Non-marketed Impacts of Ground Water Extraction

Paper presented to
Australian Agricultural and Resource Economics Society,
Adelaide, 23-25 January 2001.

Geoff Kerr, Lincoln University, New Zealand

Basil Sharp, University of Auckland, New Zealand

Paul White, Institute of Geological and Nuclear Sciences, New Zealand

Kerr@lincoln.ac.nz

Competition for the ground water resource is often intense, but little attention is sometimes paid to the values derived from extra-market uses of the resource. This paper presents the results of two valuation studies undertaken in New Zealand. One study assesses the values obtained by the community from management of ground water abstractions to preserve spring, river and wetland flows. The other study measures willingness to pay for domestic water quality. Results show that the community can place high values on these items, which need to be considered in developing water supply and management options.

KEY WORDS – Contingent valuation, water management

1. Introduction

Competition for the ground water resource is often intense, but little attention is sometimes paid to the values derived from extra-market uses of the resource. Christchurch City utilises an extremely high quality ground water resource for domestic, industrial and municipal uses. The aquifer is also used to irrigate agricultural land. The water requires no chemical treatment. However, as the city grows it is placing more pressure on the resource and must address options for potential future supply enhancements. In the four years to June 2000 the population of Christchurch City has grown at an average annual rate of 0.65% to reach 324,900 people. Annual water use is dependent upon weather conditions as well as population, but the city council pumps in the order of 50 million cubic metres per year (van Toor, pers. comm.). Average daily consumption in the city across all uses is 450 litres/person/day, with summer peaks of about 1000 litres/person/day. Between 1965 and 1995 the total take from the Christchurch aquifer, including agricultural and industrial uses has doubled to about 100 million cubic metres per annum. The city is faced with a number of options for future water supply.

One option (EXISTING) is to draw more heavily upon the aquifers beneath the city without recourse to other supplies. This option would entail eventual water rationing and would also reduce artesian flows with serious consequences for wetlands and rivers in and near the city. Another option (WAIMAKARIRI) is to supplement the city's water supply from the nearby Waimakariri River. The Waimakariri catchment hosts intensive agriculture and horticulture and carries a significant suspended sediment load, all of which have affected water quality to the point where it would need chemical treatment before it could enter the Christchurch supply. A third option (ELLESMERE) entails exploiting a presently unused ground water supply to the south of the city. This supplementary supply would not need chemical treatment.

This paper reports the results of studies undertaken to value the existing Christchurch ground water supply as well as the relative perceived benefits of the three major options for addressing the future supply problem.

2. Methods

Because alternative water supplies exist for Christchurch City, benefits of the existing ground water supply are derived using an opportunity cost approach. This requires estimation of the additional supply costs associated with each of the alternative supplies, plus a measure of the external benefits or costs associated with each of those supplies. Christchurch aquifers supply Christchurch City (approximately 120,000 households) as well as the Lyttelton harbour basin (2,344 domestic water supply connections) in the neighbouring Banks Peninsula District. Information on water use and supply costs to Banks Peninsula is not available, so analysis is restricted to Christchurch City.

Two methods were employed to obtain information for this study. Representatives of Christchurch City Council were interviewed to obtain estimates of the costs of each of the supply options. A postal survey of householders was utilised to measure the non-market impacts of changes in water supply.

Surveys of Christchurch householders aimed to assess the in-situ values associated with the ground water resource, particularly the maintenance of ground water quality and quantity. A total of 931 questionnaires were sent to a random selection of households. Christchurch City Council made the random selection from the Christchurch City database.

Two surveys were undertaken. One survey addressed willingness to pay for water quality by asking people to identify whether they were prepared to pay a premium for high quality ground water drawn from deep aquifers, rather than to meet Christchurch's water needs by drawing and treating water from the Waimakariri River (WAIMAKARIRI). The other survey 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 water use restrictions (ELLESMERE).

Only responses providing valid contingent valuation question responses were retained for analysis. Some responses were excluded because of item non-response, while others were excluded because the respondent refused to accept the scenario presented (e.g. the respondent may have expressed an opinion such as "Christchurch water shortages are a myth"), or protested about the payment mechanism (e.g. "should use electricity company sale proceeds to pay for this", or "rates are too high already").

