VALUING WATER OF THE ASHBURTON RIVER:
IN-STREAM FLOWS VERSUS IRRIGATION

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ABSTRACT

Recent legislative changes in New Zealand allow much greater flexibility in the procedures
used by regional authorities to allocate water resources. In certain river catchments
where competition for water in alternative uses is high, estimates of the economic value
of water could prove useful in designing an allocation scheme. This paper reports on our
recent experience in using two methods to value the Ashburton River. First, we use a
contingent valuation approach to estimate the value of in-stream flows of the Ashburton
to the residents of the Canterbury region. This value is estimated at between $2.47
million and $5.15 million. Second, we use a mathematical programming approach to
estimate the value of water to farmers in the Ashburton catchment. This value is about
$0.62 million. We assess the methods and the results for implications in allocating
Ashburton water between irrigators and in-stream flows.

I. INTRODUCTION

Historically, water in New Zealand has been allocated by appropriation for beneficial uses.
These include primary and secondary industry, local authority public water supplies,
fisheries, wildlife habitat, and recreational use. Responsibility for water allocation has
resided with local catchment boards, who received authority from central government.

In a 1990 reorganisation and decentralisation of government functions, catchment boards
(along with a myriad of other local speciality boards) were consolidated into 14 regional
authorities. These authorities allocated water under the 1967 Water and Soil Conservation
Act and associated amendments. This enabled the authorities to set minimum stream
flows, establish priorities for utilisation of water, to specify the allocation between in-stream
and out-of-stream uses, to manage applications for abstractive water rights and
discharges into water, and to monitor and enforce abstractions and discharges.

specifically encourages the use of economic instruments to manage the use and quality
of natural resources, including water, and provides regional authorities with broader powers than previously existed. In particular, the Act replaces the concept of "water right" with "water permit" and promotes an integrated consent procedure for obtaining water permits. The Act places fixed time limits on water permits and allows transfers of permits to occur, if authorised by a regional management plan (Resource Management Act, 1991: Miller, 1990).

The Canterbury Regional Council seeks to complete a water management plan for the Ashburton River by 1992. Traditionally, the river has been the primary source of stockwater and irrigation water for farms in the catchment and much of the river has been committed to these uses. But the river also supports anadromous and freshwater fisheries, wildlife habitat, and recreation. Because of the conflicting interests between continued water abstraction and in-stream uses, the management plan must address the balance between consumption and nonconsumption of flows in the Ashburton River.

In the next section, we provide a brief overview of the water situation in the Ashburton catchment and identify issues for economic analysis that can contribute to the management plan. In the third section, we report on a mathematical programming approach that we used to estimate the economic value of water to farmers in the Ashburton. The fourth section reports on a contingent valuation approach that we used to estimate the economic value of in-stream flows of the Ashburton to residents of the Canterbury region. Finally, we discuss our results and raise issues related to allocating Ashburton water.

II. WATER AND THE ASHBURTON RIVER CATCHMENT

The Ashburton River flows from its origins in the Winterslaw and Moorhouse ranges in two branches that meet a short distance above the town of Ashburton. The South Branch of the river is the main branch. It flows through two gorges before emerging onto the Canterbury plains. Here, the width of the river bed increases and the river wanders over a stony shingle bed enroute to the sea. For most of the distance across the Canterbury plains, the river flows in a braided channel. Figure 1 shows the location of the Ashburton River.

High stream flows, caused by melt of the winter snow pack, occur from September through December. Low stream flows occur from mid-February to mid-April. At a point about midway between the river source and mouth, high stream flows run about 18 cubic metres per second and low stream flows run about 6 cubic metres per second. At the town of Ashburton, near the mouth of the river, high stream flows run about 40 cubic metres per second and low stream flows run about 10 cubic metres per second (Scarf, 1983).
Figure 1  Braided Rivers in Canterbury

Source O’Donnell and Moore (1983)
Water of the Ashburton River is used for municipal supplies and effluent disposal, stockwater and irrigation, wildlife and fisheries, and recreation. Municipal water supplies (primarily for the towns of Ashburton - population about 17,000 - and Methven - population about 1500) use about 0.3 cubic metres per second of river water. Authorised stockwater withdrawals account for nearly 10 cubic metres per second of flow, but actual withdrawals account for about 4 cubic metres per second of water. Authorised irrigation withdrawals total about 9.5 cubic metres per second. About 7 cubic metres per second of this amount could be diverted from the South Ashburton into the Rangitata Diversion Race syphon. The actual abstraction is about 3-4 cubic meters per second. When stream flows are insufficient to sustain that level of abstraction, the intake into the Rangitata Diversion Race is restricted to allow 1 to 2 cubic metres per second of flow to remain in the river (Scarf, 1983). Irrigation development from the Ashburton occurred rapidly during the 1970s and 1980s such that the water resources of the Ashburton have been severely taxed.

