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The economics of augmenting Christchurch's water supply

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Abstract

Increasing abstraction from high-quality ground water systems to meet the growing demand for urban water can adversely affect other water users, the general population, and ecosystems. Continued pressure on the aquifer used to supply Christchurch City has resulted in a need to assess alternatives for augmenting the supply. This paper presents the results of an economic valuation study to estimate the value to the Christchurch community of managing groundwater abstractions to preserve spring, river and wetland flows. Conservative estimates of the perceived community benefits associated with avoiding increased abstraction from existing wells outweigh the cost of augmenting the supply from at least one of the alternative sources. The results show that the community can place high values on avoiding adverse environmental impacts, which need to be considered in developing water supply and management options.

Introduction

Christchurch City uses the Christchurch-West Melton aquifer for domestic, industrial and municipal supply. This is an extremely high-quality groundwater resource and the water requires no chemical treatment. Growth in abstractive demand has led to concern over sustainable use of the aquifer and the prospect of augmenting the supply from another source. Intensified competition for this scarce high-quality resource raises important economic questions. While abstraction of water from an aquifer can provide readily apparent economic benefits, it also creates costs, either because of its effects on the long-term viability of the resource, or because of cultural, environmental, recreational and/or aesthetic impacts. To illustrate, water supplied to agriculture and industry, used in combination with other inputs such as labour and capital, is necessary in the production of goods and services. In principle, the economic benefits to these water users can be quantified. However, if water is scarce, we must pay close attention to the opportunity costs[1] associated with abstraction *viz.* other use and non-use values. Economic efficiency requires that the marginal costs and marginal benefits of groundwater abstraction be equated (White *et al.*, 2001). At present there is no mechanism in place that signals relative value, leaving decision makers with little idea as to the comparative value of using the water

[1] Opportunity costs refer to benefits foregone because of resource use. For example, a decision to preserve a river in its natural state has opportunity costs from potential industrial, agricultural, domestic, municipal and other uses of the water that have been foregone.

versus leaving it *in situ.* Consequently, limits to resource use are set in political forums without explicit consideration of the trade-offs associated with alternative strategies for water management.

This paper addresses the economic impacts of groundwater abstractions on stream flows in Christchurch. It seeks to measure the costs of diminished stream flows and restrictions on water use, and to measure the net benefits of augmenting the Christchurch water supply from an alternative source. The paper begins with a brief introduction to the water system, a description of how Christchurch water is managed, and an introduction to perceptions and preferences of Christchurch residents for water management. An economic framework for analysis of potential changes in water management is introduced, followed by a description of the methods used for measuring non-market impacts of water management. Results of a non-market valuation study are then used to investigate the economic implications of augmenting Christchurch City's water supply from an alternative source.

The water system

Christchurch's rivers (Avon, Heathcote, Styx, Otukaikino, and Halswell) flow continually because groundwater rises to the surface and discharges through springs. Consequently, changes in groundwater levels result in changes in river flows, which in turn affect the character of rivers dependent on those flows. Flows in the system may be characterised very simply as:

$$Q_T + Q_R = Q_A + Q_{DS} + Q_{DU} + \Delta GW$$

where:

Q_T ≡ Natural aquifer inflow from rivers and rainfall recharge

Q_R ≡ Quantity of artificial recharge to the aquifer

Q_A ≡ Quantity of water abstracted from the aquifer by users

Q_{DS} ≡ Quantity of water discharged to the surface (springs, wetlands, etc.)

Q_{DU} ≡ Quantity of water discharged to the sea or to other aquifers

ΔGW ≡ Flow of groundwater to, or from, storage

An increase in groundwater abstraction (Q_A) will be compensated by some combination of changes—in discharges to the surface (Q_{DS}), in discharges to the sea or to other aquifers (Q_{DU}), or in groundwater storage. These consequences of increased abstraction can have serious repercussions. Decreases in groundwater pressure can increase the risk of contamination by pollutants and can result in aquifer collapse and surface slumping. Decreases in discharges to the sea can allow the freshwater/saltwater interface to move landwards, resulting in saltwater contamination of aquifers, rendering them useless for abstraction. Decreases in discharges to the surface can decrease stream and river flows, reduce wetland areas, and affect well yields. This report addresses the impacts of abstraction on stream and river flows, and seeks to identify indicators of the costs imposed by reduced surface discharges in Christchurch City.