3. Results

Opportunity cost of supply

Christchurch City Council estimates of the costs of establishing and operating alternative water supplies are reported in Table 2.

For Christchurch City Council the benefit obtained from access to the Christchurch ground water resource is $6.0 million per year, which is the cost saving from avoiding utilisation of the Ellesmere ground water resource, the next cheapest option. The Ellesmere resource is not fully utilised, so opportunity costs (now) are zero.

Clearly, if cost of supply is the only concern then Christchurch City should continue to meet its water needs by drawing further upon its existing supply. Incorporation of non-market effects could change this position, however. In particular, continuing to draw on the existing supply could reduce stream and wetland flows and would ultimately require some form of rationing to allocate the finite resource. Measurement of Christchurch residents' willingness to pay to avoid these outcomes was undertaken in the ELLESMERE option survey.

Abstracting water from the Waimakariri River to augment ground water supplies would have no detectable effect on flows in the Waimakariri River, so opportunity costs of using Waimakariri River water are assumed to be zero. However, Christchurch residents are extremely proud of their pristine water quality and are expected to derive diminished benefits from water use subsequent to supplementation by treated Waimakariri River water. The WAIMAKARIRI option survey addresses people's willingness to pay to avoid the costs associated with diminished water quality because of augmentation from the Waimakariri River.

Non-market impacts

(i) WAIMAKARIRI option

Models fitted to the Waimakariri Survey data are reported in Table 3. Maximum likelihood models were used throughout. Confidence intervals were obtained from 600 bootstrap iterations of the maximum likelihood procedure. The models and the data are graphically displayed in Figure 1.

The overall fit of the models is adequate, with signs as expected and with very similar point estimates of median WTP. The log-logistic and Weibull models are both highly skewed, resulting in higher estimates of the mean than the logistic models, with the log-logistic models yielding mean WTP of infinity. Men are willing to pay less than women are to avoid use of Waimakariri River water. Ownership of a business has an ambiguous effect on WTP, increasing WTP in the logistic model and decreasing WTP in the log-logistic model.

(ii) ELLESMERE option

Maximum likelihood models were fitted to the River Flows Survey data. Results are reported in Table 4. The data and the fitted models are illustrated in Figure 2. Again, the overall fit of the models is adequate, with signs as expected, although the Money coefficient in the Weibull model is not significant at the 95% confidence level. Bootstrap estimates of the median and mean could not be derived for the Weibull model because of convergence problems for some of the bootstrap samples. For these reasons, the Weibull model is not considered further. The river flows models have better goodness-of-fit than the quality models despite the lack of significance of non-money independent variables. The log-logistic model produced a point estimate of the mean more than 4 times that derived from the logistic model, although those differences were not statistically significant.

It is readily apparent from Figure 2 that the ELLESMERE Survey would have benefited from inclusion of higher money values in the dichotomous choice question. The highest value employed was $400. The mean and median are both in excess of this amount, however the results are representative of the unstructured responses obtained from a contingent valuation question response validation item completed by nearly all respondents. Responses uniformly indicated a strong commitment to environmental preservation and/or large benefits relative to costs of Option B. Many responses argued along the lines of “$4 per week is a very low cost to preserve the environment”. The perceived importance of these flows to Christchurch is exemplified by a recent statement of the chief executive of Christchurch and Canterbury Marketing, Darryl Park “People who come to the city expect to see punting, the gardens, and the rivers. If the rivers are drying up I’ll get out there with my garden hose and fill them up.” (Robson, 2000).

4. Discussion and Conclusions

Alternative supply

Over-utlilisation of the Christchurch ground water resource could lead to aquifer collapse or salt water intrusion, which would make the aquifer unusable for city supply. The aquifer could also become unusable because of chemical contamination. If the Christchurch ground water resource were not available the best available options for the city would be to source water from the Waimakariri River or Ellesmere ground water. It should be noted that these alternative water sources are not guaranteed to be available as utilisation requires consent from Environment Canterbury.

