#1148472

Malory Osmond

From: Malory Osmond
Sent: Friday, 23 November 2012 12:12 p.m.
To: Mark Utting
Cc: Doug Mzila; 'Belinda Van Eyndhoven'
Subject: Hutt Valley conjunctive water management document

Attachments: Hutt Valley and other areas Framework for Conjunctive Water Management Report.pdf

Hi Mark,

Doug mentioned he has spoken to you today about the Heretaunga Water Limited consent application and has asked me to email you this document which we use for our assessments of water takes in the Hutt Valley.

"Application of Proposed Framework for Conjunctive Water Management - Hutt Valley and areas outside nominated groundwater management zones"

Hutt Valley and other areas Fr...

Kind regards

Malory Osmond | Senior Resource Advisor, Environmental Regulation
GREATER WELLINGTON REGIONAL COUNCIL
Te Pane Matua Taiao
142 Wakefield Street | PO Box 11646, Manners Street, Wellington 6142
T: 04 830 4015 | www.gw.govt.nz

Application of Proposed Framework for Conjunctive Water Management

Hutt Valley and areas outside nominated groundwater management zones

Liquid Earth
July 2012

Application of Proposed Framework for Conjunctive Water Management

Hutt Valley and areas outside nominated groundwater management zones

- July 2012

Liquid Earth Limited
Level 2, 11 Deans Avenue
Riccarton
Christchurch

Executive Summary

The groundwater resources of the Wellington Region form an integral component of the overall hydrological cycle and have a significant role in sustaining freshwater ecosystems in riverine and wetland habitats. Significant use is also made of the groundwater resource for domestic, municipal, industrial and irrigation water supplies. Managing potential conflicts between maintenance of environmental values associated with the groundwater resource (including hydraulically connected surface water) and the potential social and economic benefits arising from water use presents a major resource management challenge.

Hughes and Gyopari (2011) proposed a methodology for conjunctive management of groundwater and surface water resources in the Wairarapa Valley to enable management of groundwater abstraction in a manner consistent with environmental flows and water levels established for hydraulically connected surface water resources. The proposed management framework involves delineation of three hydraulic connection categories:

- Category A: areas with a direct hydraulic connection with surface water where stream depletion effects may be mitigated by application of minimum flow or level cut-offs;
- Category B: areas where groundwater abstraction effects on surface water may be significant and can potentially be managed through application of pumping controls depending on localised hydrogeological conditions and the rate of abstraction; and,
- Category C: areas of the groundwater system which exhibit limited connectivity to surface water where cumulative effects on surface water are best addressed through management in terms of a fixed allocation volume.

This report is intended to provide recommendations for application of the proposed conjunctive management framework across the remainder of the Wellington Region to the extent practicable given constraints on data and technical tools available to characterise and quantify the nature and extent of groundwater/surface water interaction.

Available geological, hydrogeological and hydrological information are utilised to develop a conceptual model of groundwater/surface water interaction for the Hutt Valley and Kapiti Coast areas. This conceptual model is utilised to provide recommendations for the application of the proposed hydraulic connection categories to each of the groundwater management zones defined in the Regional Freshwater Plan. The report also considers options for future groundwater resource management including amendment of existing groundwater zone boundaries to better reflect the spatial and depth distribution of hydrogeological environments and improve the management of both localised and cumulative effects of groundwater abstraction on significant wetland areas.

For areas outside the groundwater zones defined in the Regional Freshwater Plan, or where insufficient information exists to characterise the potential nature of groundwater/surface water interaction, the report also provides a simple methodology to enable evaluation of the potential significance of effects on surface water associated with individual resource consent applications.

Table of Contents

Table of Figures

1. Introduction

1.1. Background

In May 2011 Greater Wellington Regional Council (GWRC) published a technical report (Hughes and Gyopari, 2010) outlining a proposed framework for the management of groundwater and surface water abstraction in the Wairarapa Valley. This framework was based on the concept of conjunctive management whereby groundwater and surface water allocation is integrated to ensure the cumulative effects of water use are consistent with environmental flows and water levels established for hydraulically connected surface water resources.

The proposed framework conjunctive water management in the Wairarapa Valley was the outcome of five years detailed investigation and modelling, particularly in terms of the potential nature of groundwater-surface water interaction in response to groundwater abstraction. The proposed management framework included criteria for the application of pumping regulation to mitigate direct effects of groundwater abstraction on stream flows and established cumulative effects on surface water as a primary criterion for establishing sustainable groundwater allocation limits. More recently, development of a regional groundwater model has facilitated application of the proposed conjunctive management framework to the Kapiti Coast (GWRC, 2012).

1.2. Report Objectives

The objective of this report is provide recommendations for the application of the proposed framework for conjunctive water management across areas of the Wellington Region not included recent re-assessments of groundwater allocation for the Wairarapa Valley and Kapiti Coast areas. This includes groundwater zones (as defined in the Regional Freshwater Plan (RFP)) in the Hutt Valley, as well as areas outside of current groundwater management zones. The report is primarily focussed on delineation of the spatial and depth distribution of hydraulic connectivity categories and development of a methodology to support application of groundwater pumping regulation to mitigate direct stream depletion effects in areas with limited hydrogeological information. Due to these limitations the report does not provide recommendations for revision of existing groundwater allocation volumes specified in the RFP.

1.3. Report Structure

The report comprises the following sections:

Section 2 - *Management Framework*: An overview of the primary concepts underlying conjunctive water management and the management framework proposed for the Wellington Region

Section 3 - *Hutt Valley*: Recommendations for the management of groundwater-surface water interaction in the Upper and Lower Hutt groundwater zones

Section 4 - *Other Areas*: A proposed methodology for characterising potential stream aquifer connectivity in areas with limited hydrogeological information

Section 5 - *Summary and Conclusions*

2. Management Framework

The groundwater resources of the Wellington Region form an integral component of the overall hydrological cycle and have a significant role in sustaining freshwater ecosystems in riverine and wetland habitats. Significant use is also made of the groundwater resource for domestic, municipal, industrial and irrigation water supplies. Managing potential conflicts between maintenance of environmental values associated with the groundwater resource (including hydraulically connected surface water) and the potential social and economic benefits arising from water use presents a major resource management challenge.

As described in the following sections, groundwater and surface water resources throughout the Wellington Region commonly exhibit a high degree of interconnection, particularly within the recent gravel deposits (denoted as Q1) along the riparian margins of the main river systems. Managing both localised and cumulative effects of groundwater abstraction on hydraulically connected surface waters is therefore a key component of a framework for managing surface and groundwater allocation to ensure environmental values can be maintained at or above thresholds established by the community through the Regional Plan review process.

2.1. Conjunctive water management

Recognising that surface water and groundwater resources within a catchment are fundamentally linked means that management of these resources needs to be undertaken in a coordinated way. Such an integrated approach has been termed *conjunctive water management.* In its simplest application, the term conjunctive water management describes '*the management of hydraulically connected surface water and groundwater resources in a coordinated way, such that the total benefits of integrated management exceed the sum of the benefits that would result from independent management of the surface and groundwater components'* (Sahuquillo and Lluria, 2003).

In this report, the term conjunctive water management is used to describe a framework for the management of groundwater allocation in the Wellington Region which recognises the hydraulic connection between groundwater and surface water in certain hydrogeological environments and enables abstraction of groundwater in a manner that is consistent with environmental flow and water levels established for hydraulically connected surface water resources. A more detailed description of the basic concepts relating to groundwater / surface water interaction is provided in Hughes and Gyopari (2011).

2.2. Proposed conjunctive management framework

The proposed conjunctive water management framework comprises two main components:

1. Management of groundwater abstraction which has a direct or immediate effect on the surface water environment through application of pumping controls based on minimum flows (or levels) established for hydraulically connected surface waterbodies; and
2. Determination of fixed allocation volumes for individual groundwater management zones that recognise that groundwater abstraction may cumulatively cause a reduction in river or stream

baseflow. These allocation limits will apply where groundwater abstraction does not result in an immediate or direct streamflow depletion effect[1].

Hughes and Gyopari (2011) utilised the concept of '*hydraulic connectivity*' to differentiate areas where groundwater abstraction has the potential to result in direct and immediate effects on surface water from those where there is a considerable lag between pumping and resulting effects on surface water. In order to implement the conjunctive water management framework, a three-tier management approach was proposed for managing groundwater abstraction as follows:

Category A: Direct Hydraulic Connectivity

Category A includes areas of the hydrogeological system which exhibit direct connectivity with surface water. Stream depletion effects occur shortly following the commencement of groundwater abstraction, rapidly increase to a level close to the overall pumping rate and dissipate quickly once pumping stops. As a consequence, a high proportion of the overall volume of groundwater pumped from Category A areas effectively represents induced flow loss from local surface waterways. Due to the immediacy of impact, groundwater abstraction from Category A aquifers can be considered analogous to direct surface water abstraction and managed in terms of the environmental flow and water level regimes established for hydraulically connected surface waterbodies.

Category B: High Hydraulic Connectivity

Category B 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 or groundwater allocation depending on localised factors (e.g. local aquifer hydraulic parameters, abstraction rate and location of pumping with respect to surface waterbodies).

Category C: Moderate Hydraulic Connectivity

The Category C classification applies to those areas of the hydrogeological system where, although groundwater abstraction may contribute to an overall cumulative reduction in baseflow discharge at a catchment scale, active regulation of pumping does not provide effective mitigation of potential effects on surface water.

Specification of the spatial and depth distribution of the various hydraulic connection categories is therefore a key component of the overall conjunctive management framework. In both the Wairarapa

[1] As noted in the previous section, this report is primarily focussed on delineating hydraulic connectivity zones for the Hutt Valley and areas outside of groundwater management zones defined in the RFP and does not re-evaluate existing groundwater allocation volumes

Valley and Kapiti Coast areas, this process involved detailed investigations and analysis of the regional hydrogeological setting assisted by the development and application of numerical groundwater models. In contrast, areas covered by this report typically have much more limited data available to characterise the nature of groundwater-surface water interaction (the Upper and Lower Hutt groundwater zones being the exceptions). As a consequence, application of the proposed hydraulic connection categories has largely been approached through the development of a conceptual model of groundwater-surface water interaction in each groundwater zone based on available data, or by the development of a generic methodology to guide information and assessment requirements in areas with little or no hydrogeological information.

2.2.1. Management of groundwater-surface water interaction

Under the proposed conjunctive management framework areas of the hydrogeological system where there is a direct hydraulic connection with surface water (identified as *Category A*) it is proposed that groundwater abstraction will effectively be managed as equivalent surface water abstraction. In those areas where there is a moderate to low hydraulic connection (*Category C*), groundwater abstraction will be managed in terms of a groundwater allocation volume established to limit the maximum cumulative depletion of baseflow at a catchment (or sub-catchment) scale. In intervening areas (*Category B*) it is proposed to manage groundwater abstraction through a combination of temporal pumping restrictions (i.e. river and stream minimum flow cut-offs) and groundwater allocation determined on the basis of local hydrogeological conditions and abstraction rates.

The following section provides a summary of the management controls proposed for each hydraulic connection category. A more comprehensive description of the proposed management controls (including justification for the arbitrary thresholds adopted) is provided in Hughes and Gyopari (2011).

<u>Category A</u>

Category A effectively encompasses the portion of the hydrogeological system which exhibits a direct and immediate hydraulic connection with surface water. In these areas groundwater abstraction is effectively managed as part of the environmental flow and water level regime established for relevant hydraulically connected surface water bodies.

Spatial Definition	Generally limited to the Q1 gravel aquifers along the riparian margins of the major river systems.
Application	All groundwater takes which require resource consent (i.e. excludes permitted uses under RMA s14(b) and takes permitted under the Regional Freshwater Plan).
Pumping Regulation	Groundwater takes requiring resource consent will be subject to minimum flow or water level controls set for hydraulically connected surface water bodies.
Allocation	Groundwater abstraction from Category A aquifers will be included in the primary allocation for hydraulically connected surface water based on the <u>average weekly</u> rate of groundwater abstraction.
Assessment	No specific assessment of stream depletion is required unless an applicant wishes

Requirements to advance a case that the degree of hydraulic connection for an individual groundwater take does not meet criteria requiring application of minimum flow criteria. However, all takes will be assessed in terms Policy relevant to other environmental effects such as well interference effects and saline intrusion.

Category B

Category B includes those areas of the hydrogeological system which exhibit a moderate to high degree of connectivity with surface water but where application of pumping regulation may or may not provide effective mitigation of stream depletion effects depending on both local hydrogeological conditions and the rate of groundwater abstraction. The proposed management regime for Category B can be summarised as:

Spatial Definition The spatial extent of Category B has been determined for each water management zone based on observed hydrogeological characteristics and modelling of potential stream depletion effects resulting from groundwater abstraction.

Application All takes with a weekly average abstraction rate **>5 L/s** require assessment of potential stream depletion effects.

Pumping Regulation Groundwater takes from Category B areas will be subject to minimum flow or water level controls (based on those established for hydraulically connected surface water bodies) when the calculated stream depletion effect exceeds **60 percent (i.e. q/Q>0.6)** of the seasonal average pumping rate or is greater than **10 L/s** calculated using the average seasonal abstraction rate.

Allocation Calculated stream depletion effect from those takes subject to minimum flow control will be included in primary allocation for relevant hydraulically connected surface waterbodies with the balance of seasonal allocation counted as part of the total groundwater allocation for the relevant water management zone. Remaining takes (including those with a weekly average rate of take <5 L/s) will be counted as part of the total groundwater allocation for the relevant groundwater management zone.

Assessment Requirements Hydrogeological assessment of potential stream depletion utilising relevant numerical or analytical modelling techniques based on the cumulative (direct) stream depletion effect on hydraulically connected surface water. Assessment of stream depletion effects should be based on continuous abstraction at the long-term average abstraction rate being sought.

Category C

The Category C classification includes those areas of the hydrogeological system which exhibit a moderate to low degree of connectivity with surface water, where application of pumping regulation is unlikely to provide mitigation of stream depletion effects during low flow periods.

3. Hutt Valley

3.1. Introduction

The Hutt Valley follows a north-easterly alignment along the trace of the active Wellington Fault to the north of Wellington City. Structual deformation associated with movement along the fault has resulted in the formation of several discrete fault-bound sedimentary basins which are traversed by the lowland section of the Hutt River.

The main alluvial basins in the Hutt River catchment include the Lower Hutt Basin which extends southwards from Taita Gorge across Wellington Harbour and the Upper Hutt Basin which extends north of Taita Gorge to Birchville. Other smaller alluvial basings include the Pakuratahi Basin and the Mangaroa Valley which lie north-east and east of Upper Hutt respectively, and the Akatarawa Valley which follows the narrow gorge of the Akatarawa River to the north of Upper Hutt. Extensive urban development covers a significant proportion of both the Upper and Lower Hutt basins.

Flat-lying areas of the Hutt Valley typically recieve rainfall of between 1,100 and 1,300 millimetres per year. Orographic enhancement occurs on the surrounding hills with annual rainfall totals in excess of 5,000 millimetres per year recorded in the southern Tararua Range (WRC, 1995). While rainfall in the Hutt Valley is relatively evenly distributed throughout the year, extended periods of low rainfall may occur during the summer and autumn resulting in periods of flow recession in the Hutt River catchment. Such periods of low rainfall and river flows can be particularly pronounced during strong La Niña conditions.

The water resources of the Hutt catchment (both surface and groundwater) are extensively utilised for municipal supply both within the Hutt Valley and across the greater Wellington urban area. Increased demand during periods of low rainfall commonly results in significant pressure on the available water resource and has necessitated the development of water storage and investigation of alternative water sources to meet current and anticipated future demand.

3.1.1. Geological Setting

The geological setting of the Hutt Valley reflects a combination of structural deformation (faulting and folding) associated with the extensive active fault system which crosses the lower North Island, combined with effects of late Quaternary climate variations and associated changes in relative sea level.

