AQUIFER CAPACITY STUDIES – PROTECTION OR PREVENTION

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ABSTRACT

The proposed National Environmental Standard (NES) on Ecological Flows and Water Levels by the Ministry for the Environment, March 2008 suggests environmental flows be applied to all aquifers, where no environmental flow exists through a regional plan. This guidance is intended to avoid over-allocation of groundwater. It means, however, that when a catchment reaches its allocation limit, no more applications to take and use groundwater will be granted; unless the applicant is able to provide sufficient evidence that additional groundwater exists.

This NES is an important step in managing New Zealand's water resources and has been adopted by a number of regional councils. In some cases, resource consents to take and use groundwater will not be processed until an aquifer capacity study/through-flow analysis has been completed.

There are minimum requirements to undertake a through-flow analysis and the more information available, the more reliable the through-flow analysis. However, this data is not collected consistently by regional councils, making it very difficult to undertake an aquifer capacity study with confidence.

This paper suggests and recommends improvement of the application and reliability of these studies so that the consenting processes are expedited and our groundwater resource is better monitored and managed.

KEYWORDS

Environmental flows, groundwater allocation, national environmental standard, regional council's, through-flow analysis, bore construction records, SWL's, transmissivity.

1 INTRODUCTION

In 2005, the government held meetings throughout New Zealand to discuss freshwater management issues and the present framework for managing these. The conclusion drawn from the meetings was the need for greater consistency and clarity in the way increasing demand on water resources is managed throughout New Zealand (MfE, 2008).

In April 2006, the Minister for the Environment and the Minister of Agriculture and Forestry jointly released the implementation package for the Sustainable Water Programme of Action for the purpose of:

- Improving the sustainable management of freshwater;
- Protecting freshwater in the future; and
- Acknowledging the fundamental importance of water to all New Zealanders.

Consultation as part of the Sustainable Water Programme identified:

1. There remains water bodies (both small streams and groundwater systems) for which specific environmental flows and water levels have not yet been determined.

2. Environmental flows and water levels do not clearly define available water, creating uncertainty for existing and potential users regarding continued security of supply and avoidance of adverse effects.

3. Existing processes for evaluating the impacts of alternative flows and water levels are costly and contentious (MfE, 2008).

Recognising that establishing environmental flows and water levels is a critical part of effective water management, the Proposed National Environmental Standard (NES) for ecological flows and water levels was collated and issued for public feedback and submissions in 2008.

2 NATIONAL ENVIRONMENTAL STANDARD ON ECOLOGICAL FLOWS AND WATER LEVELS (NES)

National Environmental Standards are regulations issued under the Resource Management Act by Central Government that prescribe technical standards, methods or requirements for environmental matters. Each local or regional council must enforce the same standard, unless stricter standards are imposed that are explicitly allowed by the NES (MfE, 2008).

The following sets out the primary purpose of the Proposed NES:

- Set interim limits on alterations to flows and water levels in catchments where there are currently no such limits set in a proposed or operative regional plan (or other statutory order/standard);
- Facilitate effective management in a cost-effective and expedient manner;
- Direct the selection of technical methods for evaluating the ecological component of environmental flows or water levels.

The setting of environmental flows and water levels under the proposed NES applies on or after the date the standard becomes operative, meaning it would exclude consent or plan processes that had already reached a notifiable state (or a decision not to notify had been made).

The proposed NES recognises water as being an integral part of the natural and physical environment and that it has significant environmental, social and cultural values for New Zealanders, while providing essential services for the economic and social wellbeing of the country. The NES states that environmental flows and water levels shall make provisions to protect water ecosystems and provide for existing and future uses of water, while optimizing environmental, social, cultural and economic outcomes for the community (MfE, 2008).

Having environmental flows and water levels set for a particular water body allows the amount of water needed to sustain a given set of values to be clearly specified and the total amount of water available for development to be identified, to enable intelligent decisions to be made about how the available water[1] should be used (MfE, 2008).

2.1 NES INTERIM LIMITS FOR GROUNDWATER

The NES states that environmental flows and water levels are set to limit the amount of water that can be taken, and to maintain spring flow, aquifer pressure and recharge flows to rivers and wetlands. Groundwater trigger levels can also be used for preventing salt-water intrusion or adverse pressure gradients.