The Ashburton River has historically been an important recreational fishery, supporting primarily salmon, trout, whitebait, and flounder. Although the river attracts both local and nonlocal anglers, the fish resource has declined in the last ten years (Hughey, 1991). To flourish, migratory fish such as salmon require a continuous surface flow from headwaters to the mouth. This has been a problem in the Ashburton for two reasons: extended periods of artificially-induced low stream flows and periodic closure of the river mouth, particularly during the summer months. This occurs when tide and wave action move beach sediments into the mouth and when the river stream flows are insufficient to scour out this beach material.

An extensive wetland wildlife habitat is supported by the Ashburton, which provides for a large number of bird species, one of which - the black billed gull - is considered endangered. Habitat ranges from the headwater lakes and their surrounding wetlands to sections of braided river channel with large quantities of clean shingle and shingle islands. Recreation activities in addition to fishing include boating, swimming, bird-watching, and picnicking (O'Donnell and Moore, 1983).

Issues for Economic Analysis

For water allocation, the Canterbury Regional Council can base a management plan for the Ashburton River on the economic efficiency of the competing water uses, equity and distribution considerations, or pure ecological factors. In the past, allocation of the Ashburton has drawn on the latter two of these paradigms and the management plan has been based around specified minimum stream flows and development of regulations for sharing flows above the minimum. This has led to regulations that address technical issues of how and why water can be abstracted.
In the current climate that promotes economic efficiency in resource management, the Canterbury Regional Council may seek to place more emphasis on that criterion in the latest management plan. In that event, the Council will need two important pieces of information: the value of water to abstractive users (agriculture) and the value of in-stream river flows to regional residents. Once these values have been estimated, the Council could consider designing an allocation scheme that attempts, in part, to maximise the value of the river to regional residents.

The value of Ashburton River water to agriculture can be estimated by considering the changes in farm activities with and without the river water. Farmers may alter cropping patterns, livestock activities, or change the mix of inputs used, such as labour or irrigation systems. The difference in the returns to land, machinery, management, and other fixed investment costs with and without river water is the value of that water to agriculture.

The value of in-stream flows of the Ashburton River to regional residents can be estimated through a nonmarket valuation approach. Although a contingent valuation approach is appropriate to estimate the total value of in-stream flows, the value of certain uses, such as fishing, might be estimated with a travel cost approach.

Besides allocation of existing water in the Ashburton, the Regional Council may choose to decide if development projects to smooth the stream flows throughout the year are warranted. One option for development includes damming the river near its source in the high country and using the impounded water to regulate stream flows. The Council may also choose to decide whether technical improvements for abstractive users, which would decrease the amount of abstraction efficiency of these options would be useful to the Council; such an analysis would rely on estimates of the economic value of water for agriculture or in-stream flows.

III. ESTIMATING THE VALUE OF THE RIVER TO AGRICULTURE

Of the nearly 550,000 hectares in the Ashburton River catchment, nearly half is mountains and upland valleys. About half of that is unfarmable. Of the 280,000 hectares of plains, about 200,000 hectares are shallow soils with low holding capacity for water and low natural fertility; 50,000 hectares are free-draining cropping soils along the river banks, and the remaining 30,000 hectares are deep cropping soils with drainage problems. Annual rainfall in the region ranges from about 600 millimetres per year at the coast to about 1000 millimetres per year at the foothills. On average, soil moisture deficits can be expected to occur for at least 40 days per year (Ministry of Agriculture and Fisheries, 1984).

Three major irrigation schemes exist in the catchment, with about 55,000 hectares under irrigation. Technically, as much as another 120,000 hectares could be irrigated, but only about 20,000 hectares in close proximity to the river has been identified as a high priority, if water becomes available. Irrigation systems include border-dyke and spray.
In 1989, the Ashburton catchment housed about 1650 farms. The farming systems employed on these farms vary from predominantly sheep enterprises to all crop systems, where the entire farm is harvested every year. Crops grown include wheat, barley, peas, oats, grass seed, white clover, linseed and rapeseed. Fertiliser requirements are not high and crop yields with supplemental irrigation water average only roughly 30 percent higher than yields without water (Ministry of Agriculture and Fisheries, 1989).

