches between the model and measured;
3. Local interference effects on neighbouring bores; and
4. Efficient use.

Requests for further information (RFI) relating to these items have been listed in HBRC's RFI letter (HBRC, 2021)[2]. Our response to these queries are discussed below. Some factual errors are noted in PDP's reply, and these are separately noted towards the end of this memorandum.

There are additional aspects of this RFI that are not addressed herein but will be responded to by others in the applicant group (for example additional assessments on wetlands, ecological review, discharge considerations and individual land use consents).

1. Effects on Smaller Streams and Rivers

All of the existing or proposed Tranche 2 bores are (or will be) screened deeper than 50 m below ground level. At these depths, the takes will not be directly stream depleting, but effects will develop slowly and will be spread over a wide area. This is simulated by the numerical model. However, due to the catchment scale of the model, not every single stream is included. Furthermore, stream reaches that are located upstream of any augmentation discharge location may experience depleted flows.

Therefore, HBRC have requested an assessment of effects on these other smaller streams. This is sometimes achieved using an analytical equation. However, analytical methods for assessing stream depletion are not directly applicable to the Ruataniwha basin as they assume a single, straight stream. They do not accommodate multiple, meandering rivers,

[1] PDP (2021): *Tranche 2 Groundwater Consent Applications – Ruataniwha Basin*. Memorandum prepared for Hawke's Bay Regional Council. 29 September 2021.
[2] HBRC (2021): *Tranche 2 Water Permit Applications.* Letter from Paul Barret to Sage Planning dated 1/10/2021.

nor do they accommodate augmentation (augmentation in one stream positively affects flows in the receiving reaches, but can also positively affect adjacent streams via shallow groundwater recharge). Hence, analytical methods will over-predict the effects. They are simply not suitable for assessing the potential effects from the proposed Tranche 2 activities effects.

Furthermore, all river sites gauged by HBRC within the basin are located on rivers that have been included in the model (refer to Figure 1 in Weir, 2021b)[3]. Therefore, the flow regimes of reaches that are not gauged are unknown. Based on the lack of gaugings and the available topographic information, these sites are likely to be naturally dry at times. Analytical stream depletion methods do not allow for this.

For sites that naturally dry, the general modelling results suggest that flows in these streams might dry a few days (1-3 days) earlier with the Tranche 2 takes, and similarly flows would likely return a few days later. As these streams are dry during the very dry periods, further stream depletion assessments are not sensible.

In addition to the streams that are already included in the model, the following streams have been identified that are likely to remain flowing along some or all of their reaches:

- Black Stream near I&P Farming; and
- Avoca River, near Tuki Tuki Awa)

PDP note in Section 7.5 of their memorandum (referring to Springhill Dairies) that 'the low value of leakage [derived from the aquifer test] means that local stream depletion effects due to pumping…may be assessed via the numerical model' (allowing for model uncertainty). We agree with this. Furthermore, the leakage value reported for the Springhill Dairies' property is generally of a similar magnitude or larger than leakage values reported by PDP for aquifer tests at other property locations. It therefore follows that the numerical model is valid for assessing stream depletion at other locations too, for those reaches that are included in the model.

Therefore, although the model is not calibrated to all river flow sites, additional modelling outputs have been processed to quantify the change in flows in additional streams nearby the applicants' properties. In addition, depletion in the above two streams (that are not modelled) have been interpolated based on the modelled depletion from relevant nearby streams. This assessment is provided in Appendix A and focusses on sites where the maximum change is expected (e.g. just above and below augmentation locations). From these results, the following conclusions are drawn:

- Flow differences are both positive and negative. Negative differences are typically located above reaches that receive augmentation water.
- The negative flow differences are very small (1-10 l/s), less than both model and measurement precision. The larger differences typically occur in the rivers with the larger flows. Hence, the effects on the rivers are likely to be negligible.

The calculations summarised in Appendix A present estimates of stream depletion, but the consequential impact of this flow change is not assessed herein. This requires an assessment of ecological values which will be undertaken by others.

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[3] Weir (2021b): *Ruataniwha Tranche 2 Groundwater Modelling – Response to PDP's 2nd Review.* Memorandum to Paul Barret. WL18045-14. 13 August 2021.