(i) Waimakariri River

Switching to supply from the Waimakariri River would impose an increased annual supply cost of $17.0 million (Table 2). It would also decrease the annual benefits of water consumption by $75.4 million relative to a ground water supply because of diminished water quality (Table 3, model B). Utilisation of Waimakariri River water would ensure that Christchurch river and wetland flows are maintained and avoid water rationing, yielding a further annual benefit of $63.2 million relative to further utilisation of the existing resource (Table 4,model F). Recalling that opportunity cost of the water itself is assumed to be zero, net costs of switching to the Waimakariri River supply are $29.2 million per year when Christchurch City river and wetland flows are threatened. Some commentators report that these flows are already threatened (Robson, 2000, 2001; Watson, 2000).

(ii) Ellesmere ground water

Switching to the Ellesmere ground water supply would not impose any quality changes on Christchurch water consumers and would maintain flows in Christchurch wetlands and rivers. Assuming zero impacts on alternative users (there is little present consumptive use of the resource) and no significant impacts on Ellesmere area surface water flows or dependent biological populations, the net benefit of switching to the Ellesmere supply is $57.2 million per year when abstraction is at a level that would reduce Christchurch City surface water flows. This figure derives from the $63.2 million benefits derived from maintenance of Christchurch City river and wetland flows, minus the $6.0 million of additional supply costs incurred by switching to this supply.

Supply augmentation

Supply augmentation is the utilisation of alternative water sources to supplement the existing Christchurch City ground water supply. The existing resource would still be utilised, but would not be the only supply for Christchurch City. Augmentation avoids impacts on Christchurch river and wetland flows and also avoids the potential of water use restrictions. Consequently, augmentation costs are simply the additional supply costs incurred, the opportunity costs of the water, and the costs associated with any diminution of water quality in Christchurch. Augmentation schemes can be smaller than schemes which meet all of the city's water needs and so cost less. Eric van Toor of the Christchurch City Council has done some initial costing of these schemes. These costings are extremely rough, but provide a basis from which to make an initial investigation of the options.

(i) Waimakariri River

The Waimakariri River presents a number of opportunities to enhance the existing supply. These include: (I) direct recharge of Christchurch rivers, (ii) recharge of Christchurch rivers through ground water augmentation, and (iii) reticulation of treated Waimakariri River water to households in the north-west part of the city. The first option is probably unsatisfactory because it would require continual augmentation and times of low flow in Christchurch rivers are likely to occur at the same time as low flows in the Waimakariri River preclude further abstraction because of low flow restrictions set by the regional council. Consequently, direct recharge of Christchurch rivers is not considered here. Ground water augmentation can be achieved for an estimated cost in the order of $1.5 million per annum.

Using Waimakariri River water to replace the reticulated supply in part of the city would entail large capital costs and would also reduce water quality for those residents who are served by the new water source. Supply costs ($15 million per year), opportunity costs (assumed to be zero), and water quality costs ($25 million per year) lead to a total annual cost of augmentation of the reticulated supply from the Waimakariri River in the order of $40 million.

(ii) *Ellesmere ground water*

There has been little investigation of the supply costs for augmentation from Ellesmere ground water. van Toor (pers. comm.) believes that supply costs are likely to be of the same order as costs for augmentation from the Waimakariri River. While the Ellesmere water does not require treatment, utilising it would require an extended well field and a long pipeline, so capital costs would be higher than for augmentation from the Waimakariri River. A rough estimate of supply costs is $15 million per year. Because opportunity costs are assumed to be zero, and water quality costs are also zero, total annual cost of augmentation from the Ellesmere ground water supply is $15 million.

(ii) *Further abstraction from the existing source*

The costs associated with this option are those incurred because of diminished stream flows and the need for water use restrictions in Christchurch City. These costs are estimated to be $63.2 million per year, with a 95% confidence interval of $49 million - $134 million based on model F.