To estimate the value of water to a farmer in the Ashburton River catchment we first specified four representative farms which adequately represent the agricultural use of water in the catchment. The primary representative farm is a mixed cropping farm of 200 hectares, with about 25 percent of land devoted to crop production. The major representative crops include spring sown cereals or peas and the stock rate is 16 stock units\(^1\) per hectare of pasture, with 25 percent cattle and 75 percent sheep. Other representative farms include a sheep and beef farm with no crops, an intensive cropping farm with a wide range of crops, such as cereals, peas, and small seeds, and a seasonal supply dairy farm.

We obtained variable costs for farm activities using 1989 data (Ministry of Agriculture and Fisheries, 1989) and by conducting a survey of small sample of farmers in the catchment. For product prices, we used an average of the reported prices of the past five years (Burtt and Fleming, 1990). We estimated production functions for consumptive water use and yield using agricultural engineering data (Heifer, 1982). Table 1 shows the prices, variable costs, yields, and consumptive water requirements for each crop and livestock activity.

Second, we modeled the expected response of farmers to changing water supplies by using mathematical programming. This has been a common approach to water valuation in the U.S. and Australia (for example, see Bernado, Whittlesey, Saxton, and Bassett, 1988; Hamilton, Whittlesey, and Halverson, 1989; Hall, Mallawaarachi, and Batterham, 1991; Jones, 1991).

For each representative farm, we developed a model to evaluate the profitability of several short-run management alternatives available to irrigators responding to water supply limits. Each model maximises net returns for a one year period and thus provides an estimate of the short-run returns to land, capital, and management. Constraints are the technical, economic and resource constraints imposed by the production setting. Supplemental irrigation, crop substitution, reallocation of water among crops, idling land, and the use of alternative irrigation labour practices are available to the irrigator responding to water supply reductions.

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\(^1\)The stock unit (SU) conversion relates the total yearly energy requirements of various classes of stock to the requirements of one 55 kilogram breeding ewe producing one lamb per annum. Stock units are conventionally calculated for the winter tally at 30 June (Fleming and Burtt, 1991).
By parametrically varying the supply of water available to the farmer, changes in the level of production activities and net margins are obtained. Table 2 shows the results for the representative mixed cropping farm. As water availability begins to decrease, the model suggests that the farmer initially reduces water to pasture, decreasing sheep and beef production. As water becomes increasingly scarce, the model shows that the farmer changes to winter sown cereals and reduces crop irrigation and selects those activities with the highest marginal value product of water use.

We note that the water constraint in the models represents the net irrigation requirements (that is, the net consumption required for irrigation) and not the amount of water delivered to the farm. This accounts for the fact that a certain percentage of water applied (that which is not consumed by the crops or evaporated) will return to the river.

The parametric variation also produces a derived demand curve for water. This relates the shadow price of water (which is the average opportunity cost of water across all farm activities) to the quantity of water available. As with all demand curves, this indicates the farmer's willingness-to-pay for water.

Third, we estimated an aggregate demand curve for irrigation water in the Ashburton catchment. To do this we determined the amount of hectares in the catchment accounted for by each representative farm. Then we weighted the individual demand curves for each of the representative farms by the associated percentage of total agricultural hectares in the catchment. Finally, we summed the weighted individual demand curves to obtain the aggregate demand curve. Figure 2 shows the aggregate demand curve.
<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Winter Wheat</th>
<th>Spring Wheat</th>
<th>Spring Barley</th>
<th>Field Peas</th>
<th>Ryegrass Seed</th>
<th>Pasture Stock*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Price</td>
<td>$/t</td>
<td>$236</td>
<td>$262</td>
<td>$184</td>
<td>$327</td>
<td>$1125</td>
<td>$63.93</td>
</tr>
<tr>
<td>Yield</td>
<td>t/ha</td>
<td>5.5</td>
<td>5.0</td>
<td>5.0</td>
<td>3.2</td>
<td>1.2</td>
<td>12</td>
</tr>
<tr>
<td>NIR^c</td>
<td>mm/ha</td>
<td>225</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>441</td>
</tr>
<tr>
<td>Variable Costs^d</td>
<td>$/ha</td>
<td>$823</td>
<td>$779</td>
<td>$621</td>
<td>$704</td>
<td>$724</td>
<td>$50</td>
</tr>
</tbody>
</table>