2. Modelled Gaining and Losing Reaches

PDP have concluded that the model 'appears to broadly replicate the pattern of gaining and losing reaches across the across the model area.' We agree with this. However, they then state that the model tends to over represent the scale of observed losses and under represent the scale of observed gains. We disagree with this conclusion. From Table 1 of our reply to PDP's 2nd review, the differences between gains and losses are mixed, some are a little under (both gains and losses), some a little over (both gains and losses), and some about right (both gains and losses). This is expected from any numerical model representing a complex system.

Regardless, the model has been used to predict the *changes* in river flows (i.e. the stream depletion) from the proposed Tranche 2 takes and augmentation. The effects of stream depletion in a river are the same whether the activity results in an increase in flows from the river (for losing reaches) or a reduction of flow to the river (for gaining reaches). The reported differences in river flow gains and losses therefore have little influence on the model predictions. This is further supported by the consistency in the stream depletion rates reported under the sensitivity assessments (Weir, 2021a)[4].

3. Local Interference Effects

In Section 12.0 of their memorandum, PDP discuss their reservations with the well interference assessment previously undertaken. Key concerns are summarised below with our response:

- *Interference reported for deep bores for layer 6 of the model.* We agree with this concern and have addressed this below by extracting from the model the drawdown from the layer within which the bores are screened. The subsequent interference effect also depends on the layers from which the proposed Tranche 2 bores abstract water.
- *Inaccurate estimation of seasonal changes in groundwater levels due to the presence (or not) of rivers that act to control the groundwater level.* We disagree with this conclusion. The assessment of seasonal variation has been separated into shallow and deep bores. The shallow bores naturally have variation influenced by rivers, and the effect is lesser for deeper bores. Hence, the approach appropriately accommodates these natural controls. We note that the seasonal variation in bore 15048 (referred to by PDP) as reported in the Appendix 3 of the Well Interference report is 7.4 m. This is conservatively larger than the seasonal variation reported by PDP after Figure 3 of their memorandum (5-6 m).
- *The use of an 'arbitrary' threshold of 20% of the remaining drawdown*. This method is commonly utilised in Canterbury. It was first introduced in Environment Canterbury's Natural Resources Regional Plan in 2011 and is still commonly used to provide rapid assessments of interference effects over a large number of wells. It is conservative in terms of effects, and is particularly helpful where there is insufficient data to complete a more rigorous assessment. It is therefore an acceptable method to apply to the Ruataniwha basin.
- *No consideration for cumulative effects:* Both the static groundwater levels and the seasonal variation in groundwater levels (assessed for different well depths) include effects of all existing takes. Therefore, these are considered in the assessment.

Given PDP's concerns, they have recommended that the well interference assessment be

[4] Weir (2021a): *Ruataniwha Tranche 2 Groundwater Modelling – Response to PDP's Preliminary Comments.* Memorandum to Paul Barret. WL18045-14. 29 March 2021.

reassessed using local aquifer parameters. While we disagree that this is necessary, we have revisited the well interference assessment as follows:

1. Undertaken individual interference assessment on a subset of bores (adjacent to the Tranche 2 property locations, excluding applicant-owned bores) using site-specific parameters; and
2. Compared these to interference results from the model for the layers within which the bores are screened.

The pump rates assumed for this assessment are described in Appendix B. The *'possible peak flow rate per bore'* are different to the pump rates included in the numerical model. The numerical model represents, as best as possible, what is likely to occur. The interference assessments presented by PDP and the *'possible peak flow rate per bore'* presented in Appendix B assume higher pump rates and therefore represent conservative, extreme potential effects which are less likely to occur.

Aquifer parameters are presented in Appendix C. These are different to the values assumed by PDP as they include additional tests nearby each applicant's property. Furthermore, greater weight was given to tests with the following criteria:

- Test located closer to the property;
- Tests at similar depths to the applicants' bores;
- Tests with multiple values reported; and
- More recent tests.