Abstraction from aquifers can be mitigated by artificial recharge (Q_R), which entails taking water from some other water supply and introducing it into the aquifer. Alternatively, reduced stream flows can be augmented from alternative sources. Spring-fed stream flows are therefore largely dependent upon the natural flows in the aquifer(s) feeding them, the quantity of water abstracted from the aquifer, and the quantity of artificial recharge to the aquifer.

The Christchurch-West Melton aquifer system that supplies Christchurch City is not intentionally artificially recharged, however 5% of groundwater infiltrates from stock-water races, supplementing seepage from the Waimakariri River (60%) and rainfall infiltration (35%). The groundwater is used for irrigation (10%) and reticulated supply and industry (15%), or discharges to spring-fed streams (55%) and offshore (20%) (Environment Canterbury, 2000).

In the year to June 1999, 103.6 million cubic metres of water were abstracted from the Christchurch-West Melton aquifer system, with 35% of that going to private irrigation, 14% to private industry, and 51% to public reticulation (Environment Canterbury, 2000). Christchurch City Council draws groundwater from 150 bores throughout the city. In the year to June 1999, the city used 50.5 million cubic metres of groundwater, with 57% of that for residential use, 21% for commercial and industrial uses, 17% unaccounted for, and 5% for public use. In addition to the city's supply, there are 27 wells not owned by the council that are used for drinking water supplies, and many businesses have their own wells (Christchurch City Council, 2000).

Water management

Regional councils are responsible for water allocation and management of water quality. Environment Canterbury has published a Regional Policy Statement (Canterbury Regional Council, 1998) and is in the process of producing a Natural Resources Regional Plan that will provide guidance on, among other things, management of Christchurch water. The draft plan (Environment Canterbury, 2001a) recognises multiple goals for water management, including protection of the natural environment; cultural, social, recreational, economic and amenity benefits, and efficient supply of drinking water. It also recognises the important effects of stream depletion. At the national level, the Ministry for the Environment has identified the critical importance of managing the impacts of groundwater abstraction on surface water resources and maintaining water and habitat quality of lowland streams, particularly those with urban catchments (Ministry for the Environment, 2000).

Environment Canterbury has surveyed residents' preferences for managing flows in the Avon and Heathcote Rivers. The survey presented three options for each river. These were: (i) increased river flows, requiring frequent restrictions on water use, (ii) 10% lower flows, requiring some restrictions on use, and (iii) 25% lower flows, with no restrictions on water use. A total of 5369 replies were received, with 60% wanting increased flows in the Avon and 47% choosing increased flows in the Heathcote (Environment Canterbury, 2001b). Very few respondents were willing to reduce stream flows by the 25% necessary to avoid restrictions on water use (6% of respondents for the Avon and 9% for the Heathcote). Christchurch residents are clearly concerned about flows in these rivers and are prepared to face restrictions on water use to maintain those flows.

The role of economics

The primary purpose of the Resource Management Act 1991 is to promote sustainable management of New Zealand's resources. This has led to some debate over the primacy of the natural environment relative to the social environment (Skelton, 2002). Furthermore, Section 32 of the Resource Management Act directs administrators to consider the costs and benefits of alternative courses of action. The draft Natural Resources Regional Plan (Environment Canterbury, 2001a) adopts an environmental perspective and gives ecological functions a higher priority than amenity and recreational values. While this approach may relegate economic efficiency to a secondary role, there is nonetheless a potential role for economics after environmental sustainability goals have been attained. Given that environmental requirements have been satisfied, there is still the question of whether flow re-allocation above minimum environmental requirements is worthwhile. The importance of economics is further emphasised by the Local Government Act 2002, Section 3 of which 'provides for local authorities to play a broad role in promoting the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach'.

The role of efficiency is recognised in the draft Natural Resources Regional Plan, which states (Environment Canterbury, 2001a)

> 'Excessive use of water ... can have the following adverse effects: ... (e) the economic and social wellbeing of the community is not being maximised because water available for allocation is not being used efficiently or effectively, or its geographic distribution does not optimise its use between surface water and groundwater' (p. 5-59).

Canterbury residents also perceive a strong role for economics, with 58% wanting economics to be used as part of the basis for allocating river flows to uses other than abstraction. However, only 8% of respondents wanted economics to be the sole criterion for flow allocation (Canterbury Regional Council, 1999).

