BEFORE THE PROPOSED NATURAL RESOURCES PLAN HEARINGS PANEL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of Water Allocation
AND	
IN THE MATTER	of the submissions and further submissions set out in the S42a Officer Report

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STATEMENT OF PRIMARY EVIDENCE OF BRYDON NICHOLAS HUGHES ON BEHALF OF WELLINGTON REGIONAL COUNCIL

TECHNICAL – WATER ALLOCATION: THE FORM AND CONTENT OF THE PROPOSED CONJUNCTIVE MANAGEMENT FRAMEWORK

7 August 2017

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1. INTRODUCTION

1.1 My name is Brydon Nicholas Hughes. I am a hydrogeologist with 23 years' experience working with local government authorities and as a consultant. I am director of Liquid Earth Limited, a hydrogeology and water resource management consultancy, a position I have held for 9 years. Prior to this my experience includes 5 years as a Senior Hydrogeologist at Sinclair Knight Merz (SKM) Limited, and a further 10 years experience as a Groundwater Scientist working for Regional Councils in the Southland and Wellington regions. My principal areas of expertise lie in the areas of groundwater resource assessment, management and planning.

1.2 I hold the qualifications of Bachelor of Science (Geology) and a Master of Science in Engineering Geology (1st Class) from the University of Canterbury.

1.3 Greater Wellington Regional Council have requested that I provide evidence to this hearing relating to my role in developing the GWRC conjunctive water allocation framework for the Wellington Region. My input into this framework included development of the underlying policy framework as well as its practical application to the Wairarapa, Hutt Valley and Kapiti areas.

2. CODE OF CONDUCT

2.1 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. I agree to comply with this code of conduct. Except where I am relying on evidence of another person, this evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

3. SCOPE OF MY EVIDENCE

3.1 My evidence focuses on submissions relating to the form and content of the proposed Conjunctive Water Management Framework outlined Proposed Natural Resources Plan for the Wellington Region. These submissions primarily relate to the classification and delineation of the proposed management framework, and the criteria utilised to determine classification of hydraulic connection for individual groundwater takes (Schedule P).

3.2 To address the submissions, my evidence will provide background to the proposed conjunctive management framework and outline the rationale for resolution, delineation and mapping of hydraulic connection categories. The evidence also provides background to the criteria proposed to assess and manage stream depletion effects resulting from individual groundwater takes.

4. SUMMARY OF SUBMISSIONS ADDRESSED BY MY EVIDENCE

4.1 The main submitters - WWU, Irrigation NZ, Federated Farmers of New Zealand, Jim Headley and AJ Barton focus on seeking clarification and verification concerning the groundwater take categories in the interpretation sections, Policy 107, and Schedule P.

4.2 These submitters are concerned that the models used to describe and derive the conjunctive management framework (including Category A, B and C definitions, allocation limits, catchment management units and sub units and Schedule P) are too uncertain for the Ruamahanga catchment. The submitters' assert that the models have a regional based approach, are formulated on limited data and have too many assumptions.

4.3 My evidence, in conjunction with the evidence of Dr Gyopari, will address these concerns. My evidence will describe how the various hydraulic connection categories (zones A, B, C) were identified and delineated, and the basis for the assessment criteria proposed. Dr Gyopari will describe how the groundwater models were used to define the sub-catchment groundwater management zones and to show how some zones were identified as having high surface water connectivity attributes.

5. OVERVIEW OF THE CONJUNCTIVE MANAGEMENT FRAMEWORK

5.1 Throughout the Wellington Region, lakes, rivers, streams, wetlands and aquifers form part of a complex, interconnected hydrological system. Recognition that surface water and groundwater resources within a given catchment are fundamentally linked has required development and application of an integrated management approach to ensure sustainable management of the Region's water resources. Such an integrated approach has been termed conjunctive water management.

5.2 Development of the proposed groundwater allocation methodology for the Wellington Region is based on this concept of conjunctive management. This approach differs from the previous management framework outlined in the Regional Freshwater Plan whereby groundwater and surface water resources were management separately.

5.3 There are two fundamental components to the proposed conjunctive management framework for groundwater allocation:

- Management of groundwater takes that result in direct or immediate effect on the surface water environment through application of pumping controls based on minimum flows established for hydraulically connected surface waterways; and

- Establishment of fixed allocation volumes for groundwater abstraction from spatially defined groundwater management zones which do not have a direct or immediate connection to surface water but which contribute to a cumulative reduction in baseflow at a catchment scale.

5.4 The following sections provide background to concepts underlying the development of the proposed conjunctive management framework.

6. GROUNDWATER/SURFACE WATER INTERACTION

Hydraulic Connectivity

6.1 The concept of hydraulic connectivity describes the nature and extent of interconnection between groundwater and surface water in a given physical environment.

6.2 Groundwater and surface water bodies can be regarded as exhibiting a high degree of hydraulic connection if water can readily flow from surface water into, or out of, an adjacent groundwater resource. Examples of highly connected water resources include:

- Shallow unconfined gravel aquifers which are recharged by flow loss from overlying rivers and streams; and,
- Streams where groundwater inflow provides significant baseflow during low flow conditions.

6.3 Stream-aquifer systems may be described as exhibiting a low degree of hydraulic connection if the movement of water between these systems restricted (i.e. occurs at a low rate). Examples of groundwater and surface water resources with a low degree of hydraulic connection include:

- Streams separated from an underlying aquifer by a layer of low permeability sediments;
- Deep confined aquifers where flow exchange between groundwater and overlying surface water resources occurs at a low rate.

6.4 The hydraulic connection between groundwater and surface water within a catchment may range from high to low depending on local topography, geology and climate conditions. The extent of stream-aquifer connectivity may also vary over time in response to seasonal variation in relative water levels.

Gaining and Losing Streams

6.5 In situations where rivers or streams are hydraulically connected to an adjacent aquifer, water may flow into, or out of, the aquifer system according to the relative hydraulic gradient. Where groundwater levels are higher than river stage, groundwater will discharge to the stream. In this case the stream is defined as a gaining stream and the groundwater discharge termed baseflow. Conversely, where surrounding groundwater levels are lower than stream stage, water may flow from the stream into the surrounding aquifer. In this case the stream is defined as a losing stream and the recharge to groundwater commonly referred to as stream leakage. Figure 1 below shows an example of a gaining stream while Figure 2 illustrates a losing stream.

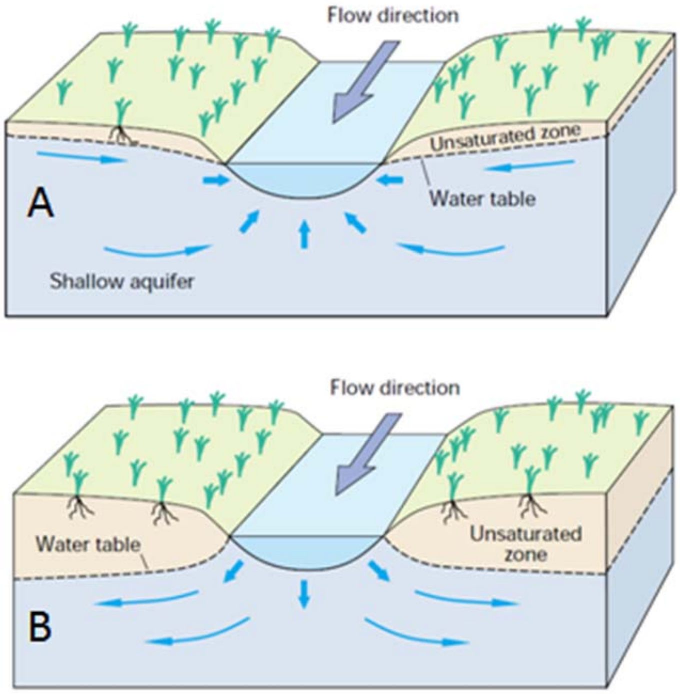

Figure 1: Illustration of natural groundwater surface water interaction: A = gaining stream, B = losing stream (from Winter et al., 1998)

6.6 A stream may also be classified as disconnected where there is a zone of unsaturated material between the base of the stream and the underlying water table (such streams are also commonly referred to as perched). In this situation although water may infiltrate vertically into underlying groundwater, there is no direct hydraulic connection between the stream and aquifer.

Effects of groundwater abstraction on stream flow

6.7 Drawdown in groundwater levels resulting from groundwater abstraction has the potential to impact on stream flow in hydraulically connected surface waterways.

6.8 In the case of a losing stream, the drawdown in groundwater levels resulting from abstraction increases the hydraulic gradient between the stream and aquifer, resulting in an increased rate of stream leakage.

6.9 In the case of a gaining stream the effect of groundwater abstraction can be twofold. The initial effect of abstraction is to reduce baseflow discharge. This reduction occurs because groundwater abstraction effectively intercepts a portion of the groundwater flowing through the aquifer that would otherwise have naturally discharged to the stream. Over time, the drawdown in groundwater levels caused by pumping eventually reaches the stream. If the pumping rate is high enough, or pumping continues for a sufficient period, groundwater levels will fall below the water level in the stream and the stream will start losing water to the aquifer.

6.10 The transition from a gaining stream to a losing stream is illustrated in Figure 2 below. Under the natural conditions represented in diagram A, groundwater is recharged from the land surface and flows through the aquifer following the natural topographic gradient and ultimately provides baseflow discharge to the stream. In diagram B, groundwater abstraction results in a localised decline in the natural water table which reduces baseflow discharge. In diagram C, the drawdown in groundwater levels resulting from abstraction is sufficient to reverse the natural hydraulic gradient and the stream starts to lose water to the aquifer system.

