SINCLAIR KNIGHT MERZ

SKM

environment SOUTHLAND

Management of Confined Aquifers in the Southland Region

REPORT TO ENVIRONMENT SOUTHLAND

- Final
- 28 February 2008

Management of Confined Aquifers in the Southland Region

REPORT TO ENVIRONMENT SOUTHLAND

- Final
- 28 February 2008

Sinclair Knight Merz
Level 2, 321 Manchester Street
PO Box 8298
Christchurch New Zealand
Tel: +64 3 379 0135
Fax: +64 3 377 2209
Web: www.skmconsulting.com

Contents

1. Current Policy 1
   - 1.1 Introduction 1
   - 1.2 Background 1
   - 1.3 Current Policy 2
   - 1.4 Application of Current Policy to Resource Consents 4
   - 1.5 Limitations of current approach 5
   - 1.6 Summary 6

2. An Alternative Allocation Approach 7
   - 2.1 Background 7
   - 2.2 Establishing Sustainable Allocation 8
   - 2.3 Alternative Staged Approach 14
   - 2.4 Application to resource consents 19
   - 2.5 Monitoring and information requirements to support alternative management options 22
   - 2.6 Management of situations where existing allocation approaches or exceeds primary allocation 23
   - 2.7 Summary 24

3. Application of Proposed Allocation Framework to Confined Aquifers in the Oreti Basin 26
   - 3.1 North Range Aquifer 26
   - 3.2 Lumsden Aquifer 31

4. Summary and Recommendations 38

5. References 40

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
Draft	20 February 2008	Karen Wilson	BNH	29 February 2008	
Draft	20 February 2008	Ken McKenzie	BNH	27 February 2008	

Distribution of copies

Revision	Copy no	Quantity	Issued to

Printed:	22 September 2009
Last saved:	22 September 2009 11:23 AM
File name:	D:\AENV\AE02453\Lumsden Aquifer\AE02453C0077.doc
Author:	Brydon Hughes
Project manager:	Brydon Hughes
Name of organisation:	Environment Southland
Name of project:	Lumsden Aquifer Sustainability Project
Name of document:	Management of Confined Aquifers in the Southland Region
Document version:	Final
Project number:	AE02453

1. Current Policy

1.1 Introduction

The existing framework for groundwater allocation contained in the Regional Freshwater Plan was developed by Environment Southland in 2003 in response to a significant increase in groundwater abstraction in the Southland Region in the early 2000's. Due to limited knowledge of aquifer hydrogeology a generic approach, based on management of water level drawdown, was adopted to manage allocation from confined aquifers. Over the subsequent period a number of difficulties have arisen with regard to the practical application of the proposed management controls, particularly in regard the management of the cumulative effects of abstraction from multiple bores.

SKM were commissioned to review the existing policy framework for groundwater allocation from confined aquifers and identify an alternative approach to address current issues with regard the management of confined aquifers in the Northern Southland area.

1.2 Background

Large-scale development of groundwater resources is a comparatively recent phenomenon in the Southland Region. Prior to 2000 abstraction of groundwater was largely limited to small-scale abstraction for domestic and farm supply with a limited number of large takes for industrial (e.g. Tiwai Aluminium Smelter, Alliance Makarewa) and municipal supply (including Gore, Winton and Te Anau). However, since 2001 significant development of groundwater resources to supply pasture irrigation has occurred in many parts of Southland, particularly in the Northern Southland area between Te Anau and Mandeville.

Due to the relatively limited extent of groundwater development in Southland at the time, the Regional Freshwater Plan proposed by Environment Southland in 2000 contained relatively basic provisions in regard the management of groundwater allocation. However, in response to a significant increase in the number of resource consent applications for large-scale groundwater abstraction in the early 2000's, combined with projections of future regional water demand contained in the Southland Water Resources Study (Lincoln Environmental and MWH, 2003), Environment Southland initiated Variation 2 (Groundwater) to the Proposed Regional Water Plan in 2003 to establish a more robust policy framework for the management of groundwater quality and quantity in the Southland Region.

Development of a detailed framework for groundwater allocation was complicated by limited knowledge of regional hydrogeology and the comparatively short history of both resource development and environmental monitoring. In order to address these issues policy development adopted a staged approach to the allocation of groundwater within nominated management zones. Each management zone identified was classified according to aquifer 'type' and nominal allocation volumes defined as appropriate for each aquifer type based on estimated rainfall recharge. Under the staged approach, groundwater takes within the first allocation volume were classified as restricted discretionary activities. Takes within the second allocation volume were then classified as discretionary activities with those above the second allocation limit classified as non-complying activities.

The basic premise of the management framework developed was the concept of adaptive management whereby the level of information and assessment required to support a resource consent application increases as the level of allocation from a particular groundwater zone increases. Thus, the final allocation framework does not establish definitive allocation limits rather it recognises that a sufficient understanding of the resource to set final groundwater allocation will, in a practical sense, only become available through further investigations, monitoring and resource development. The overall philosophy being to establish an iterative process for groundwater allocation which enables information derived from initial resource development and resource monitoring to be utilised to inform the resource consent decision-making process as levels of allocation increase.

The allocation limits defined for Riparian, Terrace, Lowland and Fractured Rock aquifer types were based on varying percentages of estimated land surface recharge (LSR). However, due to the limited knowledge of the spatial extent, hydrogeology and recharge characteristics at the time of plan development, such an approach was not considered appropriate for confined aquifers. As an alternative, criteria to manage allocation from confined aquifers were established on the basis of the drawdown of groundwater levels in response to abstraction.

The following section provides a summary of the current policy relating to groundwater allocation from confined aquifers and reviews practical application of the policy through the resource consent process.

1.3 Current Policy

1.3.1 Definitions

An aquifer is defined in the Southland Regional Water Plan as a *"saturated rock or soil material capable of transmitting and yielding water in sufficient quantities for abstraction"*. For the purposes of management the differing hydrogeological characteristics of aquifer systems are recognised by the classification of aquifer systems into five broad categories: riparian, terrace, lowland, fractured rock and confined aquifers. Under the Plan a confined aquifer is further defined as an *"aquifer which is overlain by a low permeability or impermeable layer where water in the aquifer is under pressure"*.

1.3.2 Policies and Objectives

Policies and objectives contained in the Regional Water Plan relevant to the management of groundwater allocation include:

Objective 9

To ensure that the total volume and rate of groundwater abstraction is sustainable.

Policy 28 To Manage Groundwater Abstraction

To manage groundwater abstraction to avoid significant adverse effects on:

- *long-term aquifer storage volumes*
- *existing water users*
- *surface water flows and aquatic ecosystems and habitats*
- *groundwater quality*

Policy 30 Groundwater abstraction

a) Use a staged management approach to allocate groundwater for abstraction in Southland to allow the knowledge gained by the progressive development of the region's groundwater resources to be built into its future management.

b) Recognise the different characteristics of the following aquifer types when managing groundwater abstraction:

(i) riparian aquifers;
(ii) terrace aquifers;
(iii) lowland aquifers;
(iv) confined aquifers;
(v) fractured rock aquifers.

c) Provide for a level of permitted groundwater abstraction where there is a minimal risk of adverse effects.

1.3.3 Regional Rules

Rules defining the activity status of groundwater abstraction from confined aquifers are defined in Rule 23 Abstraction and Use of Groundwater. This rule states that:

(a) *In addition to the takes authorised by Section 14(3) of the Act and the abstraction and use of groundwater permitted under Rule 23(b), the abstraction and use of up to 20,000 litres of groundwater per landholding per day is a permitted activity provided the following conditions are met:*

(i) the rate of abstraction does not exceed 2 litres per second, except where the abstraction is for the purpose of carrying out an aquifer test or hydrological study; and

SKM

(ii) the abstraction does not result in adverse effects on existing water users, surface water ecosystems or groundwater quality.

(c) *Except as provided for in Rules 23(a) and 23(b) and the takes authorised by Section 14(3) of the Act, the abstraction and use of groundwater from any of the following sources is a restricted discretionary activity, provided the rate of take is less than or equal to 2 litres per second:*

(ii) *a confined aquifer where pumping of an individual bore results in a maximum reduction of less than 25 percent in the potentiometric head at a distance of 250 metres from the pumped bore*

The Council will restrict its discretion to the following matters:

(i) any effects on aquifer storage volumes, existing bore or well yields, river and stream flows and wetland and lake water levels (stream depletion effects), and groundwater quality;

(ii) the efficiency of water use;

(iii) the need for the installation of a water measuring device;

(iv) the need for pump tests;

(v) monitoring requirements.

(d) *Except as provided for in Rules 23(a) and 23(b) and the takes authorised by Section 14(3) of the Act, the abstraction and use of groundwater from any of the following sources is a discretionary activity:*

(iii) a confined aquifer where pumping of an individual bore results in a maximum reduction of between 25 and 50 percent in the potentiometric head at a distance of 250 metres from the pumped bore ;

(e) *Except as provided for in Rules 23(a) and (b) and the takes authorised by Section 14(3) of the Act, the abstraction and use of groundwater from any of the following sources is a non-complying activity:*

(iii) a confined aquifer where pumping of an individual bore results in a maximum reduction of more than 50 percent in the potentiometric head at a distance of 250 metres from the pumped bore.

1.4 Application of Current Policy to Resource Consents

The policies and rules contained in the Regional Water Plan have been utilised to develop conditions on resource consents for groundwater abstraction from the confined North Range and Lumsden Aquifers in the Oreti Basin (discussed in greater detail in Section 3). Conditions applied to a majority of existing resource consents include:

- A condition restricting the volume of abstraction to 50 percent of total allocation when groundwater levels in a nominated monitoring bore reach an initial trigger level (based on 25 percent of available potentiomentric head at a point at least 250 metres from the pumping well);

- A condition requiring abstraction to cease when groundwater levels in a nominated monitoring bore reach a second trigger level (generally 1 metre lower than the first trigger level); and,
- A condition triggering review of the consent if seasonal recovery is inadequate (generally a 1.5 metre drop between 1 August groundwater levels between consecutive irrigation seasons or a 2 metre decline over 3 consecutive irrigation seasons).

However, not resource consent decision making has strictly followed the allocation criteria established in the Regional Water Plan. For example, the staff report on resource consent application 202786 recommended consent be declined on the basis of potential sustainability issues. In this case, while available groundwater level data did not show a decline in piezometric levels sufficient to trigger non-complying activity status, the temporal trends in groundwater levels combined with records of water usage showing abstraction at levels well below total allocation raised concerns regarding the potential sustainability of additional allocation. In this case the application remains on hold pending collection of data to support the application.