Measures of the public's willingness to pay to protect stream flows allow comparison of the costs and benefits of flow protection. An indicator of Christchurch residents' willingness to pay for flow protection is revealed in a recent City Council survey (Christchurch City Council, 2001). Twenty-seven percent of respondents said they were *extremely willing* and 42% said they were *quite willing* to pay $5 to $10 per ratepayer per year to 'ensure that water use does not contribute to lower flows in Christchurch streams'. Only 20% were *not very willing to pay* or were *not at all willing to pay.*

Assuming that 69% of 116,000 households (Statistics New Zealand, 1996) are willing to pay between $5 and $10, these results yield a rough measure of total willingness to pay for flow maintenance of about $400,000 to $800,000 per year. Unfortunately, the survey design precludes any estimation of median and mean willingness to pay. The results may also be subject to bias because of the way the question was asked, so the findings of this particular survey should not be used as a basis for judgement of the net benefits of flow-enhancement initiatives. They do, however, indicate that Christchurch residents generally support maintaining river flows and are prepared to pay a substantial amount to ensure them. On this basis alone, further investigation of the economic implications of river flow protection appears to be warranted.

Options

Flows in Christchurch rivers and streams can be maintained or enhanced by managing water use, by changing or augmenting the water supply, or by augmenting groundwater or river flows. Alternatively, increased demands for water could be met by further abstractions from the Christchurch-West Melton aquifer system, which would further reduce river flows. Drawing more heavily upon the aquifers beneath the city without recourse to other supplies would entail eventual water rationing, as extraction reaches the sustainable supply from the aquifer. It would also reduce artesian flows, with potentially serious consequences for wetlands and rivers in and near the city, and their landscape, recreational, ecological, *tangata whenua* and economic values (Environment Canterbury, 2000).

The Canterbury Regional Council has investigated options for aquifer augmentation since 1990. One of the expected benefits is the enhanced flow of spring-fed streams (Woodward-Clyde, 1998). Residents appear to support augmentation of groundwater and river flows, with 41% wanting to see provisions for augmentation in regional plans (Canterbury Regional Council, 1999). Residents also support water supply augmentation, with 38% wanting water supplies augmented from other sources when demand exceeds supply (Christchurch City Council, 2001).

One option to meet growing demands for water while maintaining the flows of spring-fed rivers is to supplement the city's water supply from the nearby Waimakariri River. This option was not favoured by Christchurch residents because the poor quality of Waimakariri River water would necessitate chemical treatment, because it is more expensive than an alternative groundwater supply (E. van Toor, pers. comm., March 1999), and because of potential costs for agriculture.

Another option entails exploiting presently unused groundwater supplies to the south of the city in the Ellesmere area. Although ground water from the Ellesmere area would not need chemical treatment, it would have to be piped approximately 15 km to the city boundary, imposing significant capital and operating costs. The Ellesmere aquifer system is not heavily used for agriculture and would be capable of supplying a considerable fraction of the city's demand (E. van Toor, pers. comm., March 1999). One proposal is to use it as an alternative source to supply 60,000 residents on the western boundary of the city.

This paper reports the results of a study undertaken to value the perceived benefits of augmenting the Christchurch water supply using groundwater from the Ellesmere area for addressing potential future water supply problems. A simple cost-benefit framework is adopted for economic analysis. Net benefits of augmentation are defined as:

$$NB = N^*B - C$$

Where:

- NB ≡ net annual benefits of augmentation from the Ellesmere supply
- N ≡ number of households in Christchurch City (116,000)
- B ≡ mean annual household benefits of augmentation
- C ≡ annual cost of the Ellesmere supply

Methods

Implementation of the cost-benefit framework, as envisaged by Section 32 of the Resource Management Act, requires estimation of additional supply costs as well as estimates of non-market benefits of flow protection. Two methods were employed to obtain information for this study. Representatives of Christchurch City Council were interviewed to obtain estimates of the costs of augmenting the supply. A survey of Christchurch householders sought people's willingness to pay to avoid reduced flows and water levels in rivers and wetlands, and also to avoid the possibility of eventual restrictions on water use.

Questionnaires were delivered by mail to randomly selected Christchurch households. Each questionnaire included a reply-paid envelope and cover letter. The cover letter indicated that the survey was part of a national study of groundwater values funded by the Foundation of Research Science and Technology. Respondent anonymity was assured. In order to encourage participation, the cover letter explained that all returned surveys would enter a draw for a mystery prize and that a summary of survey findings would be sent to everyone who returned the completed survey.

A total of 471 surveys were mailed out in May 2000. There was no follow-up mailing. Responses were accepted up to 16 days from when the survey was mailed out. The survey instrument included questions to measure the use of Christchurch water bodies in the preceding 12 months, perceptions about the impacts of groundwater use, demographics, and the values associated with different groundwater uses. The valuation questions used a dichotomous choice referendum format (Arrow *et al.*, 1993). Participants were given two options and were constrained to vote for only those options. Open-ended questions were used to validate respondent votes and also to seek reasons for not voting when that occurred.