The basement rocks underlying the Hutt Valley and forming the surrounding hills comprise moderately to well indurated mudstone and sandstone sequences (collectively termed greywacke) of the Triassic to early Jurassic (250 - 180 Ma) Rakaia Terrane. These rocks are extensively deformed by folding and faulting reflecting their deposition and subsequent accretion along an active tectonic margin. Many lithologies within the Rakaia Terrane also exhibit well developed bedding, jointing and fracturing.

The present-day geometry of the Wellington Region reflects the onset of extensive movement along a series of dextral faults over the Tertiary Period. Major faults within this zone include the north-

northeast trending Northern Ohariu, Shepherds Gully/Pukerau, Ohariu, Wellington and Wairarapa Faults (Begg and Johnson, 2000).

The Wellington Fault is the dominant geological feature of the Hutt Valley and essentially defines the catchment of the Hutt River through the foothills of the Tararua Range and Western Hutt Hills. Tilting and warping of the basement block bounded by the Wellington Fault to the west and Wairarapa Fault to the east over the last two million years (Begg and Johnson, 2000) resulted in the formation of a series of fault-bound basins which are infilled with a sequence of alluvial gravels deposited and reworked by the Hutt River during late Quaternary (Otira and Waimea) glacial and associated interglacial periods.

In the Lower Hutt basin, marine sediments extend inland from the present-day coast forming laterally continuous layers of fine-grained sediment within the thick alluvial gravel sequence. In the inland basins, the asymmetric basin geometry resulting from subsidence along the Wellington Fault restricted the Hutt River to the western side of the valley for extended periods, resulting in the accumulation of extensive deposits of fine-grained and organic-rich sediments toward the shallower eastern basin margins.

3.1.2. Hydrogeology

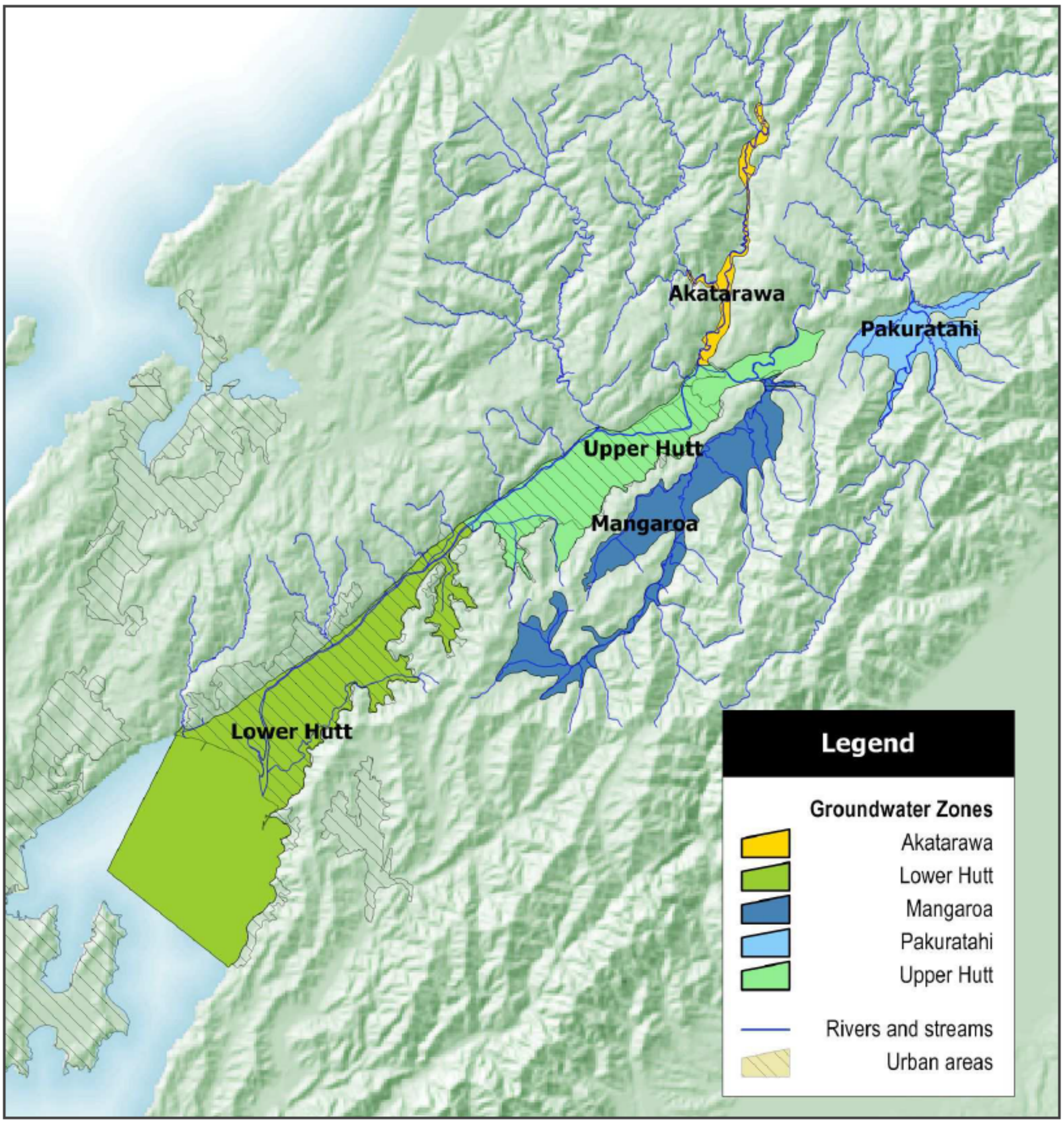
The groundwater resources of the Hutt Valley primarily occur within the alluvial gravel sediments infilling the various sedimentary basins formed along the Wellington Fault. Groundwater in this area occurs within two primary hydrogeological settings:

- Shallow, highly permeable unconfined aquifers hosted in postglacial (Q1) alluvial gravels associated with the Hutt River; and,
- Low to moderately permeable aquifers hosted in deeper water bearing alluvial gravel layers which are confined by overlying layers of fine-grained silt, sand and organic materials representing deposition in swamp or wetland environments (inland basins) or marine derived silt and sand deposits (Lower Hutt basin)

A limited groundwater resource also occurs in the greywacke basement rocks in areas where sufficient secondary permeability occurs within joints, fractures, bedding planes and other discontinuities within the rock mass.

For the purposes of resource management WRC (1995) divided the Hutt Valley into the five groundwater management zones illustrated in **Figure 1** below. These zones define areas of similar hydrogeological characteristics and are utilised as the primary unit for groundwater allocation in the RFP.

Figure 1. Groundwater Management Zones in the Hutt Valley



3.1.3. Groundwater / surface water interaction

The Hutt River and tributaries exhibit a significant degree of interaction with the surrounding groundwater resource in many parts of the Hutt Valley. The following sections utilise available hydrogeological information to develop a conceptual model of groundwater / surface water interaction for the Upper Hutt and Lower Hutt groundwater zones and provide recommendations for the management of potential effects of groundwater abstraction on surface water.

Due to the limited information available to describe the likely nature of groundwater/surface water interaction, the remaining groundwater zones (Mangaroa, Pakuratahi and Akatarawa) are included in

Section 4 which provides recommendations for management of groundwater/surface water interaction in areas with limited hydrogeological information available.

3.2. Upper Hutt groundwater zone

The Upper Hutt groundwater zone occupies the central section of the Hutt River catchment extending from Silverstream in the south to Te Marua in the north. **Error! Reference source not found.** shows the spatial extent of the Lower Hutt groundwater zone including primary surface water features, flow gauging sites, groundwater level monitoring sites as well as the location of bores recorded on the GWRC Wells database.

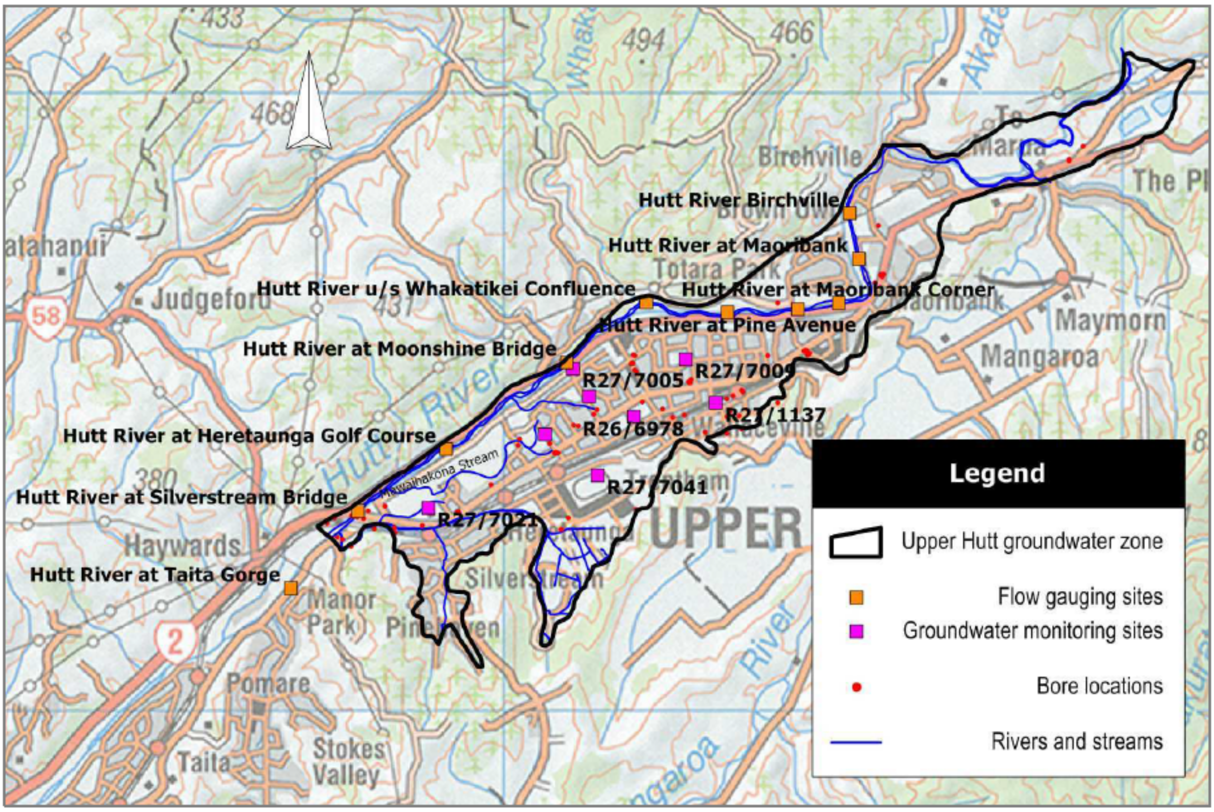


Figure 2. Upper Hutt groundwater zone

3.2.1. Geology

The Upper Hutt basin occupies a fault-bound sedimentary basin formed within the greywacke hills at the southern end of the Tararua Range. The basin extends from Taita Gorge in the south following the north-easterly strike of the Wellington Fault to Te Marua in the north. The well defined western margin traces the alignment of the Wellington Fault while the eastern margin follows the base of the foothills separating the Upper Hutt and Mangaroa Valleys.

Greywacke basement is exposed in the bed of the Hutt River at Maoribank, near Birchville and at Taita Gorge indicating Quaternary sediments infilling the basin are thin (or absent) to the north and south of these locations respectively. Structure contours for the greywacke basement underlying the

Upper Hutt groundwater zone derived from available geological and geophysical data (Begg, 1993) indicate the thickness of sediments infilling the basin is greatest in the middle section of the valley between Trentham Memorial Park and Maidstone Intermediate (Clyma Park). The structure contours also indicate an asymmetric basin geometry with sedimentary infill greatest adjacent to the middle section of the Wellington Fault with basement gradually shallowing to the north, south and eastern basin margins. The thickness of the sedimentary infill near the central section of the basin is illustrated by the geological log of an investigation bore drilled at Trentham Memorial Park which encountered weathered greywacke basement at a depth of approximately 200 metres (see **Figure 3** below).

Bore logs indicate the central area of the valley is underlain by a sequence of alluvial gravels and sand containing variable proportions of silt over the upper 50 metres of the stratigraphic column. These deposits are inferred to represent materials deposited and reworked by the Hutt River during the late stages of the Otarian glaciation (approximately 10,000 to 25,000 years BP) and subsequent interglacial period. Bore logs from the few bores penetrating deeper levels of the Upper Hutt basin record a variable sequence of relatively weathered silty gravels containing frequent layers of fine sand and organic sediments. These sediments are likely to represent deposition during the Waimea and early stages of the Otarian glaciations when appreciable erosion occurred from the Tararua Range. Intervening layers of finer-grained sediment and organic material may represent periods when drainage from the Upper Hutt basin was impeded by relative uplift and subsidence along the Wellington Fault resulting in sediment accumulation in extensive wetland areas. **Figure 3** provides a representative geological log from investigation drilling undertaken at Trentham Memorial Park by the Hutt Valley Underground Water Authority (HVUWA) in the late 1960's.

In the Te Marua area, located at the northern end of the Upper Hutt groundwater zone, available data suggest that the subsurface geology comprises an uplifted section of greywacke basement surrounded by an elevated alluvial terrace which represents a remnant of the extensive fluvioglacial outwash deposits which infilled the Upper Hutt basin during the last (Otarian) glaciation but which have been extensively reworked by postglacial entrenchment of the Hutt River across the middle and lower sections of the basin.

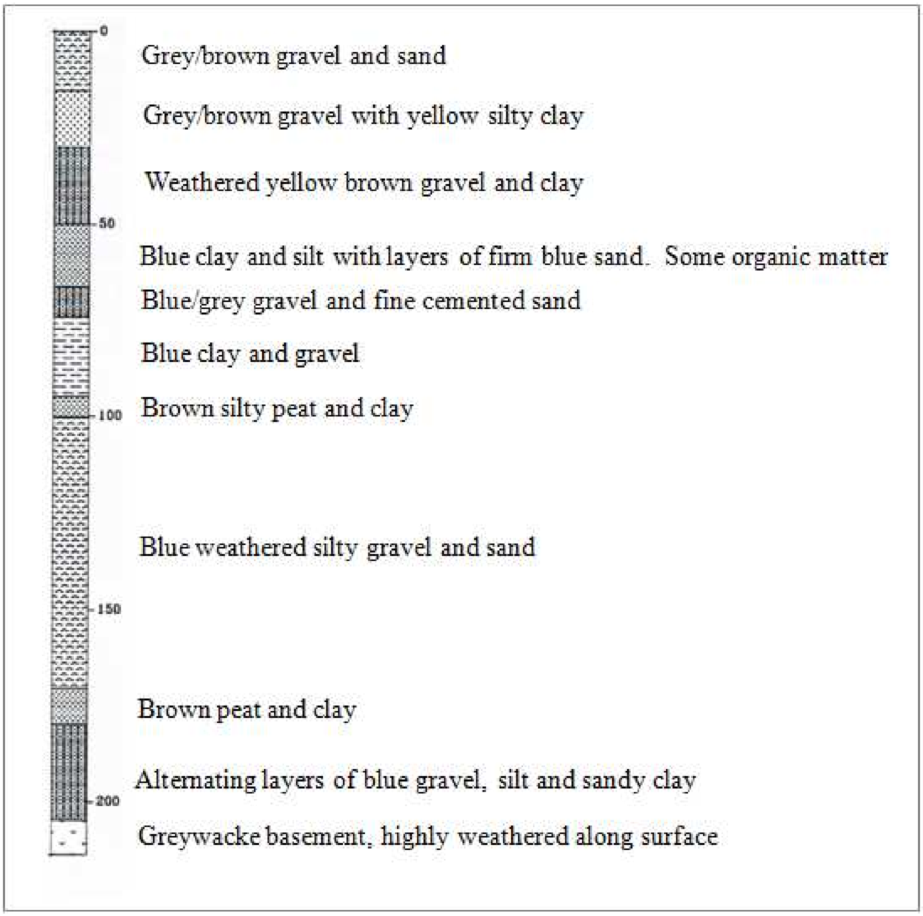


Figure 3. Representative bore log for Trentham Memorial Park (WRC, 1995)

3.2.2. Hydrogeology

Error! Reference source not found. shows a relatively limited number of bores across the Upper Hutt groundwater zone reflecting the restricted utilisation of the resource for industrial and irrigation supply from bores typically screened at depths of between 20 to 30 metres below ground. However, it is noted that the groundwater resource potential of the Upper Hutt basin has recently been investigated as a possible source of supplementary supply to augment existing municipal supplies to the Greater Wellington area (MWH, 2008).