Results of this revised interference assessment are summarised in Appendix D. Key outcomes from this assessment are:

- For most bores, the reassessed drawdown from the numerical model is the same as, or less than, the original predicted drawdown. For a few bores, the drawdown is larger.
- Generally, the analytical model predicts drawdowns in the same order of magnitude as the numerical model for deeper bores. However, the analytical model typically predicts larger drawdowns than the numerical model in shallower bores (less than 50 m deep). This is because the analytical model does not account for multiple river boundaries, nor augmentation, both of which dominate shallow aquifer response. The only method to realistically accommodate multiple rivers and augmentation concurrently is the use of a numerical model. Therefore, predictions of drawdown from the numerical model should be considered in preference to the analytical model.
- For most of the bores assessed, there is little-to-no predicted change to the drawdown compared to the original assessment. For other bores, the drawdown as a percent of available drawdown increases, but does not breach the 20% limit considered in the original application.
- For one bore (bore 5425, on the TAFT property), the drawdown as a percent of available drawdown in the bore increases from approximately 11% to 21%, which is larger than the 20% limit considered. However, given the conservative nature of the assessment and the small margin above the limit, this is not expected to adversely affect the bore. Furthermore, the bore is owned by TAFT, so no further consideration is required.

Given the above, the original well interference and shallow bore assessments supplied with the Tranche 2 consent application remain valid.

PDP have also compared modelled groundwater level changes (as reported in Weir, 2020)[5] (subsequently updated) for 1 March 2001, representing an extreme dry period, with their calculations of local interference using an analytical equation for a selection of bores. This is not a direct like-for-like comparison, for several reasons:

- The analytical equation assumes that the neighbouring bore is located either in the same hydrogeological layer as the pumped bore or in the uppermost layer (depending on what analytical equation is used). This is often not the case. The existing or proposed Tranche 2 bores are screened at varying depths (below 50 m) and can be at quite different depths to neighbouring bores. In this regard, the assumptions of the analytical equation are not necessarily valid (interference will be less where neighbouring bores are located in deeper or shallower formations to the pumped bore). The numerical model is three-dimensional and multi-layered, and therefore automatically accommodates these vertical separations.
- PDP have not considered all aquifer tests in the vicinity of some properties. There are additional tests that result in spatially variable parameters (and therefore effects). The model includes these spatially-variable properties.
- PDP's drawdown calculations do not accommodate the cumulative effects of multiple wells and multiple applicants pumping. This is what the model does.
- PDPs' calculations appear to assume either all the abstracted rate is taken from only one bore (for the smaller takes) or an arbitrary 100 l/s (for the larger takes). These rates are different than allowed for any one well in the model, which provides an estimate of actual use spread over the different bores proposed. Therefore, any interference calculated by PDP will, as a result, also be different than reported from the model. For nearby wells, the drawdown calculated by PDP will be larger than the model's predictions (as PDP have assumed larger flow rates).
- For some properties, PDP have used 100 days continuous pumping, some sites 150 days, and one site uses 35 days. This is inconsistent and gives different values to compare to. Generally, the longer the pump period, the larger the interference.

The numerical model incorporates results from all available aquifer test data, as reported in PDP (2018)[6]. Hence, all stream interference (and stream depletion) outputs from the model include these local parameters. Therefore, if like-for-like parameters are used, the model gives consistent results to the analytical equations, so far as possible without accommodating the positive effects from augmentation and the complexity of multiple streams. Table 1 presents a comparison between interference (in both the deep pumped aquifer and the shallow overlying layer) calculated by the numerical model and interference calculated by an analytical equation (Hunt & Scott, 2007)[7], when consistent input values are assigned, for a selection of bores (including those considered by PDP). This considers the maximum interference calculated over different model layers (not just layer 6 as reported in Weir, 2020). This comparison uses the following parameters:

[5] Weir (2020): *Ruataniwha Basin. Tranche 2 Groundwater Modelling.* Prepared for Various Collaborative Participants. WL18045. 28 October 2020.

[6] PDP (2018): *Ruataniwha Aquifer Properties Analysis and Mapping.* Parped for Hawke's Bay Regional Council. Job reference C02591543. Pattle Delamore Partners Ltd. 14 December 2018.

[7] Hunt, B and Scott, D (2007): *Flow to a well in a two-aquifer system*. ASCE Journal of Hydrologic Engineering, Vol. 12, No. 2: 146-155.

- The expected peak rate per bore noted in Appendix B;
- A continuous pumping period of 100 days;
- The average parameters presented in Appendix C; and
- A top layer porosity value of 0.05 and a top layer transmissivity of 1,000 m^2/day.