The NES has proposed interim limits for groundwater that will apply to all water bodies that are not covered by environmental flows and water levels established through proposed or operative regional plans. The interim levels will apply until an alternative is established through regional plans.

For shallow or coastal aquifers, the allocation of, the greater of:

- 15 % of the average annual recharge as calculated by the regional council; or

[1] Available water - the total quantum of water that can be allocated from a resource for consumptive use, including both existing and potential authorized uses.

- The total allocation from the groundwater resource on the date that the standard becomes operative, less any resource consents surrendered, lapsed, cancelled or not replaced.

For all other aquifers, an allocation of, the greater of:

- 35 % of the average annual recharge as calculated by the regional council; or

- The total allocation from the groundwater resource on the date that the standard becomes operative, less any resource consents surrendered, lapsed, cancelled or not replaced.

The NES also lists situations where the interim limits may be exempt, they include:

- Water bodies for which a high level of protection of natural values is achieved by allowing only a small or minor amount of allocation. In this situation an interim limit may not be necessary to protect the environment.

- Community and stock health water bodies as resource consents are often exempt from Environmental flows (MfE, 2008).

Existing approaches to environmental flows by regional councils are summarized below:

Table 1: Existing Approaches to Environmental Flows (Souce: MfE, 2008)

Regional Council	Environmental levels in place	No Environmental levels in place	Some levels in place	Notes
Northland		**P**		High use aquifers listed in plan. Groundwater trigger levels in some sensitive aquifers.
Auckland			**P**	Water availability identified in 22 aquifers, groundwater levels in 3 aquifers.
Waikato			**P**	Sustainable yields established for aquifers. Restrictions in water levels.
Bay of Plenty		**P**		Aquifers mapped for establishing sustainable yields.
Gisborne District		**P**		Trigger levels on large aquifers.
Taranaki		**P**		
Horizons	**P** (50% of land surface recharge)			
Hawkes Bay		**P**		
Wellington	**P**			Conceptual models of aquifers are being developed to refine assessment of availability i.e. Lower Hutt groundwater system. Safe yields on all aquifers are listed in the water plan. Where no detailed model is developed, water balance or aquifer through flow used for setting a sustainable yield.
Marlborough District	**P**			Through flow approach used to set sustainable levels. Models exist for some aquifers.
Nelson City		**P**		
Tasman City			**P**	Detailed hydrogeological models used to determine limits of abstraction for key groundwater systems.
West Coast		**P**		
Canterbury	**P**			Initial estimate is 50% of the annual average land-surface recharge; if insufficient data is available it is 15%.
Otago			**P**	Restrictions on groundwater use on 7 aquifers. Allocation limits are set using different methods.
Southland	**P**			Ranges from 15% to 25% depending on the aquifer type. Staged management based on the level of risk.

The table above shows that several regional councils have yet to set environmental flows/levels for their entire regions and there is variation in the methods for setting these levels.

2.2 METHODS FOR DETERMINING ENVIRONMENTAL FLOWS

As part of the process of establishing the NES, MfE sought technical input to the selection of appropriate methods for determining ecological flows and water levels. It was acknowledged that the approach towards groundwater differs to the approach for rivers; therefore a 'cumulative approach[2]' is used in response to the uncertainties associated with groundwater systems.

The guidelines present technical methods considered for the assessment of the risk of potential change to groundwater levels.

Table 2: Proposed Technical Methods for Assessing Water Level Requirements (Source: MfE, 2008)

Potential degree of hydrogeological alteration from groundwater allocation	**Groundwater: Resource Values and their Relative Significance**		
	Low (not sensitive)	**Medium**	**High (extremely sensitive)**
Low (up to 10% of recharge)	Conceptual model / water balance Historical levels	Conceptual model / simple water balance	Detailed water balance Time series analysis Analytical models Numerical quantity models – steady state Numerical quantity models – Transient Numerical quality models - transport
Medium (11-25% of recharge)	Conceptual model / simple water balance Historical levels Expert panel	Detailed water balance Time series analysis Analytical models Numerical quantity models – steady state	Numerical quantity models – steady state Numerical quantity models – Transient Numerical quality models – transport Consolidation models
High (over 25% of recharge)	Detailed water balance Time series analysis Analytical models Numerical quantity models – steady state Numerical quantity models – Transient Numerical quality models – transport	Numerical quantity models – steady state Numerical quantity models – Transient Numerical quality models – transport Consolidation models	Numerical quantity models – steady state Numerical quantity models – Transient Numerical quality models – transport Consolidation models.