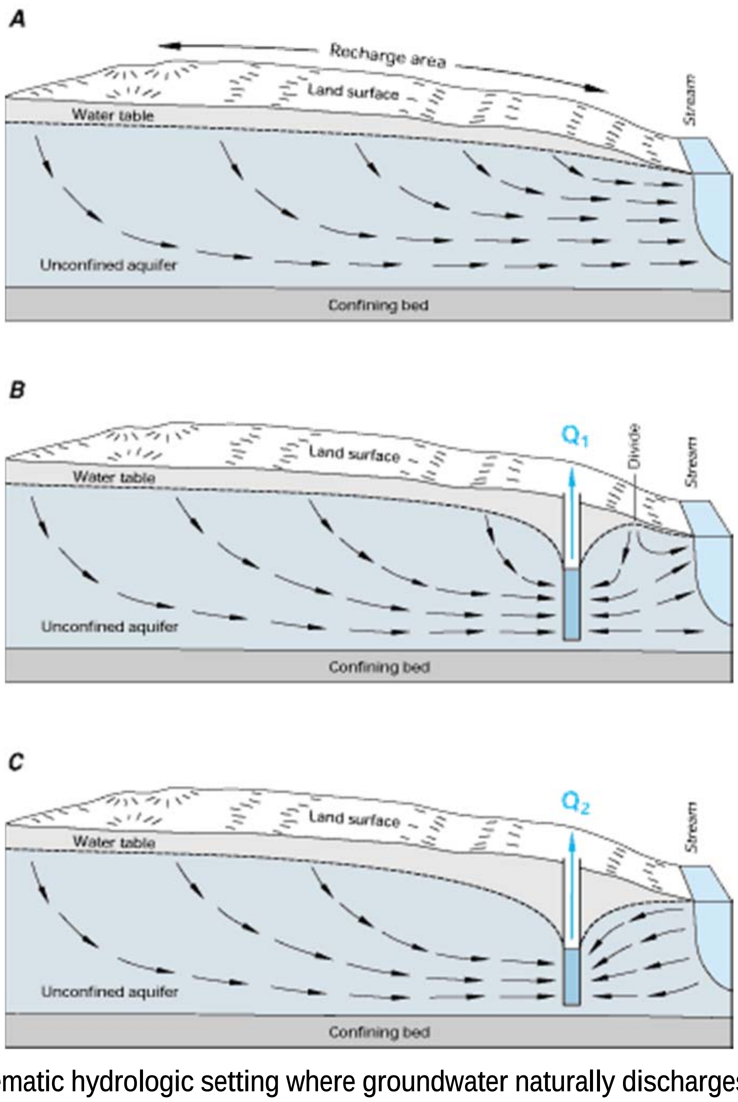

Figure 2: Schematic hydrologic setting where groundwater naturally discharges to a stream (A). Groundwater abstraction at a low rate (Q1) near the stream will intercept a portion of the groundwater that would naturally discharge to the stream (B). Groundwater abstraction at a higher rate (Q2) may reverse the natural hydraulic gradient and draw water from the stream into the aquifer (C). Reproduced from Winter et al., 1998.

6.11 In summary, groundwater abstraction from an aquifer system hydraulically connected to adjacent surface waterways has the potential to impact on stream discharge (an effect referred to as stream depletion) in two ways:

- By increasing the rate of stream leakage into an aquifer; or
- By decreasing baseflow discharge to surface waterways (including springs).

Magnitude and timing of stream depletion effects

6.12 Where there is a high degree of hydraulic connection between surface water and groundwater, stream depletion effects occur rapidly and may approach the rate of groundwater abstraction in a short period. Conversely, where there is a low degree of hydraulic connection, stream depletion effects may take considerable time to develop and occur at a rate considerably lower than the rate of groundwater abstraction.

6.13 The rate and timing of stream depletion effects resulting from groundwater abstraction is influenced by a range of factors including:

- The rate of abstraction;
- The distance between the pumping bore and adjacent surface waterways;
- The hydraulic properties (permeability and storage characteristics) of the aquifer materials; and
- The permeability of materials accumulated on the streambed (referred to as the streambed *clogging layer*).

6.14 Figure 3 illustrates the effect of the spatial location of groundwater abstraction on the calculated rate and duration of stream depletion effects. The example shows a series of curves representing the calculated direct stream depletion ratio (i.e. the ratio of stream depletion to the overall pumping rate) for a bore pumped at a constant rate for a period of 150 days at varying distances from a stream.

6.15 The stream depletion curves show that, for a bore located adjacent to a hydraulically connected surface waterway, stream depletion occurs shortly following the commencement of pumping and rapidly increases toward the rate of pumping. However, as the distance between the pumped bore and stream increases, the overall magnitude of stream depletion reduces and there is increased lag between pumping and resulting stream depletion effects.

6.16 It is important to note that in the example shown in Figure 3, if the x-axis was extended sufficiently, the area under the respective stream depletion curves would effectively be equal. Thus, in an idealised aquifer system, although the location of pumping may alter the timing and magnitude of stream depletion, it does not alter the overall volume of water lost from the stream[1].

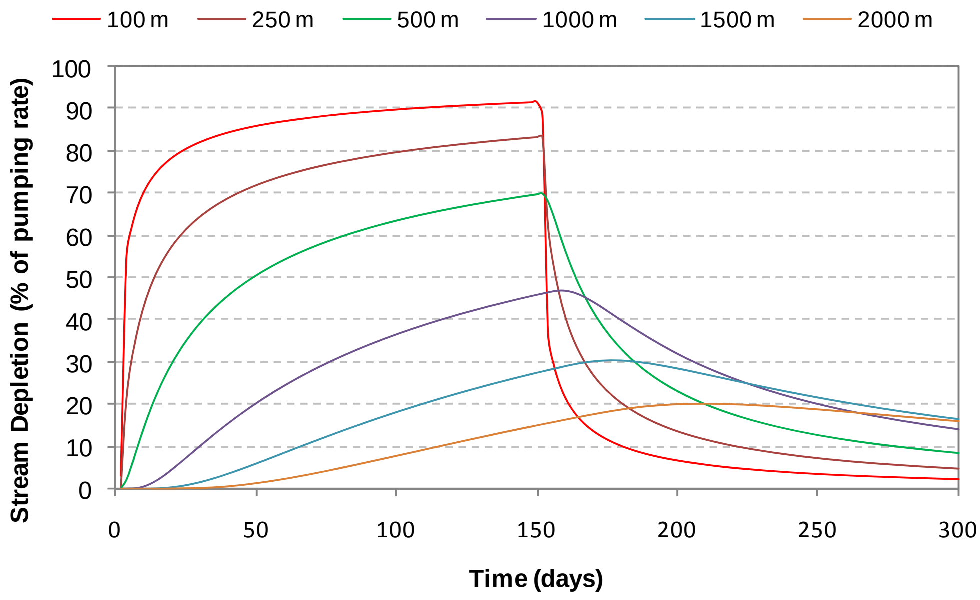

Figure 3: Calculated stream depletion (expressed as a % of groundwater abstraction rate) resulting from a bore located at varying distances from a hydraulically connected stream

6.17 The stream depletion curves illustrated in Figure 3 illustrate an effective trade-off between the magnitude of stream depletion and temporal response to changes in pumping rate. Stream depletion effects resulting from groundwater abstraction with a high degree of hydraulic connection respond rapidly to changes in pumping rate. So, although stream depletion represents a significant proportion of the water pumped, regulation of pumping rate provides a means to manage the rate of stream depletion occurring at a given time.

6.18 In contrast, while groundwater takes with a moderate or low connectivity to surface water may have a lower overall effect (in terms of the proportion of groundwater abstraction derived from surface water) than takes with a high

[1] In the natural environment, such long-term effects are significantly influenced by temporal variations in aquifer recharge. Thus, in temperate areas such as New Zealand, long-term stream depletion effects tend to be significantly reduced by recharge during the winter months.

hydraulic connection, they are less amenable to control by pumping regulation. Therefore, where groundwater occurs away from the immediate surrounds of rivers and streams there will be an effect that cannot effectively be controlled or mitigated during periods of low flow.

Managing stream depletion effects at a catchment scale

6.19 Given the variability in stream depletion effects in both time and space, managing the effects of groundwater abstraction on surface water flows at a catchment scale requires a management approach that:

- Manages the effects of groundwater abstractions with a high degree of hydraulic connection at a local scale by application of controls on pumping that mitigate effects during periods of low flow; and
- Accounts for the cumulative effects of groundwater abstractions that cannot effectively be mitigated by application of pumping controls by establishing allocation limits that take into account cumulative reduction in catchment baseflow.

6.20 This two tier approach to managing effects of groundwater abstraction on surface water flows underpins the conjunctive management framework.

7. PROPOSED CONJUNCTIVE MANAGEMENT APPROACH

7.1 The conjunctive management framework proposes four hydraulic connection categories, which effectively resolve to the two management categories outlined in the previous section.

7.2 In areas of the hydrogeological system where there is clear evidence for a high degree of hydraulic connection (identified as *Category A*), it is proposed that groundwater abstraction will effectively be managed as equivalent surface water abstraction (in terms of allocation and application of minimum flow cut-offs).

7.3 In those areas where there is moderate to low hydraulic connection to surface water (*Category C*), groundwater abstraction will be managed in terms of an annual groundwater allocation volume established to limit the maximum cumulative depletion of baseflow at a catchment scale.