1.5 Limitations of current approach

Based on experience with the practical application of the existing provisions for allocation from confined aquifers a number of limitations with the current approach to management of groundwater allocation from confined aquifers are apparent. These include:

- Not all consent holders are treated equitably. Some consents have conditions requiring cut-back or cessation of abstraction based on minimum lever triggers and seasonal recovery while others do not;
- Existing minimum level cut-offs have been assigned in a relatively arbitrary manner and do not relate to either environmental effects or reliability of supply criteria;
- Minimum level cut-offs in a single aquifer may be referenced to different monitoring bores (as is the case in the Lumsden Aquifer) with the respective levels not directly correlated. This situation has arisen for two reasons. Firstly the existing policy refers to the drawdown in piezometric levels in excess of 250 metres from the abstraction point. Where pumping wells are widely spaced this has required reference to local monitoring points. Secondly, in the Lumsden Aquifer a central monitoring point suitable for monitoring ‘representative’ aquifer levels was not installed until a number of consents had already been issued;
- The use of piezometric levels as a means to manage groundwater allocation can be problematic if a groundwater level site referenced in existing consents is impacted by localised drawdown from later abstraction. This situation may arise in any situation (unconfined or confined aquifers) where groundwater levels are utilised to control groundwater abstraction as the Regional Freshwater Plan contains no specific provisions (other than the interference effects policy) regarding setback requirements from nominated groundwater level monitoring sites;

- Minimum aquifer levels have been assigned in a stepwise fashion as resource consents issued with progressively higher minimum levels assigned to later consents. No assessment has been undertaken to ascertain the impact of additional allocation on the reliability of supply for existing users;
- Due to the rapid nature of resource development and limited abstraction over the past two summers due to relatively wet summer conditions, it is difficult to reliably validate aquifer response to abstraction;
- The potential impacts of future climate change and/or variability are not readily accounted for under the existing allocation framework;
- The overall criteria for management (i.e. drawdown in piezometric levels 250 metres from the pumped bore) is arbitrary, influenced by factors such as interference effects between neighbouring bores and fails to take into account the potential impact of abstraction on hydraulically connected water resources; and,
- Conditions applied to trigger consent review in the case of inadequate seasonal recovery may not identify situations where temporal trends in groundwater levels indicate issues with sustainability of the resource.

1.6 Summary

The existing framework for groundwater allocation contained in the Regional Freshwater Plan was developed by Environment Southland in 2003 in response to a significant increase in groundwater abstraction in the Southland Region in the early 2000's. Due to limited knowledge of aquifer hydrogeology a generic approach, based on management of water level drawdown, was adopted to manage allocation from confined aquifers. Over the subsequent period a number of difficulties have arisen with regard to the practical application of the proposed management controls, particularly in regard the management of the cumulative effects of abstraction from multiple bores. These issues include:

- Arbitrary assignment of minimum water level controls;
- Difficulty ensuring ongoing sustainability of abstraction;
- The use of multiple reference sites for a single aquifer;
- Equity for resource users; and
- Management of localised drawdown impacts on monitoring bores linked to minimum water level cut-offs.

2. An Alternative Allocation Approach

2.1 Background

The policy framework for groundwater allocation contained in the Regional Freshwater Plan establishes an allocation system for unconfined aquifers (defined in terms of groundwater management zones) based on staged management approach where the activity status (restricted discretionary, discretionary and non-complying) for groundwater takes varies according to the volume of allocation as a percentage of estimated aquifer recharge. The overall premise of this approach is to utilise information collected by resource development and monitoring to inform subsequent resource consent decision-making. Therefore, although no allocation limits are set, ideally over time overall allocation will be limited to the volume shown by resource monitoring to be sustainable.

Due to the limited knowledge of the spatial extent, hydrogeology and recharge characteristics of confined aquifers in Southland at the time of plan development a similar water balance approach was not considered feasible for application to this aquifer type. As an alternative criteria to aquifer recharge, the existing allocation framework for confined aquifers was based on ensuring aquifer drawdown resulting from abstraction does not exceed nominated thresholds. However, as described in Section 1.4, difficulties have arisen with the practical implementation of Water Plan provisions related to allocation from confined aquifers, particularly in regard the management of the cumulative effects of multiple takes. Experience has shown that it is difficult, under the existing policy framework, to ensure groundwater abstraction meets the overall policy objective of ensuring groundwater abstraction is sustainable.

Drawing on experience with application of existing Regional Water Plan provisions, the following points were considered as the main criteria for establishing an alternative allocation methodology for confined aquifers that may address some of the shortcomings of the current approach:

- The need to establish allocation from confined aquifers on the basis of overall aquifer water balance rather than localised aquifer response even where information available to define aquifer hydrogeology is limited;
- A means to establish a primary allocation limit that can be used to prevent further allocation until aquifer response to abstraction is adequately validated;
- The ability to factor in the cumulative effects of abstraction on hydraulically connected water resources, particularly in regard leakage induced by pumping and the need for conjunctive management of confined and unconfined aquifers, as well as the effects of abstraction on cumulative stream depletion; and,

- A means to enable efficient utilisation of the available groundwater resource where actual abstraction is generally well below seasonal allocation specified by resource consent conditions.

2.2 Establishing Sustainable Allocation

The following section provides an outline of some of the technical background and definitions, as well as resource management issues that have shaped the alternative allocation framework described in Section 2.3.

2.2.1 Aquifer Throughflow

As an alternative to using localised aquifer drawdown as the primary means of controlling groundwater abstraction from confined aquifers it is proposed that the criteria for determining activity status (and consequently information requirements to support resource consent applications) is amended to refer to aquifer throughflow. As it is based on overall aquifer water balance, throughflow is analogous to the criteria for managing abstraction from unconfined aquifers (i.e. proportion of aquifer recharge).

Under natural conditions the volume of water flowing through a given cross section of an aquifer system (termed throughflow in this report) represents a balance between aquifer recharge and discharge. The storage of water within the aquifer system (represented by changes in groundwater levels) provides a buffer between variable climate-driven recharge processes and the relatively constant outflow the aquifer system occurring via spring discharge and more general leakage to other hydraulically connected water resources.

Following Darcy's Law, the volume of water flowing through a given cross section of an aquifer system is dependent on the permeability of the aquifer materials, the cross sectional area of the aquifer and the hydraulic gradient:

$$Q = K \times A \times {}^{dh}/_{dl}$$

where:

Q = flow through aquifer system

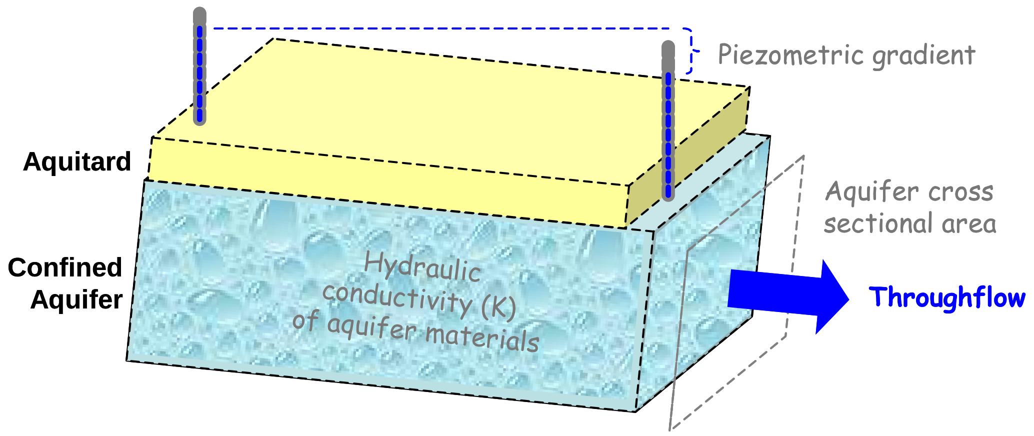
K = hydraulic conductivity of aquifer materials

A = cross sectional area of aquifer system

${}^{dh}/_{dl}$ = hydraulic gradient

Given that aquifer properties and dimensions are effectively fixed, aquifer throughflow is therefore proportional to the piezometric gradient in the aquifer system. Figure 1 provides a schematic illustration of throughflow in a confined aquifer system.

SKM



- **Figure 1. Schematic illustration of aquifer throughflow**

Calculation of aquifer throughflow can be undertaken by a variety of means ranging from simple estimates based on measured aquifer characteristics through to detailed numerical modelling studies. In its most basic application, throughflow can be estimated from relatively simple measurements of the physical characteristics of an aquifer system including:

- **Aquifer permeability -** derived from analysis of aquifer test results. Commonly expressed in terms of transmissivity (T) which is equivalent to hydraulic conductivity multiplied by aquifer thickness
- **Aquifer cross sectional area -** given that aquifer thickness is inherent in calculation of transmissivity, estimation of aquifer throughflow requires an estimate of a representative aquifer width perpendicular to groundwater flow
- **Hydraulic gradient -** estimation of hydraulic gradient requires measurement of piezometric levels at a minimum of three points within an aquifer system. This allows identification of relative hydraulic gradient perpendicular to groundwater flow direction.

For example, a confined aquifer system with a measured aquifer transmissivity of 1000 m^2/day, a width of 4000 m and a hydraulic gradient of 0.001 will have a calculated throughflow of 4,000 m^3/day. On an annual basis this equates to a throughflow of 1,460,000 m^3. This calculation may be suitable to establish basic aquifer sustainability criteria where the level of allocation is low compared to overall aquifer water budget.

However, as the level of allocation from an aquifer system increases more detailed quantitative estimates of throughflow are likely to be required to support resource consent applications. This may include quantification of aquifer leakage, as well as detailed estimates of recharge and discharge. Therefore, in keeping with the staged management approach, definition of aquifer throughflow required to support a resource consent application may vary according to the level of allocation from an aquifer system.

2.2.2 Aquifer Leakage

Confined aquifers, by definition, are partially isolated from overlying water resources by intervening low permeability layers (termed aquitards). However, aquitard layers may still able to store and transmit appreciable quantities of water (although at much lower rates than the aquifer materials themselves). Therefore, depending on the hydraulic properties of the aquitard layer, abstraction from a confined aquifer may induce vertical leakage from overlying aquifers.

As a result, determination of aquifer leakage is an important consideration in the sustainable management of abstraction from confined aquifers. Where vertical leakage is limited, abstraction is unlikely to result in any significant effects on natural recharge to the aquifer system. However, where leakage is more significant it may alter the fundamental water balance of the aquifer. While this may serve to increase the volume of abstraction possible on a sustainable basis from a confined aquifer, it may also result in adverse effects on hydraulically connected water resources. These effects may include drawdown of groundwater levels in overlying aquifers as well as consequent impacts in terms of stream depletion or spring flows.