Available data indicate the Upper Hutt groundwater zone contains two primary hydraulic units, the shallower being a moderate to highly permeable unconfined to semi-confined aquifer hosted in the recent (Q1/Q2) alluvial gravels which extend to a depth of approximately 50 metres across a majority of the Upper Hutt basin. This aquifer system is highly heterogeneous comprising a sequence of coarse water-bearing alluvial gravels alternating with more compact gravel layers containing varying proportions of sand and silt reflecting deposition on the active floodplain of the Hutt River.

The groundwater resource at depths greater than 50 metres is poorly characterised with few bores penetrating to this depth. Based on the available data, deeper water bearing gravel intervals appear to be separated from the shallow alluvial aquifer system by a laterally continuous layer of sand, clay and organic material and comprise a separate, low to moderately permeability, confined aquifer system.

The shallow alluvial aquifer is recharged by a combination of flow loss from the Hutt River and infiltration of local rainfall and runoff from the surrounding hills. Available groundwater level information suggests the water balance in the shallow alluvial aquifer across the central and western parts of the Upper Hutt groundwater zone is dominated by interaction with the Hutt River while land surface recharge is more significant toward the eastern margin. Piezometric level data (WRC, 1995) indicate groundwater flow in a south-westerly direction following the general topographic gradient with baseflow discharge occurring to the Hutt River downstream of Whakatikei River confluence and a series of spring-fed streams which originate in the southern section of the Upper Hutt basin.

Overall, due to the geometry of the surrounding greywacke basement, the Upper Hutt groundwater zone effectively comprises a closed groundwater flow system. Under natural conditions, all recharge to the aquifer system ultimately exits the basin via the Hutt River in the vicinity of Taita Gorge. The unconfined aquifer system hosted in recent alluvial gravels extending to depths of around 50 metres below ground exhibits a significant degree of interaction with the Hutt River. Deeper levels of the Upper Hutt groundwater zone (>50 metres) appear to form a confined aquifer which is relatively isolated from short-term variations in recharge flux and which may have limited interaction with the shallow alluvial aquifer.

3.2.3. Hydraulic properties

Odlin (1972) described a series of aquifer tests undertaken by the HVUWA on three investigation bores screened approximately 30 metres below ground at Trentham Memorial Park in the late 1960's. Data from these tests show a consistent pattern of drawdown in response to abstraction with the rapid stabilisation of water levels (as illustrated in **Figure 4** below) attributed to the interception of a recharge boundary (in this case the nearby Mawaihakona Stream) shortly following commencement of pumping. While there may be some uncertainty with regard the interpretation of the observed leakage boundary[2], test results indicate moderate permeability and semi-confined conditions in the alluvial gravel aquifer at this location.

WRC (1994) summarised the results of five aquifer tests undertaken in the Upper Hutt groundwater zone. Again these data suggest semi-confined conditions (storativity 0.002 to 0.003) and moderate to high aquifer permeability (1,500 to 17,500 m^2/day)[3].

MWH (2008) describe aquifer testing undertaken on two investigation bores installed near Heretaunga College. Results of this analysis indicate the highly permeable, heterogeneous nature of the shallow alluvial gravel aquifer in this area with transmissivity estimated to be of the order of 23,000 to 28,000 m^2/day in one production bore and between 6,000 to 7,000 m^2/day in the second test bore approximately 200 metres distant.

[2] Given the location of the test bores with regard the Mawaihakona Stream, depth of the screened interval (~26 to 30m bgl) screen depth and duration of pumping

[3] With one exception (R27/7025) exhibiting anomalously low permeability

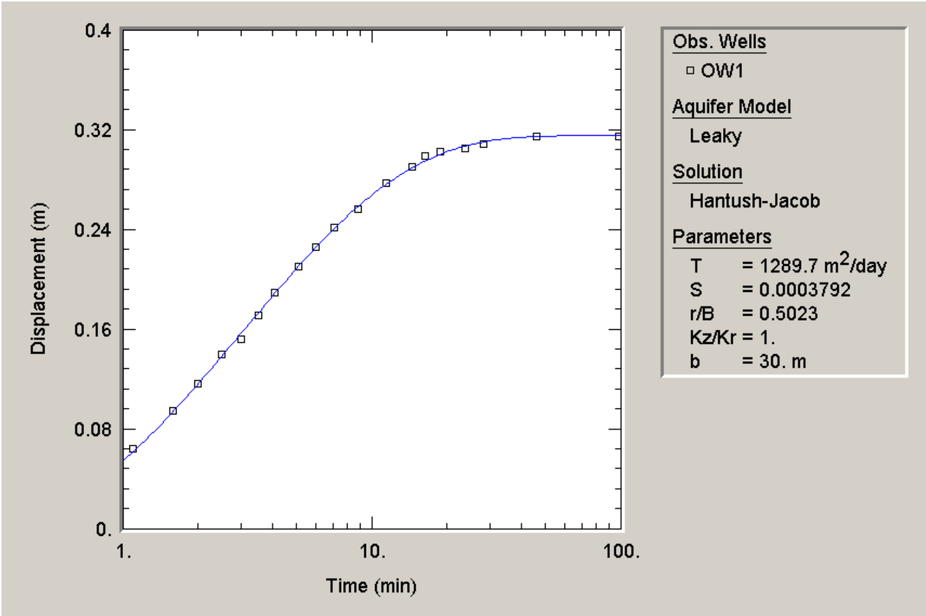


Figure 4. Aquifer test data from HVUWA investigations at Trentham Memorial Park fitted to Hantush-Jacob type curve

3.2.4. Surface water features

The Hutt River is the primary surface water feature in the Upper Hutt groundwater zone flowing along the base of the Western Hutt Hills in close proximity to the Wellington Fault. A number of spring-fed streams emerge along the margins of the Hutt River over the reach between the Whakatikei confluence and Silverstream Bridge. The largest of these springs is the Mawaihakona 1 Stream which drains from the Trentham Memorial Park area through the Heretaunga golf course and discharges to the Hutt River immediately upstream of Silverstream Bridge. Other significant spring-fed streams include the Mawaihakona 2 Stream and Hulls Creek. No significant wetland areas are recorded in the Upper Hutt groundwater zone reflecting the largely urbanised nature of land use in the area.

Figure 5 shows a plot of concurrent gauging data from the Hutt River between Birchville and the Silverstream Bridge. The data show a consistent pattern of flow loss between Birchville and the Whakatikei River confluence with a corresponding flow gain between Moonshine Bridge and Taita Gorge (allowing for flow inputs from the Whakatikei River). The observed flow losses over the upstream reach range between 470 to 930 L/s while the corresponding gain between Moonshine Bridge and Taita Gorge Range between 1,000 and 1,700 L/s. The net surplus in downstream flow gain over upstream flow loss is attributed to drainage of groundwater storage derived from a combination of rainfall recharge and flow loss from the Hutt River during high river stage events (see **Section 3.2.5**).

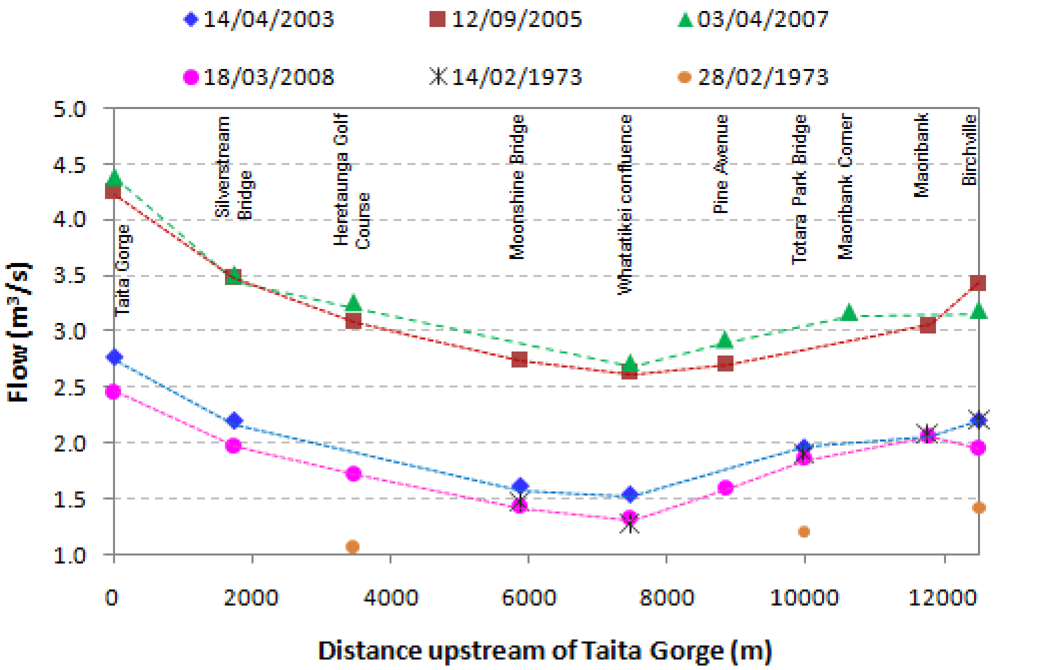


Figure 5. Concurrent gauging data from the Hutt River between Birchville and Taita Gorge

Figure 6 shows the correlation between measured discharge at Birchville and Moonshine Bridge. Based on the observed relationship, flow loss from this reach is estimated to be of the order of 600 L/s (52,000 m^3/day) which is similar to the magnitude of flow loss estimated by WRC (1995) and MWH (2008).

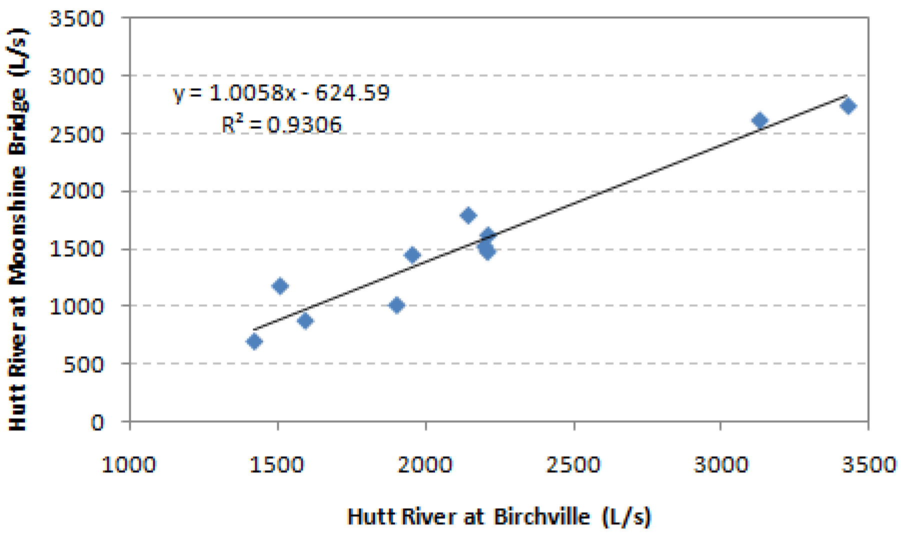


Figure 6. Correlation between Hutt River flow at Birchville and Moonshine Bridge (allowing for Whakatikei River inflows)

Appreciable discharge occurs in spring-fed streams draining the southern section of the Upper Hutt groundwater zone. Based on available gauging results, MWH (2008) estimated the combined discharge from these streams at around 100 l/s (8,640 m^3/day) during stable summer baseflow conditions.

In late 2006 a continuous flow recorder was installed on the Mawaihakona 1 Stream at the Heretaunga Golf Club site. Although data from this site is of variable quality (due in part to excessive macrophyte growth), the available flow record indicates discharge in the range of 70 to 800 L/s. As illustrated in **Error! Reference source not found.**, spot gaugings undertaken at this site are relatively well correlated with groundwater levels in the alluvial gravel aquifer across the wider Upper Hutt groundwater zone confirming temporal variations in groundwater storage are the primary control on spring-fed stream baseflow.

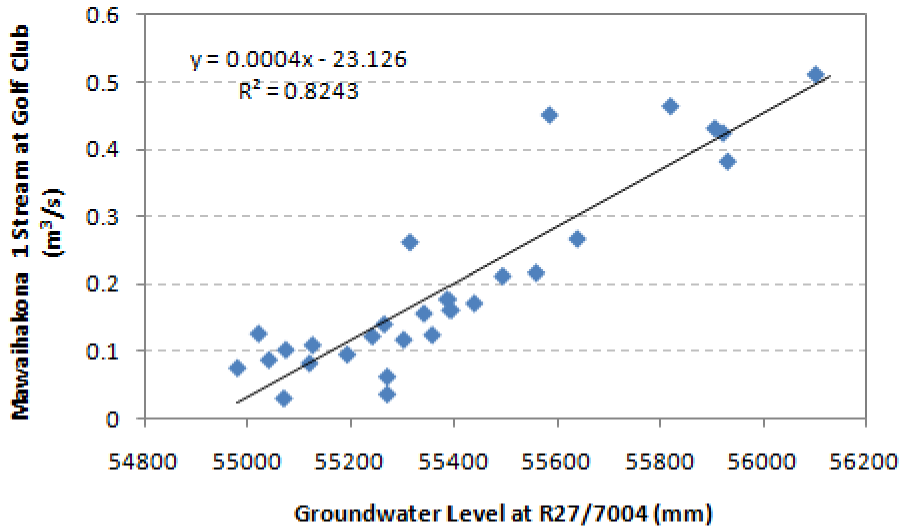


Figure 7. Correlation between groundwater levels at R27/7004 and Mawaihakona 1 Stream at Golf Club discharge

Overall, available data indicate a high degree of hydraulic connection between groundwater and surface water in the Upper Hutt groundwater zone with the Hutt River providing significant recharge flux to the unconfined alluvial gravel aquifer upstream of the Whakatikei River confluence and, in turn, drainage of groundwater across the southern section of the basin providing appreciable baseflow to spring-fed streams and the Hutt River between Moonshine Bridge and Taita Gorge.

3.2.5. Groundwater levels

Groundwater level data are available from a number of bores distributed across the Upper Hutt groundwater zone. However, with the exception of a 32 metre deep bore located at Trentham Memorial Park (R27/7004), the monitoring record from individual monitoring bores is generally relatively short and/or intermittent.

Figure 8 shows a plot of groundwater levels in the Upper Hutt groundwater zone recorded in a network of monitoring bores maintained by the HVUWA during the 1970's[4]. The plot shows a rapid response to changes in flow in the Hutt River in a shallow bore adjacent to the Hutt River (R27/7005) and at Maidstone Intermediate (R27/7009) in the central area of the Upper Hutt Basin. A similar, although much reduced response is observed in R27/7004 located at Trentham Memorial Park (possibly reflecting the semi-confined nature of the aquifer in this area as discussed in **Section 3.2.4**) while no response to variations in river flow is observed in a shallow bore at Trentham Racecourse (R27/7041), approximately 1.7 kilometres from the river.