* Stock figures are per stock unit
^ Yield is stock units per hectare
^c NIR is net irrigation requirement for full irrigation
^d Variable costs include the cost of labour
Table 2  Effect of Reduced Water to the Representative Mixed Cropping Farm

<table>
<thead>
<tr>
<th>Reduction in Irrigation Water</th>
<th>0 %</th>
<th>20 %</th>
<th>40 %</th>
<th>60 %</th>
<th>80 %</th>
<th>100 %</th>
</tr>
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<tr>
<td>Net Return</td>
<td>$104596</td>
<td>$99645</td>
<td>$90371</td>
<td>$79106</td>
<td>$67841</td>
<td>$53787</td>
</tr>
<tr>
<td>Net Irrigation Water (mm)</td>
<td>81150</td>
<td>64920</td>
<td>48690</td>
<td>32460</td>
<td>16230</td>
<td>0</td>
</tr>
<tr>
<td>Gross Water (mm)</td>
<td>128809</td>
<td>103048</td>
<td>77286</td>
<td>51524</td>
<td>25762</td>
<td>0</td>
</tr>
<tr>
<td>Shadow Value</td>
<td>$0.00</td>
<td>$0.31</td>
<td>$0.69</td>
<td>$0.69</td>
<td>$0.69</td>
<td>$1.20</td>
</tr>
<tr>
<td>Net Irrigation Water ($/mm)</td>
<td>$0.00</td>
<td>$0.19</td>
<td>$0.44</td>
<td>$0.44</td>
<td>$0.44</td>
<td>$0.76</td>
</tr>
<tr>
<td>Winter Wheat (ha)</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>50 ha</td>
<td>50 ha</td>
<td>50 ha</td>
</tr>
<tr>
<td>Irrigation Percentage</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50 %</td>
<td>50 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Spring Wheat (ha)</td>
<td>50 ha</td>
<td>50 ha</td>
<td>50 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
</tr>
<tr>
<td>Irrigation Percentage</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Barley (ha)</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
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<tr>
<td>Irrigation Percentage</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pea Area (ha)</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
<td>0 ha</td>
</tr>
<tr>
<td>Irrigation Percentage</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pasture Area (ha)</td>
<td>150 ha</td>
<td>150 ha</td>
<td>150 ha</td>
<td>150 ha</td>
<td>150 ha</td>
<td>150 ha</td>
</tr>
<tr>
<td>Irrigation Percentage</td>
<td>100 %</td>
<td>75 %</td>
<td>65 %</td>
<td>40 %</td>
<td>16 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Total Stock Units (SU)</td>
<td>2406</td>
<td>2209</td>
<td>2073</td>
<td>1745</td>
<td>1417</td>
<td>1203</td>
</tr>
</tbody>
</table>
Figure 2  Aggregate Demand
By integrating the area under the demand curve, we estimate the irrigators' total consumer surplus for Ashburton water to be about $16.7 million. To estimate the value of water equivalent to an increase in the minimum stream flow by 50 percent requires estimating the equivalent loss of water to irrigation from increasing the in-stream flow. An increase in stream flow means that restrictions on abstractions would occur earlier and last longer than currently occurs. Therefore, to estimate the opportunity cost of increasing the minimum stream flow the following assumptions are made:

a) an increase in the minimum stream flow of 50 percent over the eight month period from September to May reduces the available water for irrigation by 61.6 million cubic meters. This equates to 38.8 million cubic meters of net irrigation water.

b) the reduced irrigation water will be distributed equally amongst all irrigators, including those on the Mayfield-Hinds and Valetta schemes.

To increase the minimum stream flow by 50 percent by reducing the available water for irrigation results in a net loss of $0.62 million to farmers in the Ashburton District.

The effect of the assumptions is to overestimate the amount of water unavailable for irrigation, and to underestimate the value of the water to some users, especially users whose only source of irrigation water is the Ashburton River, because at times restrictions will affect them more than others who have alternative sources.