7.4 For remaining areas (*Category B*), where there is uncertainty regarding the exact nature of hydraulic connectivity, groundwater abstraction will be managed in terms of either surface water allocation and minimum flows or groundwater allocation, depending on the outcome of hydrogeological assessment.

7.5 The following section summarises the typical characteristics of each hydraulic connection category.

Category A

7.6 Category A includes areas of the hydrogeological system which exhibit direct connectivity with surface water. Due to the high degree of hydraulic connection, stream depletion effects occur shortly following the commencement of groundwater abstraction and rapidly increase to a level close to the overall pumping rate. Due to the immediacy of impact, groundwater abstraction from Category A aquifers can be considered as being analogous to direct surface water abstraction in terms of the magnitude and temporal response in effects on surface water flows.

7.7 Figure 4 shows a representative stream depletion curve resulting from a Category A groundwater take over a nominal pumping period of 100 days. The figure shows stream depletion effects develop rapidly once abstraction commences and dissipate quickly when abstraction ceases.

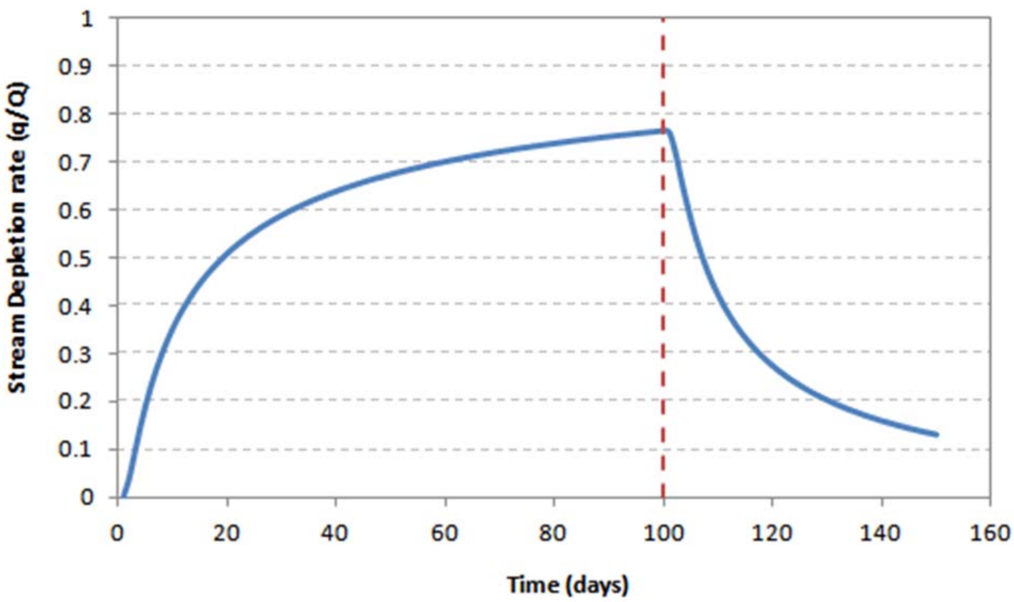

Figure 4: Representative stream depletion curve resulting from abstraction of Category A groundwater (red line denotes cessation of pumping)

7.8 Figure 5 shows a plot of the relative contribution of groundwater storage and stream depletion to the overall volume of water abstracted by a Category A groundwater take. The figure shows a majority of water pumped is derived from surface water with only a relatively minor contribution from groundwater storage.

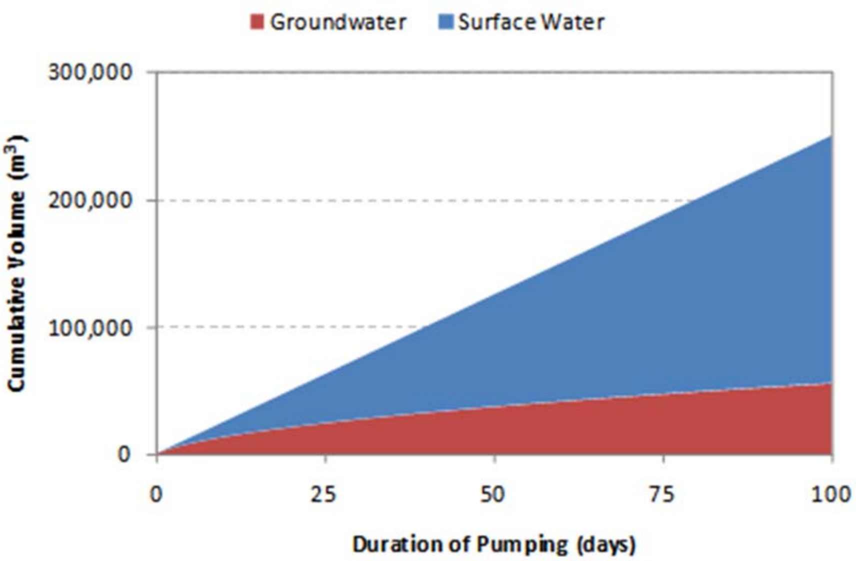

Figure 5: Relative contribution of groundwater storage and surface water (stream depletion) to the total volume of water pumped by a Category A take.

Category B

7.9 Category B includes those components of the hydrogeological system where groundwater abstraction may potentially result in significant impacts on surface water but where pumping regulation does not always provide an effective option for mitigating effects on surface water.

7.10 Figure 6 illustrates a representative range of stream depletion curves resulting from Category B groundwater abstraction. The curves indicate that, as the degree of hydraulic connectivity decreases, the overall magnitude of stream depletion decreases and there is increased lag in response following the cessation of pumping.

7.11 Figure 7 shows a plot of the relative contribution of groundwater storage and stream depletion to the cumulative volume of groundwater pumped from a Category B aquifer. The graph shows that while a majority of water is derived from aquifer storage during the initial pumping period, stream depletion makes an increasing contribution to the total volume of abstraction over time, representing almost half of the total volume pumped after a nominal period of 100 days.

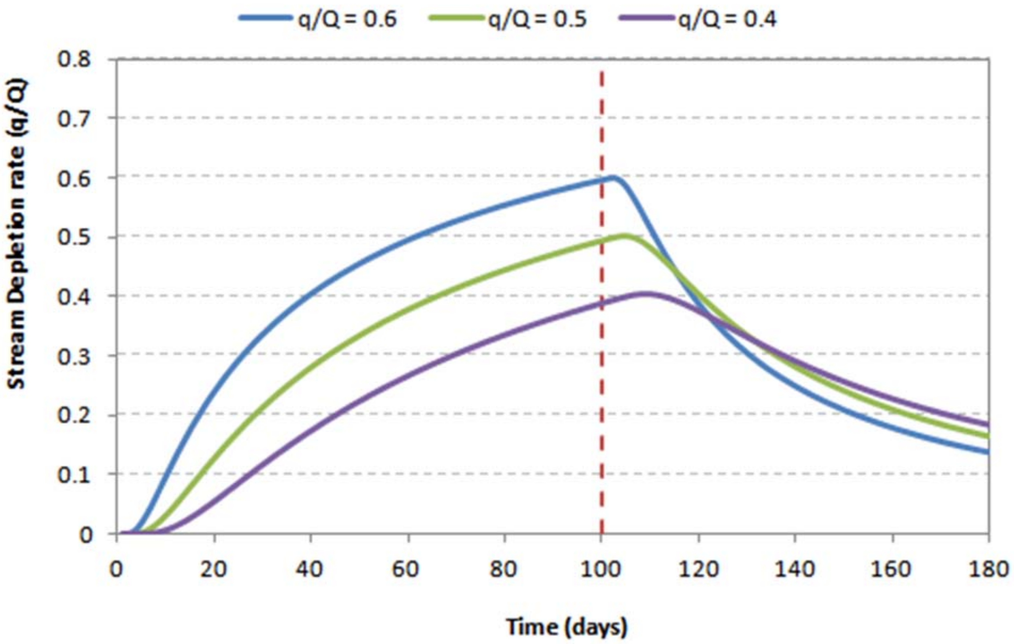

Figure 6: Representative stream depletion curves resulting from Category B groundwater abstraction (red line demotes cessation of pumping)

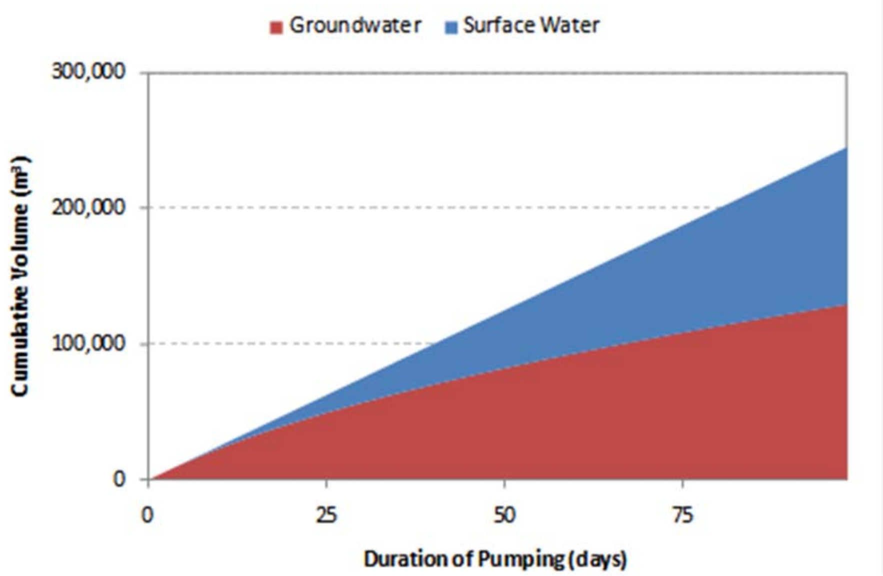

Figure 7: Relative contribution of groundwater storage and stream depletion to the total volume of water pumped from a Category B take

Category C

7.12 Category C includes those areas of the hydrogeological system where groundwater abstraction may contribute to an overall reduction in baseflow discharge at a catchment scale but where active regulation of pumping does not provide mitigation of effects on surface water.