Policy implications

The implications of all the policies identified above are summarised in Table 5. Immediate replacement of the existing supply with either the Waimakariri River source or the Ellesmere source cannot be justified because of the additional costs involved. However, when levels of extraction from the existing source increase to the point where they threaten Christchurch City artesian flows the move to utilisation of the Ellesmere resource yields net benefits. This conclusion is based on the presumption that there are no environmental costs from utilisation of the Ellesmere ground water resource, so it is only tentative at this stage.

The response rates to the two surveys indicate the potential for sample self-selection biases to occur. However, the qualitative results reported in Table 5 are unchanged when columns B and C are modified on the assumption that all non-respondents place zero value on the amenities measured.

The large costs associated with diminished water quality indicate that future domestic supply from the Waimakariri River would not yield positive net benefits, even if the water could be delivered for free. This result arises because people value high quality water more than they value maintenance of river flows and avoidance of water use restrictions. However, the results are not significantly different, so caution is necessary. The lower bound estimate of willingness to pay to avoid low flows and water use restrictions is $49 million per year. This exceeds the cost of sourcing all of Christchurch's water from the Ellesmere ground water supply and indicates that augmentation from that supply would be preferable to further draw down of the Christchurch aquifers.

References

Robson, S. (2000) Avon River may start to dry up. *The Christchurch Press 11/12/2000.*

Robson, S. (2001) Keeping river flows may cost $10m. *The Christchurch Press 10/01/2001.*

Watson, L. (2000) Christchurch water crisis predicted. *The Christchurch Press 15/12/2000.*

Van Toor, E. Water planning Engineer, Christchurch City Council. Personal communication.

Table 1: Contingent valuation survey response rates

	WAIMAKARIRI option survey	ELLESMERE option survey
Number Delivered	463	471
Number Returned	180	171
% Returned	39%	36%
Number Useable	126	130
% Useable	27%	28%

Table 2: Annual costs of alternative water sources

Supply Option	**Operating costs**	**Capital costs**	**Total annual cost**
Existing scheme	$5.5 m	$15 m	$20.5 m
Waimakariri	$7.5 m	$30 m	$37.5 m
Ellesmere	$6.5 m	$20 m	$26.5 m

Table 3: Waimakariri option models

(t-scores in parentheses)	**Model A Logistic**	**Model B Logistic**	**Model C Log-logistic**	**Model D Log-logistic**	**Model E Weibull**
Constant	1.815	2.773	5.845	7.090	0.7514
	(5.07)	(4.58)	(4.10)	(4.45)	(3.55)
Money	-0.00307	-0.00339	-0.9179	-0.9887	0.001047
	(-3.30)	(-3.43)	(-3.60)	(-3.73)	(2.55)
Male		-1.448		-1.4615	
		(-2.62)		(-2.65)	
Own Business		-0.994		1.0028	
		(-1.78)		(1.79)	
LL_R	-75.382	-75.382	-75.382	-75.382	-75.382
LL_U	-69.630	-64.953	-67.777	-63.027	-67.929
McFadden's R^2	0.08	0.14	0.10	0.16	0.10
Median (per annum)	$591	$590	$583	$590	$586
(95% conf. interval)	($425-$1049)	($425-$995)	($353-$1841)	($358-$1885)	($377-$1678)
Mean (per annum)	$640	$628	∞	∞	$1135
(95% conf. interval)	($445-$1204)	($440-$1079)	($999-∞)	($828-∞)	($534-$12945)
Aggregate value (using the mean)	$76.8 million	$75.4 million	∞	∞	$136 million

LL_R = Restricted Log-likelihood (constant only model)

LL_U = Unrestricted Log-likelihood

Table 4: Ellesmere option models

(t-scores in parentheses)	**Model F** **Logistic**	**Model G** **Log-logistic**	**Model H** **Weibull**
Constant	3.697	9.198	1.287
	(5.75)	(3.65)	(2.56)
Money	-0.007062	-1.377	0.001057
	(-3.23)	(-2.97)	(1.72)
LL_R	-40.020	-40.020	-40.020
LL_U	-34.444	-33.311	-33.349
McFadden's R^2	0.14	0.17	0.17
Median (per annum)	$524	$795	$711
(95% confidence interval)	($403-$1107)	($445-$4190)	
Mean (per annum)	$527	$2,386	$875
(95% confidence interval)	($406-$1115)	($609-∞)	
Aggregate value (using the mean)	$63.2 million	$286 million	$105 million