III. ESTIMATING THE VALUE OF IN-STREAM FLOWS

As abstractions from the Ashburton increased, in-stream flows have decreased. As a consequence, environmental amenities associated with in-stream flows have become more scarce. In particular, changes have been observed in fish populations, recreation opportunities, and wetlands (Hughey, 1991). Implicit in economic scarcity is the notion that individuals are willing to pay for access to or use of a scarce resource based on the value they attribute to the resource. In addition, individuals might be willing to pay to provide the option for future use of the resource (possibly by future generations) or just to keep the resource in existence, regardless of whether the individuals will actually use the resource.

Individuals throughout New Zealand (and possibly even elsewhere) might have a positive value for the environmental amenities provided by the in-stream flows of the Ashburton. But the values of those who reside in the Canterbury region are of the most relevance to the Canterbury Regional Council since, in this case, the costs of any decisions on the Ashburton will be borne by those in the region. Therefore, we estimated the total economic value (use, option, and existence) of the in-stream flows of the Ashburton to residents of the Canterbury region.
To do so, we used a contingent valuation approach. The contingent valuation method uses economic theory and methods of survey research to elicit directly from consumers the values they place upon public goods. It circumvents the absence of markets by presenting consumers with hypothetical markets. One advantage of the contingent valuation method is that values other than use values may be obtained for a range of goods, including those not yet provided.

Although we relied on hypothetical rather than real market data (we acknowledge that this choice has been the source of some scepticism - see for example, Freeman, 1979), the hypothetical nature of the method made quantifying the benefits of an alternative in-stream flow level feasible.

We sought to establish the respondents’ tradeoffs between having a given amount of income or a 50 percent increase in the minimum in-stream flow. That is, our method paired alternative income levels with an increased in-stream flow such that the respondent is left with the same amount of utility.

Since its introduction by Davis in 1963, a substantial amount of both applied and theoretical research has developed and refined the method (for example, see Mitchell and Carson, 1989 or Cummings, Brookshire, and Schultz, 1986). The most popular approaches to the method are those based upon respondent bidding. In these approaches, individuals are asked to state the maximum amount he or she is willing to pay for the resource. The question can be asked open-ended or by an iterative bidding process. Open-ended question and iterative bidding approaches have been reported in many studies, including Brookshire, Randall and Stoll, 1980; Randall, Ives, and Eastman, 1974; and Walsh Loomis, and Gilman, 1984.

Bishop and Heberlein (1979) originally suggested that the open-ended approach does not reflect very accurately the way individuals make choices in markets. In a market, the price is stated and the person must indicate whether they would buy at that price or not. The iterative bidding process is closer to a market type of choice. But this procedure may find people allowing themselves to be bid up beyond their true willingness-to-pay. In addition, the starting point for the bidding game may introduce a bias into the responses.

An alternative elicitation method to either an open-ended question or an iterative bidding process is the dichotomous choice or take-it-or-leave-it approach. A large number of predetermined prices are chosen to bracket the expected willingness-to-pay amounts of most respondents. Each respondent is quoted one of the prices and asked if he or she would pay that amount, all-or-nothing, for the resource. Prices are randomly assigned to respondents so that each price has an equivalent subsample. Pioneered by Bishop and Heberlein (1979), other recent research on the dichotomous choice approach has been reported by Hanemann, 1984; Sellar, Chavas, and Stoll, 1986; Loomis, 1988; Cameron, 1988; Greer and Sheppard, 1990 and Loomis, 1990.
We used both the iterative bidding and the dichotomous choice methods of elicitation. We used a bracketed bidding procedure, which was designed to minimise both starting point and upward bidding bias. In this case, a respondent was given a very low initial price; the next price given was very high, such that a high-low bracket was established. Subsequent bidding narrowed the high-low range until the respondent settled on a final price.

A sample was randomly drawn from telephone books for the households from the Canterbury region. The sample was split such that of the 1000 completed surveys, 350 respondents were questioned with iterative bidding and the remainder questioned with the dichotomous choice. In addition, the sample was split by geographic location, with 650 respondents chosen from the Ashburton district and the remainder coming from elsewhere in the Canterbury region.

We conducted the survey via phone during June, using phone interviewers provided by Information Insight, Ltd. Although this approach precluded using pictures or other visual aids to describe alternative in-stream flows, it did allow a relatively quick collection of data and allowed us to use a bidding game approach. In addition to the willingness-to-pay questions, we collected information on household use of the river, reasons for valuing the river, and demographic data of each household. A sample copy of the survey is available from the authors on request.