The techniques range from a simple conceptual model to a detailed numerical/consolidation models, depending on the assessed potential for environmental alteration and value/significance of the groundwater resource.

Each technique requires information about the groundwater resource and the more information available, the greater the credibility of the determination of groundwater availability.

However, even the basic information on an aquifer is not being collected and collated by Councils, making it difficult to undertake any of the methodologies above with great confidence. The more detailed the method, the

[2] Cumulative approach – where simple models are used to build more complex models.

more data is required. Applications to take water for industry, farming and community water supply may be declined based on the findings of these assessments. Adding undue conservatism to such assessments may result in costly alternative supplies being developed, which may not be the best environmental or economic solution.

The following sections discuss the minimum requirements for undertaking a conceptual model using through-flow analysis as an example (a technique required to be applied by a number of regional councils) and the availability of this data.

3 CONCEPTUAL MODEL BY THROUGH-FLOW ANALYSIS

A method of assessing through-flow in a particular aquifer is to identify well pairs in the same aquifer formation and calculating the gradient between these pairs. When the gradient and transmissivity (T) are known, the flow between the wells can be calculated using Darcy's Law:

$$Q = \frac{T_1 \Delta \mathbf{h} W_1}{L_1} = \frac{T_2 \Delta \mathbf{h} W_2}{L_2}$$

Where T is transmissivity, $\Delta h/L$ is the gradient of the water table, and W is the width of the aquifer.

Such analyses can be 'verified' with a mass balance analysis.

3.1 MINIMUM INFORMATION REQUIREMENTS

To undertake a through-flow analysis, the following is required as a minimum:

- § Ground surface/well head elevations;
- § Borehole construction records; including but not limited to total depth, diameter, stratigraphic profile, screened interval, well co-ordinates;
- § Static water levels;
- § Transmissivity/storativity values obtained from reliable long-term pumping tests.

Well information[3] has been requested by the authors from the following regional councils for various projects. We use the responses here to assess the availability of this data:

- § Environment Waikato;
- § Auckland Regional Council;
- § Environment Waikato;
- § Environment Bay of Plenty;
- § Environment Canterbury; and
- § Greater Wellington – Data gathered for entire Wellington City.

3.1.1 GROUND SURFACE AND WELL HEAD ELEVATIONS

Well head/ground surface elevations are important in a through-flow analysis for calculating static water levels in relative level (RL) and to assist in calculating groundwater gradients. SWL data in RL is also important for determining drawdown interference on neighboring wells.

Well head information is however not always available, as it is currently not requested by many regional councils as part of the consenting process for bore construction. Table 3 is a list of regional councils[4] approached that were able to provide records of well head/ground surface elevations.

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[3] Well data was collected from a 10 km radius or greater from a selected location.

Table 3: Wellhead Elevation Data Held by Regional Councils

Regional Council	Percentage of Wellhead Elevation Data[1]
Environment Waikato	94%
Auckland Regional Council	0%
Environment Bay of Plenty	0%
Environment Canterbury	26%
Greater Wellington	1%

[1] Percentage of wells consented for which council had a record.

The table demonstrates the variation in the collection of this data by regional councils.

If wellhead elevations are not available, contour data is relied upon for estimating the well head elevation and SWL's in RL. This is very inaccurate when only 20 m contour data is available and a little better if lidar data is available, provided the location of the well is correct.

An application to take and use groundwater was lodged with a regional council that does not hold such data recently; interference on neighboring wells was assessed using RL's obtained from 20 m contours, as elevation data was not available for each well but this level of accuracy was not accepted. It was requested that the applicant survey the elevation of each well in proximity to the proposed water take to determine more accurately the drawdown interference on each neighboring well. This is a very expensive task, which could have been avoided if each groundwater user was required to survey the well head following construction of the well.