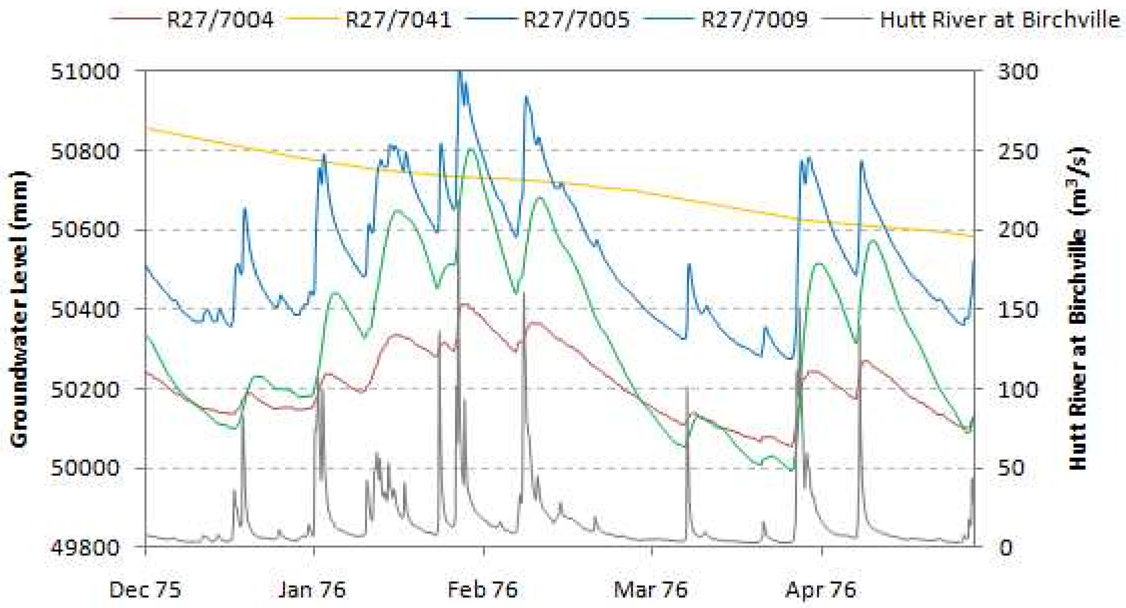


Figure 8. Groundwater levels in the Upper Hutt groundwater zone, December 1975 to May 1976

Figure 9 illustrates observed groundwater level variations in the Upper Hutt groundwater zone in response to a single high stage event in the Hutt River in December 1976. The data suggest the rapid propagation of a pressure wave associated with increased river recharge through the aquifer system with the magnitude and delay in groundwater level response reflecting both the distance of individual bores from the river as well as local hydraulic properties of the aquifer system. Although the data show a rapid rise in groundwater level in response to increase river stage, the subsequent recession is appreciably slower (also evident over a longer timescale in **Figure 8**) suggesting recharge 'pulses' associated with high river flow events are stored in the unconfined aquifer system and slowly released back to the river via baseflow discharge occurring across the downstream section of the aquifer system (i.e. bank storage).

[4] For clarity the reduced levels from individual bores have been adjusted to allow presentation on a single axis

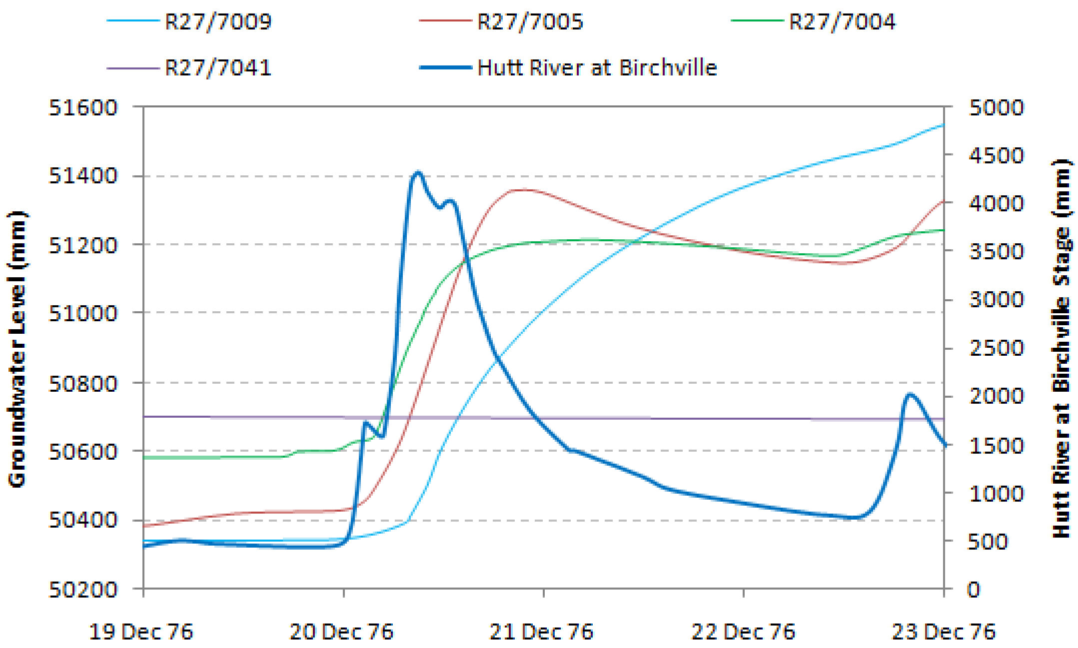


Figure 9. Groundwater level response in the Upper Hutt groundwater zone to a single high stage event in the Hutt River, December 1976

Although local rainfall recharge during high stage events[5] may contribute recharge to the aquifer system, both the timing of the observed groundwater level rise and the lack of groundwater level response observed in R27/7041 at Trentham Racecourse suggest that river recharge is the major factor controlling temporal variations in groundwater level across much of the Upper Hutt groundwater zone.

More recent groundwater level monitoring data recorded in the Upper Hutt groundwater zone show a similar pattern to that illustrated in **Figure 8** and **Figure 9,** indicating river recharge rather than rainfall is the primary control on temporal variations in groundwater levels.

3.2.6. Conceptual model of groundwater / surface water interaction

Available data indicate a high degree of hydraulic connection between groundwater and surface water across the entire Upper Hutt groundwater zone. Temporal variations in aquifer storage (i.e. groundwater levels) indicate the rapid propagation of recharge flux associated with high stage events in the Hutt River through the highly permeable alluvial gravel materials comprising the upper 50 metres of the stratigraphic sequence. In turn, progressive drainage of groundwater storage contributes to baseflow discharge across the southern section of the Upper Hutt groundwater zone which is equal to the flow loss across the upstream section plus the volume of land surface recharge occurring across the Upper Hutt basin.

[5] High stage events in the Hutt River are typically associated with widespread heavy rainfall across the contributing catchment, including the Upper Hutt basin.

Due to the geometry of the surrounding greywacke bedrock the Upper Hutt basin effectively forms a closed groundwater system with all outflow from the system occurring via the reach of the Hutt River upstream of Taita Gorge. As a consequence, groundwater abstraction from the unconfined alluvial gravel aquifer (<50 m) has the potential to effect surface water either by inducing additional flow loss from the upstream section of the Hutt River (Birchville to the Whakatikei River confluence) or contributing to reduced baseflow discharge (spring-fed stream discharge or diffuse leakage to the Hutt River) over the downstream section between Taita Gorge and the Moonshine Bridge.

Williams (2008) described modelling of the potential effects of large-scale groundwater abstraction in the Upper Hutt groundwater zone using both the numerical flow model described in MWH (2008) and the Greater Wellington Water Sustainable Yield Model (SYM). Results of the abstraction scenarios modelled for a wellfield situated at Wallaceville (approximately 1,600 m from the river) indicate stream depletion in the Hutt River occurs shortly following the commencement of abstraction and rapidly increases to a level in excess of 75% of the total abstraction rate. The modelled scenarios suggested an approximate 60:40 percent split between additional flow loss from the Hutt River upstream of the Whakatikei River confluence and reduced baseflow in the downstream section between Moonshine Bridge and Taita Gorge for the pumping location simulated. For the variable rate pumping scenarios modelled the cumulative stream depletion effect was estimated to approximate the 60-day average abstraction rate consistent with a high degree of hydraulic connection between groundwater and surface water across the entire Upper Hutt valley.

3.2.7. Recommendations for management of groundwater / surface water interaction

Recommendations for the management of groundwater/surface water interaction in the Upper Hutt groundwater zone include:

- That the recent alluvial (Q1/Q2) gravel aquifer be managed as Category A to an arbitrary depth of 50 metres.
- That water-bearing gravel layers at depths greater than 50 metres be managed as Category B. Under this classification, applications for large-scale abstraction (i.e. meeting the criteria for a weekly average abstraction rate >5 L/s) would have to be supported by aquifer test data and assessment of local hydrogeological conditions sufficient to characterise potential effects on the hydraulically connected surface water.

3.3. Lower Hutt groundwater zone

The Lower Hutt groundwater zone occupies the Lower Hutt - Port Nicholson sedimentary basin (Donaldson and Campbell, 1977) which extends from Taita Gorge southwards across the Lower Hutt area and Wellington Harbour to a poorly defined margin south of Somes Island. Alluvial gravel sediments infilling this basin host a significant groundwater resource which is utilised to supply up to 40 percent of the municipal water demand for the Geater Wellington metropolitan area.

Figure 10 shows the spatial extent of the Lower Hutt groundwater zone including primary surface water features, flow gauging sites, groundwater level monitoring sites as well as the location of bores recorded on the GWRC Wells database.

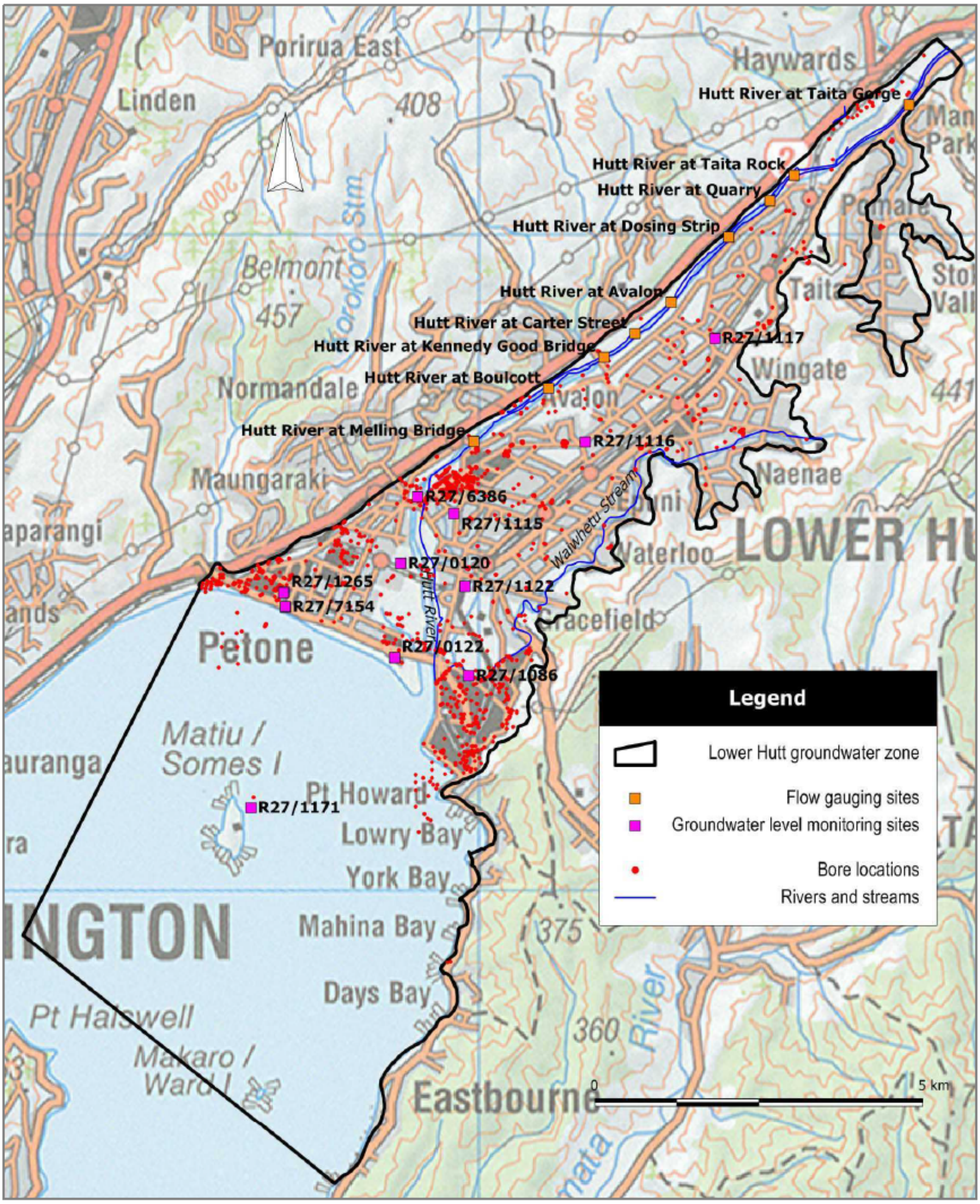


Figure 10. Lower Hutt groundwater zone

3.3.1. Geology

The Lower Hutt - Port Nicholson basin is a large fault-angle basin formed as a result of structural deformation along the Wellington Fault during the late Quaternary period. The basin is bounded to the north and east by uplifted greywacke basement which forms the southern foothills of the Rimutaka Range. The western boundary follows the NE-SW trend of the Wellington Fault which exhibits in excess of 600 metres of vertical displacement between the Western Hutt Hills and deeper parts of the Lower Hutt - Port Nicholson basin near Kaiwharawhara (Wood and Davey, 1992). Similar to the Upper Hutt basin, the geometry of the Lower Hutt - Port Nicholson basin is asymmetric with the depth to basement shallowing from around 300 metres below ground adjacent to the Wellington Fault toward the eastern side of the basin. Somes Island and Ward Island in Wellington Harbour are interpreted to represent an uplifted basement ridge which follows the central axis of the valley toward the harbour entrance (possibly a horst structure bounded by normal faults).

The Lower Hutt - Port Nicholson basin is infilled with a sequence of alluvial gravel materials deposited by the Hutt River which are interspersed with fine-grained marine sediments accumulated during late Quaternary glacial and interglacial cycles. During glacial periods, sea levels fell resulting in the deposition of a broad alluvial delta by the Hutt River extending across the Lower Hutt Valley and (current) Wellington Harbour area. During intervening interglacial periods sea levels rose and the shoreline retreated up the Lower Hutt Valley resulting the deposition of fine-grained nearshore (silt and fine sand) deposits across the underlying alluvial sediments.

This succession of alluvial gravel layers overlain by fine-grained marine sediments extending approximately two thirds of the way from the current foreshore to Taita Gorge forms the basic geological framework for the Lower Hutt groundwater zone. Detailed evaluation of the geological setting is presented in WRC (1995) with re-interpretation and analysis of available geological data provided in Brown and Jones (2000) and Phreatos (2003).

3.3.2. Hydrogeology

In the area to the north of Kennedy Good Bridge the Q1/Q2 alluvial materials deposited by the Hutt River form an unconfined aquifer (referred to as the *Taita Alluvium*) which is recharged by local rainfall and flow loss from the Hutt River. South of this point layers of fine-grained marine sediment divide the aquifer system into two main hydraulic units; the *Waiwhetu Aquifer* and the underlying *Moera Aquifer*, both of which become increasingly well confined down the valley, becoming artesian approximately 2 to 3 kilometres inland from the Petone foreshore.

Phreatos (2003) provides a detailed description of the hydrostratigraphic units identified in the Lower Hutt groundwater zone which include:

<u>Taita Alluvium</u>

Postglacial gravel, sand and silt deposits underlying the recent floodplain of the Hutt River. These deposits primarily consist of buried river channel and alluvial fan gravels but also contain flood and over bank deposits of sand, silt and clay. The near-surface gravels form an unconfined aquifer while deeper layers may exhibit semi-confined characteristics due to the stratified nature of the alluvial deposits. South of Kennedy Good Bridge the Taita Alluvium is interbedded with, and underlies contemporaneous postglacial Petone Marine Beds and Melling Peat. Due to the nature of deposition and subsequent reworking by the active Hutt River channel, the Taita Alluvium deposits typically exhibit very high permeability.

Petone Marine Beds and Melling Peat

The Petone Marine Beds are predominantly comprised of fine-grained silt and sand deposits which commonly contain shell and wood fragments. These deposits are up to 30 metres thick in the harbour area and progressively thin inland to an irregular margin in the vicinity of Kennedy Good Bridge. The thickness of these deposits also decreases toward the eastern side of the Lower Hutt basin reflecting greater subsidence along the western side of the valley associated with movement on the Wellington Fault. Due to their fine-grained texture the Petone Marine Beds exhibit low permeability and form a confining layer over the underlying Waiwhetu Artesian gravels.