Definition of aquifer leakage therefore increases in importance as the volume of allocation from a confined aquifer increases. This is particularly the case where overlying aquifers may be hydraulically connected to surface water resources that are at or near full allocation. Quantification of leakage requires quality aquifer test information involving an extended duration of pumping and monitoring of groundwater level responses in both the pumped aquifer and overlying aquifers. In many cases, while a single take from a confined aquifer may not result in significant effects on an overlying aquifer, the cumulative effects of multiple takes on aquifer leakage may make a significant impact on the water balance of overlying aquifers and/or hydraulically connected water resources.

2.2.3 Validation of aquifer response to abstraction

Management of allocation from confined aquifers, particularly in a region such as Southland where large-scale resource development is a comparatively recent phenomenon, presents a complex resource management challenge. In a majority of cases, knowledge of aquifer hydrogeology (even at a relatively basic level e.g. aquifer dimensions) is relatively limited, so estimates of sustainable allocation during the initial stages of resource development are likely to be approximate only. Validation of aquifer response to abstraction can therefore only occur in conjunction with review and assessment of data that quantify overall aquifer water balance.

In order to validate allocation limits it is therefore important that good quality information is available to determine:

- Groundwater abstraction - records of water use on both a daily and seasonal basis;
- Groundwater levels - representative groundwater levels from across the aquifer system to assist determination of the variation in aquifer storage in response to abstraction and climate; and,
- Aquifer recharge - climate and hydrological parameters that may affect recharge to the groundwater system including rainfall, soil moisture and river flow.

2.2.4 Seasonal Allocation vs Actual use

Most consents for groundwater abstraction in the Southland Region have associated conditions that specify a maximum instantaneous or daily abstraction rate as well as the total volume of abstraction within a 12 month interval (termed *seasonal allocation*). While recording of water use is a standard condition on large-scale groundwater takes, provision of the required data to Environment Southland has not been universal.

In terms of resource management the maximum instantaneous or daily rate of take is important for managing short-term effects resulting from abstraction (e.g. interference effects on existing users, streamflow depletion effects). Seasonal allocation is a more important consideration in ensuring long-term sustainability of abstraction by ensuring the cumulate volume of water abstracted does not exceed the rate of aquifer recharge minus an allowance for the maintenance of natural discharge (e.g. stream baseflow contribution, spring discharge).

Available data on actual groundwater usage provided by resource consent compliance monitoring indicates that since 2004 actual groundwater abstraction for irrigation consents in Southland (from all aquifer types) has been well below seasonal allocation (generally <50%). Since 2004 Southland has experienced a sequence of average to wetter than normal summers. These conditions have reduced seasonal irrigation requirements and may serve to highlight that crop water requirements used to calculate seasonal allocation tend to reflect extreme rather than average conditions.

The variance between calculated seasonal demand and actual use may, in large part, be explained by the vagaries of the Southlands temperate climate, where it is rare for periods of low rainfall, sufficient to result in soil moisture deficits that may adversely impact on pasture growth, to occur across an entire irrigation season. Dry spells in Southland tend to be of relatively limited duration (generally <3 months) compared to the seasonal rainfall deficits occurring in areas of the South Island, particularly eastern areas from Marlborough to Central Otago.

The observed disparity between seasonal allocation and actual groundwater use raises a number of potential issues for Environment Southland in ensuring efficient management of water resources. These issues include:

- Where there is a fixed volume of allocation available an aquifer system may be considered fully allocated even though only a small proportion of this allocation is used in a given year. This may preclude additional users accessing the resource even though the available allocation is not utilised. This significantly reduces *allocative efficiency* and is potentially inconsistent with the definition of sustainable management as outlined in Part II of the Resource Management Act;
- If seasonal allocation is established at a level that represents actual groundwater use under extreme conditions, a significant portion of the available resource is likely to remain unused under less extreme conditions. Again this can reduce *allocative efficiency* and preclude additional users from accessing the resource within the defined allocation limit;
- Assessment of the cumulative effects of abstraction based on seasonal allocation may significantly over-estimate impacts of actual abstraction. This can not only limit future development of the source aquifer but may also impact on allocation from hydraulically connected water resources;
- Where aquifer response to abstraction is utilised to inform the resource consent decision-making process on future resource consent applications, the disparity between seasonal allocation and actual use may make it difficult to validate allocation limits particularly where information to quantify actual groundwater abstraction is limited.

In order to address this situation it is recommended that Environment Southland consider the following in regard future options for groundwater allocation:

- A review of conditions of existing resource consents to bring seasonal allocation into closer alignment with actual water use. This would require initiation of a consent review process under s128 of the RMA following variation to the existing Regional Water Plan. Alternatively, given the relatively short duration of water permits issued in Southland (generally 10 years) it may be as timely to alter conditions of existing resource consents upon application for renewal;
- Enable a flexible allocation system whereby additional users can access the unused portion of existing allocation on a seasonal basis. Such a system must however be designed to ensure that the security of supply for existing users is not adversely impacted as a result of the grant of additional resource consents; and,
- Undertake a review of anticipated climate change effects in terms of future changes in aquifer recharge and likely crop water requirements.

2.2.5 Calculation of Seasonal Allocation

For irrigation consents the standard practice in Southland has been to calculate seasonal allocation on the basis of the maximum daily rate of take over a 150 day irrigation season multiplied by a factor of between 0.55 and 0.65 to allow for the reduction in crop water requirements that occurs during shoulder portions of the irrigation season due to reduced evapotranspirative demand.

Given that current methods appear to significantly over-estimate actual water requirements for irrigation consents it is recommended that Environment Southland review the method used to estimate seasonal water requirements for future resource consent applications to ensure closer alignment with actual use. The review should include assessment of actual water use records and climate data (particularly during a significant dry period) to establish a reliable estimate of actual irrigation requirements during a season with high demand. One simple option to ensure better alignment between seasonal allocation and actual use may be to alter the existing methodology to reduce the nominal irrigation season from the current assumption of 150 days to a figure of 120 or 100 days.

2.2.6 Reliability of supply

The volume of water available for abstraction from an aquifer system normally varies over time in response to changes in aquifer storage resulting from abstraction and temporal variability in aquifer recharge. Reliability of supply refers to the ability of the aquifer to provide the allocated volume of abstraction on a sustainable basis. In general terms, the more water allocated from an aquifer system, the lower the reliability of supply (i.e. the more frequently criteria established to protect environmental baselines are reached). Thus, a fixed allocation limit aims to achieve a balance between accessibility to the resource (i.e. the total volume of water allocated) and the reliability of supply to individual users.

Existing resource consents for large-scale groundwater abstraction in Southland are generally not granted on the basis of the reliability of supply. A crude attempt to ensure higher priority for existing users has been implemented in the Lumsden Aquifer where later resource consents are subject to higher minimum level cut-offs, but even this measure is arbitrary with no assessment of the variable restrictions in terms of absolute reliability.

In a situation such as Southland where current seasonal allocation is generally not fully utilised, the use of varying supply reliability provides opportunity to increase access to the available resource (i.e. provide for efficient utilisation of the available resource) while protecting access rights granted under existing resource consents.

2.2.7 Reservation of Allocation

Under current RMA provisions resource consent applications are processed sequentially in the order they are received by the appropriate regulatory authority. Under existing Regional Water Plan provisions no priority is established for particular ‘sectors’ of use. However, given the range of potential consumptive uses for the available resource, it is suggested that Environment Southland may consider reserving a portion (or portions) of the primary allocation for particular uses. In particular, a reservation of (for example 10 percent) of primary allocation for permitted and/or community supply would retain access to the resource for future potable water supply thereby assisting Environment Southland achieve the purpose of the RMA as outlined in s5:

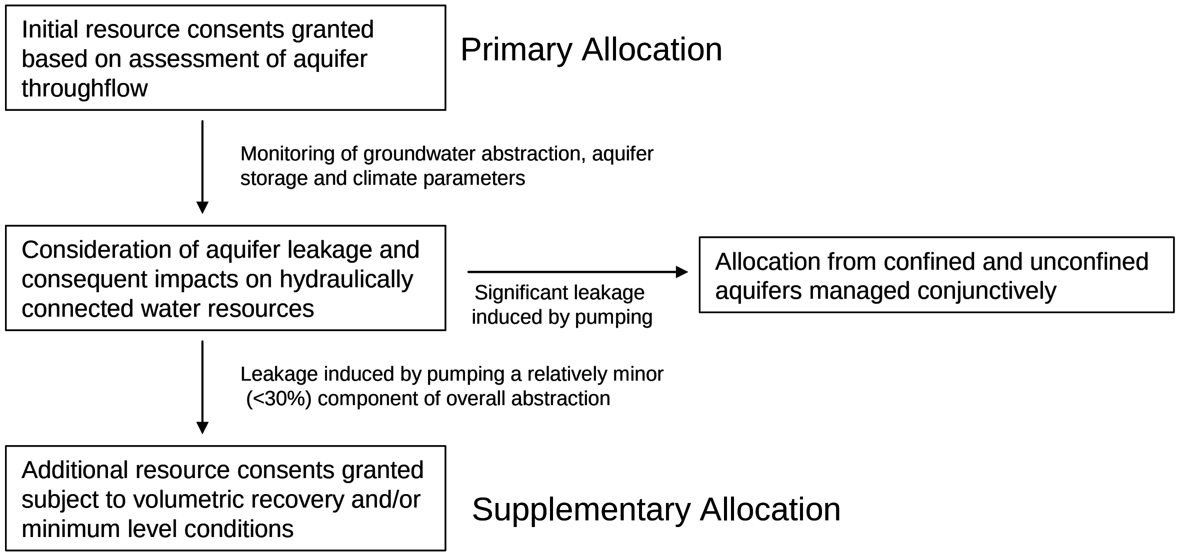
'…managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables communities to provide for their social, economic and cultural wellbeing and for their health and safety…'

2.3 Alternative Staged Approach

As an alternative to the current approach to managing allocation from confined aquifers detailed in the Regional Freshwater Plan it is suggested that Environment Southland consider an alternative two-tier approach. This approach would involve establishing a primary allocation limit on the basis of a simple estimate of aquifer throughflow. Further supplementary allocation could be made above the primary allocation limit to enable efficient utilisation of the available resource where it can be shown that some or all of the following criteria are met:

- Actual groundwater abstraction is lower than total seasonal allocation specified by resource consents;
- Aquifer leakage induced by abstraction does not represent a significant component of overall aquifer water balance. If leakage is significant, then abstraction from both unconfined and confined aquifers has to be managed jointly; and,
- Assessment of resource monitoring data (abstraction, groundwater levels and climate) or detailed numerical modelling indicate additional water is available over and above the primary allocation limit.