3.1.2 BOREHOLE CONSTRUCTION RECORDS

Well construction records and borelogs provide valuable information on depth, geology, screened interval, well diameter, co-ordinates etc. Screened interval identifies water bearing horizons and how many wells are screened in the same aquifer. Depth information can help determine available drawdown on neighbouring wells. Table 4 summarises the bore construction records provided by the regional councils in response to recent requests:

Table 4: Well Construction Records Held by Selected Regional Councils

Regional Council	Depth	Screened Interval	Borelog	Co-ordinates
Environment Waikato	92%	10%	14%	100%
Auckland Regional Council	78%	13%	55%	100%
Environment Bay of Plenty	82%	67%	40%	100%
Environment Canterbury	98%	60%	60%	100%
Greater Wellington	85%	26%	30%	100%
Note: percentages of records provided that show this data.				

The table shows that the majority of selected councils hold information on well co-ordinates and depth. Few collect data on or enforce collection of screened interval or bore logs.

3.1.3 STATIC WATER LEVEL INFORMATION

Static water level data is required to gain an understanding of groundwater flow, groundwater gradients and aquifer catchment boundaries. The more data available, the more accurate the conclusions will be.

One must be careful however to consider the accuracy of the data collected, as the majority of the static water level data submitted to Councils is measured by the drilling contractor during construction of the well or the contractor may have measured the groundwater level immediately following construction of the well, without allowing groundwater levels to stabilize. It is therefore important to develop a groundwater contour map to compare water levels across the catchment. The more data available, the more credible the contour map will be.

Table 5 gives a summary of static water level data included on records provided by regional councils.

Table 5: Static Water Levels

Regional Council	Percentage of SWL Data[1]
Environment Waikato	3%
Auckland Regional Council	30%
Environment Bay of Plenty	58%
Environment Canterbury	18%
Greater Wellington	19%
[1] Percentage of records provided that provide SWL data.	

The table shows that little information is being gathered on static water levels.

Access points into wells are needed to allow static water levels to be obtained and monitoring of groundwater levels to be carried out. In 2009 a groundwater monitoring round was undertaken within a 10 km radius of Helensville, Auckland. Of the 143 properties visited, 11 were able to be accessed for measuring groundwater levels. A few of the inaccessible wells were drilled in 2009. Knowing the groundwater level is essential for completion of any one of the methods listed in Table 3.

Why are wells continuing to be drilled without an access point and why are regional councils not collecting this data?

3.1.4 TRANSMISSIVITY

Transmissivity is a measure of how much water can be transmitted for example horizontally to a pumping well. The values are derived from a pumping test of a well, preferably of a duration of 7 days, with monitoring in associated observation wells.

Typically little information is held by regional councils on pumping testing results. In the Auckland Region, only 1.4 % of the wells have associated long-term pumping testing data and 11 % have associated airlift test results.

The majority of pumping tests undertaken are airlift tests. A transmissivity value can be derived by applying the Cooper-Jacob Successive Approximation Method to the specific capacity results derived from the airlift. This method assumes that there is no well loss. The well loss component of the total drawdown could vary from 80 to 90 % in a poorly constructed well to 10 – 20 % in a properly constructed well. Therefore the magnitude of transmissivity calculated from airlift tests is smaller (and far less reliable) than that calculated in a longer pumping test involving observation bores.

In reality, transmissivity cannot be derived directly from airlift test results because:

- The test only provides an estimate of the specific capacity;
- The test is only for a short duration, typically 1-3 hours and drawdown is only measured at the end. The short duration of the test affects the specific capacity of the well and therefore the Transmissivity because often the specific capacity is based on drawdown that has not reached steady-state;
- Airlifting involves installing an airline into a well and airlifting a slug of water. The volume of water removed through air lifting is approximate (as it is difficult to collect the volume removed, if the proper set-up is not installed) and in most circumstances is not constant through time because airlifting produces a pulsating flow not a constant flow.
- Given the short duration of the airlift test, only the aquifer in the immediate vicinity of the well contributes to the discharge;
- Air-lifting is most often undertaken in undeveloped wells, where smearing of low permeability confining layers on the wall of the well or fine sediments from drilling may reduce the yield;
- Tests are often undertaken in narrower diameter wells used for domestic/stock water supply.