7.13 Figure 8 shows a representative stream depletion curve resulting from Category C groundwater abstraction. The figure shows stream depletion effects take an extended period to develop but persist for an extended period (even increasing in magnitude for a time) once abstraction stops.

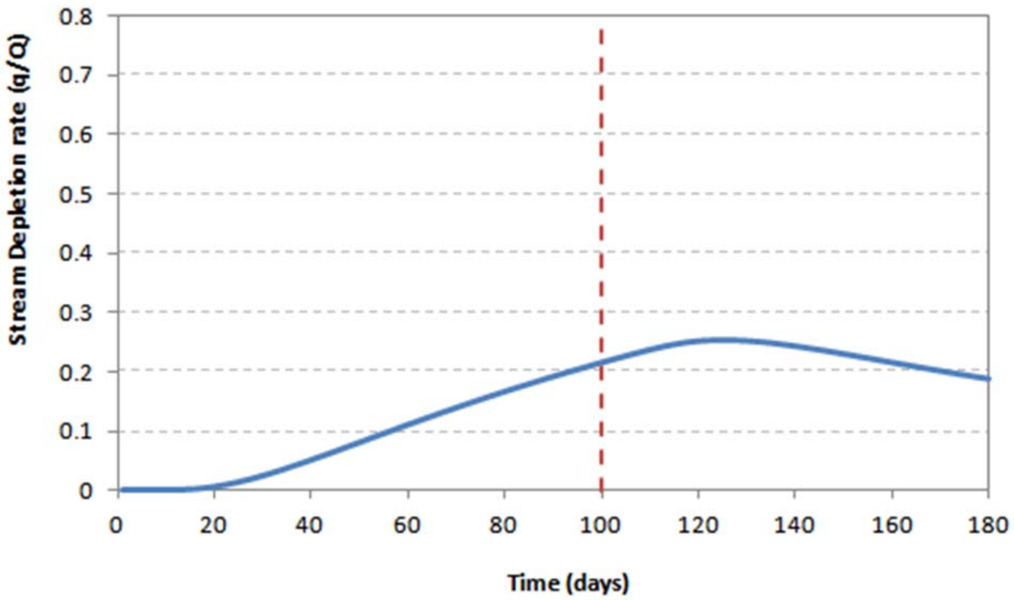

Figure 8: Representative stream depletion curve resulting from abstraction of Category C groundwater (red line demotes cessation of pumping)

7.14 Figure 9 shows a plot of the relative contribution of groundwater storage and stream depletion to the cumulative volume of groundwater pumped from a Category C groundwater take. The graph shows that during the initial pumping period a majority of water is derived from aquifer storage, with stream depletion making a minor contribution to the total volume of abstraction over time.

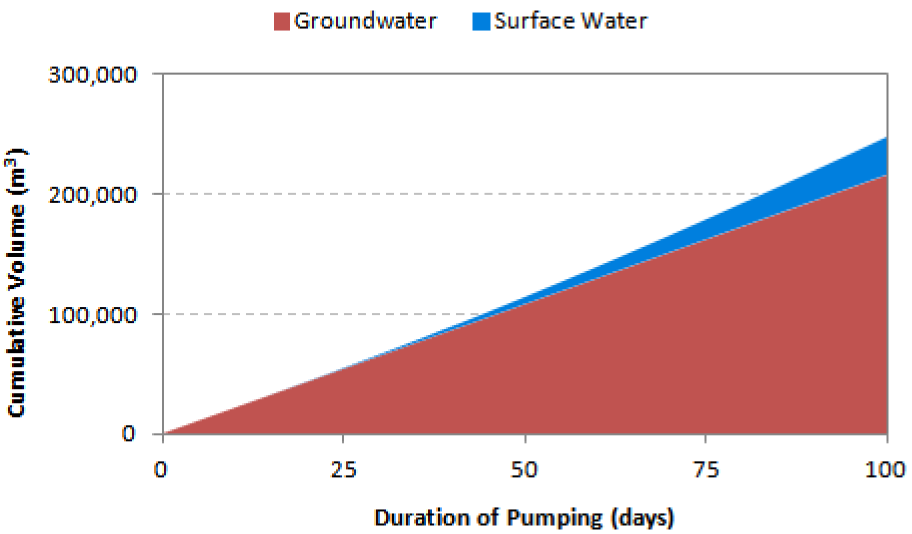

Figure 9: Relative contribution of groundwater storage and stream depletion to the total volume of water pumped from a Category C take.

Spatial delineation of hydraulic connection categories

7.15 The spatial and depth distribution of hydraulic connectivity categories are mapped for the Wairarapa Valley, Hutt Valley and the Kapiti Coast in the relevant Whaitua chapters of the pNRP. The mapping of hydraulic connectivity zones in the pNRP is intended to provide surety for consent applicants (in terms of potential water availability and likely management controls), reduce requirements for hydrogeological assessment and simplify the resource consent process.

7.16 It is noted that the approach of mapping hydraulic connectivity zones differs from that adopted by other Regional Plans that contain similar stream depletion provisions (e.g. ECan Natural Resources Regional Plan, Environment Southland Proposed Land and Water Regional Plan). Under these Plans, water availability and reliability of supply can generally only be established once an assessment of hydraulic connectivity is completed.

7.17 A number of submitters seek clarification of the spatial delineation of the proposed hydraulic connection categories. The following section outlines the process involved in delineation of the hydraulic connectivity maps included in the respective Whaitua chapters of the pNRP.

Category A

7.18 In the Wairarapa Valley, the spatial extent of the Category A classification was largely mapped on the basis of the spatial extent of Q1 alluvium deposits in the QMap geological coverage. This subdivision was supported by multiple lines of evidence including:

- A review of aquifer hydraulic properties which showed aquifers hosted in Q1 alluvium are typically unconfined and highly permeable (specific yield ~5-15%, transmissivity ~1,500 to 6,000 m^2/day), compared to surrounding alluvial deposits;
- Analysis of temporal variation in river stage and groundwater levels indicating a high degree of connection between groundwater and surface water (illustrated in Figure 10 below);
- Observed gains and losses in stream flow indicating significant recharge/discharge flux between surface and groundwater (illustrated in Figure 11 below);
- The occurrence of springs and spring-fed streams;

- Groundwater quality and hydrochemistry which indicate recharge associated with distal surface water recharge sources (e.g. delta ^{18}O) and/or significant dilution of local land surface recharge.

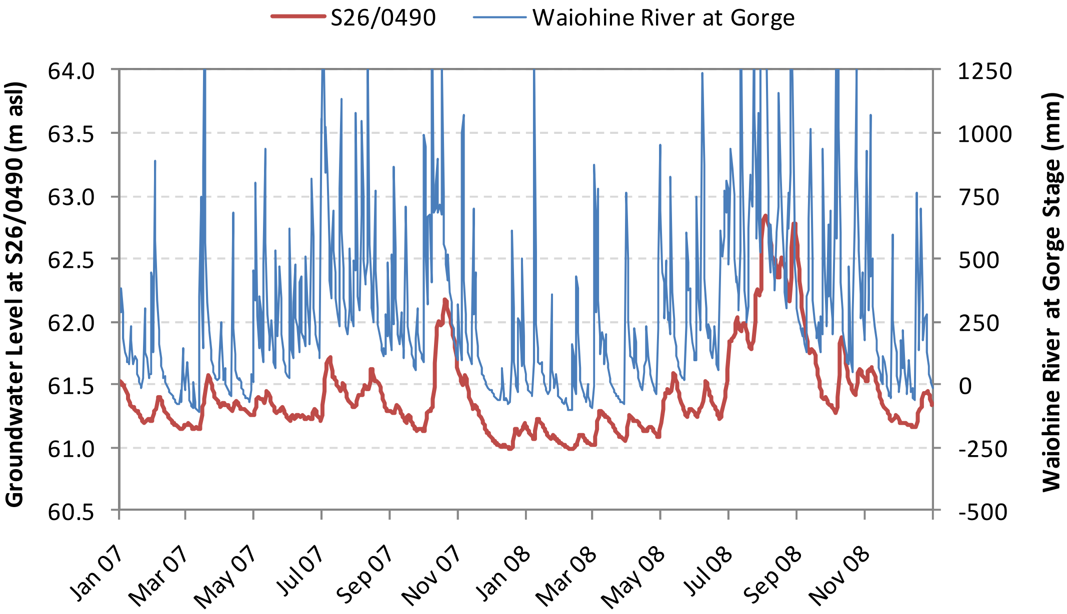

Figure 10: Example of temporal variations in groundwater level in a shallow bore screened in Q1 alluvium in the Greytown area (S26/0490) compared to Waiohine River stage