Of the respondents in the Ashburton district, about 48 percent use the Ashburton River. Picnicking and swimming are the predominant activities, with 74 percent of river users partaking in these activities. About 36 percent of river users are salmon anglers. Other major activities include shooting, fishing other than for salmon, and bike riding. Of the households outside the Ashburton district, only about 9 percent use the Ashburton river.

Of the respondents in the Ashburton district who do not use the river, about 20 percent indicated they would use the river if the minimum stream flow was increased by 50 percent. Of the respondents outside the Ashburton district who do not use the river, about 13 percent indicated that they would use the river if stream flows increase. Basically, those activities directly involved with water (for example, salmon fishing) show a marked increase in expected usage if the stream flows increase. Activities not directly related to water (for example, shooting or bike riding) showed a minimal expected increase in usage.

In analysing the responses from the dichotomous choice elicitation, the exact magnitude of the respondent’s valuation is unknown; all that we know is whether that magnitude is greater or less than the price we offered. To estimate an equation that infers willingness-to-pay requires a function that translates the yes or no responses into a range of probabilities that vary with the offered prices. We chose the logit model: it is consistent...
with utility theory (Hanemann, 1984) and it has been recently used with success in other applications (for example, Sellar, Chavas, and Stoll, 1986; Cameron, 1988; and Greer and Sheppard, 1990).

We specified two logit models: one for respondents in the Ashburton district and one for respondents outside the district. We tested a variety of independent variables in each model: bid price, household income, an overall river use variable, a fishing variable, occupation. For the Ashburton district, the best model estimated is:

For the Ashburton district, the best model estimated is:

\[
\log\left(\frac{\text{Prob Yes}}{1 - \text{Prob Yes}}\right) = -0.3059 + 0.7536F - 0.00584P
\]

\[\begin{align*}
(1.34) & \quad (2.91) \quad (5.70)
\end{align*}\]

Pearson’s Chi square = .69

where \(t\) values are given in parenthesis

\(F\) indicates whether the respondent fishes in the river

\(P\) is the price offered

For the respondents outside the Ashburton district, the best model estimated is:

\[
\log\left(\frac{\text{Prob Yes}}{1 - \text{Prob Yes}}\right) = -0.4498 - 0.00877P
\]

\[\begin{align*}
(1.45) & \quad (4.08)
\end{align*}\]

Pearson’s Chi square = .64

Since the yes and no responses to the valuation question are mutually exclusive events, the probability of a yes is equal to \([1 - \text{prob no}]\) and \([\text{prob no}]\) is a cumulative distribution.

We calculated the expected value of willingness to pay by integrating the cumulative distribution function identified by each logit equation. Mathematically,

\[WTP = \int_0^\infty \left[1 - \frac{1}{1 + e^{-z}}\right] dP\]

where \(z\) represents a function of the independent variables, including the initial price offer
For the Ashburton model, the mean willingness-to-pay for households that fish or expect to fish the Ashburton River is about $161 per household per year, as calculated from zero dollars to infinity. For households in the Ashburton district who do not fish the river, the mean willingness-to-pay is about $94 per year. For households outside the Ashburton district, the mean willingness-to-pay is about $56 per household per year. The difference in means is accounted for by location, by fishing activity, and overall utility derived from the Ashburton River.

Duffield and Patterson (1991), argue that the overall mean (calculated by integrating from zero to infinity) is inconsistent with economic theory as the plausible upper limit to willingness-to-pay is not infinity but something less than income. An alternative method of estimation is obtained by truncating the range of integration at a fixed percentile of the estimated logit distribution, as suggested by Duffield and Petterson (1991) and Boyle and Bishop (1988). Truncating the mean at the 90 percentile (this is where the probability of the respondent being willing to pay the price offered is 0.1), results in mean willingness-to-pay of about $98 for Ashburton district residents, and about $44 for households outside the Ashburton district.

An alternative measure to the mean willingness-to-pay is the median willingness-to-pay. This is, where 50 percent of respondents are willing-to-pay the price offered. The median value for households who live in the Ashburton district and who fish or expect to fish the Ashburton River is about $77 per household per year. The median value for Ashburton nonanglers and non Ashburton district residents is $0.

In analysing the responses from the iterative bidding elicitation, we estimate the mean willingness-to-pay for households in the Ashburton district at about $84 per household per year. For those households outside the Ashburton district, we estimate the mean willingness-to-pay at about $63 per household per year. To account for outlier observations, we trimmed the top and bottom 10 percent of bid responses, as suggested by Mitchell and Carson (1990). We estimate the adjusted means to be about $65 per household per year in the Ashburton district and $47 per household per year outside the district.