Waiwhetu Artesian Gravels

The Waiwhetu Artesian Gravels comprise the primary aquifer in the Lower Hutt groundwater zone. These deposits represent gravel materials accumulated on the floodplain of the Hutt River during the last (Otarian) glaciation, attaining a maximum thickness of approximately 55 metres along the western side of the valley. These sediments typically comprise coarse gravel and sand with discontinuous layers of sand, silt and clay and form a highly permeable confined aquifer system. Based on drilling investigations and the re-interpretation of existing geological information, Jones and Brown (2000) proposed the subdivision of the Waiwhetu Aquifer into two hydraulic units separated by a laterally continuous aquitard comprising sand, silt and clay with interbedded carbonaceous material. Available information indicate significantly higher permeability and rates of groundwater throughflow in the Upper Waiwhetu Aquifer which is utilised as the primary source of all existing municipal and industrial groundwater abstraction in the Lower Hutt groundwater zone.

Wilford Shell Bed

The Wilford Shell Bed underlies the Lower Waiwhetu Aquifer and comprises a layer of low permeability silt, sand and clay containing abundant shell material which extends from the harbour area inland to a poorly defined margin, possibly extending up to 4.5 kilometres inland from the Petone foreshore. The Wilford Shell Bed attains a thickness of up to 25 metres near the coast and forms an aquitard which confines groundwater occurring in the underlying Moera Gravels and older alluvial sediments.

Moera Gravels

The Moera gravels are a layer of water bearing weathered alluvial gravels accumulated during the Waimea glaciation approximately 25 metres thick near the Petone foreshore which extend up the Lower Hutt basin toward Taita Gorge. These gravels form a moderate to low permeability confined aquifer which exhibits higher artesian pressure than observed in the overlying Waiwhetu Aquifer and contains water with slightly elevated major ion concentrations reflecting moderate to low rates of groundwater throughflow.

A thick succession of older alluvial and marine sediments overlie greywacke basement in deeper parts of the Lower Hutt - Port Nicholson basin. These deposits typically contain water with elevated major ion concentrations suggesting limited or negligible groundwater circulation through these deeper strata.

Groundwater flows southward through the aquifer system from the Taita Alluvium recharge area following the natural topographic gradient. Near the inland margin of the aquitard layers, groundwater flows down-valley through the confined Waiwhetu or Moera Aquifers with the excess throughflow discharged back to the Hutt River via throughflow in the Taita Alluvium to the south of the confined aquifer margin (i.e. downstream of Boulcott). The Waiwhetu Stream also carries baseflow discharge originating along the inland margin of the upper confining layer (i.e. Petone Marine Beds) on the eastern side of the Lower Hutt Valley. Groundwater flowing through the Waiwhetu and Moera aquifers is discharged via diffuse leakage through the confining layer materials which in places is sufficiently concentrated to form submarine springs on the harbour floor.

Figure 11 provides a schematic cross section of the hydrogeological setting in the Lower Hutt groundwater zone.

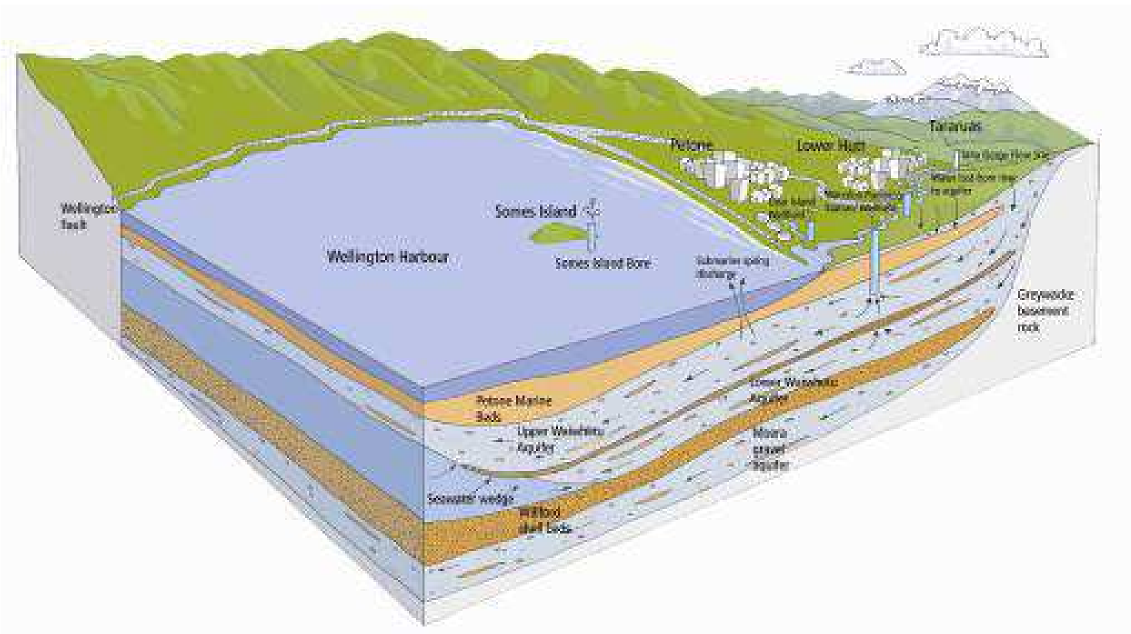


Figure 11. Schematic cross section of the Lower Hutt groundwater zone (from Jones and Baker, 2005)

3.3.3. Hydraulic Properties

Available data indicate the alluvial materials comprising the Taita Alluvium and (Upper) Waiwhetu Aquifer are highly permeable.

Aquifer testing undertaken in the Taita Alluvium near Avalon Studios yielded a range of transmissivity values from 2,700 to 52,700 m^2/day, with an average value of 4,500 m^2/day. The significant variation in estimated aquifer permeability being interpreted as reflecting the heterogenous nature of the gravel deposits (WRC, 1995).

Several large-scale pumping tests were undertaken on the GWRC Gear Island and Waterloo municipal supply wellfields during the 1990's at rates of up to 600 L/s (50 MLD). Analysis of these tests indicate the highly permeable nature of the Upper Waiwhetu Aquifer with geometric mean transmissivity values calculated from a large number of observation bores ranging from 22,000 to 28,000 m^2/day and a storage co-efficient ranging between 0.0005 and 0.0008 (Butcher, 1996).

Hughes (1998) reported the results of a free-flow test undertaken on a bore screened in the Moera Aquifer at Hutt Park which indicated a transmissivity value of approximately 1,150 m^2/day and a storage co-efficient of 0.0002. Aquifer testing undertaken during installation of a investigation bore in the Melling area (Brown and Jones, 2000) indicated aquifer transmissivity in the Moera Aquifer in the range of 2,100 to 2,600 m^2/day with a storage co-efficient of between 0.00004 to 0.00008.

3.3.4. Surface Water Features

The Hutt River is the main surface water feature in the Lower Hutt groundwater zone flowing in a south-westerly direction from Taita Gorge along the western side of the valley until Melling where it swings to a more south-easterly alignment to reach Wellington Harbour near Seaview.

As illustrated in **Figure 12**, concurrent flow gaugings in the Hutt River downstream of Taita Gorege indicate significant interaction between the river and surrounding unconfined aquifer. The available data indicate a relatively consistent pattern of flow loss between Taita Gorge and Kennedy Good Bridge with a progressive gain in flow below this point[6].

[6] Although it is noted that the magnitude of flow gain in the Hutt River below Melling is poorly constrained due to the tidal nature of this section of the river.

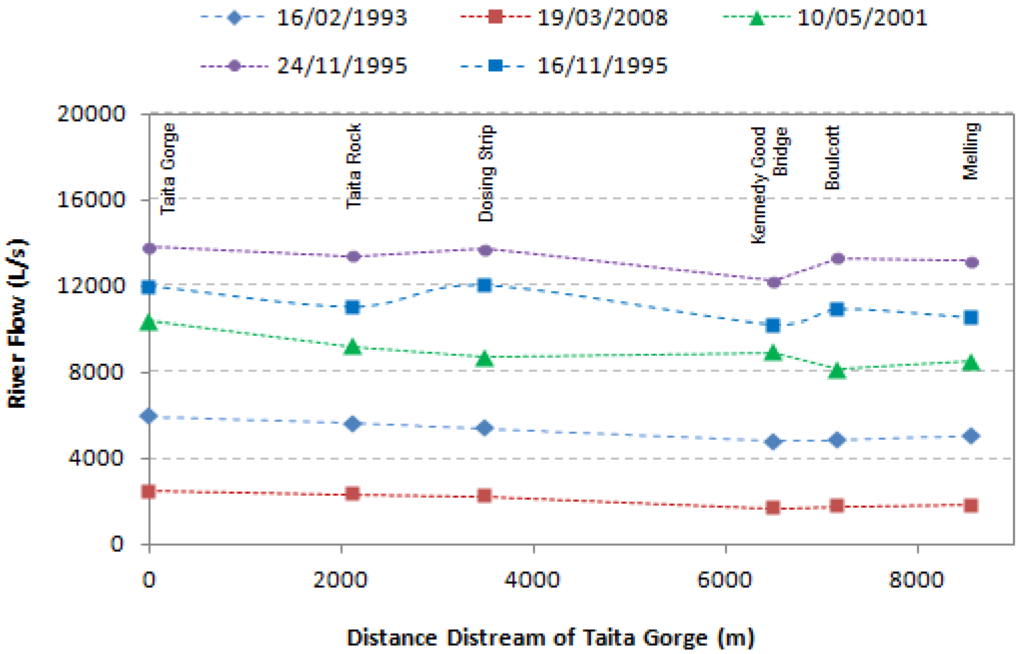


Figure 12. Selected concurrent gauging runs undertaken in the Hutt River between Taita Gorge and Melling

Figure 13 shows the observed correlation between measured discharge in the Hutt River at Taita Gorge and Kennedy Good Bridge derived from concurrent gaugings undertaken since the late 1960's. Based on the observed relationship flow loss from the Hutt River to the Taita Alluvium is estimated to range between 1,750 L/s (~150,000 m^3/day) at median flow (14.3 m^3/s at Taita Gorge) and 810 L/s (~75,000 m^3/day) at MALF (3.1 m^3/s). This volume of flow loss is consistent with previous estimates (e.g. WRC (1995) and Phreatos (2003)) and reflects the major recharge flux to the Lower Hutt groundwater zone.

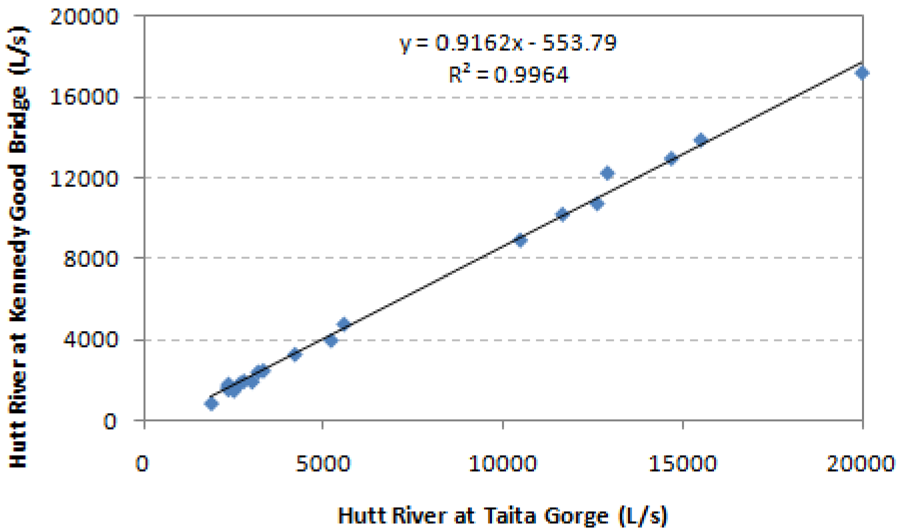


Figure 13. Correlation between measured discharge at Taita Gorge and Kennedy Good Bridge

Under natural (i.e. pre-development) conditions, an appreciable proportion of the recharge flux from the upstream section of the Hutt River is likely to have been discharged back to the river via throughflow in the Taita Alluvium south of the confined aquifer margin with a relatively small proportion (equal to the volume of water water lost via diffuse leakage and submarine springs in the Wellington Harbour) flowing southwards through the confined aquifers. However, under the current management regime, a significantly greater proportion of throughflow in the Taita Alluvium is likely to flow into the confined aquifer system to balance the volume of water abstracted for municipal and industrial supply from the Upper Waiwhetu Aquifer (up to 120,000 m^3/day at peak abstraction rates).

In addition to the section of the Hutt River downstream of Kennedy Good Bridge, the Lower Hutt Groundwater Zone also provides baseflow to the Waiwhetu Stream which flows along the eastern margin of the Lower Hutt Valley. This stream has headwaters in the foothills to the east of the Lower Hutt Valley but recieves appreciable baseflow discharge near the inland margin of the Petone Marine Bed aquitard. **Figure 14** shows the moderate correlation observed between groundwater levels in the Taita Alluvium and discharge in the Waiwhetu Stream at White Lines East. It is inferred that stormwater discharge to Waiwhetu Stream may be responsible for a significant component of the scatter observed in the data. Regardless, the relatively consistent flows of the order of 100 to 150 L/s (9,000 to 13,000 m^3/day) observed during extended periods of low rainfall indicate discharge to the Waiwhetu Stream comprises a relatively significant component (~10%+) of the overall water budget for the Lower Hutt groundwater zone during low flow periods.

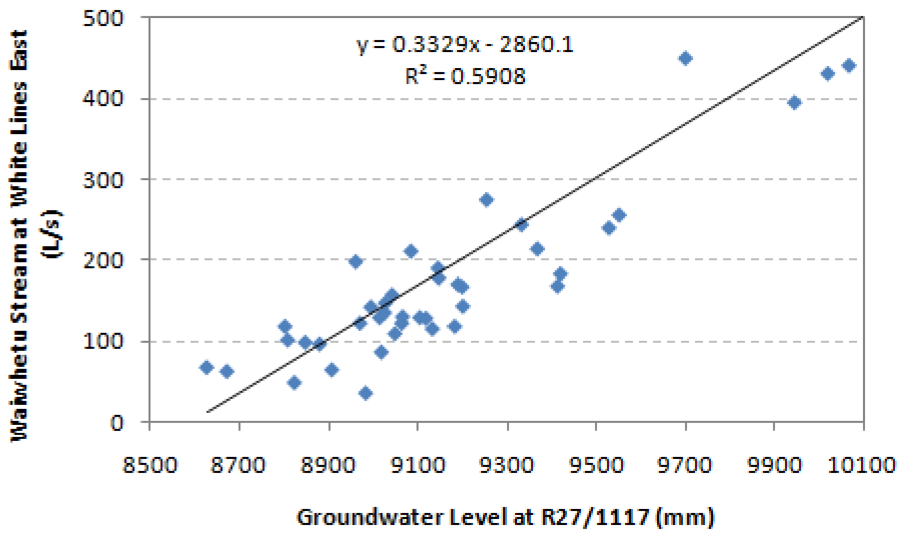


Figure 14. Correlation between groundwater levels in the Taita Alluvium at R27/1117 and discharge in Waiwhetu Stream at While Lines East

3.3.5. Groundwater Levels

Groundwater levels in the Lower Hutt groundwater zone are influenced by a range of factors including river stage, rainfall recharge and abstraction along with tidal and barometric pressure variations in confined aquifers near Wellington Harbour.

In the Taita Alluvium, variations in Hutt River stage are frequently coincident with local rainfall meaning it is often difficult to identify the primary recharge processes influencing short-term variations in groundwater level.