The survey was introduced with the following statement:

> *The population of Christchurch continues to grow, and so does the City's demand for water. At least two options are available for managing water supply.*
> ***Two options for the future are: ...***

The two options, shown in Table 1, were the result of extensive pre-testing and provided simple language explanations of the alternatives. The survey allowed respondents to express their willingness to pay to avoid two things, decreased flows in spring-fed rivers, and future restrictions on water use. The money values in Option B ($x) were selected randomly from the set {$20, $50, $100, $200, $400}. These values were chosen to provide a range that covered all bids obtained from an open-ended valuation question included in pre-testing.

The referendum scenario followed immediately after the voting options:

> *Imagine that a referendum amongst all residents of Christchurch City were scheduled for tomorrow. While there may be other options you can think of, in this referendum you can choose only from options A and B. The option gaining the most votes would be implemented. Which option would you vote for?*

Respondents were asked to record their vote in a box alongside the option of choice. Only valid contingent valuation question responses were retained for analysis. Some surveys were excluded from analysis because of no response to this question, while others were excluded because the respondent refused to accept the scenario presented (e.g. 'Christchurch water shortages are a myth'), or protested about the payment mechanism (e.g. 'should use SouthPower sale proceeds to pay for this', or 'rates are too high already').

Table 1 – Voting options

Option A: Increased use of existing wells
Christchurch could keep using existing wells.

This would:
- ❐ Provide water just the same as you get out of the tap now.
- ❐ Reduce water flows in rivers and springs, including the Avon and Heathcote Rivers, the Groynes, and other small streams and wetlands in the Christchurch area
- ❐ Affect visual appeal of waterways because of lower flows.
- ❐ Change the habitat for plants and animals that live in streams, wetlands, and the Estuary.
- ❐ Eventually cause water use restrictions to ensure that the natural environment was protected from serious damage.
- ❐ Cause the natural environment to be permanently different from the way it is now.
- ❐ Not cost anything. Your household rates or rent would stay the same as now.

Option B: New wells
Christchurch could sink more water wells, especially in locations far from surface water sources.

This would:
- ❒ Prevent lower flows in Christchurch waterways.
- ❒ Avoid water use restrictions.
- ❒ Provide water just the same as you get out of the tap now.
- ❒ Be expensive because of the costs of locating new water supplies and drilling the wells. These costs would have to be met by increased rates. **Your household rates or rent would increase by $x per year.**

Response rates are summarised in Table 2.

Table 2 – Survey response

Number Mailed	471
Number Returned	171
% Returned	36%
Number Useable	130
% Useable	28%

Results

The Christchurch City Council (E. van Toor pers. comm., August 2003) estimates the cost of the current Christchurch City water supply scheme as $14 million per year. This annual cost includes running costs, fixed operating costs, capital works (but does not include capital works due to growth), depreciation at 1% per annum, and financial charges. The annual cost of a water supply scheme for Christchurch that includes a water supply in the Ellesmere area would be greater than in the present scheme. An Ellesmere groundwater supply for Christchurch would require wells and pipelines to get water to the City. Annual costs to Christchurch would rise by an estimated $6.7 million. This rise is calculated using the cost of capital ($60 million at 8% per annum), plus depreciation ($60 million at 1% per annum), plus additional running costs of $1.3 million per annum. The additional cost of $6.7 million per year for Christchurch is equivalent to around $60 per Christchurch household per year, assuming that the additional annual cost is spread equally across all households, or around $40 per Christchurch household per year, assuming costs are shared between households and commercial users.

Supply augmentation benefits

Maximum likelihood estimation methods were used to fit response models to the non-market valuation data obtained from Christchurch residents. Models utilised were exponential, Weibull, logistic, log-logistic and pinched log-logistic, which are capable of accommodating a range of different distributions within responses (Kerr, 2000). The logistic and log-logistic models fitted best. For brevity, only these models are reported here. The response models were specified as:

Logistic $P_{WTP} = 1/(1+\exp(-(\beta X))$

Log-logistic $P_{WTP} = 1/(1+\exp(-(\beta \ln X))$

P_{WTP} is the probability of being willing to pay under the conditions identified by the vector X, with the money amount (that is, Option B($x) in Table 1) being one element of X. β is a vector of estimated coefficients.