Figure 2 shows an overview of the proposed allocation framework.



- **Figure 2. Suggested alternative allocation framework for confined aquifers**

2.3.1 Primary Allocation

Under the proposed allocation framework a primary allocation would be established for a confined aquifer system based on estimated aquifer throughflow.

During the initial stages of resource development throughflow may be estimated following the methodology outlined in Section 2.2 and therefore requires sufficient data to determine:

- Aquifer hydraulic properties;
- Approximate (or nominal) aquifer dimensions; and,
- Piezometric gradient

Initial estimates of aquifer throughflow made by Environment Southland should be based on conservative assumptions and place the onus on future resource consent applicants to prove that additional allocation is within a valid throughflow estimate. Such estimates, based either on water balance or numerical modelling, should be validated by appropriate resource monitoring including soil moisture, river flow, groundwater level and water use data.

Resource consent applicants should also be required to conduct aquifer tests of an appropriate scale to determine the leakage characteristics of the source aquifer. Criteria used to assess aquifer leakage should be based on the potential for significant vertical leakage to occur in response to long-term abstraction (i.e. abstraction at the maximum rate up to the total seasonal allocation). It is suggested that if assessment of aquifer test results indicate that greater than 50 percent of water abstracted on a seasonal basis is derived from leakage induced by pumping then allocation from the confined aquifer system should be managed as part of that for hydraulically connected aquifers. If estimated leakage falls between 30 to 50 percent of the pumped volume, a resource consent application should include consideration of the consequent impacts on the water balance of hydraulically connected aquifers. Where leakage is determined to be significant, assessment of potential environmental effects should consider factors such as cumulative stream depletion effects and interference effects on shallow bores.

Resource consents for primary allocation should be granted on the '*first-in, first-served*' basis prescribed by the RMA and be subject to consistent minimum level controls intended to deliver a relatively high reliability of supply (e.g. subject to restriction twice every 10 years or 80 percent reliability). The only exception to this may be in regard provision for reservation of allocation for municipal supply. Policy 16 of the Regional Freshwater Plan exempts community water supplies derived from surface water from relevant minimum flow and level regimes on the grounds of human health and safety. Applying similar criteria to community supplies derived from groundwater would suggest that such takes should not be subject to minimum level criteria thus conferring a higher level of supply security than takes for other consumptive uses.

2.3.2 Supplementary Allocation

Once allocation from a confined aquifer has reached the primary allocation limit, Environment Southland may consider allowing further allocation from the aquifer system subject to appropriate controls to protect the reliability of resource consents for primary allocation. Supplementary allocation therefore provides a management option to enable efficient utilisation of the available groundwater resource in situations where:

- Actual abstraction is consistently lower than seasonal allocation; or,
- Resource monitoring indicates that there is additional water available on a sustainable basis from the aquifer system in excess of the primary allocation.

To ensure the ongoing sustainability of the resource and protect the reliability of supply for primary allocation the following controls are suggested as a means to provide for supplementary allocation from a confined aquifer system:

1) Specification of seasonal allocation for supplementary resource consents in terms of both a maximum volume as well as a '*resource share*'. This arrangement would specify the maximum seasonal allocation for an individual resource consent but enable actual seasonal allocation in a given irrigation season to be restricted to a 'share' of the water available for allocation over and above that required to supply primary allocation. Thus, in years where recharge is above average and aquifer storage relatively high, consents for supplementary allocation consents may receive their full seasonal volume. However, in seasons where winter recharge is below average or aquifer recovery incomplete due to heavy pumping during the

SKM

preceding irrigation season, seasonal allocation for supplementary consents would be reduced on a proportional basis as determined appropriate by Environment Southland.

Criteria for setting seasonal allocation on the basis of 'resource share' could be based on the seasonal recovery of aquifer levels on a nominated date, with level restrictions specified by Environment Southland based on knowledge of aquifer response to abstraction over previous irrigation seasons. For example, criteria for establishing seasonal allocation for supplementary consents in a confined aquifer system could follow a scheme similar to that shown in Table 1 below

- **Table 1 Example of seasonal recovery criteria to manage supplementary allocation from a hypothetical confined aquifer system**

Groundwater level in Environment Southland monitoring bore E44/xxxx on 1 September (m asl)	Restriction on seasonal allocation available to supplementary resource consents (%)
250.5	0
249.0	25
248.0	50
247.5	75
247.0	100

2) Minimum level cut-offs for supplementary resource consents. Such minimum level cut-offs would be set at a level that ensures an appropriate reliability of supply for consents issued as primary allocation. Minimum level cut-offs would increase sequentially for additional supplementary resource consents thus reducing the reliability of supply for later consent applicants. This sequential reduction in supply reliability would effectively restrict supplementary allocation to a level at which the reliability of supply was considered by resource consent applicants as adequate to justify investment in infrastructure associated with abstraction and use of water.

2.3.3 Summary of Proposed Allocation Framework

Table 2 provides a summary of the proposed allocation framework for confined aquifers, including associated testing and reqource assessment requirements. Following the criteria established in Rule 23 of the Regional Freshwater Plan, takes in excess of 2 litres per second from confined aquifers would be classified as either discretionary or non-complying activities. The distinction between activity status should be made on the basis of estimated throughflow and leakage induced by pumping (i.e. on a case by case basis).

Allocation of water up to 90 percent of estimated aquifer throughflow (allowing reservation of 10 percent of throughflow for community supply) would be classified as a discretionary activity and granted as primary allocation. Such allocation would be subject to minimum level controls that confer a fixed reliability of supply (e.g. 80 percent reliability) and be granted subject to assessment of leakage induced by pumping. Where leakage was assessed to be in excess of 25 percent of the total volume abstracted such applications would be considered in terms of potential effects on hydraulically connected water resources. Where leakage was assessed to be greater than 50 percent of the total volume abstracted, allocation would be made on the basis of consideration of cumulative allocation from all hydraulically connected water resources (i.e. cumulative allocation from confined and unconfined aquifers).

Allocation of water in excess of 90 percent of estimated aquifer throughflow with the same reliability of supply as conferred to primary allocation would be considered a non-complying activity. However, allocation of water in excess of primary allocation with a lower reliability of supply (i.e. subject to progressively increasing minimum level controls and/or resource share criteria) would be a discretionary activity.

Table 2 Alternative Allocation Criteria for Confined Aquifers

Allocation Tier	Activity Status	Criteria	Information requirements
Primary	Controlled	Up to 10 % of estimated throughflow for community supply purposes (allowing for permitted use)	▪ Bore construction standards ▪ Aquifer tests - sufficient to define basic hydraulic properties and nature of aquifer confinement ▪ Saline intrusion assessment ▪ Proximity and potential impact on water level monitoring sites ▪ Conceptual aquifer model ▪ Analysis of temporal and seasonal aquifer response to abstraction ▪ Assessment of interference effects on existing users ▪ Investigation of aquifer storage volumes e.g. aquifer dimensions and storage characteristics ▪ Hydrochemical identification of recharge sources ▪ Detailed assessment of aquifer water balance including recharge/discharge characteristics
	Discretionary	Allocation <100% of estimated throughflow[a] and Leakage <30% of total volume abstracted	
	Discretionary	Allocation <100% of estimated throughflow[a] and Leakage 30-50% of total volume abstracted	▪ Detailed aquifer test information sufficient to support detailed assessment of aquifer leakage ▪ Assessment of potential impacts on hydraulically connected water resources (leakage, spring discharge, effects on unconfined aquifer yields, cumulative stream depletion effects on surface waterways)
	Discretionary	Allocation <100% of estimated throughflow[a] and Leakage >50% of total volume abstracted	▪ Detailed aquifer test information sufficient to support detailed assessment of aquifer leakage ▪ Consideration of total allocation and associated environmental effects from all hydraulically connected water resources
	Non-Complying	Allocation >100% of estimated throughflow[a] with reliability of supply	▪ Detailed assessment of aquifer water balance and/or numerical modelling sufficient to justify increase in primary allocation

Allocation Tier	Activity Status	Criteria	Information requirements
		equal to primary allocation	
Supplementary	Discretionary	Allocation >100% of estimated throughflow[a] and/or Leakage <30% of total volume abstracted	▪ Assessment of actual water use versus existing seasonal allocation ▪ Review of primary allocation volume incorporating an assessment of environmental monitoring results ▪ Assessment of impacts of abstraction on reliability of supply for existing users

[a] includes a reservation of 10 percent of throughflow for permitted use and community supply

2.4 Application to resource consents

The proposed allocation framework for confined aquifers would establish a two-tiered approach to groundwater allocation and potentially offers a number of advantages over existing Regional Water Plan provisions in terms of efficient utilisation of water resources. However, a number of factors require consideration in determining appropriate management controls to support such an approach. These factors are reviewed in the following section.

2.4.1 Setting of minimum water levels

The suggested management framework for confined aquifer includes provision for minimum level cut-offs applied to both primary and supplementary resource consents.

Minimum level cut-offs should be established for primary allocation to protect environmental baselines (e.g. minimum water levels in coastal aquifers to prevent saline intrusion or the base of the confining layer to prevent dewatering of the aquifer system) and not as a means to ensure sustainability of abstraction which should be implicit in the primary allocation determined for an individual aquifer system. Any minimum levels applied to primary allocation should be set in a consistent manner (i.e. to ensure a standard supply reliability) and be referenced to a single groundwater level monitoring site.

Minimum level cut-offs applied to supplementary allocation could be determined on the basis of providing a sufficient volume of storage to remain in the aquifer system to meet projected demand (possibly established at an 8 in 10 year threshold) from primary allocation over a nominal period of 30 to 60 days. Minimum level cut-offs applied to supplementary allocation may sequentially increase with additional consents granted thus reducing supply reliability for later consent applicants and effectively limiting total allocation to the point at which the reduced reliability makes investment in infrastructure uneconomic.

One important factor to ensure that minimum level cut-offs are applied in an appropriate manner is the need to avoid allowing groundwater takes that may result in a significant localised drawdown effect on monitoring bores. In this regard it is proposed that the proximity and impact of a proposed abstraction is considered as part of the criteria outlined in Table 2 used to inform the resource consent decision-making process. This provides the opportunity for Environment Southland to decline consent where potential effects are judged to be excessive.