A comparison of transmissivities derived from airlift tests verses long-term pumping tests in Waitemata Rock aquifers within the Rodney District of the Auckland Region is given in Table 6.

Table 6: Transmissivity Values Derived from Long-term Pumping Tests and Airlift Tests

Test Type		Location	Transmissivity (m^2/day)
14 day pumping Test	Production Well	Western Warkworth	432
	Observation Bores		432 to 1037
7 – day pumping test	Production Well	Northern Warkworth	1607 – 2169
	Observation Bores		1192 – 3949
Derived from constant-head test		Helensville	1477
7 – day pumping test	Production Well	Wellsford	420
	Observation Bores		435 – 455
Airlift Test		Wellsford	3 to 167
Constant Discharge Test for 24 hours		Helensville	134
Constant discharge test for 48 hours		Helensville	80

Although there is a significant difference between transmissivity values derived from long-term pumping tests with observation wells and those derived from airlift tests, more weighting is often given to transmissivity values derived from airlift tests by Councils, simply because they are lower (and hence more conservative) values.

3.1.5 AQUIFER RECHARGE BOUNDARIES

It is common practice for councils to adopt for the surface water catchment or in some cases a line drawn on a map as a deep groundwater aquifer catchment.

Surface water boundaries may be similar when dealing with shallow aquifer systems but this may not be the case for deep aquifers, as recharge may extend well beyond the surface water catchment. Catchment extent is critical when calculating available water with a mass balance analysis. It is also crucial for a through-flow analysis when determining current use in the aquifer catchment and aquifer width (used in Darcy's Law). Ways of determining the extent of an aquifer may include:

- SWL's plotted on a contour map to determine water flow (hence the importance to have as many SWL measurements to increase the reliability of the contour map);

- Use of dips and strikes on a geological map to determine the dip direction of bedding. Bedding may indicate the flow direction.

3.2 DISCUSSION

The data shows that of the regional councils approached, most are not collecting valuable information that is essential for developing even a basic conceptual model. This data could easily be collected during the consenting process for construction of a bore and data collection can continue if an access point to the well is enforced.

A few of the regional councils are currently applying the NES to current applications to take and use water. Auckland Regional Council in particular will not process consents to take and use water until the applicant can 'prove' that water is available when the limits set out in the NES are applied. The NES however clearly states that numerical models could be prepared using finite models such as 3D visual MODFLOW-PRO, which are valid and in our view likely to provide a more accurate assessment of the well and its surrounding environment. The NES also specifies that community and stock health water bodies may be exempt from interim limits, however a number of consents to take and use groundwater for potable supply to districts around New Zealand are being delayed in order for the applicant to prove that water is available once these interim levels are imposed.

4 CONCLUSIONS

The proposed National Environmental Standard (NES) for ecological flows and water levels was collated and issued for public feedback and submissions in 2008.

The NES recognises that establishing environmental flows and water levels is a critical part of effective water management and should make provisions to protect water ecosystems and provide for existing and future uses of water, while optimizing environmental, social, cultural and economic outcomes for the community.

As part of the NES, interim limits for groundwater have been proposed. The interim limits will apply to all water bodies that are not covered by environmental flows and water levels established through proposed or operative regional plans and will apply until an alternative water level has been established through a regional plan.

In addition to the interim limits, the NES has developed a document which recommends methods for developing environmental flows and water levels. The methods range from simple conceptual models to numerical/consolidation models and the type of method selected is dependant on the potential degree of hydrological alteration from allocation and the value/significance of the groundwater resource.

However, data to even develop the simplest model is not being collected and collated by regional councils, making it difficult to undertake any of the methods suggested by MfE with confidence. This is disconcerting, especially when applications to take and use water for community water supply and industry can potentially be declined based on the results concluded from setting environmental flows/allocation etc. The collection of this data by each regional council should be undertaken when a land use consent to construct a bore/well is sought or the well is constructed.

The NES is a good step in requiring all regional councils to apply environmental flows/levels to each water body in its region in order to manage our valuable resource; however ensuring the collection of useful data should be the first step in the process and requiring the applicant to carry out such data collection and assessments would seem to be a shifting of responsibility.

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