We estimated the aggregate willingness-to-pay for an increase in Ashburton stream flows by multiplying the mean household willingness-to-pay times the number of households in and out of the Ashburton district.

In aggregating the results (see Table 3), assumptions have to be made regarding the households that declined to partake in the study. The 30 percent and 47 percent refusal rate for the Ashburton district and outside the district, respectively, is reasonably high for telephone surveys. The refusal rate for telephone surveys in New Zealand is normally between 20 to 30 percent (McGuinness, 1991). Mitchell and Carson (1989), suggest that refusals occur because of general, rather than survey specific reasons. Three scenarios have been considered:
1) The views and values expressed by the respondents are representative of both the Ashburton district and the Canterbury region.

2) The respondent population is not representative of the general population. Nonrespondents place zero value on the Ashburton River and are not willing to fund an increase in the minimum stream flow.

3) The refusals in the Ashburton district are representative of the level of refusals for general, rather than survey-specific reasons. The additional 17 percent of refusals outside the Ashburton district occur because those respondents have no interest and place zero value on the Ashburton River.

Accepting the assumptions in scenario 1, the willingness-to-pay values would be aggregated across all households. With scenarios 2 and 3, the appropriate number of zero bids could be added to the sample and the means and trimmed means recalculated.

The dichotomous choice results could be adjusted to reflect the response rate. Ideally, in this case, a record of the price offered to respondents should be made and then the price of those declining to participate added to the sample as no responses. Because this was not done by the interviewers, it is not possible to adjust the dichotomous choice results.
### Table 3: Aggregated Willingness-To-Pay

<table>
<thead>
<tr>
<th></th>
<th>Ashburton</th>
<th>Non Ashburton</th>
<th>Aggregated Value $ million per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anglers</td>
<td>Nonanglers</td>
<td>Ashburton Only</td>
</tr>
<tr>
<td>Households</td>
<td>2777</td>
<td>5794</td>
<td>139920</td>
</tr>
<tr>
<td><strong>Dichotomous Choice</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>$161.25</td>
<td>$94.48</td>
<td>$56.25</td>
</tr>
<tr>
<td>Truncated Mean*</td>
<td>$143.21</td>
<td>$76.44</td>
<td>$44.24</td>
</tr>
<tr>
<td>Median</td>
<td>$76.65</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td><strong>Iterative Bid</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>$109.66</td>
<td>$64.35</td>
<td>$62.85</td>
</tr>
<tr>
<td>Trimmed Mean* b</td>
<td>$84.97</td>
<td>$48.30</td>
<td>$44.87</td>
</tr>
<tr>
<td>Median</td>
<td>$60.00</td>
<td>$50.00</td>
<td>$30.00</td>
</tr>
<tr>
<td><strong>Scenario 2 Iterative Bidding</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>$77.13</td>
<td>$45.14</td>
<td>$33.38</td>
</tr>
<tr>
<td>Trimmed Mean* b</td>
<td>$50.25</td>
<td>$28.93</td>
<td>$15.43</td>
</tr>
<tr>
<td>Median</td>
<td>$30.00</td>
<td>$1.00</td>
<td>$0.00</td>
</tr>
<tr>
<td><strong>Scenario 3 Iterative Bidding</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>$109.66</td>
<td>$64.35</td>
<td>$52.06</td>
</tr>
<tr>
<td>Trimmed Mean* b</td>
<td>$84.97</td>
<td>$48.30</td>
<td>$33.11</td>
</tr>
<tr>
<td>Median</td>
<td>$60.00</td>
<td>$50.00</td>
<td>$10.00</td>
</tr>
</tbody>
</table>

* Mean truncated at the 90 percentile
b Mean trimmed at an alpha level of 0.1
Depending on the assumptions made, the aggregated value to the households of the Canterbury region for an increase in the minimum stream flow of the Ashburton River by 50 percent is between $0.09 million and $9.47 million per year. This reflects that nonmarket valuation is an imprecise science, and the assumptions made can markedly influence the final result. However, the alternative elicitation methods when using the same assumptions gave aggregated results of similar magnitude. The values derived appear to be consistent with possible actions of respondents. For example, anglers who will receive increased utility from increased stream flows do consider this in their valuation function. Yet use values are only a small portion of the total economic value.