2.4.2 Criteria for determining supplementary seasonal allocation

Under the proposed management framework for confined aquifers it is proposed that seasonal allocation for supplementary allocation be determined on a seasonal basis according to the recovery in aquifer levels at the end of the preceding winter. Determination of appropriate restrictions requires assessment of temporal variability in aquifer storage in response to climate and abstraction to establish a reliable estimate of aquifer storage.

2.4.3 Consent renewal

Under the RMA consents are processed in the sequence they are received by Environment Southland. Thus initial resource consents for abstraction from a confined aquifer system would receive primary allocation while applications processed after the primary allocation limit has been reached would receive supplementary allocation. Under this approach Environment Southland would have to establish appropriate means to deal with re-consenting of existing takes once current resource consents expire. Over the long-term this process is likely to be complicated where replacement consents are not sought or seasonal volumes revised downward thus creating opportunity for additional primary allocation.

One option to deal with additional primary allocation becoming available at the expiry of existing resource consents would be to sequentially move consents (in the order granted) from supplementary to primary allocation as and when allocated volumes change as a result of consent renewal. However, such an approach is likely to be administratively complex.

Over the long-term, as existing resource consents come up for renewal, it is suggested that Environment Southland consider transferring the portion of primary allocation becoming available (either through non-renewal of consents or revision of the methodology for setting seasonal allocation) firstly to the reservation for permitted use and community supply. Once Environment Southland consider sufficient reservation has been made for these uses the balance of primary allocation becoming available could then be transferred to increase the volume of supplementary allocation available from the aquifer system.

In order to establish a more workable process to determining water allocation from confined aquifer it may also be worth establishing common expiry dates for all resource consents in a given aquifer system. This would enable cumulative effects from all takes to be considered at the same time and avoid the need for individual consents applications to be assessed in an ad-hoc manner as they expire.

2.4.4 Consent Duration

At the present time there is a tension between investment certainty and planning flexibility with regard to the terms of resource consents issued. While the RMA provides for a maximum consent term of up to 35 years, it is common practice for water permits in Southland to be issued for significantly shorter durations (generally 10 years). In many instances the reluctance to grant consents for the maximum duration reflects uncertainty inherent in the resource consent decision making process. With improved ability to review or control total allocation through a tiered consent system, it may be possible to increase the term of resource consents to provide greater ongoing certainty of access to the resource.

2.4.5 Market-based mechanisms for water allocation

Market-based mechanisms are widely used overseas for the initial allocation and subsequent reallocation of water between resource users. This approach provides for regulatory control of the framework for water allocation (generally in terms of allocable volumes and abstraction restrictions) but allows distribution of available allocation between individual users to occur on an economic basis and may involve:

- Initial allocation
- Secondary market transfer

These mechanisms provide for the initial allocation and subsequent transfer of allocation between resource users with the overall outcome being efficient utilisation of the available resource by highest-value uses.

Transfer of water allocation between users in New Zealand is provided for by Section 136(2)(b) of the RMA. Transferable water permits are also provided for in the Regional Water Plan which states:

Policy 20 - Transferable water permits

Provide for the transfer of water permits to take and use water in accordance with Section 136(2)(b) of the Resource Management Act 1991 provided the transfer occurs in the same catchment or aquifer and is consistent with provisions of this Plan.

In practice however, the transfer of water permits in New Zealand only occurs on any significant scale in the case of property sales where a water permit is transferred to a subsequent owner. Other methods for the transfer of allocation between resource users are only beginning to be utilised on any significant scale in Regions such as Canterbury and Otago where water availability is significantly constrained. At the current time issues surrounding "*ownership*" of water resources presents a significant impediment to wider utilisation of mechanisms for consent transfer.

This report does not consider the application of market-based mechanisms for management of confined aquifer in Southland although clearly the potential exists for this to occur at some level under current policy. Rather this report is primarily concerned with the establishment of a wider framework for water allocation within which transfer of allocation may/may not occur.

2.5 Monitoring and information requirements to support alternative management options

As previously discussed, effective management of water allocation from a confined aquifer system requires the collection of a range of environmental monitoring information. As detailed in Table 3 this information includes volumetric usage, groundwater level and more general climate parameters. Responsibility for collection of groundwater use and level information is primarily the responsibility of individual resource consent holders. However, in reality, Environment Southland has a significant role to play in the audit of this information and, in many cases, may be best placed to undertake data collection on a cost-recovery basis.

Given the importance of volumetric usage data to the effective management of groundwater resources, it is suggested that Environment Southland take a more active role in ensuring requisite data is provided. This may either be in the form of ensuring better compliance with existing consent conditions or undertaking information collection on a cost recovery basis behalf of resource consent holders in the case of non-compliance with consent conditions. This issue is likely to be given greater focus with the impending release of the National Environmental Standard on Water Measuring Devices.

Table 3 Information required to support effective management of groundwater allocation

Information	Monitoring requirements	Responsibility
Volumetric Usage	▪ Cumulative seasonal volume for takes less than 250 m^3/day ▪ Daily volume for takes of between 250 to 750 m^3/day ▪ Automated recording of instantaneous abstraction rate for takes in excess of 750 m^3/day	▪ Resource consent holders ▪ Compliance audit by Environment Southland or collection on a cost-recovery basis
Groundwater Levels	▪ Monitoring of groundwater levels at representative points within the aquifer system ▪ Monitoring of the impacts of changes in aquifer discharge on hydraulically connected waterbodies	▪ Resource consent holders ▪ Environment Southland (possibly on a cost-recovery basis)
Recharge	▪ Rainfall - at least 1 representative rainfall site in or near the recharge area ▪ River Flow - relevant flow records and spot gauging of relevant rivers and streams	▪ Environment Southland (possibly on a partial cost-recovery basis)

Information	Monitoring requirements	Responsibility
	▪ Soil Moisture - monitoring of representative soil moisture to calculate groundwater recharge and assist assessment of water use efficiency	

Under the proposed allocation framework determination of aquifer leakage is a critical factor in establishing hydraulic characteristics of a confined aquifer. In order to ensure aquifer tests undertaken to support resource consent applications are adequate to address the issue of potential aquifer leakage it is suggested that Environment Southland establish minimum aquifer test requirements for confined aquifers such as those outlined in Table 4. While a degree of flexibility may be required to take account of site-specific factors, such a guideline would ensure that aquifer tests are undertaken to a consistent minimum standard.

Table 4 Minimum aquifer test requirements to support management of allocation from confined aquifers

Size of take	Aquifer test requirements
<250 m^3/day	Standard yield test - 2 hour pumping test at required rate and measurement of recovery
250 to 750 m^3/day	24 hour constant rate test plus recovery, monitoring of groundwater levels in at least 1 piezometer in source aquifer within the area of localised drawdown
>750 m^3/day	Step-rate aquifer test to confirm bore efficiency
	72 hour test plus recovery, water levels monitored in at least 1 piezometer in pumped aquifer within the area of localised drawdown and 1 piezometer in overlying aquifer within the area of drawdown in source aquifer

2.6 Management of situations where existing allocation approaches or exceeds primary allocation

Where existing levels of allocation from a confined aquifer system exceed the primary allocation limit, Environment Southland may be required to implement a range of measures to ensure that allocation does not adversely impact on the sustainability of the resource. In this situation further allocation from the resource should be delayed until sufficient environmental monitoring data is available to give confidence that further supplementary allocation can be made.

However, where environmental monitoring data indicate that current levels of allocation are not sustainable, the following measures should be considered to ensure ongoing sustainability of the resource:

- Establishment of an aquifer users group. Such groups can be utilised as a means to inform consent holders in regard potential concerns regarding sustainability of the resource and to investigate voluntary methods to reduce groundwater usage such as a review of efficiency of use;

- Initiatives to ensure efficient utilisation of water including the provision of soil moisture data to inform management of pasture irrigation;
- Where voluntary means are not sufficient to ensure sustainability of the resource, implementation of pro-rata reductions in seasonal allocation through consent reviews or at the time of consent renewal. This process could involve transfer of a portion of existing primary allocation to supplementary allocation available subject to aquifer storage and minimum level criteria.
- Establishment of common expiry dates for all consents through a Regional Plan variation process to enable cumulative effects of all consents to be assessed. This process may include imposition of pro-rata reductions in seasonal allocation or alternatively the transfer of a portion of existing allocation to supplementary allocation.

2.7 Summary

In order to address some of the practical issues associated with effective implementation of the current policies for management of groundwater allocation from confined aquifers, an alternative approach that may be considered for future policy development has been developed. The suggested approach follows the staged management framework established by the existing policy but proposes alternative criteria for establishing activity status for groundwater abstraction from confined aquifers. The alternative approach follows the framework for surface water allocation contained in the Regional Freshwater Plan and would establish a two-tier allocation system for confined aquifers as follows:

Primary Allocation: An initial allocation for consumptive use based on a conservative assessment of aquifer throughflow and subject to defined supply reliability;

Supplementary Allocation: Additional allocation in excess of the primary allocation but subject to a lower reliability of supply. Supplementary allocation may be granted with a seasonal volume varying according to aquifer storage criteria and subject to minimum level controls to protect the reliability of supply for primary allocation.

This approach would enable a primary allocation volume to be established on the basis of a relatively simple estimate of aquifer sustainability and allow additional allocation above this volume once sufficient data had been collected to establish a reliable relationship between groundwater abstraction, climate and aquifer storage. The suggested approach would also alter existing information and monitoring requirements to support groundwater allocation from confined aquifers and include consideration of the potential for leakage induced by pumping to impact on hydraulically connected water resources.

One of the main advantages of the proposed allocation framework is that establishes a framework for groundwater allocation based on a conservative estimate of aquifer sustainability. It would also enable better utilisation of the available groundwater resource where actual groundwater use appears to be well below seasonal allocation except under extreme conditions. Supplementary allocation would enable additional users to access the resource and utilise the portion of seasonal allocation that remains unused by primary resource consents. It would also enable users to access the resource in situations where abstraction and resource monitoring data confirm additional water is available over and above the initial (conservative) primary allocation limit.

Over the medium-term, as existing resource consents come up for renewal, it is suggested that Environment Southland consider transferring the portion of primary allocation becoming available (either through non-renewal of consents or revision of the methodology for setting seasonal allocation) firstly to the reservation for permitted use and community supply. Once Environment Southland consider sufficient reservation has been made for these uses the balance of primary allocation becoming available could then be transferred to increase the volume of supplementary allocation available from the aquifer system.