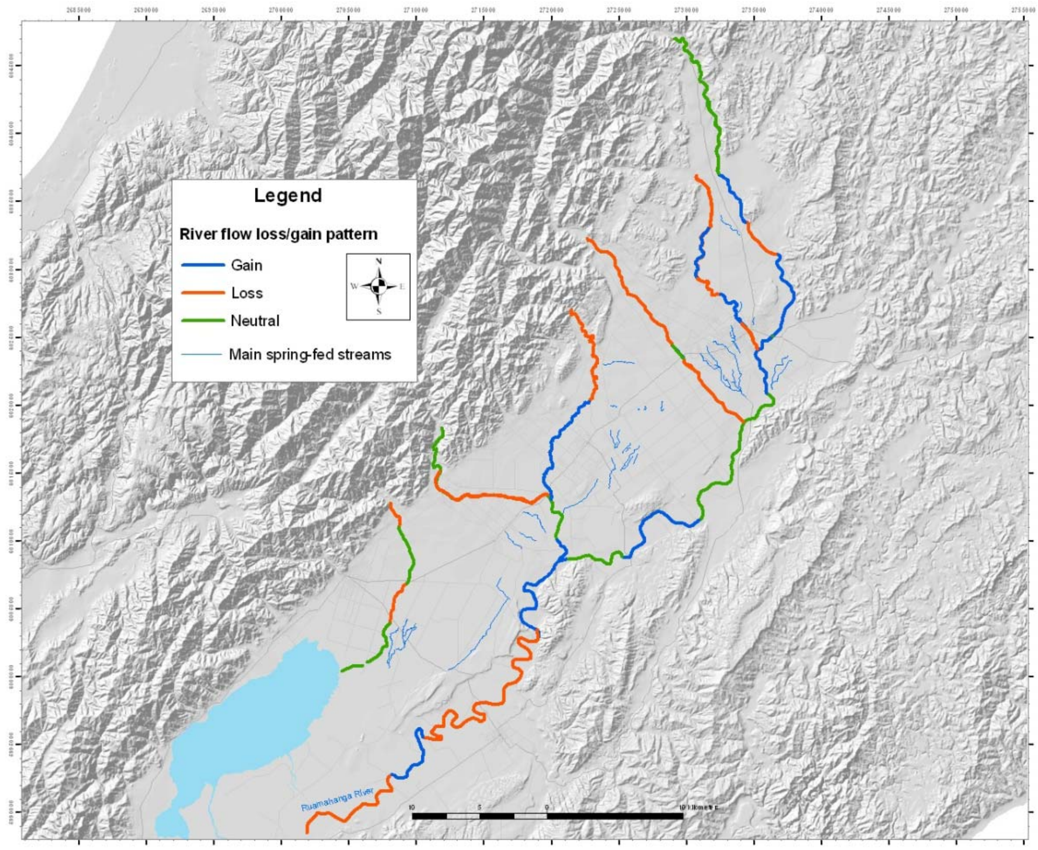

Figure 11: Observed flow gains and losses in the major river systems in the Wairarapa Valley

7.19 The spatial extent of the Category A classification was extended beyond the Q1 alluvium boundary to include the groundwater catchments of the major spring-fed streams (e.g. the Greytown Springs, Stonestead and Poterau Steams) to reflect the sensitivity of these environments to changes in flow induced by relatively small reductions in groundwater levels. As described below, the Category A classification was also extended to include semi-confined aquifers in the middle Ruamahanga Valley.

7.20 Analytical and numerical modelling was utilised to independently verify the assumed high degree of hydraulic connection between areas delineated as Category A and adjacent surface water bodies, for a range of pumping scenarios.

7.21 Figure 12 below, shows a comparison of stream depletion calculated using an analytical model (Hunt, 1999) and the Middle Valley FEFLOW model (described in Dr Gyopai's evidence) for a theoretical bore in the Greytown area situated 500 metres from the Waihone River. The data shows good agreement between the model results, with the rate of calculated stream depletion rapidly increasing following commencement of pumping to comprise a significant proportion of the water abstracted (>60%) within a short period (approximately 20 days). Stream depletion effects then decline rapidly once pumping is stopped. It is noted that the higher stream depletion calculated by the analytical model reflects potential effects on spring-fed streams which are not accounted for in the analytical modelling (which only calculated the effect on the Waiohine River).

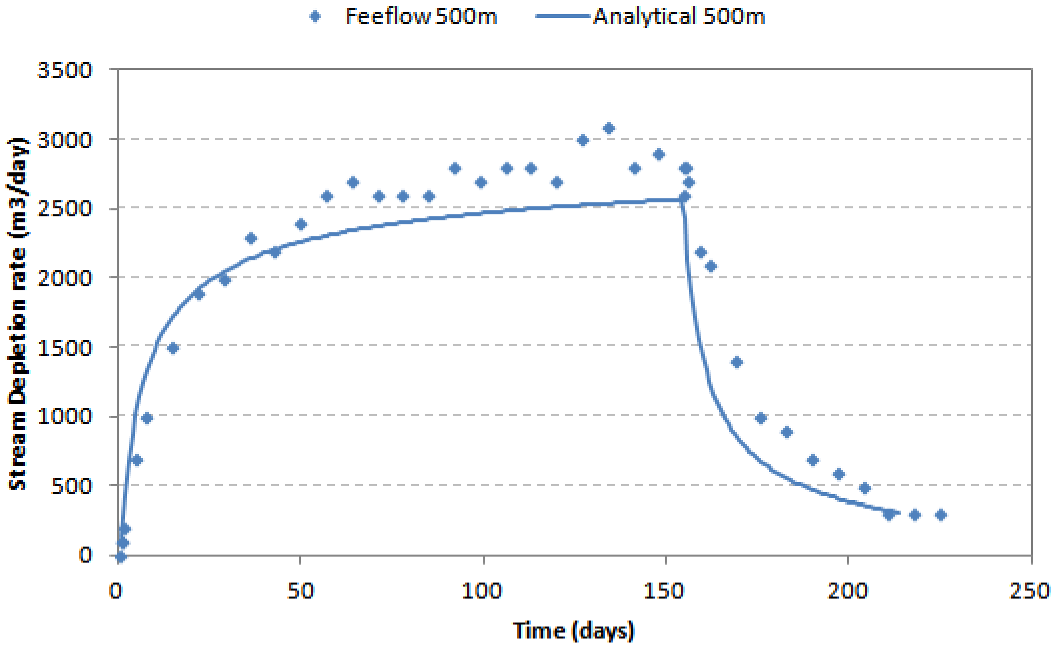

Figure 12: Comparison of analytical and numerical estimates of stream depletion for a nominal pumping scenario in the Waiohine groundwater zone

7.22 Figure 13 shows application of the Middle Valley FEFLOW model to estimate the contribution of groundwater abstraction located in Category A areas in the Waiohine groundwater zone. The figure clearly shows that the overall stream depletion effect (including impacts on the Waiohine River and Greytown springs) approximates the rate of groundwater abstraction, with limited lag between abstraction and effects on surface water[2]. The plot also shows the rate of stream depletion reduces rapidly once pumping ceases.

[2] It is noted that the calculated stream depletion effect in the pumping scenario illustrated actually exceeds the rate of abstraction at some times. This is due to the effects of abstraction from surrounding alluvial fan aquifers.

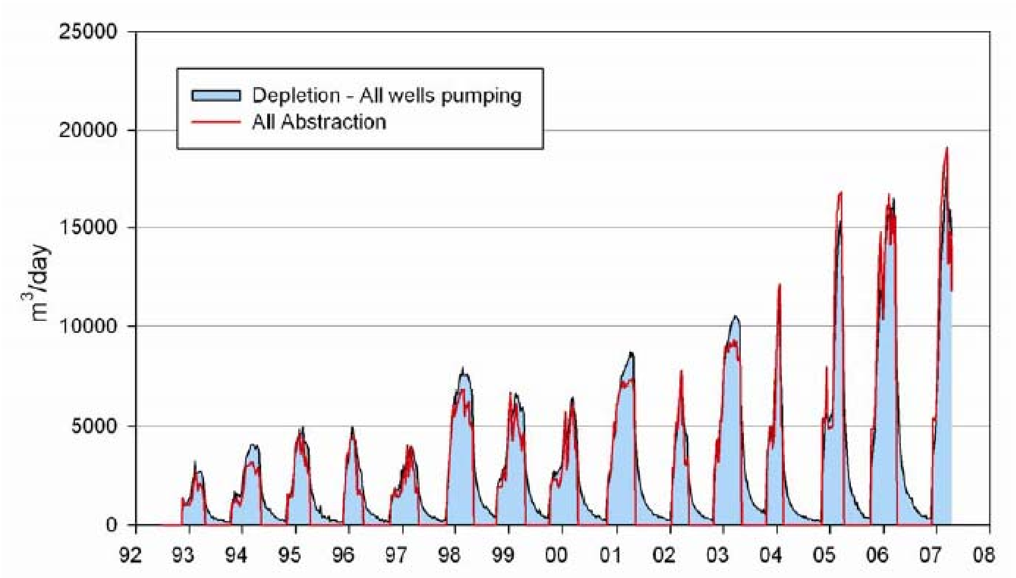

Figure 13: Calculated stream depletion resulting from groundwater abstraction from the Waiohine groundwater zone (Middle Valley FEFLOW model)

7.23 Similar analysis was undertaken to verify the assumed high degree of hydraulic connection between groundwater and surface water in other Category A areas in the Wairarapa Valley. It is noted that this analysis also indicated that, due to a combination of high transmissivity and low storage, unconfined to semi-confined aquifers in the Moiki and Lower Ruamahanga groundwater zones (in part comprising Q2 alluvium) also exhibit a high degree of hydraulic connection to surface water. Model scenarios from this area are illustrated in Figure 14 below and show stream depletion represents a significant proportion of total groundwater abstraction (even though, in part, the aquifers in this area are classified as semi-confined), justifying inclusion in the Category A classification.