Table 1: Comparison of approximate predicted interference effects using consistent parameters

Property	Radius assessed by PDP (m)	PDP's predicted interference (m) (excl. streams and augmentation)		Hunt & Scott (2007) interference using parameters consistent with the numerical model (m) (excl. streams and augmentation)		Max. interference from the numerical model (1 March 2001) (m)	
		Deep	Shallow	Deep	Shallow	Deep	Shallow
TAFT	500	3.5	< 0.1	8.9	0.03	8-18	0.06
Papawai	500	> 4.0	> 0.1	3.1	0.08	3.8	0.4
Tuki Tuki Awa	500	(none)	(none)	3.5	0.49	5.1	0.05
PRD	1,500	> 7.5	(none)	1.1	0.13	2.1	0.3
Springhill	1,300	1.7	> 0.1	1.0	0.28	6.0	0.6
I & P Farming	750	> 1.0	(none)	1.7	0.10	1.2	0.35
Buchanan	750	> 5.0	(none)	3.1	0.14	4.5	0.45
Purunui	750	1.3	< 0.1	0.7	0.18	2.2	0.50

This demonstrates that, counter to PDP's conclusion, the model's prediction of interference effects is sound. In some cases, the predicted interference is larger (and therefore more conservative) than the interference calculated by PDP and the Hunt & Scott (2007) analytical equation.

In Section 11.0 of PDP's review, they query the spatial response of drawdown in the shallow aquifer, particularly in the southern area of the model away from applicants' properties. For clarification, the shallow drawdown is dominated by rivers and augmentation, and the apparent unusual pattern is a result of this. The southern areas of the model are still influenced by discharge into the Tukituki River. Furthermore, drawdown in deep layers (as a result of the deep proposed Tranche 2 takes) propagates across a large area, but this is regulated in the shallower layers by rivers. This is seen as only a small drawdown near the rivers and larger drawdowns at increasing distances from the rivers. Because of this, the effects are not uniform. This is a common and expected hydrogeological response.

3. <u>Efficient Use</u>

With the exception of Tuki Tuki Awa (discussed below), the volumes of irrigation water applied for have been calculated based on 90-percentile seasonal water use (mm/year) as calculated by IrriCalc. This depth is then multiplied by the area of land proposed to be irrigated by this water to derive a volume. As noted in Weir (2020) (and the subsequent updated report), this area assumes pasture. However, the same volume of water could be distributed over a larger area of less water intensive crop to achieve a similar or more efficient water use.

For Tuki Tuki Awa, the Tranche 2 water is now proposed to be used to 'gap fill' their existing surface water take when this is restricted to provide reliable irrigation. Under model scenario 'Combined 4', the volume of Tranche 2 groundwater applied for has been derived from historical records of restrictions applied to the Tuki Tuki Awa surface water take. Therefore, a measure of efficient use is not relevant. We also noted that the 90-percentile volume for Tuki Tuki Awa listed in Table 27 and 28 of the model report has been incorrectly entered as 678,000 m^3/year. This should be 612,000 m^3/year (as applied) and the total reduced accordingly. These changes have been applied to the model report. This makes no difference to the model simulations. We draw your attention to footnote 2 in Table 27 regarding Tuki Tuki Awa's proposal to only use their volume for gap filling when surface water is restricted. Hence, the irrigated volume used in most years will be less than the 90-percentile value listed in the table.

4. <u>Clarification of Some Statements</u>

The follow items correct and/or clarify some statements listed in PDP's memorandum:

- Section 2.2: PDP comment that the groundwater model does not use available aquifer test data. As noted above, the numerical model incorporates results from all available aquifer test data, as reported in PDP (2018).
- Section 2.3, last paragraph: PDP note that the 'absolute values of changes in the shallow aquifer have been used in these assessments, which may not be appropriate'. This is a broad statement. Mixing the term 'absolute' and 'change' is contradictory. The model has been used to calculate the *change* in groundwater levels and river flows as a result of the proposed Tranche 2 activities. This is to reduce the influence of measurement and model uncertainty (as noted in Weir, 2020 and subsequent updates) when considering absolute values. Furthermore, it is these changes during low-flow periods that the augmentation is designed to mitigate. Therefore, the use of these changes is very much appropriate.
- Section 3.1: TAFT propose to irrigated 540 ha of land, not 490 ha noted by PDP.
- Section 3.6: PDP state that 'there may be wetlands that have not been identified'. This is an unhelpful comment. Clarification of the intent of this statement would be appreciated.
- Section 5.1: PDP list Tuki Tuki Awa's augmentation volume as 129,600 m^3/year, but the value listed in Table 28 of the latest version of (2020) is 29,600 m^3/year.
- Section 5.4: PDP state that because there are no observation bores in the vicinity of Tuki Tuki Awa then the model is 'not expected to provide accurate estimates of potential drawdown interference effects'. This is speculation. The model predictions could also be right. Furthermore, rivers flow past this property and measurements in downstream flow sites have been used for calibration. There is also an observation bore located approximately 2 km east of the property. Therefore, model parameters at the Tuki Tuki Awa property have a degree of calibration.
- Section 5.5: All proposed wells are to be screened 50 m or deeper, which is deemed by HBRC as not directly stream depleting.
- Section 6.7: Discharging into the Kahahakuri Stream will benefit this stream and shallow groundwater regardless of the aquifer parameters or location of gaining and losing reaches. This paragraph is unhelpful.
- Section 7.4, paragraph 2: The model accommodates all aquifer test information and therefore accommodates spatially-variable parameters. It also includes the use of all bores pumping, not just bore 2870. This paragraph is confusing.
- Section 13.1: We are not aware of a flow restriction site for the Kahahakuri Stream at Ongaonga Bridge listed in Table 5.9.3 of HBRC's PC6 document. Rather, we understand that this site is a flow allocation site, as listed in Table 5.9.4 of this document.

Appendix A: Summary of modelled stream depletion

Property	River	Location	Modelled flow change in 7-day MALF due to Tranche 2 activities (l/s)	Comment
TAFT	Mangaonuku	u/s augmentation site	-4	
	Mangaonuku	d/s property	-1	
	Mangamate	u/s Mangaonuku	0	
	Mangamauku	u/s Mangaonuku	-2	
Papawai	Waipawa	u/s augmentation site	-10	
	Waipawa	d/s augmentation site	+2	
Tuki Tuki Awa	Tukituki	u/s augmentation site	0	
	Tukituki	d/s augmentation site	+2	
	Avoca	u/s Tukipo	0	Estimated from effect on Tukipo
PRD	Kahahakuri	u/s augmentation site	0	
	Kahahakuri	d/s property	+2	
	Ongaonga	u/s Tukituki	-	
Springhill	Mangaoho	u/s Mangaonuku (u/s augmentation)	-7	
	Mangaonuku	d/s Mangaoho (d/s augmentation)	+35	
	Waipawa	u/s Papawai augmentation site	-10	Same site as Papawai
I&P	Tukituki	u/s augmentation site	+8	
	Tukituki	d/s augmentation site	+22	
	Black Stream	d/s property	-1	Estimated from effect on Ongaonga
Buchanan	Ongaonga	u/s augmentation site	0	
	Ongaonga	d/s augmentation site	0	
	Kahahakuri	u/s PRD augmentation site	0	Same site as PRD
Purunui	Waipawa	u/s augmentation site	+1	
	Waipawa	d/s augmentation site	+2	
	Kahahakuri	d/s PRD property	+2	Same site as PRD

Appendix B: Pump rates assumed for local interference assessments

Property	Bore number	Expected peak rate per bore applied to the numerical model (l/s)	Total peak flow rate (l/s)	Possible peak flow rate per bore (l/s)	Comment
TAFT	Bore 16563	82	529	95	Peak irrigation rate applied to all bores. Augmentation take as proposed.
	Bore 16592	63		95	
	Bore 16593	69		95	
	Bore 5515	32		95	
	Proposed	95		95	
	Augmentation take	189		189	
Papawai	Bore 16508	87	150	87	Peak combined take applied to all bores.
	Bore 1859	63		87	
Tuki Tuki Awa	4 x proposed (modelled as one)	94	104	94	Peak irrigation rate applied assuming only one bore. Augmentation take as proposed.
	Augmentation take	10		10	
PRD	4830	95	384	98	Peak irrigation rate applied to all bores. Augmentation take as proposed.
	Proposed 1	88		98	
	Proposed 2	98		98	
	Augmentation take	103		103	
Springhill	Bore 5167	81	123	81	Peak irrigation rate applied assuming two bores, plus augmentation.
	Bore 4593	-		81	
	Bore 1518	-		81	
	Bore 3870	42		81	
	Bore 4122	-		81	
	Bore 5497	-		81	
I&P	Proposed	137	137	137	One proposed bore.
Buchanan	16408	37	142	71	Combined peak rate applied assuming two bores.
	Proposed 1	36		71	
	Proposed 2	36		71	
	Proposed 3	33		71	
Purunui	Proposed 1	22	57	57	Combined peak rate applied assuming one bore.
	Proposed 2	14		57	
	Proposed 3	21		57	