A number of other recommendations are made that may assist sustainable management of groundwater allocation from confined aquifer (and may be applicable to other aquifer types):

- Consideration of allocation from confined aquifers in terms of aquifer leakage induced by pumping. Where leakage is significant, ensuring potential adverse effects on hydraulically connected water resources (e.g. cumulative stream depletion) are included in assessment of proposed allocation;
- Establishing a standard reliability of supply for all primary allocation. Minimum level cut-offs should be applied consistently to all primary allocation and be referenced to a single monitoring point;
- Reserving a portion of available allocation for permitted water use and community water supply;
- A review of the methodology used to establish seasonal allocation to ensure better alignment between consented volume and actual use; and,
- Using common expiry dates for resource consents as a means to enable assessment of cumulative effects of abstraction.

3. Application of Proposed Allocation Framework to Confined Aquifers in the Oreti Basin

This section of the report reviews existing allocation and resource monitoring results from the North Range and Lumsden Aquifers in the Oreti Basin and provides an outline of the potential application of the allocation of the confined aquifer allocation criteria proposed in Section 2 to future management of these water resources. Both these aquifer systems have seen a significant increase in the volume of water allocated since early 2004. The description of aquifer hydrogeology is based on that described in SKM (2005) and includes updated information provided by monitoring and investigations undertaken by Environment Southland over the subsequent period.

Application of the proposed alternative management criteria to the North Range and Lumsden Aquifers may also have applicability to future management of confined aquifers within the Gore Lignite Measure sequence in Eastern Southland. These aquifers, currently used on a relatively limited basis for stock and farm supplies, have the potential to be developed on a large scale associated with coal bed methane extraction or mining of the associate lignite resource.

3.1 North Range Aquifer

The North Range Aquifer occurs extends over an approximate area of 4,500 hectares west of Edwards Road, Castlerock to a poorly defined margin in the vicinity of Mossburn. The southern boundary of the aquifer follows the base of the North Range while the northern boundary corresponds to the trace of the active Castlerock Fault that runs southeast from Hillas road, Five Rivers to Castle Rock.

3.1.1 Conceptual hydrogeology

The North Range is hosted in a layer of relatively permeable alluvial gravels between 15 to 30 metres in thickness that occur approximately 30 metres below ground over a significant area of the Castlerock Terrace. The aquifer appears to be relatively well confined for much of its lateral extent, becoming artesian between Sutherland Road and Edwards Road. In 2004 head a difference ranging from -9.0 metres to +4.5 metres was measured between the upper unconfined aquifer and the North Range Aquifer indicating the aquifer is relatively well confined by the intervening layer of claybound gravels.

The North Range Aquifer is assumed to be recharged by infiltration of rainfall and runoff of the alluvial fans that extend along the lower slopes of the North Range where the aquitard materials interfinger with locally derived colluvial materials. The assumption that the main recharge area occurs in along the foot of the North Range is supported by Oxygen-18 data that indicate values elevated above those occurring in local rainfall but significantly lower that those occurring in the Oreti River. Groundwater level monitoring data also show no correlation between groundwater levels in the North Range Aquifer and flows in the overlying Oreti River indicating a limited vertical hydraulic connection where the river crosses the central portion of the aquifer system.

The piezometric gradient of 0.001 measured in the North Range Aquifer in the September 2004 piezometric survey reported by SKM (2005) indicates groundwater flow in an easterly direction. However, levels in some of the bores monitored near the interpreted eastern margin of the aquifer system along the Castlerock Fault (E44/0267, E44/0266) show some evidence of depressurisation along this boundary. This observation would be consistent with upward vertical leakage along the fault zone under the natural upward gradient.

Groundwater quality sampling results from the North Range Aquifer also indicate ongoing throughflow in the aquifer system. In general, major ion concentrations are slightly elevated over those observed in the overlying unconfined aquifer indicating a degree of water-rock interaction due to extended residence time. However, the slightly elevated nitrate concentrations (2-3 mg/L) and the oxidised nature of the water suggest that residence times are not excessive reflecting the ongoing movement of water through the aquifer system.

Based on the methodology outlined in Section 2 the rate of throughflow in the North Range Aquifer is conservatively estimated as follows:

Aquifer Transmissivity - based on available aquifer test results (Table 6, SKM 2005) geometric mean aquifer transmissivity is calculated as approximately **910 m^2/day**.

Aquifer Width - although somewhat irregular in shape, aquifer width is estimated to be approximately **3500 m** perpendicular to calculated groundwater flow direction in the area between Sutherland and Edwards Road (where a majority of the abstraction occurs)

Piezometric Gradient - the piezometric gradient of **0.001** measured in the September 2004 survey is considered to be typical for the aquifer system under unpumped conditions.

Throughflow = 910 x 3500 x 0.001

= 3,185 m^3/day

= 1,162,525 m^3/year

3.1.2 Existing allocation

Table 5 contains a summary of existing allocation from the North Range Aquifer. This data indicates current seasonal allocation currently totals 2,328,750 m^3/year with an application for a further 900,750 m^3/year currently on hold at the request of the applicant.

SKM

- **Table 5 Existing Allocation from the North Range Aquifer**

Consent Number	Well Number	Grid Reference	Maximum Abstraction Rate (m^3/day)	Seasonal Allocation (m^3/year)
204485	E44/0186	E44:509-877	250	72,000[a]
201447	E44/0226	E44:440-912	5,800	870,000[b]
202708	E44/0258	E44:469-909	6,480	630,000
			6,005	900,750
202706	E44/0265 E44/0262	E44:471-899 E44:471-890	8,500[c]	828,750[c]
Total			**21,030**	**2,328,750**
204282[d]	E44/0266 E44/0267	E44:480-887 E44:482-896	6,005	900,750

[a] Assumes abstraction at an average rate of 80 percent of maximum over 365 days
[b] Seasonal allocation does not include allowance for net use across irrigation season
[c] Does not include abstraction of 1,900 m^3/day from Lumsden Aquifer authorised by this consent
[d] Current application

Calculation of actual water usage is hampered by the lack of data supplied by existing consent holders. Although all existing irrigation takes from the North Range Aquifer are required to supply records of daily water abstraction, data is only available from consent number 201447. This lack of this data hampers interpretation of aquifer monitoring results, particularly in terms of the adequacy of seasonal recovery. Table 6 provides a summary of the available water usage data from the North Range Aquifer. This data shows water usage varied between 22.5 to 57.4 percent of seasonal allocation (allowing for net use) over the past three irrigation seasons. It is uncertain if this total reflects usage by other consents in the North Range Aquifer as anecdotal reports report quite significant differences in irrigation management between individual properties.

- **Table 6 Water usage data from the Consent No. 201447**

Irrigation Season	Total Usage (m^3)	Percent of Seasonal Volume[1]	Percent of Seasonal Volume[2]
2004-05	311,040	35.6	55.0
2005-06	127,017	14.6	22.5
2006-07	324,640	37.3	57.4

[1] Compared to seasonal volume of 870,000 m^3/year as specified in existing consent conditions
[2] Compared to an adjusted seasonal total of 565,500 m^3/year allowing for seasonal usage

3.1.3 Monitoring results

Figure 3 shows piezometric levels in the North Range Aquifer recorded in the Environment Southland monitoring bore E44/0196 located near the intersection of Sutherland Road and Mossburn-Lumsden Highway. The plot shows natural variation in aquifer levels until early 2004 when abstraction for Consent No. 201447 commenced. Subsequent years show larger declines in groundwater levels during summer corresponding to the commencement of abstraction from the two remaining consents (202706 and 202708).

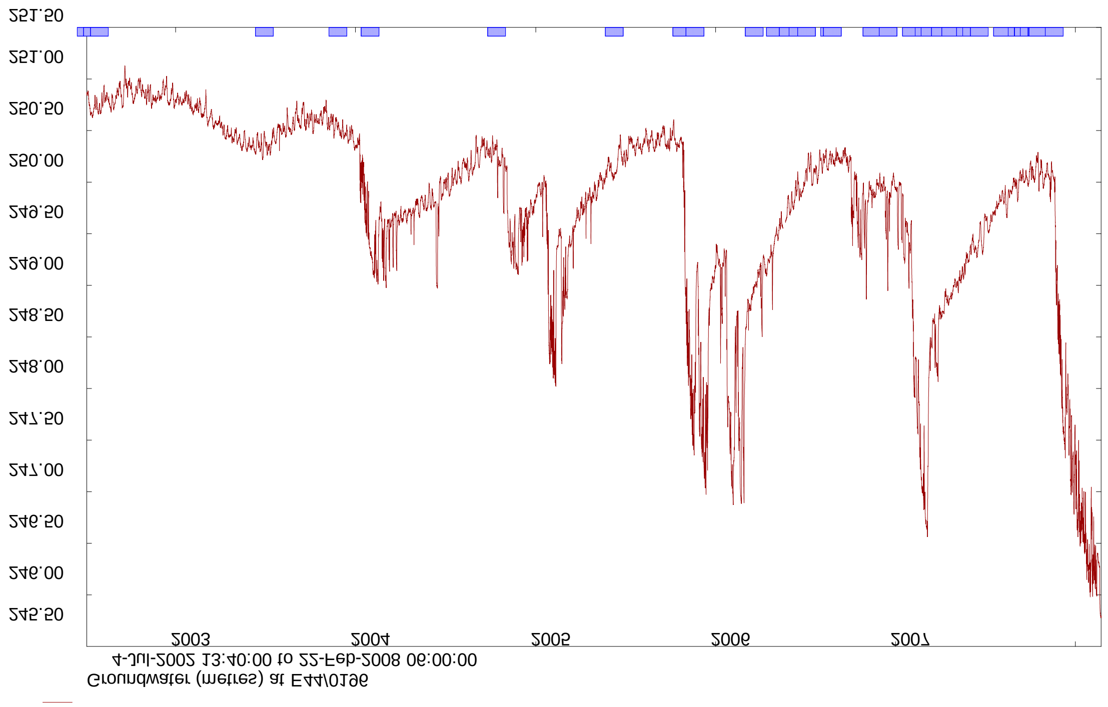


Figure 3 Groundwater levels (mAMSL) in the North Range Aquifer at E44/0196, 2002-2008

Of note is the ongoing downward trend in winter maximum piezometric levels over the period of record. While this may be partially explained by seasonal variations in aquifer recharge (e.g. the decline between 2002 and 2003 prior to large-scale abstraction commencing) the ongoing decline over subsequent years indicates incomplete seasonal recovery following summer abstraction. In addition, the significant drawdown in aquifer levels (as far as the first restriction level of 246.0 m asl) during the 2007-08 reflects likely effects of sustained operation all consents during this season compared to the intermittent or short-term abstraction over previous seasons. If the rate of recovery during winter 2008 follows that observed during previous years it is likely that levels going into the 2008-09 irrigation season will be less than 250 m asl significantly increasing the probability that minimum level restrictions will be reached even with moderate rate of abstraction.