Figure 15 shows an example from late 2007 which illustrates the relative contribution of land surface recharge and flow loss from the Hutt River to groundwater level variations observed at at the GWRC Taita Intermediate groundwater monitoring site (R27/1117). In the example shown, two rainfall events of between 20 and 25 mm on the 18/19th and 25/26th December 2007 (accompanied by an increase of approximately 300 mm in Hutt River stage at Taita Gorge) result in a rise of approximately 50 mm in groundwater level at R27/1117. In contrast, a similar size rainfall event on the 7/8th January 2008 accompanied by a 2.2 metres rise in Hutt River stage resulted in an almost 400 mm rise in groundwater level.

Similar variations in groundwater level in the Taita Alluvium are observed throughout the monitoring record indicating recharge flux during high river stage events exert a significant influence on temporal variations in groundwater levels in the unconfined section of the Lower Hutt groundwater zone.

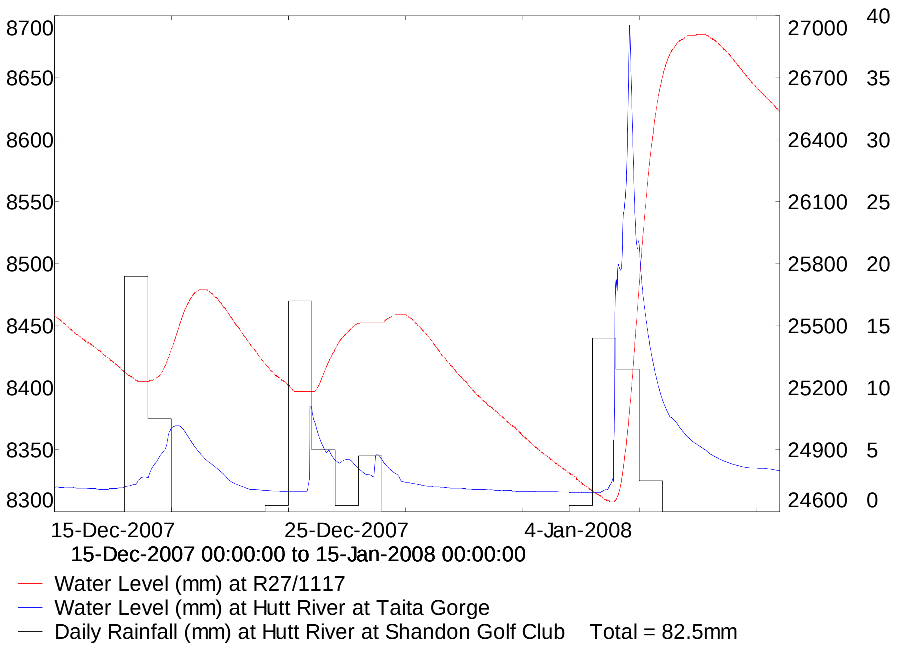


Figure 15. Variations in groundwater level in the Taita Alluvium in response to rainfall and variations in Hutt River Stage, December 2007 to January 2008

Figure 16 shows a plot of groundwater level recession at R27/1117 following the 7/8th January 2008 recharge event. This plot shows a characteristic bank storage response with rapid recharge to the aquifer system associated with the peak in river stage followed by a progressive decline in groundwater level as groundwater storage is dissipated by either flow loss back to the river or throughflow within the aquifer system. The rate of groundwater level recession occuring at a rate significantly lower than the equivalent reduction in river stage.

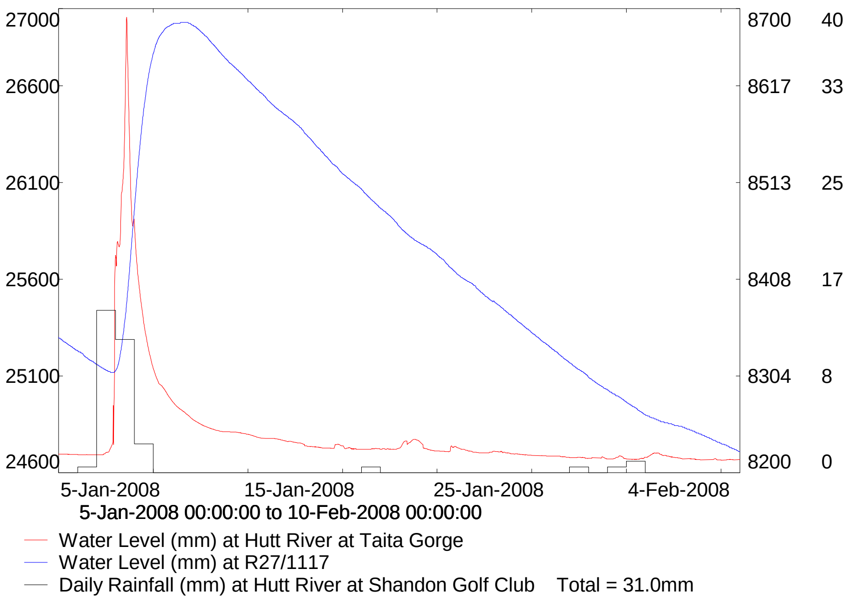
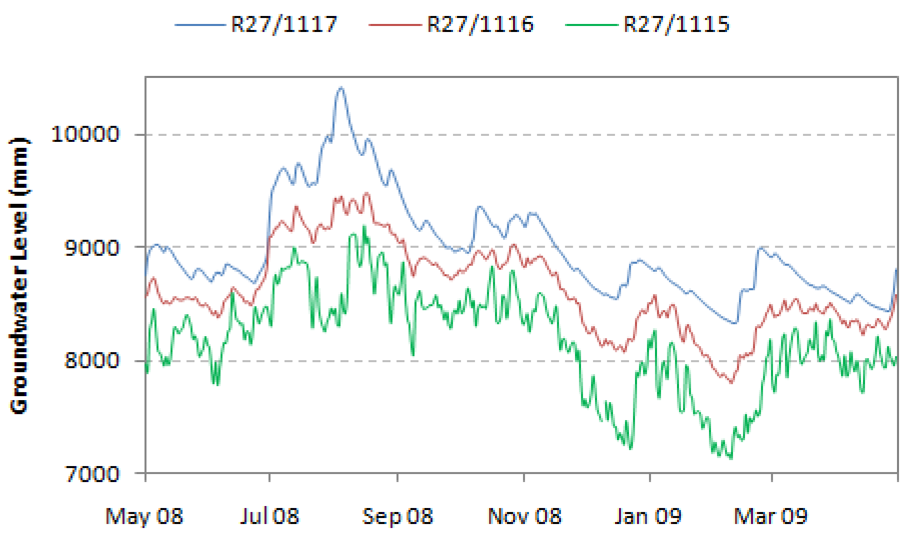


Figure 16. Groundwater level recession in the Taita Alluvium, January 2008

The limited residence time for groundwater storage within the unconfined area reflects the high degree of hydraulic connection between the Hutt River and the Taita Alluvium (essentially a result of the geometry and high permeability of the alluvial aquifer system). As a consequence, the river effectively acts as a constant head to the aquifer system with additional discharge to the downstream section of the Hutt River occuring when groundwater levels are high (e.g. following a significant recharge event). Conversely as groundwater levels decline during periods of low rainfall and stable river flow (or periods of high demand), losses to the unconfined aquifer are likely to increase as the gradient between river stage and surrounding groundwater levels increase.

As illustrated in **Figure 17** below, due to the highly permeable nature of the alluvial gravel materials, groundwater levels across the Lower Hutt groundwater zone follow a similar seasonal trend both in the Taita Alluvium (R27/1117) and the Upper Waiwhetu Aquifer (R27/1115) as well as the intermediate semi-confined zone (R27/1116). As a result, drawdown resulting from abstraction in the Upper Waiwhetu Aquifer (during December 2008 and February 2009 in the example shown) is likely to result in corresponding changes to the balance of aquifer recharge and discharge in the Taita Alluvium along the inland confined aquifer margin (i.e. increasing the proportion of throughflow entering the confined aquifer system rather than discharging to the downstream section of the Hutt



River).

Figure 17. Mean daily groundwater levels in the Lower Hutt groundwater zone, May 2008 to May 2009

3.3.6. Conceptual model of groundwater / surface water interaction

Due to the geometry and hydraulic properties of the alluvial materials infilling the Lower Hutt Basin extensive interaction occurs between the Hutt River and the surrounding unconfined aquifer system (the Taita Alluvium) in the Lower Hutt groundwater zone. Concurrent gaugings indicate flow loss of the order of 75,000 to 150,000 m^3/day occurs over the reach between Taita Gorge and Kennedy Good Bridge during median to low flows. Groundwater level variations observed in the Taita Alluvium also suggest significantly greater recharge flux occurs during high stage events in the Hutt River.

Due to the high permeability of the gravel materials, groundwater storage in the Taita Alluvium is rapidly disippated through a combination of baseflow discharge to the Hutt River downstream of the confined aquifer margin (in the vicinity of Boulcott) and throughflow into the confined aquifers in the lower valley. The magnitude of throughflow into the confined aquifer system is largely determined by the rate of groundwater abstraction from the Upper Waiwhetu Aquifer which in turn is likely to be a major factor determining the balance between recharge flux to and from the Hutt River across the unconfined zone.

3.3.7. Recommendations for management of groundwater / surface water interaction

Recommendations for the management of groundwater / surface water interaction in the Lower Hutt groundwater zone include:

- That the Taita Alluvium north of the nominal confined aquifer margin be managed as Category A due to the high degree of hydraulic connection observed across the recharge zone between Taita Gorge and Kennedy Good Bridge
- That the confined aquifer system south of the nominal confined aquifer margin be managed as Category B to ensure that the effects of current and future abstraction from the confined aquifers on recharge flux in the unconfined zone is managed with regard the potential significance of effects on the lower reaches of the Hutt River. Given the nature of current abstraction, such assessment would likely require the application of the a numerical groundwater model (e.g. Phreatos, 2003) along with an assessment of the likely ecological significance of effects in the Hutt River.

  Given the importance of the confined aquifers in the Lower Hutt groundwater zone in terms of municipal water supply, it is likely than management of saline intrusion potential will remain the primary criteron for management of the groundwater resource. However, classification of the entire Waiwhetu and Morea Aquifers as category B would ensure that any further changes in the rate or location of groundwater abstraction in these aquifers has to be cognisant of the potential significance of cumulative effects on surface water occuring via changes in the water budget in the Taita Alluvium[7].
- That groundwater abstraction from Stokes Valley be managed as Category B. While limited information exists to quantify the hydrogeology of this area and current groundwater usage is minimal, given its potential hydraulic connection to the Taita Alluvium, this classification will

[7] These highly permeable confined aquifers have limited effective storage capacity so abstraction over an extended duration is likely to have a relatively equivalent effect on the water budget of the Taita Alluvium.

enable any future abstraction from this area to be managed with regard potential groundwater / surface water interaction across the wider Lower Hutt groundwater zone.

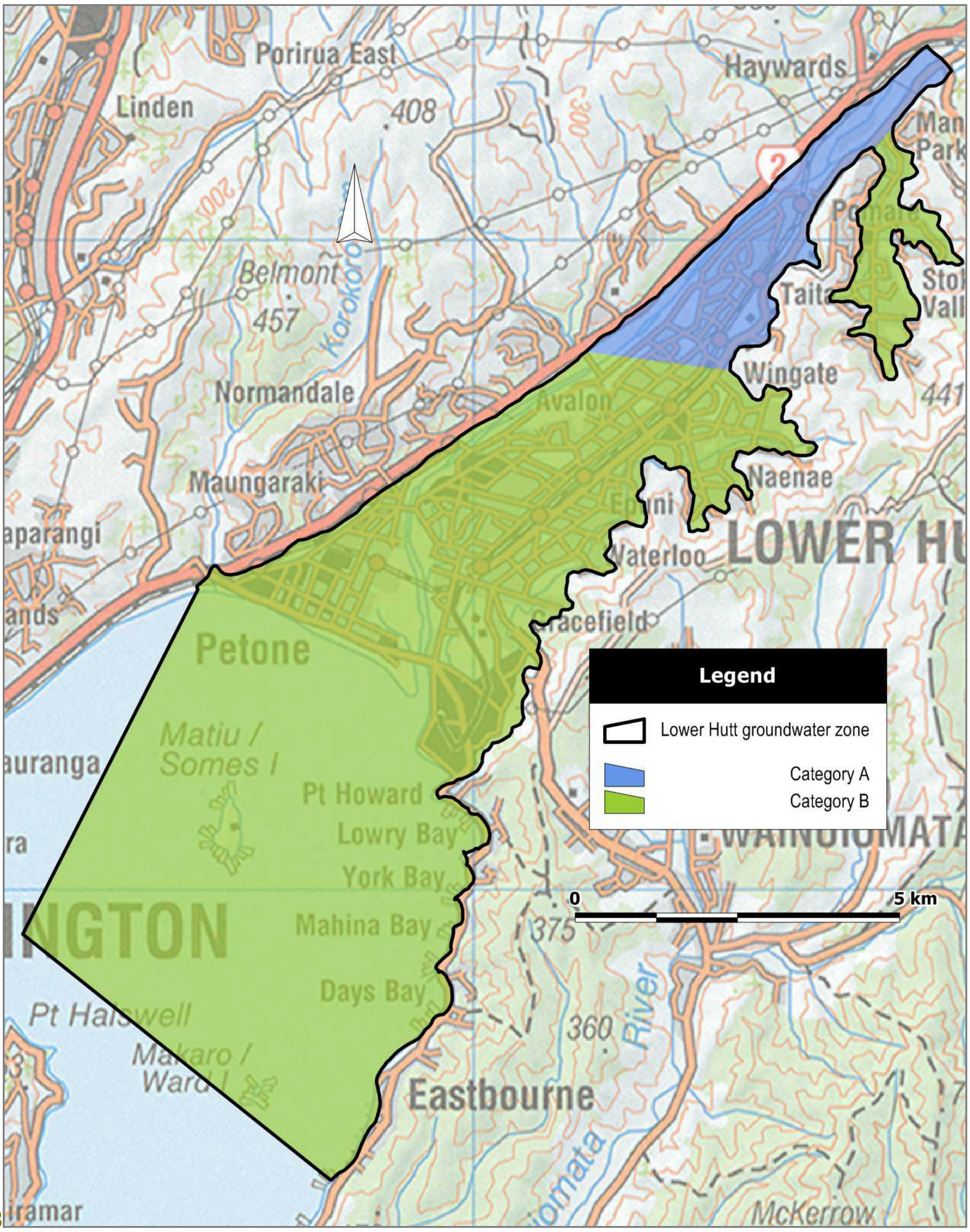


Figure 18 shows the spatial extent of the proposed hydraulic connection categories for the Lower Hutt groundwater zone.