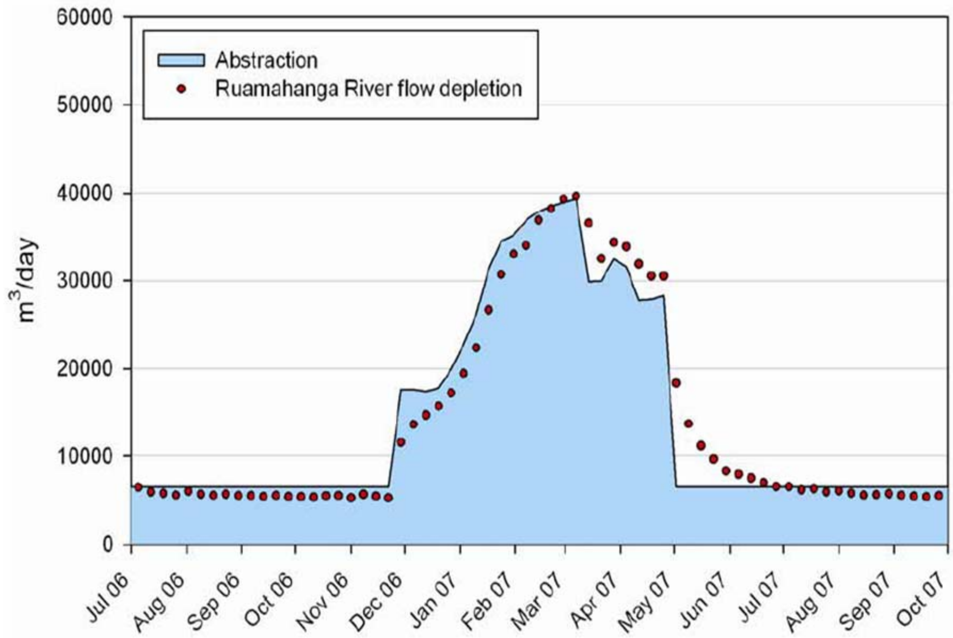

Figure 14: Simulated flow depletion in the Ruamahanga River resulting from groundwater abstraction in the Lower Ruamahanga groundwater zone over the 2006/07 irrigation season

7.24 The depth of the category A classification varies across the Wairarapa Valley based on analysis of subsurface geology (bore logs), screen depths and aquifer hydraulic properties. In some areas (e.g. the Waiohine, Moiki and Lower Ruamahanga zones) the Category A classification applies groundwater at all depths reflecting the limited impediment to vertical groundwater flow in these areas. In other locations (e.g. adjacent to the Waingawa, Waipoua and Tauherenikau Rivers) the Category A classification terminates at depths ranging from 10 to 30 metres reflecting the presence of laterally continuous low permeability (aquitard) sediments which restrict vertical flow of groundwater into deeper water-bearing layers.

Integrating management of Category A groundwater and surface water abstraction

7.25 In order to integrate management of hydraulically connected groundwater abstraction with surface water allocation and minimum flows, Category A and Category B (high connection) groundwater has been assigned to individual catchments and sub-catchments in the Whaitua chapters of the pNRP.

7.26 For example, in the Wairarapa Valley, Category A and Category B (high connection) groundwater along the margins of the Waingawa River is included in the cumulative allocation amount (defined in terms of L/s) defined for the Waingawa River upstream of the Raumakanga River confluence. This means the average weekly pumping rate for Category A takes and the stream depletion component calculated for Category B (high connection) takes is included in the cumulative surface water allocation calculated for the Waingawa catchment.

7.27 Elsewhere in the Wairarapa Valley, surface water and hydraulically connected groundwater allocation are managed on a sub-catchment and catchment basis (so allocation is managed at the individual sub-catchment scale which in turn contributes to cumulative allocation at a catchment scale). For example in the Waiohine catchment upstream of the Raumahanga confluence, surface water and hydraulically connected groundwater allocation is managed in terms of four separate allocation amounts. Smaller tributaries such as Parkvale Stream and Booths Creek which do not have specific Category A areas delineated along their riparian margins, have a cumulative allocation defined for surface water and Category B (high connection) takes. In the Mangatarere catchment, allocation volumes are established for Category A, Category B (high connection) and surface water allocation, while in the main stem of the Waiohine catchment, allocation is managed in terms of local Category A, Category B (high connection) and surface water allocation plus the contribution from the Mangatarere, Parkvale Stream and Booths Creek catchments.

Papawai Stream also has a separate allocation amount for Category A groundwater and surface water abstraction. This allocation is managed separately from the cumulative Category A, Category B (high connection) and surface water allocation for the Waiohine catchment upstream of the Papawai Stream confluence.

7.28 A similar procedure to that utilised in the Wairarapa Valley was followed to delineate Category A areas in the Hutt Valley and Kapiti Coast areas. Basic zonation was undertaken based on the spatial extent of Q1 alluvium defined in the QMap coverage. A range of physical monitoring data and modelled pumping scenarios were utilised to validate the high degree of hydraulic connectivity assumed in these areas, and the depth of the Category A classification assigned on the basis of any interpreted restriction on hydraulic connectivity with deeper water-bearing layers.

7.29 As in the Wairarapa Valley, cumulative surface water allocation (including Category A and Category B (high connection) groundwater abstraction) in the Hutt Valley and Kapiti Coast areas is managed on a local sub-catchment and cumulative catchment basis (defined in the respective pNRP Whaitua chapters).

Category C

7.30 The Category C hydraulic connectivity classification includes areas of the hydrogeological system where there is clear evidence of a moderate to low degree of hydraulic connection between groundwater and surface water.

7.31 The spatial extent of Category C areas were delineated on the basis of a conceptualisation of the potential for groundwater/surface water interaction, supported by analysis of the potential effects of groundwater abstraction on surface water using numerical groundwater models.

7.32 In the Wairarapa Valley, physical evidence utilised to identify category C areas included:

- The presence of laterally continuous aquitard layers interpreted from bore logs;
- Aquifer test data indicating low storage, low transmissivity or boundary effects;
- Analysis of temporal groundwater level variations and vertical head differences;
- Areas with deep static water levels limiting the potential for hydraulic connection to surface waterways;
- Groundwater quality and hydrochemical data which indicate limited recharge from surface water sources and/or evidence of extended groundwater residence times.

While none of these criteria alone is sufficient to justify Category C classification, in combination they are indicative of limited hydraulic connection to surface water.

7.33 Areas of the Wairarapa Valley delineated at Category C include the Martinborough, Onoke and Fernhill-Tiffen groundwater zones (comprising older, uplifted low permeability alluvial deposits) and deeper alluvial deposits between the major river systems which exhibit limited hydraulic connection to the surface environment (i.e. semi-confined to confined aquifers).

7.34 Analysis of pumping scenarios using the numerical models described by Dr Gyopari was used to validate the delineation of Category C areas (both in terms of spatial extent and depth). Figure 16 shows an example of a pumping scenario for the Parkvale groundwater zone. The figure shows abstraction of groundwater from deeper groundwater (>20 m) has limited effect on hydraulically connected surface water (i.e. the Parkvale Springs) consistent with the Category C classification.

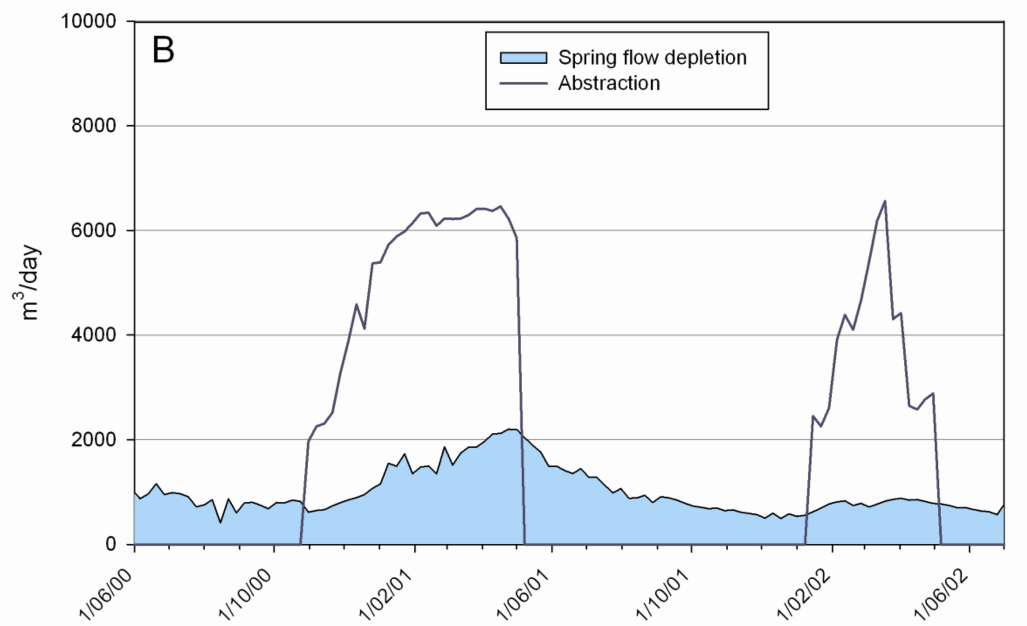

Figure 16: Simulated abstraction and associated surface water depletion resulting from deeper (>20m) groundwater abstraction in the Parkvale groundwater zone, 2000-02

Category B

7.35 The category B classification represents areas in the Wairarapa Valley, Hutt Valley and Kapiti Coast where groundwater abstraction may potentially result in significant impacts on surface water, but where pumping regulation does not always provide an effective option for mitigating direct stream depletion effects. Category B essentially represents the areas that do not clearly exhibit either high (Category A) or low (category C) hydraulic connectivity to surface water. This classification therefore represents areas where it may be appropriate to manage groundwater takes in terms of either surface water or groundwater allocation, depending on localised factors (e.g. local aquifer hydraulic parameters, abstraction rate and location of pumping with respect surface waterbodies).