Both the iterative bidding and the dichotomous choice approaches result in a skewed distribution of prices. This suggests that a small proportion of the population place a high value on in-stream flows. The problem is how to reflect this value when aggregating values. The median has appeal from a political viewpoint, in that it represents the largest amount that at least 50 percent of the population would be willing-to-pay. Therefore, if a vote was taken using the median price there would be a high probability of approval.

In this case, we favour the trimmed mean as it has the advantage in that it can adjust results for outliers yet still reflect the proportion of the population that does place a high value on the amenity.

Scenario 2 provides a lower bound on the economic value of increased in minimum stream flows. Scenario 3 is a reasonable assumption, given the poor response rate for a telephone survey. Therefore, the economic value of an increase in the minimum stream flow of the Ashburton River is between the values stated in scenario two and three. Accepting a trimmed mean with an alpha level of 0.1 to account for outliers, the economic value of increasing the minimum stream flows of the Ashburton River by 50 percent is between $2.47 million and $5.15 million per annum.

The majority of the economic value for the Ashburton River is outside the Ashburton district. This is because of the distribution of population. The majority of the Canterbury population resides in Christchurch city. No judgement has been made regarding if the values between the district and the region should be weighted. The assumption was made that individual respondents would make this judgement when responding.

Finally, the results have been calculated in a partial analysis framework. This is, the valuation of the Ashburton River has been undertaken in isolation. The value of the river could change if the river was valued in conjunction with all of Canterbury’s rivers.
IV. Economic Values and Allocating the Ashburton River Waters

There are advantages in being able to reallocate irrigation water. For example, the linear programming model suggests that currently dairy farmers have a higher valued use of water than other farming activities. If irrigation water was reallocated the advantages may be to the region and not necessary to all or existing farmers. That is, in reallocating, some farmers may receive less water than they are presently allocated.

Irrigation water could be reallocated by using a market system. The advantages include: the value of water is recognised distinctly and the reallocation is voluntary. A market system forces participants to consider the opportunity cost of water. It also provides information to do so in the form of the price of water. A market system can also help lower transaction costs.

Since the value of water is also significant for in-stream flows, reallocation on efficiency grounds would result in more water being left in-stream. If the reallocation was to occur under the present system of setting minimum stream flows, there would be a need to address how to allocate the remaining water available for irrigation. A market mechanism could be used, as opposed to some other allocation, such as, a proportional reduction which may result in differing economic impacts on existing irrigators.

It might be feasible to establish a market mechanism, such as a system of tradable permits between irrigators and those concerned with in-stream flows. However, the success of such an allocation system over time (as measured by the match between values and uses of the river) may depend on several issues besides the value of water to participants in a market.

First, the number and type of participants in the market must be such that the conditions for competitive markets are met. This will be difficult to do in the Ashburton catchment. Although there could be as many as a couple hundred farmers who would buy and sell water, it is not clear how many participants would act on behalf of the in-stream flows. It is also not clear how the in-stream participants would avoid the problems associated with the public goods nature of their values: collecting payments in a manner that would minimise free-riders might be a major obstacle.

Second, property rights will be important for the transition to a market mechanism. At one extreme, farmers initially may be granted permits at current water allocation; in-stream users would have to purchase permits from farmers to increase stream flows. At the other extreme, in-stream users could initially be granted permits for in-stream flow and farmers would face an initial reduction in available water. Although the initial allocation would likely fall somewhere between these two extremes, equity considerations (such as ability to pay) could affect the success of the market.
It is possible to reflect the value of in-stream flows within the tendering system. This can be achieved by the setting of a floor price. If the tender price does not exceed the floor price, the potential exists to leave the water in-stream. The success of this system depends on the proper administration of the floor price. This is, to ensure the floor price does not become the tender price.

There are potential benefits to abstractors by including in-stream users in the allocation process. If in-stream users have a higher value use of water, the returns to abstractors could be greater by transferring this water through a market system to in-stream users. Since the value of water in-stream is not due to water alone, but includes the habitat water provides, the abstractors could investigate the potential of alternative means of providing aquatic habitat (a precedent has occurred in New Zealand with Electricorp and the Waitaki River - see Palmer, 1990). By providing aquatic habitat, this would allow more water to be abstracted.

Further work is necessary, especially with institutional issues, to enable the in-stream values to be better reflected in market systems for water allocation. This includes how in-stream users and those concerned with protecting the intrinsic nature of free-flowing rivers may become more active in water markets.

REFERENCES