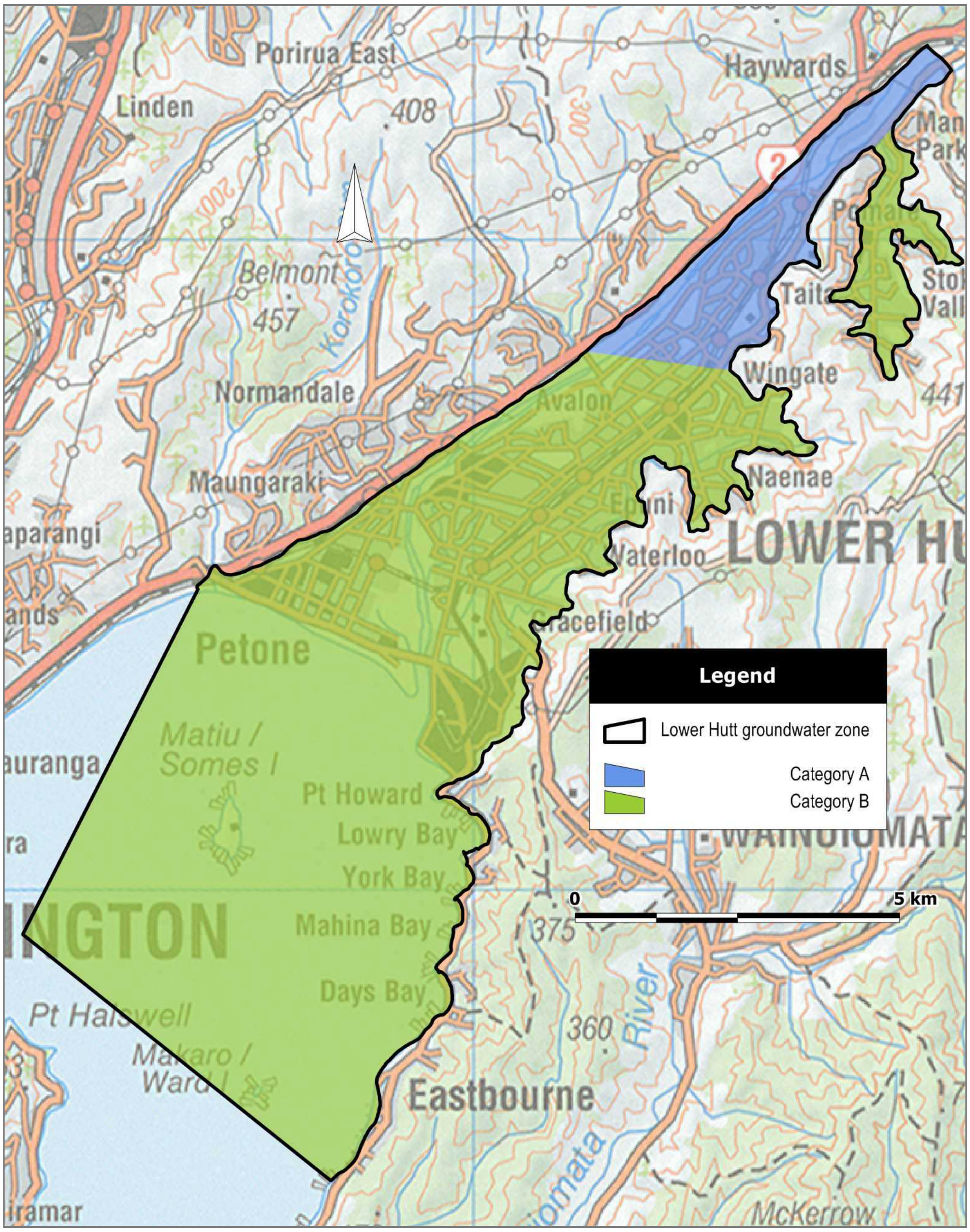


Figure 18. Proposed hydraulic connection categories in the Lower Hutt groundwater zone

3.4. Summary

The spatial and depth distribution of the proposed hydraulic connection categories in the Upper and Lower Hutt groundwater zones shown in **Figure 19** below match the two primary hydrogeological settings identified in the area:

- **Category A** - recent alluvial deposits on the floodplain of the Hutt River accumulated since the late Otarian glaciation. These deposits comprise a highly heterogenous assemblage of coasrse-grained sand and gravel deposits which host a highly permeable aquifer system which exhibits a high degree of hydraulic connection with surface water.

- **Category B** - deeper semi-confined/confined aquifers in the Upper Hutt groundwater zone confined aquifers in the southern section of the Lower Hutt groundwater zone. While these aquifer systems are physically removed from major surface waterways, abstraction from these resources has the potential to influence water balance in recharge areas with a consequent influence on hydraulicall connected water surface water bodies.

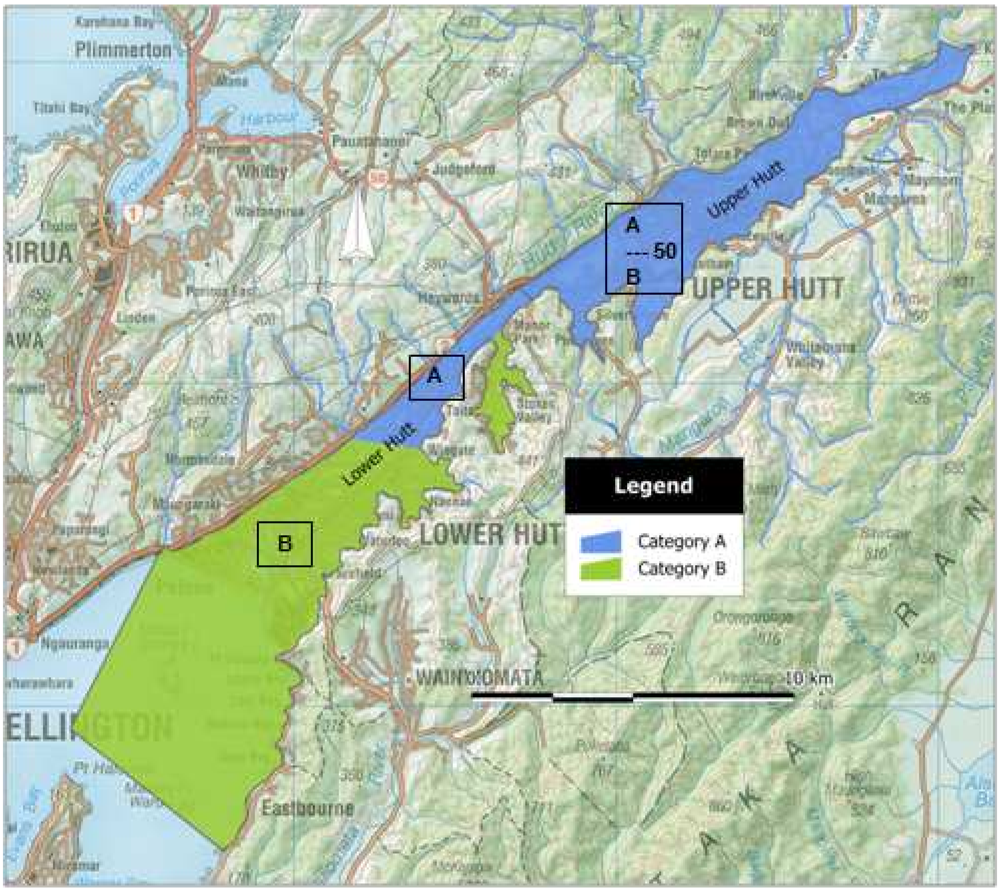


Figure 19. Distribution of proposed hydraulic connection categories in the Upper and Lower Hutt groundwater zones

3.4.1. Future management of groundwater allocation in the Hutt Valley

Abstraction from Category A aquifers in the Upper and Lower Hutt groundwater zones has a high potential to result in stream depletion effects either in the Hutt River or spring-fed streams through a combination of increased flow loss and reduced baseflow discharge. Due to the high permeability of these alluvial materials, short-term effects associated with abstraction can be substantially mitigated by application of minimum flow controls.

In the case of large-scale municipal abstraction, modelling of the abstraction from the Upper Hutt groundwater zone has shown the potential for short-term abstraction to utilise storage in the unconfined aquifer system in conjunction with other water sources to maximuse overall water resource availability (commonly termed *conjunctive use*[8]). This type of development would require management of groundwater abstraction to be integrated with environmental flows established for the Hutt River and other surface water bodies.

In terms of managing abstraction from Category A aquifers GWRC may also wish to consider the issue of consumptive vs non-consumptive water use in terms of industrial cooling water use. This type of water use is (or has been in the recent past) a significant water use in both the Upper and Lower Hutt groundwater zones. In terms of potential effects on surface water, provided all water utilised for such operations is returned to the aquifer system (i.e the take is non-consumptive) there should be no net effects on surface water (at least in terms of water qualtity). It is therefore suggested that this type of water use could be exempted from the flow cut-off restrictions applied to other water uses in Category A aquifers.

In the case of the Upper Hutt groundwater zone, limited information is available to characterise the hydraulic properties of waterbearing gravel layers deeper than 50 metres bgl. The Category B classification for these deposits reflects the potential for vertical leakage in response to abstraction to impact on the water balance of the overlying unconfined aquifer and consequently contribute to cumulative effects on surface water. Applications for abstraction from this aquifer sytem would require sufficient aquifer test information and hydrogeological analysis to adequately characterise potential effects on hydraulically connected surface water.

In the case of the Lower Hutt groundwater zone, current allocation for municipal supply and industrial use essentially mean the aquifer system is fully allocated (currently established in terms of foreshore water levels and associated saline intrusion potential). The Category B classification for this aquifer system would require any future changes to the configuration, volume or timing of abstraction authorised by resource consents to be considered in terms of potential cumulative effect on the Hutt River, particularly in terms of return flows below Kennedy Good Bridge.

[8] See for example http://www.cd.water.ca.gov/groundwater/conjunctiveuse.cfm

4. Other Areas

4.1. Introduction

Application of the proposed conjunctive management water management framework requires characterisation the hydrogeological environment in order to manage groundwater allocation in a manner consistent with environmental flows and water levels specified for hydraulically connected surface waterbodies. Previous reports have applied the conjunctive management framework to groundwater management zones in the Wairarapa Valley (Hughes and Gyopari, 2011) and on the Kapiti Coast (GRWC, 2012). **Section 3** of this report extends application of the conjunctive management framework to the Upper and Lower Hutt groundwater zones.

However, as illustrated in **Figure 20**, a significant proportion of the Wellington Region lies outside areas for where hydraulic connectivity has been defined. These areas include groundwater zones defined in the RFP for which insufficient information is available to reliably characterise the potential nature of groundwater/surface water interaction (e.g. the Akatarawa, Mangaroa, Pakuratahi, Black Creek, Wainuiomata Stream and Wainuiomata groundwater zones), as well as extensive areas in the foothills of the Tararua Range, east of the Wairarapa Valley and in the greater Wellington City metropolitan area.

These areas include a diverse range of hydrogeological environments ranging from narrow alluvial valleys to coastal sand aquifers where the potential exists for groundwater abstraction to effect surface water. In many such locations the potential magnitude of such interaction may be significant given the relatively minor discharge occurring in many headwater and tributary streams. Due to their location away from intensive agricultural/land development, such areas may also contain significant wetland areas that have the potential to be adversely impacted by groundwater abstraction.

4.2. Managing stream depletion in areas with limited hydrogeological information

Figure 21 illustrates the three basic forms of interaction between groundwater and surface water:

Gaining streams - situations where a stream gains water due to the inflow of groundwater (termed baseflow) through the stream bed from an adjacent aquifer. In this situation the rate of groundwater inflow is driven by the head difference between the aquifer and the stream as well as the hydraulic properties of the aquifer and streambed materials. Groundwater abstraction has the potential to lower groundwater levels in the aquifer resulting in a reduction in the rate of baseflow discharge;

Losing Streams - situations where streams lose water through the stream bed into a surrounding aquifer. In this situation a reduction in groundwater levels in the aquifer resulting from groundwater abstraction has the potential to increase the head difference between the stream and aquifer increasing the rate of flow loss and consequently reducing stream flow; and

Disconnected (perched) streams - situations where a stream is separated from the underlying groundwater system by an unsaturated zone or a layer of low permeability material. In this case the stream may still lose water but the rate of flow loss is unaffected by water table variations in the underlying aquifer.

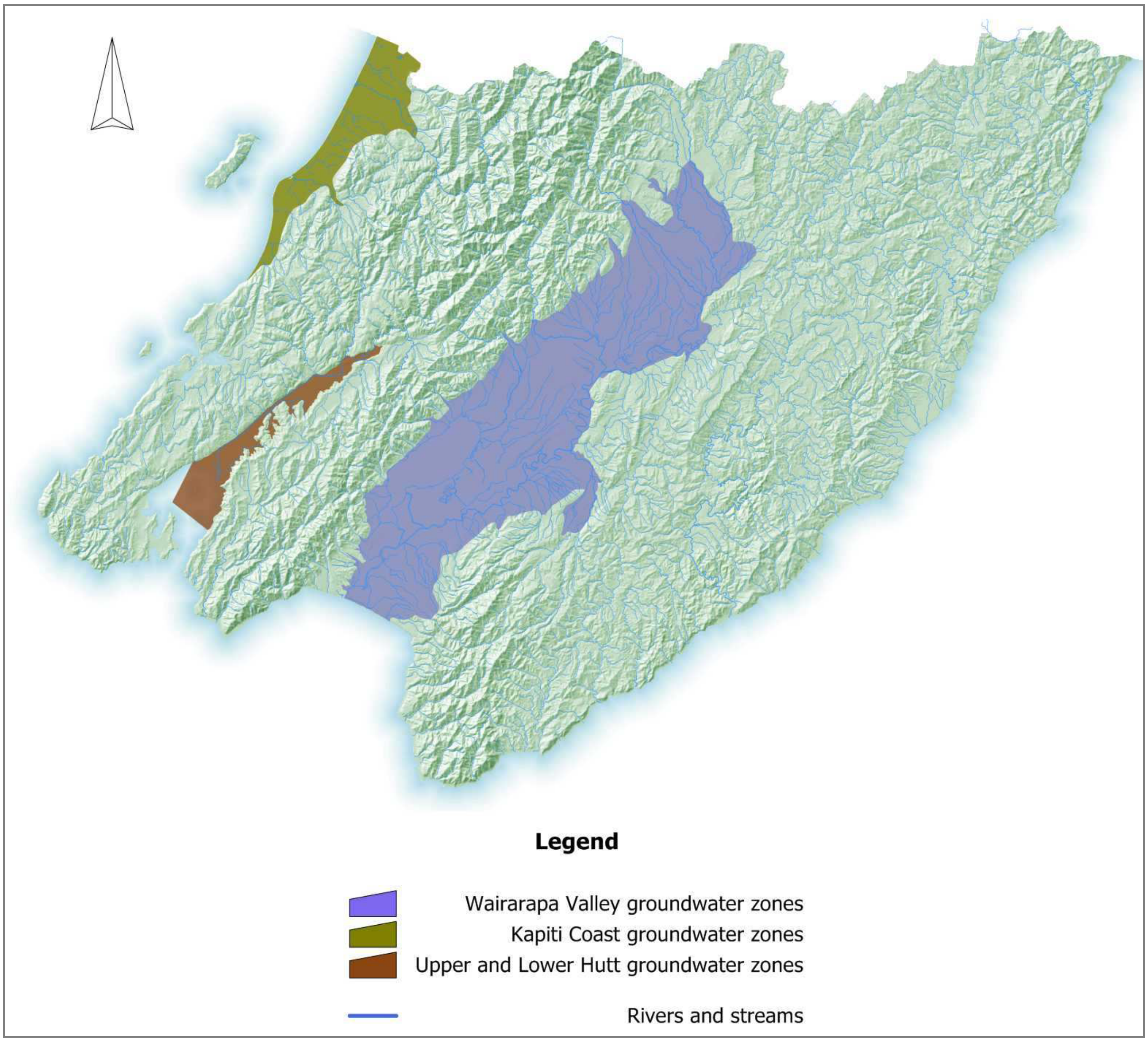


Figure 20. Map of Wellington Region with shaded areas illustrating the spatial extent of groundwater management zones covered by proposed conjunctive management framework proposed in Hughes and Gyopari (2010), GWRC (in prep) and this report.

One key point to note is that the hydraulic connection between a stream and surrounding aquifer system may change spatially and over time. For example, many streams alternately gain and lose flow over different reaches reflecting relative elevation of groundwater levels and stream stage in different landscape elements. Locations of flow gain/loss may also change over time reflecting seasonal or episodic variations in stream stage (e.g. floods, freshes) or periods of low groundwater levels. Similarly, a stream which is disconnected (perched) can change to a gaining stream in response to a rise in the underlying water table.

The following section provides a simple methodology which can be utilised to characterise the likely nature of hydraulic connection in situations where limited hydrogeological information is available and identify the potential for stream depletion to occur in response to groundwater abstraction.