LL_R = Restricted Log-likelihood (constant only model)

LL_U = Unrestricted Log-likelihood

Table 5: Policy options

Policy context	Alternative water source	(A) Change in supply cost ($m)	(B) Reduction in water quality benefits ($m)	(C) Change in benefits from stream flow reductions and rationing ($m)	Net benefit ($m) =C-A-B
Other sources replace existing supply (relative to current use of the existing supply)	Waimakariri	17.0	75.4	0	-92.4
	Ellesmere	6.0	0	0	-6.0
Other sources replace existing supply (relative to expanded use of the existing supply)	Waimakariri	17.0	75.4	63.2	-29.2
	Ellesmere	6.0	0	63.2	57.2
Other sources augment the existing supply, which is used at its current level	Waimakariri ground water recharge	1.5	0	0	-1.5
	Waimakariri reticulation	15	25	0	-40
	Ellesmere	15	0	0	-15
	No augmentation	0	0	-63.2	-63.2

Figure 1: Waimakariri models

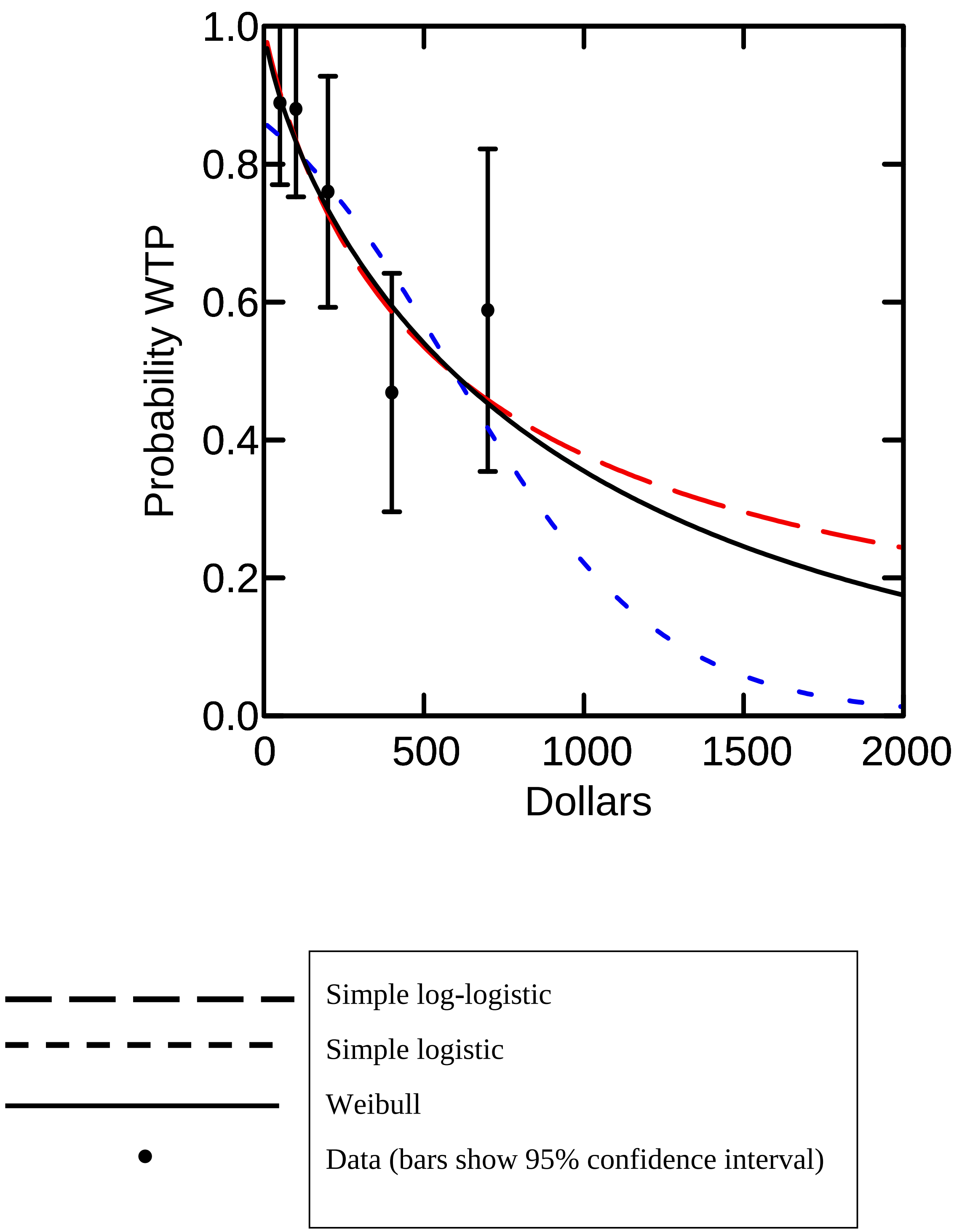
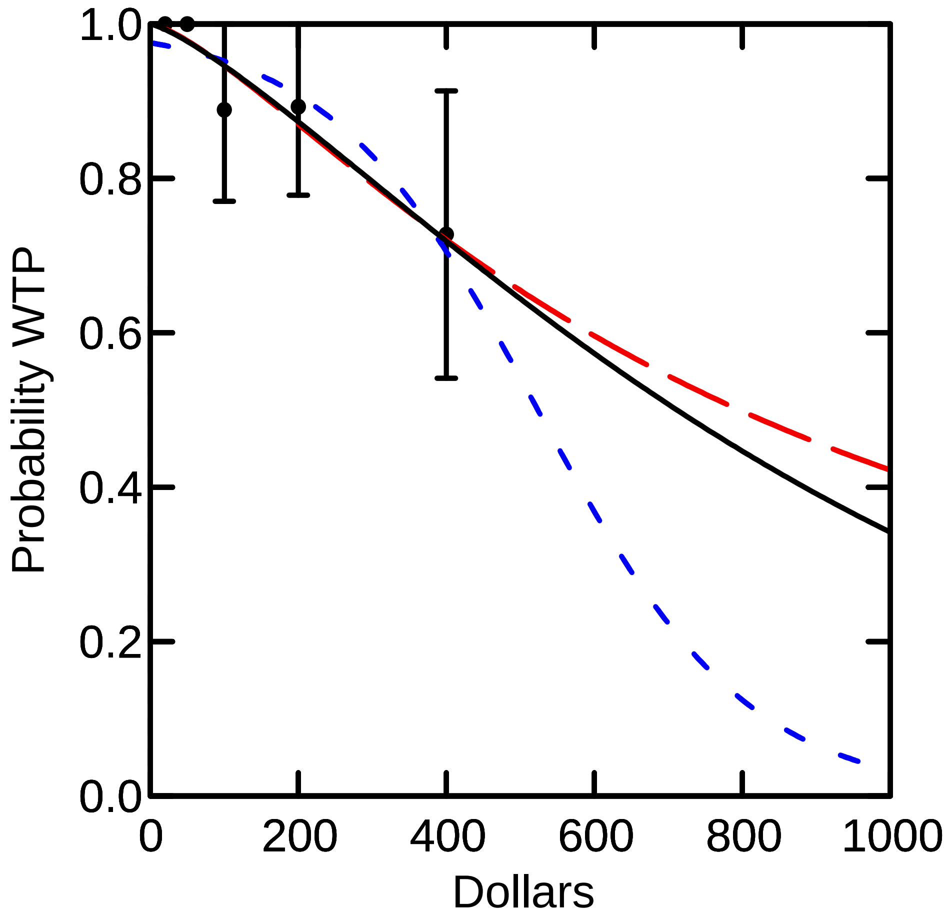


Figure 2: Ellesmere models



Weibull model

Log-logistic model

Logistic model

Data (bars show 95% confidence interval)