7.36 Numerical models were again used to used validate the assumed hydraulic connectivity in areas included in the Category B classification. Figure 17 shows an example of a pumping scenario evaluated for the Category B area in Tauherenikau groundwater zone. The figure shows abstraction at locations between 1,000 and 1,500m of the river results in a relatively high rate of stream depletion (q/Q 0.7 to 0.8) which reduces relatively quickly once pumping stops. In contrast, bores over 1,500 m from the river exhibit a much lower stream depletion effect (q/Q 0.4 to 0.5) which dissipates slowly once pumping is stopped.

7.37 This example, illustrates that while it may be appropriate to manage some Category B groundwater abstraction (in this case within ~1,500 m of the river) in terms of surface water allocation and minimum flows, takes further from the river are better managed in terms of cumulative groundwater allocation.

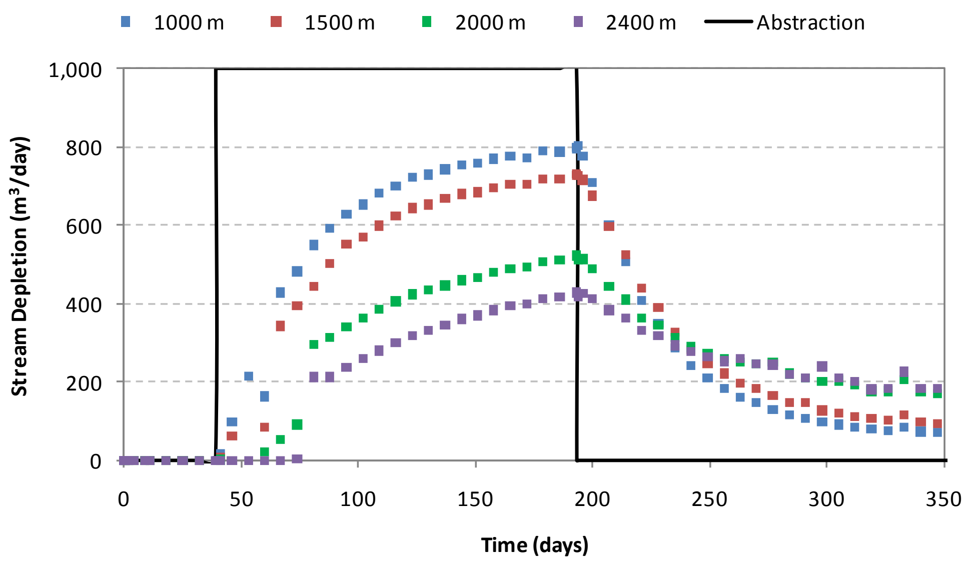

Figure 17: Stream depletion resulting from Category B groundwater abstraction at varying distances from the Tauherenikau River

7.38 It is noted that all areas outside the Category A classification in Kapiti Coast groundwater management zones are designated Category B. This reflects analysis of pumping scenarios using the numerical models which indicate significant vertical leakage in response to groundwater pumping from all depths.

8. CRITERION FOR ASSESSING AND MANAGING STREAM DEPLETION EFFECTS

8.1 Schedule P of the pNRP specifies criterion for assessing and managing stream depletion effects resulting from groundwater abstraction[3] and links to several policies including P108, P113 and P115 which relate to the management of surface and groundwater allocation.

8.2 Ms Hammond's evidence outlines a modified version of Schedule P that incorporates a number of changes made in response to stakeholder feedback. In its amended form, the hydraulic connectivity classification comprises four categories; the existing Category A (direct connection) and Category C (low connection) categories, with the Category B differentiated into Category B (high connection) and Category B (moderate connection). The proposed subdivision of the Category B classification is intended to help clarify the overall intent of the classification.

Category A

8.3 The Category A (direct connection) category includes groundwater takes located in areas identified as having a high degree of hydraulic connection with surface water. For Category A takes stream depletion effect occur almost immediately following the commencement of pumping and increase rapidly to comprise a significant proportion of the pumping rate. Once pumping stops depletion effects dissipate quickly making such takes amenable to mitigation by pumping regulation.

Inclusion in surface water allocation volumes

8.4 Given their high degree of hydraulic connection, it is proposed that Category A groundwater takes are managed as equivalent surface water abstractions. Policy P113 specifies that Category A groundwater takes will be counted as part of the surface water allocation for relevant surface water bodies (identified in the individual Whaitua chapters of the pNRP).

8.5 Schedule P specifies that surface water allocation for Category A takes will be based on the average weekly rate of take (as opposed to the instantaneous rate of take for surface water abstractions). This distinction reflects the buffering effect of groundwater storage on short term variations in the rate of groundwater abstraction.

3 It is noted that Ms Hammond's evidence recommends incorporation of this table into Policy 107 (rather than remaining as a separate schedule).

Application of minimum flows

8.6 Schedule P specifies that Category A groundwater takes will be subject to the minimum flow restrictions outlined in Policy P115 which requires takes to be reduced by 50% of the amount consented above minimum flows. As previously discussed, this restriction is intended to reduce the rate of stream depletion resulting from groundwater abstraction thereby mitigating effects on flows in hydraulically connected surface waterways during periods of low flow.

8.7 It is noted that the original conjunctive management framework proposed for the Wairarapa Valley, Hutt Valley and Kapiti Coast recommended that Category A groundwater abstractions cease take once minimum flows are reached in relevant surface waterways. As discussed in evidence by Ms Hammond, the minimum flow cease take recommendation was amended to 50% of the daily rate of take to reduce financial impacts associated with the reduced reliability of supply resulting from a full cease take.

8.8 In practical terms, the proposed 50% restriction will approximately halve the extent of mitigation afforded to low flows in hydraulically connected surface waterways compared to that which would occur under a 100% cease take restriction (the exact difference will vary between individual take locations).

Reclassification of hydraulic connection category

8.9 Schedule P also includes provision for the reclassification of the hydraulic connection category for a groundwater take located in an area designated at Category A on the basis of hydrogeological evidence indicating surface water depletion effects are more consistent with an alternative classification. This is intended to provide for situations where regional-scale mapping of hydraulic connectivity zones does not account for local-scale variability in hydrogeological conditions.

8.10 It is noted that following the pre-hearing meeting in Masterton on the 18th May 2017, a draft list of hydrogeological information required to support re-classification of hydraulic connection has been developed. Such a list will provide clear guidance for both resource consent applicants and the Council regarding information required to support reclassification. Ms Hammond’s evidence provides discussion of the relative merits of incorporating these information requirements as a Schedule to the pNRP, or as a separate guidance document.

Category B

8.11 The Category B classification includes those areas of the hydrogeological system where groundwater abstraction may potentially result in significant impacts on surface water but where pumping regulation does not always provide an effective option for mitigating direct stream depletion effects. Category B represents the transition between indirect and direct stream depletion effects where it may be appropriate to manage groundwater takes in terms of either surface water allocation and minimum flows (i.e. Category B (high connection)) or groundwater allocation (i.e. Category B (moderate connection)), depending on the local hydrogeological setting.

8.12 Schedule P establishes a number of criteria for determining the nature of hydraulic connection for an individual groundwater take. These include a minimum rate of take, and various thresholds for the stream depletion ratio and the overall magnitude of the calculated stream depletion effect.

Minimum rate of take

8.13 Takes with a minimum weekly average rate of take of greater than 5 L/s automatically default to Category C (low connection). The exemption is proposed as a pragmatic means to ensure management of groundwater takes within Category B is focussed on those most likely to result in significant effects on surface water and avoid the need for stream depletion assessment to be undertaken for small-scale groundwater abstraction in Category B areas.

Stream depletion ratio

8.14 While pumping regulation offers a means to mitigate potential effects on surface water where there is a high degree of hydraulic connection, stream depletion effects tend to persist for an increasing time after pumping ceases where there is lower connectivity. A nominal stream depletion ratio is proposed as a means to differentiate those groundwater takes amenable to regulation (i.e. Category B (high connection)) from those which are better managed in terms of cumulative groundwater allocation (i.e. Category B (moderate connection)).

8.15 Table 1 lists the calculated reduction in stream depletion effect at various times following the cessation of pumping for a nominal groundwater take assigned varying degrees of hydraulic connection. These data show that for bores with a relatively high stream depletion ratio (e.g. q/Q = 0.8), the calculated stream depletion effect reduces by over 50% within 10 days of pumping being stopped, so pumping regulation can significantly reduce effects on surface water. However, where the stream depletion ratio is lower (e.g. q/Q = 0.5), stream depletion effects decline at much slower rate once pumping creases (2% after 10 days, 18% after 20 days) so pumping regulation provides limited mitigation of stream depletion effects over the typical timescale of low flow events in the Wellington Region.

Table 1: Percentage reduction in stream depletion following cessation of pumping for different degree stream depletion ratios (q/Q)

	Time since pumping stopped			
q/Q	10 Days	20 days	30 days	40 days
0.8	54%	71%	79%	83%
0.7	31%	53%	64%	71%
0.6	13%	34%	48%	57%
0.5	2%	18%	32%	43%
0.4	-4%	2%	13%	24%

8.16 A stream depletion effect exceeding 60 percent of the rate of take (i.e. q/Q = 0.6) is proposed as an arbitrary threshold above which pumping regulation (i.e. application of minimum flows) provides an effective means of mitigating effects on surface water. Takes assessed as having a stream depletion ratio greater than this threshold are included in the Category B (high connection) category.