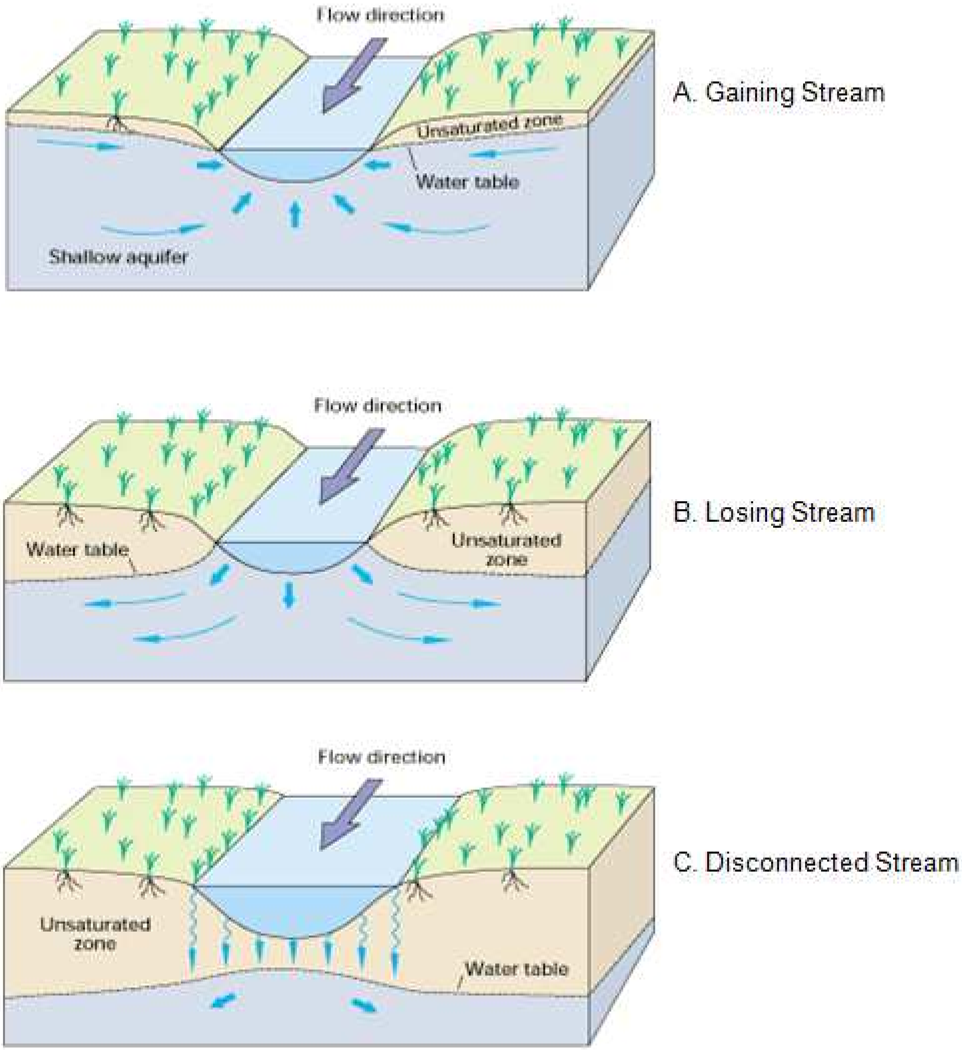


Figure 21. Schematic illustration of groundwater/surface water interaction

4.3. Proposed methodology for characterising stream/aquifer interaction

The following section provides a methodology that can be utilised to identify those groundwater takes where stream depletion is likely to be of sufficient magnitude to warrant a more detailed assessment of effects to enable consideration of the take in terms of the management controls proposed under the conjunctive management framework. The proposed methodology is designed to enable evaluation of an individual consent application based on the location of the proposed abstraction point and basic hydrogeological parameters (e.g. information that could reasonably be expected to be provided on a typical drillers log or derived from existing environmental monitoring information held by GWRC).

The methodology is based around three primary factors:

- **Location** - in hydraulically connected aquifer systems, the proximity of groundwater abstraction to surface water directly influences the potential magnitude of effect on stream flow. For the purposes of an initial screening it is assumed that effects on surface water will be minor where there is greater than1 kilometre separation between the point of abstraction and the nearest surface water body.

- **Relative water levels** - spatial and temporal variation in water levels can provide useful information to quantify the likely degree of hydraulic connection between groundwater and surface water. Where a high degree of hydraulic connection exists, stream stage and surrounding groundwater levels are typically similar reflecting the exchange of water following the natural hydraulic gradient. Conversely, a significant difference in relative stream stage and adjacent groundwater are often observed in hydrogeological settings where there is a low degree of hydraulic connectivity. Commonality in temporal groundwater level and stream stage variations can also provide a useful indicator of the likely degree of hydraulic connection in a particular location.

  Observation and/or measurement of flow loss/gain in rivers and streams is also identified as a factor than can assist categorisation of the potential for groundwater/surface water interaction in a particular hydrogeological setting.

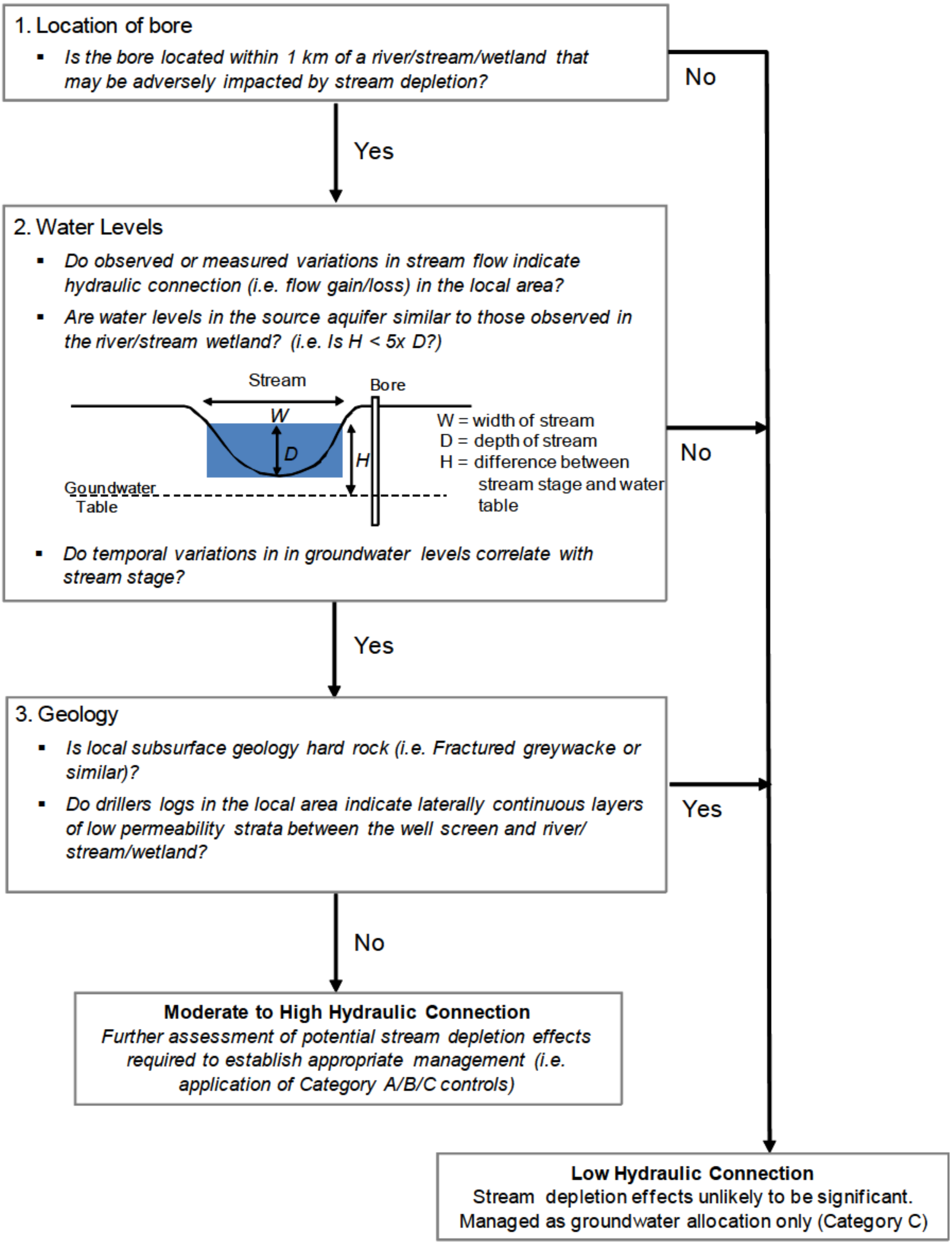
- **Geology** - subsurface geology has a significant influence on the potential for groundwater surface water interaction. As previously discussed, areas outside the existing RFP groundwater management zones include a diverse range of geological and hydrogeological settings. However two settings are identified where, in conjunction with water level information, subsurface geology can be utilised to evaluate the potential for groundwater/surface water interaction to occur. These include:

  1. Bores screened in fractured rock aquifers within the greywacke basement. Typically, due to the nature of secondary permeability water bearing zones within the greywacke basement rocks tend to exhibit limited direct hydraulic connection with the land surface

  2. Where the source aquifer is separated from the river/stream/wetland by a laterally continuous layer of low permeability materials

Figure 22 illustrates a decision-tree outlining the proposed methodology for the initial screening of groundwater takes to identify the likelihood of significant groundwater/surface water interaction. Where an individual groundwater take is identified as having classified as a low hydraulic connection it is recommended that the allocation be managed in terms of the Category C classification (i.e. managed in terms of groundwater allocation only, not subject to minimum flow controls). Where the take is identified as having a moderate to high degree of hydraulic connection then further investigation and analysis will likely be required to evaluate the take in terms of the proposed Category A and Category B definitions utilising methodologies such as those outlined in ECan (2001).

Figure 22. Proposed methodology for determining potential significance of groundwater abstraction effects on surface water



5. Summary

Hughes and Gyopari (2011) proposed a methodology for conjunctive management of groundwater and surface water resources in the Wairarapa Valley to enable management of groundwater abstraction in a manner consistent with environmental flows and water levels established for hydraulically connected surface water resources. The proposed management framework involves delineation of three hydraulic connection categories:

- Category A: areas with a direct hydraulic connection with surface water where stream depletion effects may be mitigated by application of minimum flow or level cut-offs;
- Category B: areas where groundwater abstraction effects on surface water may be significant and can potentially be managed through application of pumping controls depending on localised hydrogeological conditions and the rate of abstraction; and,
- Category C: areas of the groundwater system which exhibit limited connectivity to surface water where cumulative effects on surface water are best addressed through management in terms of a fixed allocation volume.

This report is intended to provide recommendations for application of the conjunctive management framework across the remainder of the Wellington Region to the extent practicable given constraints on data and technical tools available to characterise and quantify the nature and extent of groundwater/surface water interaction. As a result, the primary focus of this report is on the determination of hydraulic connectivity zones to identify areas where active management of groundwater abstraction through minimum flow or level cut-offs may be appropriate to manage local effects on surface water. The issue of the managing cumulative effects of groundwater abstraction by the establishment of fixed allocation volumes for individual aquifer systems is not directly addressed in this report.

Hutt Valley

The groundwater resources of the Hutt Valley occur in a series of alluvial basins formed by displacement along the Wellington Fault. Both the Upper and Lower Hutt basins contain highly permeable unconfined aquifers hosted in alluvial gravel materials deposited and reworked by the Hutt River since the last glaciation. These aquifers systems are highly permeable and exhibit a high degree of hydraulic connection with the Hutt River and various spring-fed stream systems.

In the Upper Hutt Basin the alluvial gravel deposits below 50 metres are poorly characterised but appear to host a low to moderate permeability semi-confined aquifer system. Due to the potential for abstraction from this aquifer system to impact on the water balance of the overlying unconfined aquifer system, the Category B classification is recommended for all groundwater resources below 50 metres across the Upper Hutt groundwater zone.

In the Lower Hutt groundwater zone, sea level variations associated with late Quaternary glacial cycles resulted in the deposition of fine-grained silt and sand materials across the southern section of the valley stinging out across the harbour area. These low permeability layers form aquitards which confine a highly permeable artesian aquifer system in the lower valley. The alluvial gravels to the north of the confined aquifer margin are classified as Category A to reflect the direct hydraulic connection observed with the Hutt River. In the southern portion of the valley both the highly permeable confined aquifers and overlying unconfined Taita Alluvium are classified as Category B to reflect the potential for large-scale abstraction to affect the balance of aquifer throughflow into the confined aquifers and return recharge to the Hutt River along the confined aquifer margin.

<u>Other Areas</u>

A significant proportion of the Wellington Region lies outside of the groundwater zones defined for the Kapiti Coast, Hutt Valley and Wairarapa Valley. These areas contain a diverse range of hydrogeological settings from narrow alluvial valleys to coastal plains where groundwater abstraction has the potential to impact on surface water. The report proposes a simple classification system based on relative location, water levels and geology what can be utilised in such hydrogeological settings where no hydraulic connection categories are defined to identify those groundwater takes that require detailed assessment of the potential effects on surface water.

6. References

Begg, J.G., Johnston, M.R., 2000; *Geology of the Wellington Area*. Institute of Geological and Nuclear Sciences Ltd, Lower Hutt New Zealand

Brown, L.J., Jones, A., 2000; *Moera Gravel Investigation Bore WRC Well No 6386 - Marsden Street, Lower Hutt*. Wellington Regional Council Publication WRC/RINV-T-00/30.

Butcher, G., 1995; *Report on the Pump Testing Carried out on the Waterloo Wellfield, Lower Hutt, March 1993*. Report prepared for Hydrological Services Group, Wellington Regional Council, March 1995.

Butcher, G., 1996; *Report on the Pump Testing Carried out on the Waterloo Wellfield, Lower Hutt, November 1995*. Report prepared for Hydrological Services Group, Wellington Regional Council, February 1996.

Donaldson, I.G., Campbell, D.G, 1977; *Groundwaters of the Hutt Valley - Port Nicholson Alluvial Basin*. New Zealand Department of Scientific and Industrial Research DSIR Information Series No. 124, July 1977.

Environment Canterbury, 2001; *Guidelines for the Assessment of Groundwater Abstraction Effects on Stream Flow*. Environment Canterbury Report ROO/11

Hughes B., 1998; *Moera Aquifer Investigation.* Wellington Regional Council Publication WRC/RINV-T-98/13, June 1998.

Hughes, B., Gyopari, M., 2011; *Wairarapa Valley groundwater resource investigation. Proposed framework for conjunctive water management*. GWRC Publication GW/EMI-T-11/53, May 2011.

Jones, A.; Baker, T. 2005. *Groundwater monitoring technical report*. Greater Wellington Regional Council Publication No. GW/RINV-T-05/86.

MWH, 2005; *Sustainable Yield Study for the Upper Hutt Aquifer, Stage One*. Report to Greater Wellington Regional Council, December 2005.

MWH, 2008; *Sustainable Yield Study, Upper Hutt Aquifer, Stage Two*. Report to Greater Wellington Regional Council, February 2008.

Odlin, K.S., 1972; *Trentham Memorial Park Investigations - Report on Pumping Tests*. Letter to Hutt Valley Underground Water Authority, May 1972.

Phreatos; 2001; *Revised Assessment of Groundwater Resource Availability: Upper Waiwhetu Aquifer*. Report prepared for Wellington Regional Council, October 2001.

Phreatos, 2003; *Revision of the numerical model for the Lower Hutt groundwater zone*. Report prepared for Wellington Regional Council, April 2003.

Sahuquillo, A., Lluria, M., 2003: *Conjunctive use as potential solution for stressed aquifers: social constraints*. In: Llamas R and Custodio E (eds): Intensive use of groundwater: Challenges and opportunities. A.A. Balkema Publishers.

Wellington Regional Council, 1995; *Hydrology of the Hutt Catchment. Volume I Surface Water Hydrology*. Wellington Regional Council Publication WRC/CI-T-P5/38, May 1995.

Wellington Regional Council, 1995; *Hydrology of the Hutt Catchment. Volume II Groundwater Hydrology*. Wellington Regional Council Publication WRC/CI-T-P5/38, May 1995.

Williams, G., 2008; Sustainable Yield Model. *Validation of the river depletion characteristics for the Upper Hutt aquifer componen*t. Greater Wellington Regional Council Publication B/01/07/21, July 2008.

Wood, R., Davey, B., 1992; *Interpretation of geophysical data collected in Wellington Harbour*. Wellington Regional Council Report No. 1992/78.