Appendix C: Aquifer test results used for local interference assessments

Property	Bore number	Screen interval (m bgl)	Location	T (m^2/day)	S	Max. K'/B' (day^{-1})	Comment
TAFT	15431	134-150	1 km S	898	-	-	Bore 5515 is too shallow to represent the deep aquifers on this property
	5723	61-81	2 km S	605	1.6×10^{-4}	-	
	5707	111-117	2.6 km S	210	1.4×10^{-4}	1.0×10^{-6}	
	4672	69-89	2.6 km S	300	8.0×10^{-5}	3.0×10^{-6}	
	4295	-	0.8 km S	607	9.6×10^{-5}	-	
			Average	**524**	**1.2×10^{-4}**	**2.0×10^{-6}**	
Papawai	16765	65-76	1.4 km SW	1,275	4.7×10^{-5}	-	-
	16508	86-120	On site	1,160	1.5×10^{-4}	2.0×10^{-5}	
	4764	96-120	0.1 km S	1,300	5.0×10^{-4}	-	
	2933	75-89	0.1 km W	1,250	1.7×10^{-4}	-	
	2277	57-66	1.5 km E	812	4.6×10^{-5}	-	
	2219	89-95	0.7 km SW	700	3.5×10^{-5}	-	
			Average	**1,082**	**1.6×10^{-4}**	**2.0×10^{-5}**	
Tuki Tuki Awa	4685	76-77	5 km E	340	6.5×10^{-4}	1.0×10^{-4}	No tests located in close proximity to the property
	4110	71-80	7 km SE	150	6.2×10^{-4}	2.0×10^{-4}	
	3852	112-121	7 km SE	408	-	-	
	3774	68-76	7 km SE	835	3.0×10^{-4}	-	
	1429	42-44	7 km SE	219	-	-	
			Average	**390**	**5.2×10^{-4}**	**1.5×10^{-4}**	
PRD	16765	65-76	0.4 km N	1,275	4.7×10^{-5}	1.0×10^{-4}	Bore 4830 excluded as test was compromised by other nearby pumping
	16508	86-120	3.0 km NE	1,160	1.5×10^{-4}	2.0×10^{-4}	
				350	1.2×10^{-4}	-	
	5498	133-140	0.1 km S	300	4.0×10^{-5}	-	
	5419	52-60	1.2 km S	3,000	2.0×10^{-3}	-	
	4764	96-120	2.9 km NE	1,300	5.0×10^{-4}	-	
	2933	75-89	1.8 km NE	1,250	1.7×10^{-4}	-	
	2219	86-95	1.2 km NE	700	3.5×10^{-5}	-	
			Average	**1,167**	**3.8×10^{-4}**	**1.5×10^{-4}**	
Springhill	5723	62-81	2.2 km NE	605	1.6×10^{-4}	-	Some shallower bores included as one existing and proposed bores could be screened as high as 50 m depth
	5707	111-117	1.7 km NE	210	1.4×10^{-4}	1.0×10^{-6}	
	4672	69-89	2.2 km NE	300	8.0×10^{-5}	3.0×10^{-6}	
	3870	57-77	On site	765	2.0×10^{-4}	-	
	2277	57-66	2.3 km S	812	4.1×10^{-5}	-	
	2246	50-60	1.5 km S	520	4.0×10^{-4}	1.0×10^{-3}	
			Average	**520**	**1.7×10^{-4}**	**3.4×10^{-4}**	