Goodness-of-fit is summarised using McFadden's R^2. Care should be exercised in interpreting this measure because, unlike the R^2 measure arising from linear regression procedures, it does not indicate the proportion of variance explained. McFadden's

R^2 between 0.2 and 0.4 indicates an extremely good fit (Louviere *et al.*, 2000). Confidence intervals were obtained from 600 bootstrap iterations of the maximum likelihood procedure (Cooper, 1994; Duffield and Patterson, 1991).

The overall fit of the models, as reported in Table 3, is extremely good. The signs of estimated coefficients are as expected, with males, those on high incomes, and households with more occupants willing to pay more. However, the coefficient on gender is the only one that is significant. The significance of other variables is likely to have been adversely affected by the small number of surveys analysed.

The log-logistic model produced a point estimate of the mean approximately 4 times that derived from the logistic model, although that difference was not statistically significant. Inclusion of higher money values in Option B would have been advantageous. The highest value used was $400 and the mean and median are both in excess of this amount. However, results are consistent with qualitative responses obtained from the open-ended validation question. Nearly all respondents completed the validation question, which sought reasons for the respondent choosing the selected option. Responses from people choosing Option B (sinking deeper wells) uniformly indicated a strong commitment to environmental preservation and/or the large benefits relative to costs of Option B. Many argued along the lines of '$4 per week is a very low cost to preserve the environment'.

Because responses to only a small part of the distribution of values have been obtained in the survey, the right-hand tail of the

Table 3 – Willingness to pay (WTP) for augmentation of the water supply

	Logistic	Log-logistic
Constant	2.904	9.245
(t-scores)	(4.26)	(3.29)
Money	-0.008309	-1.584
(t-scores)	(-3.30)	(-2.99)
Male	2.006	1.928
(t-scores)	(2.73)	(2.69)
$LL_{Restricted}$	-39.825	-39.825
$LL_{Unrestricted}$	-30.062	-29.141
McFadden's R^2	0.25	0.27
Mean WTP	$516	$1,939
(95% confidence interval)	($418-$961)	($387-$24,607)
Mean WTP - MALES	$592	$2,503
(95% confidence interval)	($482-$1,168)	($460-$34,300)
Mean WTP - FEMALES	$356	$741
(95% confidence interval)	($263-$649)	($223-$5,563)

$LL_{Restricted}$ = Log-likelihood of a model restricted to contain only a constant term
$LL_{Unrestricted}$ = Log-likelihood of the fitted model

distribution cannot be confidently mapped and therefore estimation of mean willingness to pay is problematic. However, use of a wide range of distributions still provides a strong indication of the likely orders of magnitude within which the mean is likely to fall. One conservative approach to dealing with uncertainty in the upper tail of the willingness-to-pay distribution is Winsorizing (Duffield and Patterson, 1991). Winsorizing involves censoring the willingness-to-pay distribution at a nominated dollar value (X). All individuals expected to pay more than X have their willingness to pay set equal to X. Setting an upper limit of $500, the Winsorized mean for the simple log-logistic model is $416. Applying the Krinsky and Robb procedure (Park *et al.*, 1991) and resampling 10,000 times yielded a minimum Winsorized mean value of $309 and a 95% confidence interval on the Winsorized mean of $359 - $449. It appears safe to conclude that mean willingness to pay to maintain Christchurch river flows and avoid restrictions on water use is likely to exceed $400 per household per year for the sample.

Discussion and conclusions

Net benefits of augmentation

Using conservative estimates from the models presented in Table 3, the annual benefits of augmentation are more than $400 per household, about $46.4 m over the whole of Christchurch City. This level of perceived benefits comfortably exceeds the costs of augmentation from the Ellesmere groundwater supply ($6.7 million per annum). Net perceived benefits of augmentation from Ellesmere therefore exceed $39 million per annum (about $342 per household per year). It should be stressed that, because of the conservative approach used to value enhanced stream flows and avoidance of restrictions on water use, these are likely to be underestimates of net benefits. Using the Winsorized mean of the log-logistic model, rather than the minimum Winsorized estimate of the mean, marginally increases net benefits of supply augmentation to $41 million per year, about $358 per household. The mean of the simple logistic model yields benefits of $53 million per year ($458 per household).