Figure 4 shows a plot of the departure from mean monthly rainfall recorded at the Mossburn at Dyer Road site over the period 2000 to 2007. While the data show extended periods of below average rainfall during 2001 and 2003, the remainder of this period generally shows rainfall close to or above normal. Natural variations in rainfall are therefore unlikely to be the sole cause of the apparent downward trend in groundwater levels in the North Range Aquifer.

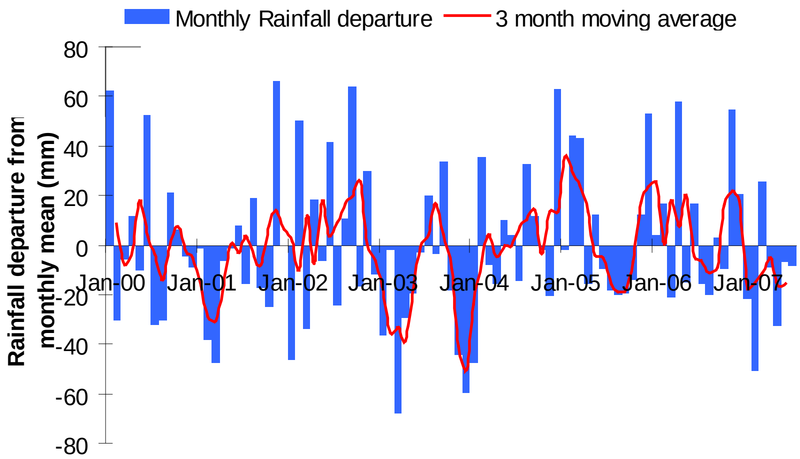


Figure 4 Departure from mean monthly rainfall recorded at the Mossburn at Dyer Road site 2000-2007

Overall, monitoring of groundwater levels in the North Range Aquifer indicate that the levels of abstraction occurring during the 2007-08 irrigation season are unlikely to be sustainable on a long-term basis.

3.1.4 Future resource management

The major impact of the observed decline in aquifer levels in the North Range Aquifer is likely to be on the reliability of supply for existing groundwater users. While Consent No. 201447 does not have a minimum level cutoff, the two remaining consents (202706 and 202708) have conditions that require abstraction to be reduced to 50 percent of maximum if levels in E44/0196 reach 246 m asl and cease if levels reach 245 m asl. The first trigger was reached during February 2008 and, given the rate of aquifer recovery observed during previous seasons, it is likely that this level will be reached with increasing frequency if current levels of abstraction are maintained. This will significantly reduce the reliability of supply for the resource consents affected.

In order to address this situation is recommended that Environment Southland consider application of a number of the management options discussed in Section 2.6. Measures adopted should include the formation of a water users group to ensure users are fully aware of the existing situation and are able to co-operatively participate in the future management of the resource in conjunction with Environment Southland. Such an option may enable users to develop a regime to maximise benefits able to be derived from the limited resource available. Options for consideration may range from rostering of water use through the setting of individual allocations based on seasonal water level recovery.

Depending on the success of user-initiated options for management of the resource Environment Southland may also wish to consider statutory processes available to reduce allocation to within sustainable limits. This may include consent review process to reduce the total volume of allocation, transferring at least part of the existing allocation to supplementary allocation subject to seasonal recovery criteria (i.e. a portion of seasonal allocation determined by seasonal recovery) and establishing common expiry dates for all consents.

3.1.5 Future allocation

Given uncertainty regarding future allocation it is recommended that resource consent applications for further allocation from the North Range Aquifer be declined until a good relationship is established between abstraction, recharge and seasonal water level recovery. Under the alternative allocation criteria discussed in Section 2 primary allocation from the North Range Aquifer would be totally utilised and supplementary allocation at a level where further allocation would be unlikely to have a reliability of supply to justify in infrastructure associated with water use.

3.1.6 Review of allocation process

Allocation from the North Range Aquifer provides a useful basis to review the effectiveness of existing Regional Water Plan provisions for allocation from confined aquifers. While the initial consent was issued before the groundwater variation was developed, subsequent consents were granted in line with the updated provisions. Based on the existing criteria in the plan, the later applications were processed as restricted discretionary activities as both were considered unlikely to exceed the associated drawdown criteria of 25 percent of potentiometric head at a distance greater than 250 metres from the point of abstraction.

At the current time, although monitoring does not indicate the magnitude of water level drawdown would be sufficient to trigger non-complying activity status, there are clearly issues associated with the sustainability of current levels of allocation. This highlights the advantage of basing allocation on an estimate of aquifer water balance derived from physical data rather than based on arbitrary criteria.

3.2 Lumsden Aquifer

The Lumsden Aquifer is encountered along the full length of Ellis Road, Five Rivers and extends southward under the Oreti River following the strike of the Castlerock Fault. The northern boundary of the aquifer system occurs along a poorly defined margin between Ellis Road and the Cromel Stream. Recent investigations by Blakemore (2006) suggest the eastern extent of the aquifer system occurs in the vicinity of the Oreti River where it encounters the north-south trending Lumsden Fault.

3.2.1 Conceptual hydrogeology

The Lumsden Aquifer is hosted in a layer of permeable gravels between 10 and 40 metres in thickness that occur in the central area of the Oreti Basin. These gravels are interpreted to represent an extensive deposit of fluvial gravels reworked by the Oreti River during the last interglacial period which interfinger with lower permeability, locally derived, fluvioglacial gravel and alluvial fan deposits across the northern section of the Five Rivers area and around the basin margins. These waterbearing gravel deposits are overlain by a tightly claybound gravel layer deposited during the last interglacial period. This unit forms an aquitard that confines the underlying alluvial gravels of the Lumsden Aquifer.

The low permeability of the claybound gravel aquitard is illustrated by the large vertical head difference between the Lumsden Aquifer and overlying unconfined aquifer that exceeds 20 metres towards the western end of Ellis Road. The Lumsden Aquifer is assumed to be recharged by lateral infiltration through the low permeability sediments accumulated around the north western and north eastern margins of the Oreti Basin with limited vertical leakage from the unconfined aquifer occurring in the central basin area. Oxygen-18 values in the Lumsden Aquifer are generally above (> -9.0) those occurring in local rainfall (~ -8.0) confirming the likelihood of a significant recharge component derived from the infiltration of runoff entering the Oreti Basin around the basin margins.

A piezometric survey conducted by Environment Southland in September 2004 indicated groundwater flow in the Lumsden Aquifer in a southeasterly direction with an approximate gradient of 0.0015 (SKM, 2005). Combined with the relatively high aquifer transmissivity indicated by analysis of aquifer test results this result indicates significant throughflow through the aquifer system. The discharge point for throughflow occurring within the aquifer system is uncertain but would logically occur in the vicinity of the eastern margin along the Lumsden Fault. Geophysical investigations by Blakemore (2006) indicate this feature trends roughly north-south slightly west of the current alignment of the Oreti River. Depressurisation of the aquifer system along or near this boundary may explain the slightly anomalous levels recorded in bores E44/0252 and E44/0255 located near the assumed alignment of the Lumsden Fault.

Based on the methodology outlined in Section 2, the rate of throughflow in the Lumsden Aquifer is conservatively estimated as follows:

Aquifer Transmissivity - based on available aquifer test results (Table 6, SKM 2005) geometric mean aquifer transmissivity is estimated as approximately **1,500 m^2/day**.

Aquifer Width - although somewhat irregular in shape, aquifer width is estimated to be approximately **6,500 m** perpendicular to calculated groundwater flow direction near the southern end of Ellis Road.

Piezometric Gradient - the piezometric gradient of **0.0015** measured in the September 2004 survey is considered to be typical for the aquifer system under unpumped conditions.

Throughflow = 1500 x 6,500 x 0.0015

= 14,625 m^3/day

= 5,340,000 m^3/year

3.2.2 Existing allocation

Table 7 provides a summary of existing allocation from the Lumsden Aquifer. This data indicates total allocation currently totals 59,490 m^3/day and with a cumulative seasonal allocation of 5,512,450 m^3/year.

▪ **Table 7 Current Allocation in the Lumsden Aquifer**

Consent Number	Well Number	Grid Reference	Maximum Abstraction Rate (m^3/day)	Seasonal Allocation (m^3/year)
202867	E44/0249	E44:511-940	7,500	780,000
204980	E44/0225	E44:500-943	7,500	780,000
202623	E44/0274 E44/0252	E44:518-933 E44:526-928	17,280	1,426,000
202622	E44/0269	E44:499-949	8,467	699,000
202706	E44/0254	E44:526-928	1,900	185,250
202926	E44/0256	E44:528-885	2,155	210,150
204364	E44/0338	E44:517-903	14,688	1,432,050
Total			**59,490**	**5,512,450**

3.2.3 Current water use

Although all resource consents sourcing water from the Lumsden Aquifer are required to supply Environment Southland with records of daily and cumulative seasonal water use, limited data is currently available to determine actual groundwater abstraction. Table 8 provides a summary of the available water use data. This data shows that, for the 2005-06 and 2006-07 irrigation seasons, actual abstraction was significantly lower than seasonal allocation for those consents that supplied records of volumetric usage to Environment Southland.

SKM

Table 8. Seasonal water abstraction from the Lumsden Aquifer

Consent Number	Seasonal Allocation (m^3/year)	2005-06		2006-07	
		Abstraction (m^3)	% of seasonal allocation	Abstraction (m^3)	% of seasonal allocation
202622	699,000	104,220	15	256,540	37
202623	1,426,000			132,070	9
202867	780,000	149,730	19	7,070	1
202926	210,150			4,138	2

The water use data from the Lumsden Aquifer highlights the significant disparity evident between seasonal allocation and actual water use evident across the Southland Region. This disparity is likely due to climatic variability which results in actual water requirements to support pasture growth being considerably lower than figures derived from estimated based on potential evapotranspiration rates and crop water requirements. However, in the case of the Lumsden Aquifer, water usage over recent years may also be artificially low (i.e lower than can be realistically expected into the future) due to significant changes in land ownership and land use occurring in the area.