Property	Bore number	Screen interval (m bgl)	Location	T (m^2/day)	S	Max. K'/B' (day^{-1})	Comment
I&P	15755	40-60	0.8 km NE	2,500	1.8×10^{-4}	-	Shallower bores included as proposed bores could be screened as high as 50 m depth
	5498	133-140	2.0 km NW	300	4.0×10^{-5}	-	
	5419	52-60	0.05 km N	3,000	2.0×10^{-3}	1.0×10^{-4}	
	4049	30-36	3.0 km NE	3,500	4.4×10^{-4}	-	
			Average	**2,325**	**6.7×10^{-4}**	**1.0×10^{-4}**	
Buchanan	16408	115-120	On site	350	1.2×10^{-4}	1.0×10^{-5}	Shallower bores included as proposed bores could be screened as high as 50 m depth
	5498	133-140	0.4 km SE	326	-	-	
	4685	76-77	1.9 km SW	340	6.5×10^{-4}	1.0×10^{-4}	
	2219	89-95	2.1 km N	700	3.5×10^{-5}	-	
	2043	77-83	0.2 km E	527	-	-	
	1880	50-56	0.8 km NE	1,306	-	-	
	1475	46-52	1.6 km N	275	-	-	
	1426	38-44	1.9 km W	177	-	-	
			Average	**500**	**2.7×10^{-4}**	**5.6×10^{-5}**	
Purunui	16508	86-120	2.3 km NW	1,160	1.5×10^{-4}	2.0×10^{-5}	Shallower bores included as proposed bores could be screened as high as 50 m depth
	4764	96-120	1.5 km NW	1,300	5.0×10^{-4}	-	
	2278	50-53	2.0 km N	1,595	1.8×10^{-4}	1.0×10^{-3}	
	2277	57-66	2.2 km N	812	4.1×10^{-5}	-	
	1881	44-50	1.6 km W	1,600	1.1×10^{-4}	-	
			Average	**1,293**	**2.0×10^{-4}**	**5.1×10^{-4}**	

Appendix D: Revised interference assessments

Property	Bore	Depth (m bgl)	Remaining head (from original well interference assessment) (m)	Original predicted DD (m)	DD calculated using analytical model (m)	Reassessed model DD (m)	Change in percent of available DD using reassessed model DD
TAFT	3483	71	30.9	8.00	8.4	8.10	No significant change
	5389	50	19.1	0.04	0.3	0.04	No significant change
	5521	41.9	9.7	0.20	0.7	0.20	No significant change
	5881	41	10.6	0.13	0.5	0.13	No significant change
	5425	95	75.7	8.14	21.0	15.6	Increase from 11% to 21%
	15892	48	14.7	0.04	0.3	0.04	No significant change
	16562	155	136.3	8.44	8.3	8.40	No significant change
Papawai	3866	95	58.8	2.14	0.9	1.50	More available
	4620	6.8	3.0	0.75	0.4	0.75	No significant change
	4700	98	79.2	2.13	1.5	1.60	More available
	4742	8	4.3	0.52	0.4	0.52	No significant change
	4764	123	74.5	1.66	1.7	2.00	Increase from 2% to 3%
	5342	8.4	6.6	0.08	0.5	0.08	No significant change
	5532	5	1.1	0.28	0.5	0.28	No significant change
	15479	36	18.0	0.30	0.4	0.30	No significant change
Tuki Tuki Awa	15938	141	115.2	0.74	0.9	0.74	No significant change
	16411	23	6.8	0.23	0.3	0.23	No significant change
	16454	77	12.6	1.10	0.4	1.20	No significant change
PRD	3218	63	8.6	1.67	1.2	0.96	More available
	3673	9	6.6	0.08	0.3	0.08	No significant change
	4736	300	279.3	0.92	2.2	0.95	No significant change
	4781	9	2.8	0.31	0.4	0.31	No significant change
	4994	68	39.4	1.12	5.5	4.60	Increase from 3% to 12%
	5343	11	1.8	0.32	0.4	0.32	No significant change
	5724	43	13.1	0.26	0.3	0.26	No significant change
	16014	33.2	17.0	0.23	0.3	0.23	No significant change
	16249	14.3	2.4	0.45	0.5	0.45	No significant change
	16363	48.7	19.1	0.37	0.5	0.37	No significant change
	16408	115	83.5	1.23	2.9	3.40	Increase from 1% to 4%
	16441	59	29.2	1.50	1.6	2.20	Increase from 5% to 7%
	16567	49.2	21.3	0.30	0.5	0.30	No significant change
	16765	76	31.5	1.91	1.9	1.70	More available
Springhill	1407	35	13.1	0.05	0.2	0.05	No significant change
	3204	73	41.1	1.81	1.1	1.60	More available
	3866	95	58.8	2.14	0.3	1.50	More available
	4700	98	79.16	2.13	0.3	2.00	More available
	4744	8.2	-4.5	0.31	0.1	0.31	No significant change