The preceding discussion has assumed that responses to the survey are representative of all Christchurch households. However, the survey's low response rate suggests the possibility of a bias in sample selection. Only 36% of mailed surveys were returned. One approach to population benefit estimation is to assume that all non-respondents were unwilling to pay anything for protecting river flows and avoiding restrictions on water use. This is an extremely conservative approach because many would not have replied for reasons other than lack of benefits from water supply augmentation. Examples include non-receipt of the survey, inability to read English, inability to comprehend the survey, accidental loss or destruction of the survey, laziness, or rejection of liability for paying for supply augmentation, amongst others. In an earlier contingent valuation study of the Christchurch population, those who didn't respond to the survey were later interviewed on the telephone to measure how their non-response would bias the survey results (Sheppard *et al.*, 1993). Sheppard's study measured the benefits of water quality improvements in the Waimakariri River, near Christchurch, obtaining a mail survey response rate of 44%. Telephone interviews showed that respondents and non-respondents were, on aggregate, very similar. Adjustments for disproportionate sampling yielded increases in estimated benefits of the order of 10-20%.

Adopting an extreme conservative approach, and assuming zero willingness to pay for those surveys that weren't returned reduces mean willingness to pay from $516 to $186 for the logistic model. The Winsorized log-logistic mean falls from $743 to $267. Lower-bound mean household willingness to pay falls from $400 to $144 per year. These estimates are sufficient to justify supply augmentation, even if households pay all augmentation costs ($58 per household per year).

The willingness to pay functions fitted in Table 3 provide the opportunity to identify the proportion of the population that would be willing to pay any nominated amount to protect stream flows and avoid restrictions on water use. Substituting ratepayer cost ($58 per household) into the willingness to pay functions yields acceptance rates of more than 92% for the simple log-logistic (92% female, 99% male) and the simple logistic (94% female, 99% male) models, underscoring the community's willingness to support supply augmentation.

Policy implications

This study has shown that, even using extremely conservative benefit figures, Christchurch residents place a very high value on protecting stream flows and avoiding restrictions on water use. Consequently, under realistic assumptions they seem prepared to pay the costs of obtaining water from supplies other than the Christchurch-West Melton aquifer system. While the cost of augmentation from alternative water supplies may appear large, these results indicate that Christchurch City should seriously consider meeting growth in demand for water from alternative ground water sources.

Efficiency of water use has not been addressed in this study. City supply augmentation from the Ellesmere groundwater supply is only one way to protect or enhance river flows. Direct augmentation of aquifers or streams could be more efficient ways of meeting this goal, as could reduction in demand for water. Some methods for recharging streams and aquifers from the Waimakariri River appear to involve lower infrastructure cost than augmenting the reticulated water supply (Environment Canterbury, 2000). However, the benefits of these alternative proposals have not been estimated, so it is not possible to draw conclusions about their overall merits. Community concerns about using Waimakariri River water for augmentation include effects on the amenity values and ecosystems of the Waimakariri, increased concentrations of pollutants in the Waimakariri, and contamination of Christchurch river waters by pesticides, fertilisers and effluent (Environment Canterbury, 2001b). Tangata whenua reject the notion of mixing waters from different sources, which may create a further impediment to augmenting stream flows using Waimakariri River water. At least one Maori group has objected to such proposals (Environment Canterbury, 2001b).

Because Christchurch City does not charge for water on a volume basis, the marginal benefits of water consumption are likely to be at, or close to, zero. Consequently, reductions in water consumption may provide the most efficient way to retain a high-quality municipal supply while protecting stream flows and avoiding restrictions on water use. Study of the costs of water-use restrictions and the impacts of charging for water would shed further light on the efficiency of augmenting the supply compared to managing the demand. However, reductions in demand may be difficult to achieve. Economic approaches to water conservation are not popular with Christchurch residents, and intensification of the voluntary conservation measures used currently appears to be largely ineffective (Kerr *et al.*, 1998).

There are several options for augmenting Christchurch river flows and avoiding restrictions on water use. The most efficient approach cannot be identified without further work into the costs and benefits of alternatives to augmenting the supply using Ellesmere groundwater. This study has shown that protection of Christchurch stream flows is likely to yield positive net benefits, at least relative to the cost of developing the Ellesmere supply. Thus some form of action to maintain stream flows and avoid restrictions on water use is justified on economic grounds. Further research is required to identify the most efficient means of doing so.

This study provides an important message for water managers. Citizens place high importance on water management and are prepared to pay significant amounts to obtain desired outcomes. Managers should not assume there is little support for environmental protection measures because of their expense. Non-market valuation procedures, like those used here, are relatively cheap and quick methods for obtaining an indication of the likely levels of support for, and willingness to pay for, water management initiatives that yield intangible benefits.

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