8.17 It is noted a stream depletion ratio of 0.6 (or 60%) is adopted as a threshold for application of minimum flow controls in other Regional Plans which contain similar stream depletion policies to the pNRP (e.g. the Environment Canterbury Natural Resources Regional Plan and the Environment Southland Proposed Land and Water Regional Plan).

Threshold for more than minor stream depletion effects

8.18 Along with the degree of hydraulic connection, the overall rate of groundwater abstraction also influences the potential magnitude of groundwater abstraction. For example, as shown in Figure 18 below, a groundwater take with a relatively high degree of hydraulic connection (q/Q of 0.7) may have a significantly lower overall effect on surface water than a take with a lower degree of hydraulic connectivity which has a higher abstraction rate.

8.19 It is therefore proposed that Category B groundwater takes with a calculated rate of stream depletion of exceeding 10 L/s are included in the Category B (high connection) classification. It is noted that while pumping regulation may not necessarily provide a significant reduction in overall effect stream depletion effect from such takes in percentage terms, the actual reduction in effect (in terms of L/s) for larger takes is likely to be sufficient to at least partially mitigate effects on surface water.

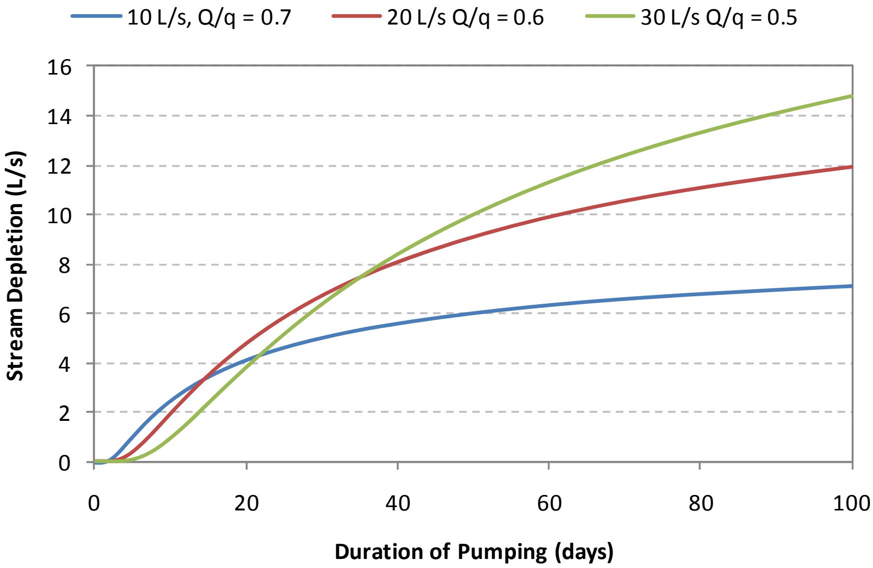

Figure 18: Calculated stream depletion resulting from groundwater takes with varying degree of hydraulic connection (q/Q = 0.5 to 0.7) and pumping rates (Q = 10 to 30 L/s)

Pumping rate and duration used for assessment of stream depletion effects

8.20 The magnitude of stream depletion effects (and associated stream depletion ratio) calculated for a groundwater take at a particular location depends on the assumed rate and duration of pumping. Concern was expressed by a number of stakeholders at pre-hearing meetings that pumping rate and duration criteria should reflect 'typical' water use in the Wairarapa. However, given the Category B assessment criteria also apply to all uses (including horticulture, municipal and industrial supply) across the whole Wellington Region, criteria adopted for the assessment also have to be representative of a range of water use types.

8.21 The proposed pumping rate and duration criteria outlined in Ms Hammond's evidence is now based on the average pumping rate occurring over the 90 day period of maximum demand occurring 1 in 10 years. The revised criteria are intended to reflect a representative rate and magnitude of pumping applicable to a range of water uses.

8.22 For irrigation takes, the 9 in 10 year, 90 day demand can be readily established from the Irrigation New Zealand online calculator (which is typically utilised to establish reasonable and efficient use under Policy P118).

Although this approach does not necessarily incorporate the maximum instantaneous rate or seasonal volume able to be abstracted by individual water permits, it is considered to represent a reasonable estimate of likely irrigation demand. As noted in Ms Hammond's evidence, a review of selected water use records indicated that the proposed criteria provide a reasonable indication of actual, dry year irrigation water use.

8.23 For other water uses such as municipal and industrial supply, the proposed criteria can be applied using projected, historical or anticipated, 1 in 10 year (90 percentile) demand. The 90 duration for the assessment ensures that calculated effects are likely to reflect those occurring toward the end of a 'typical' period of extended flow recession occurring in surface waterways across the Wellington Region.

Inclusion in surface and/or groundwater allocation volumes

8.24 Schedule P specifies that allocation for takes classified as Category B (high connection) is divided between hydraulically connected surface water and the relevant groundwater management zone, based on the calculated rate of stream depletion. The division of allocation between groundwater and surface water for Category B (high connection) takes recognises the lower overall hydraulic connection compared to Category A, and the fact that during the initial pumping period, a majority of water is derived from groundwater storage.

8.25 For groundwater takes classified as Category B (moderate connection) the entire allocation is included in the cumulative allocation volume for the relevant groundwater management zone. This recognises that surface water depletion effects from such takes are best managed in terms of cumulative effects on baseflow at a catchment scale.

Application of minimum flows

8.26 Schedule P specifies that minimum flow cut-offs may be applied to Category B (high connection) takes but does not specify and set a specific level of restriction. This provides discretion for GWRC to consider the efficacy and benefits associated with application of minimum flows to individual Category B (high connection) groundwater takes. Criteria that may influence the decision to apply a minimum flow restriction to a Category B (high connection) groundwater take may include factors such as the size, nature and ecological values of hydraulically connected surface water bodies.

8.27 Schedule P specifies that Category B (moderate connection) takes are not subject to minimum flow restrictions. This reflects the limited efficacy of pumping restrictions as a means to mitigate effects on surface water resulting from such takes.

Category C

8.28 Groundwater takes located in areas designated Category C are included in the cumulative allocation for the appropriate groundwater management zone defined in the individual pNRP Whaitua chapters. As outlined in Dr Gyopari's evidence, groundwater allocation volumes for each groundwater zone have been established on the basis of a maximum cumulative effect on surface water baseflow at a catchment scale.

8.29 Due to the indirect connection with surface water, groundwater abstraction from Category C areas is not subject to minimum flow restrictions.

9. SPATIAL RESOLUTION OF HYDRAULIC CONNECTIVITY CLASSIFICATION

9.1 A number of submitters raised concerns regarding the spatial resolution of the proposed hydraulic connectivity classification. As delineated in the pNRP, the classification is based on the best hydrogeological information available at the time. However, it is recognised that, due to local-scale heterogeneity, there may be some uncertainty regarding the defined category boundaries in some areas. This issue is addressed in two ways.

9.2 Firstly, as described previously, Schedule P provides for reclassification of hydraulic connectivity classification based on appropriate hydrogeological investigations. Such investigations can be initiated by a resource consent applicant if they consider the mapped boundaries to be incorrect (following a defined list of information requirements).

9.3 Secondly, the Category B classification was essentially established to account for uncertainties in areas where hydraulic connectivity transitions from high to low. As such, areas in the Category B classification, close to the Category A boundary are most likely to be classified as Category B (high connection) and effectively managed as Category A takes (the main difference between these classifications being the ways allocation is divided between surface water and groundwater). Similarly groundwater takes in Category B areas close to the Category C boundary are most likely to be assessed as Category B (moderate connection) and effectively managed as Category C takes.

9.4 Due to the set-up of the proposed hydraulic connectivity classification, there is little distinction between management of Category A and Category B (high connection) takes, and Category B (moderate connection) and Category C takes. As a consequence, the exact accuracy of the boundaries delineated in the pNRP are likely to have limited impact on the way individual groundwater takes are assessed and managed. Only in the case of significant inaccuracies (i.e. Category C areas delineated as Category A), will the boundary location have a significant impact on the manner in which an individual groundwater take is assessed and managed. In this situation, the provisions of Schedule P provide for reclassification of hydraulic connectivity classification based on assessment of the local hydrogeological setting.

10. SUMMARY

10.1 The proposed conjunctive management framework is intended to provide a pragmatic framework for integrating management of surface and groundwater resources across the Wellington Region. The framework is based on the underlying premise that:

- Where there is a high degree of hydraulic connection between groundwater and surface water, groundwater abstraction can effectively be managed as equivalent surface water abstraction; and
- Where there is a low degree of hydraulic connection, the effects of groundwater abstraction on surface water flows is most effectively managed in terms of a cumulative groundwater allocation volume established to cap the effect on baseflow at a catchment scale.

10.2 Three hydraulic connectivity classifications have been mapped to guide application of the conjunctive management framework based on existing knowledge of the hydrogeological environment.

10.3 Category A identifies areas where there is clear evidence indicating a high degree of hydraulic connection and groundwater abstraction can be effectively managed as part of the allocation for connected surface water resources. Category C areas delineate areas where there is a low degree of hydraulic connection and effects on surface water are best managed through a volumetric allocation limit.

10.4 The Category B classification includes those areas of the hydrogeological system where the scale and nature of effects on surface water (and the corresponding management approach) are more dependent on local hydrogeological conditions. Schedule P specifies a methodology to establish if groundwater abstraction at a particular location in the Category B classification is best managed in terms of surface water (Category B (high connection)) or groundwater (Category B (moderate connection)).