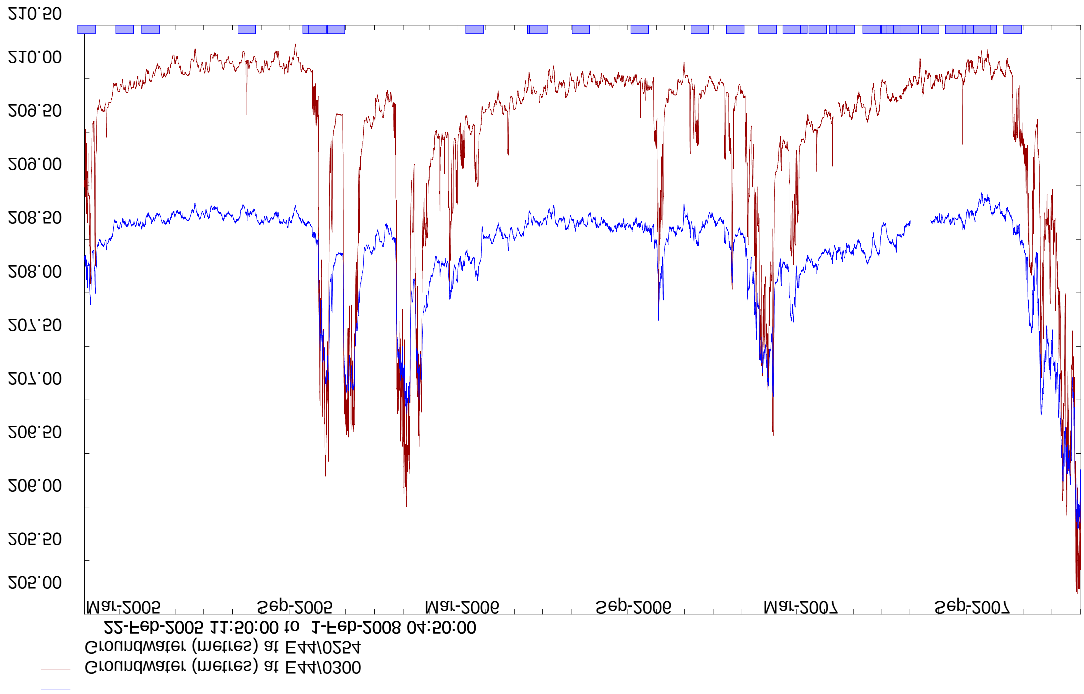
As discussed in Section 2.2.4 the large difference between seasonal allocation and actual abstraction has potential implications for resource management and future allocation in the Lumsden Aquifer including:

- The potential for significantly greater drawdown of aquifer levels than has previously been recorded if existing resource consents are exercised at or near full seasonal allocation. This is particularly important if historical groundwater level records are utilised in the resource consent decision making process;
- Assessment of potential cumulative impacts of abstraction based on seasonal allocation may significantly over-estimate actual environmental effects; and,
- If allocation is established as a fixed volume, additional users may be precluded from accessing the resource even though a significant portion of existing allocation remains unused.

3.2.4 Monitoring results

Figure 5 shows groundwater levels measured in the Lumsden Aquifer at the Ellis Road (E44/0253) and Castlerock (E44/0300) monitoring sites. Both bores show very similar temporal water level variations reflecting the relatively high aquifer transmissivity which results in the rapid equalisation of drawdown across the aquifer system.

Over the period of record both monitoring bores show a rapid decline in summer water levels in response to abstraction with the greater magnitude of drawdown recorded at E55/0253 (approximately 5 metres compared to 2.5 metres in E44/0300) reflecting the proximity of this bore to a number of production wells at the eastern of Ellis Road. However, both monitoring bores recover relatively rapidly following abstraction and show complete recovery between irrigation seasons.



▪ **Figure 5. Piezometric levels in the Lumsden Aquifer, 2005-2007**

3.2.5 Future Management

Based on information outlined in previous sections the current allocation from the Lumsden Aquifer of 5,512,450 m^3/year is slightly above the estimated annual aquifer throughflow of 5,338,000 m^3/year. Following the alternative allocation framework outlined in Section 2, this would mean that existing allocation from the Lumsden Aquifer is slightly greater than the primary allocation limit.

However, as further discussed in Section 3.2.2, existing allocation from the Lumsden Aquifer significantly exceeds actual use, with a significant proportion of seasonal allocation remaining unused. Given this discrepancy between seasonal allocation and actual use, combined with monitoring data that show current levels of abstraction are not adversely impacting on long-term aquifer storage volumes, it is recommended that Environment Southland consider the following options in terms of future allocation from the Lumsden Aquifer:

SKM

- A review of conditions associated with existing resource consents for abstraction from the Lumsden Aquifer. Such a review could be initiated under RMA s128, possibly following variation of allocation provisions relating to confined aquifers in the Regional Water Plan, and address the following issues:
  i. Better alignment of seasonal allocation and actual water use;
  ii. A review of the efficacy and utility of existing minimum water level and seasonal recovery conditions
  iii. A common expiry date for all consents

  Such a review would improve allocative efficiency and potentially allow additional users to access the resource within the primary allocation established on the basis of aquifer throughflow. It could also rationalise management of existing resource consents by establishing standard supply reliability conditions for all primary allocation rather than the range of arbitrary controls (listed in Table 9 below) currently included in conditions on individual resource consents.

Table 9 Existing minimum level and seasonal recovery criteria for existing resource consents from the Lumsden Aquifer

Consent	Reference Bore	50% Restriction m amsl	100 % Restriction m amsl	Seasonal recovery criteria triggering consent review
202687	E44/0300	202.5	201.5	1.5m decline in E44/0300 between consecutive seasons 2.0m decline in E44/0300 over three seasons
204980	E44/0300	202.5	201.5	1.5m decline in E44/0300 between consecutive seasons 2.0m decline in E44/0300 over three seasons
202623	E44/0253	202.0	201.0	1.5m decline in E44/0254 between consecutive seasons 2.0m decline in E44/0254 over three seasons
202706	E44/0196[a]	246.0	245.0	1.5m decline in E44/0196 between consecutive seasons 2.0m decline in E44/0196 over three seasons
202622	E44/0254	199.4	198.4	1.5m decline in E44/0254 between consecutive seasons 2.0m decline in E44/0254 over three seasons
202926	E44/0300	202.5	201.5	1.5m decline in E44/0300 between consecutive seasons 2.0m decline in E44/0300 over three seasons
204364[b]	E44/0300	203.5	203.0	

[a] Environment Southland monitoring bore in North Range Aquifer
[b] Does not include conditions relating to seasonal recovery

- Allow additional supplementary allocation from the Lumsden Aquifer as outlined in Section 2. Resource consents for supplementary allocation could be granted subject to a nominal seasonal allocation which would be fixed on an annual basis subject to adequate recovery of aquifer storage since the preceding irrigation season. This supplementary allocation could also be subject to minimum water level controls established to protect the reliability of supply for existing users. Criteria considered as part of the resource consent process to grant supplementary allocation could include:
  a) Existing allocation from the Lumsden Aquifer;
  b) Records of actual water usage;
  c) Monitoring of aquifer response to abstraction on a seasonal basis including any variations in recharge resulting from climatic variation; and,
  d) A robust assessment of aquifer leakage to ensure abstraction from the Lumsden Aquifer does not impact on the water balance of the overlying unconfined aquifer including the potential for cumulative stream depletion effects in the Oreti catchment.

  The seasonal allocation for supplementary consents could be determined for each irrigation season on the basis of water level recovery following the preceding winter. On this basis, provided aquifer storage recovers close to ‘normal’ levels supplementary consents would be allowed to take their full allocation. However, where seasonal recovery was incomplete (due either to high levels of abstraction during the preceding irrigation season or extended periods of low recharge) supplementary allocation would be reduced in a stepwise manner until, in the extreme case, only users with primary allocation were able to access the resource.

SKM

4. Summary and Recommendations

Based on experience with the practical implementation of existing policy provisions through the resource consent process it is clear that the current framework for the management of allocation from confined aquifers in the Southland Region has a number of limitations in terms of sustainable management and efficient resource utilisation. These include:

- An inability to effectively deal with situations where resource monitoring clearly indicates issues related to the ongoing sustainability of the resource;
- Limited effectiveness in effectively managing the cumulative effects of multiple abstractions;
- A lack of consistency in the application of consent conditions particularly with reference to the specification of minimum aquifer levels; and,
- A situation where there is significant disparity between consented volumes and actual usage making it difficult to validate aquifer response to abstraction and effectively precluding additional users from accessing the resource.

To address these issues it is recommended that Environment Southland consider an alternative methodology for water allocation from confined aquifers. The suggested methodology would follow the existing staged management approach contained in the Regional Freshwater Plan but move to an allocation framework similar to that utilised for surface water allocation comprising:

- Resource consents for **Primary Allocation** determined on the basis of a conservative assessment of aquifer throughflow and issued subject to standardised reliability of supply criteria; and,
- Resource consents for **Supplementary Allocation** granted over and above the primary allocation limit. These consents would be granted with a seasonal allocation varying up to a specified maximum according to aquifer storage and be subject to minimum level controls to protect the reliability of supply for primary allocation.

Over the medium-term, as existing resource consents come up for renewal, it is suggested that Environment Southland consider transferring the portion of primary allocation becoming available (either through non-renewal of consents or revision of the methodology for setting seasonal allocation) firstly to the reservation for permitted use and community supply. Once Environment Southland consider sufficient reservation has been made for these uses the balance of primary allocation becoming available could then be transferred to increase the volume of supplementary allocation available from the aquifer system.

A number of other recommendations to improve management of groundwater allocation from confined aquifers in the Southland Region. These include:

- Consideration of allocation from confined aquifers in terms of aquifer leakage induced by pumping. Where leakage is significant, ensuring potential adverse effects on hydraulically connected water resources (e.g. cumulative stream depletion) are included in assessment of proposed allocation;
- Establishing a standard reliability of supply for all primary allocation. Minimum level cut-offs should be applied consistently to all primary allocation and be referenced to a single monitoring point;
- Reserving a portion (at least 10 percent) of available allocation for permitted use and community water supply;
- A review of the methodology used to establish seasonal allocation to ensure better alignment between consented volume and actual use; and,
- Using common expiry dates for resource consents as a means to enable effective assessment of the cumulative effects of abstraction

SKM

5. References

Blakemore, H.N., 2006; A geophysical study of the Oreti Basin groundwater system. MSc thesis submitted for the degree of Master of Science, University of Otago, June 2006.

Lincoln Environmental and MWH Limited, 2003; Southland Water Resources Study. Stage 1-3 Report. Report prepared for Venture Southland.

SKM, 2005; Hydrogeology of the Oreti Basin. Report to Environment Southland, June 2005.