Property	Bore	Depth (m bgl)	Remaining head (from original well interference assessment) (m)	Original predicted DD (m)	DD calculated using analytical model (m)	Reassessed model DD (m)	Change in percent of available DD using reassessed model DD
	4949	25	12.5	0.45	0.2	0.45	No significant change
	4950	70	41.0	2.19	2.3	1.90	More available
	5424	20	8.0	0.11	0.3	0.11	No significant change
	5532	5	1.12	0.28	0.2	0.28	No significant change
	5707	117	92.5	4.16	0.7	4.10	No significant change
	15442	59	40.9	1.95	0.4	1.70	More available
	15479	36	18.0	0.30	0.2	0.30	No significant change
	16345	12	-0.28	0.39	0.3	0.39	No significant change
	16373	18	8.0	0.41	0.1	0.41	No significant change
I & P Farming	2467	12	4.14	0.40	0.9	0.40	No significant change
	5419	55	21.9	0.54	0.2	0.75	Increase from 2% to 3%
	15443	62	34.7	0.50	1.0	0.60	No significant change
	15755	60	14.1	0.50	1.0	0.60	No significant change
	16357	2	-0.28	0.16	0.2	0.16	No significant change
	16358	2	-0.32	0.16	0.2	0.16	No significant change
	16489	10	2.51	0.20	0.1	0.20	No significant change
	16490	79	43.2	0.86	0.6	1.60	Increase from 2% to 4%
	16499	9	5.24	0.37	0.2	0.37	No significant change
	16549	126	91.0	0.53	0.9	0.57	No significant change
	16668	102	63.9	0.79	1.4	0.70	No significant change
	16713	98.8	54.0	0.52	1.4	0.70	No significant change
	16770	10	2.21	0.30	0.1	0.30	No significant change
	16771	9	5.2	0.26	0.1	0.26	No significant change
	16773	8	4.2	0.33	0.2	0.33	No significant change
Buchanan	2728	29	17.3	0.17	0.4	0.17	No significant change
	2749	51	17.6	1.61	5.4	2.5	Increase from 9% to 14%
	3349	34	19.5	0.17	0.3	0.17	No significant change
	3441	29	19.5	0.14	0.3	0.14	No significant change
	3714	29	14.9	0.17	0.4	0.17	No significant change
	4712	36	11.9	0.16	0.3	0.16	No significant change
	4994	68	39.4	1.10	3.4	4.6	Increase from 3% to 12%
	5140	41	11.8	0.21	0.5	0.21	No significant change
	5188	35	15.2	0.17	0.3	0.17	No significant change
	5486	45	17.2	0.17	0.3	0.17	No significant change
	5671	76	41.4	1.02	3.0	2.9	Increase from 2% to 7%
	16014	33	17.0	0.23	0.2	0.23	No significant change
	16441	59	29.2	1.50	6.1	2.2	Increase from 5% to 7%

Property	Bore	Depth (m bgl)	Remaining head (from original well interference assessment) (m)	Original predicted DD (m)	DD calculated using analytical model (m)	Reassessed model DD (m)	Change in percent of available DD using reassessed model DD
Purunui	2744	8	6.1	0.30	0.6	0.30	No significant change
	3673	9	6.6	0.08	0.3	0.08	No significant change
	3843	28	0.2	0.08	0.3	0.08	No significant change
	4621	7	3.7	0.37	0.6	0.37	No significant change
	4622	13	4.3	0.37	0.6	0.37	No significant change
	4701	111	98.7	0.90	0.1	0.90	No significant change
	5082	43	13.8	0.29	0.6	0.29	No significant change
	5343	11	1.8	0.32	0.5	0.32	No significant change
	5829	33	18.0	0.33	0.5	0.33	No significant change
	16079	46	17.1	0.33	0.4	0.33	No significant change