AUGMENTATION OF URBAN WATER BY ANTARCTIC ICEBERGS

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ABSTRACT

The indigenous water resources of the south west of Australia are under increasing stress. One solution to this problem may be water importation in the form of Antarctic icebergs. This possibility is discussed in this paper. To be cost effective, an iceberg water scheme needs to provide water at less than A$ 0.14 kl^{-1} from the reservoir, and at yearly volumes of the order of 10^8 m^3. A number of analyses of the selection and towing of icebergs have been given in the past but the offshore processing of icebergs has been somewhat neglected. A conceptual solution to the processing problem is given in this paper and cost estimates for the acquisition and processing of icebergs are given. Our analysis indicates that iceberg water may be a feasible and economical urban water augmentation system for yearly volumes greater than 2×10^8 m^3. Further work on iceberg water augmentation is warranted.

1 INTRODUCTION

The water resources, especially for urban use, in the south western region of the Australian continent are under increasing stress and augmentation alternatives and demand management strategies have been examined closely during the last decade. Serious interest in the use of icebergs for water has been shown since 1973. This paper examines the process of water supply augmentation by icebergs and focuses on the largely undiscussed problem of iceberg processing. A conceptual solution to the problem of processing icebergs in the coastal zone is offered and, as the cost of water is the most important basis of comparing various methods of augmentation, indicative iceberg water costs are given.

2 URBAN WATER COSTS

A water resources study for Metropolitan Adelaide in 1978 (Engineering and Water Supply Department, 1978) included indicative costs of water supply augmentation. Table 1 has been adapted from the report of the study.

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Method	Indicative cost cents per kilolitre
Present cost including treatment	29
Mount Lofty Ranges evaporation control	36
Adelaide groundwater basin/surface supply	37 - 42
River Murray/Mount Lofty Ranges storage	40
River Murray - direct pumping	42
Mount Lofty Ranges - new storage	51
Iceberg (cost excludes harvesting uncertainties)	71
Desalination of seawater	78
Sewage effluent re-use	78
River Murray - flood cropping	93
Water tankering	101
Urban runoff	101
Rainwater tanks	144

Table 1. Cost of water supplied to Adelaide by various methods (June 1977 A$ cost levels)

The costs in Table 1 include treatment and reticulation costs.

Cost analyses have also been carried out for Perth where particular emphasis has been placed on the utilization of extensive groundwater resources present in that region of Western Australia (Metropolitan Water Supply, Sewerage and Drainage Board, 1981). For urban Perth, the ex-reservoir price of iceberg water needs to be about A$0.14 kl^{-1} for iceberg importation to be competitive with other augmentation methods.

An alternative (or complementary) strategy to water supply augmentation is to exercise demand management and improve the efficiency of water use. Demand management tends to gain recognition by water supply authorities only in times of severe drought.

Management options considered in the Adelaide study included

- Changing community attitudes to water use. (One major area of water wastage in Australia is the watering of urban gardens. Half the annual water use in some cities is for the maintenance of exotic gardens and lawns.)
- Alternative pricing. (Higher water prices could be charged during the hot dry summer.)
- Technical changes. (Toilets could be fitted with reduced discharge flushing devices.)

It is against this background of water augmentation and management alternatives that consideration should be given to Antarctic icebergs as a source of urban water.

Figure 1. Tabular Antarctic iceberg 1200 m by 400 m by 27 m freeboard. (R. Wills)

3 ICEBERG TECHNOLOGY BASICS

There are three distinct phases to the business of getting urban water from icebergs

- iceberg selection
- iceberg towing
- iceberg processing

In this paper, we shall refer to iceberg selection and towing as iceberg "acquisition".

3.1 Iceberg Acquisition

The papers which first discussed the use of Antarctic icebergs as a source of water (Weeks and Campbell, 1973 and Hult and Ostrander, 1973) were mostly concerned with iceberg acquisition. The proceedings of two subsequent international conferences on icebergs (Husseiny, 1977 and International Glaciological Society, 1980) contain further detail on the characteristics of icebergs and methods of propulsion and protection.

At present, the general consensus seems to be that an iceberg of suitable size (Fig. 1) can be transported to southern areas of continents in the Southern Hemisphere, but protection from melting and break-up will be necessary for transportation to the Northern Hemisphere. A review paper by Schwerdtfeger (1979) gives a good overview of the acquisition phase.

3.2 Iceberg Processing

After an iceberg has been delivered, it then remains to turn it into water for urban reticulation. This is not a trivial task. When delivered, an iceberg of an economic size is likely to be of the order of 100 m draft and will ground on the continental shelf several kilometers from shore. The iceberg will melt at its base and sides at a rate of between 1 and 3 m per day (Russell-Head, 1980). The energy required to process ice by various techniques has been discussed by Weeks and Mellor (1978). DeMarle's (1980) paper is another of the relatively few to deal in some detail with the processing phase. In it, he discusses an iceberg processing scheme for Saldanha Bay in South Africa and provides subjective target estimates for the costs of implementing the scheme.

Our approach was to devise a harvesting scheme based as much as possible on existing technology, and then to cost the processing component of iceberg water using the best estimates applicable to that known technology. The total augmentation cost of iceberg water is the sum of the acquisition and processing costs. We were particularly interested to find out the relationship between iceberg size and total augmentation cost.

3.2.1 Processing techniques

The main aim of the processing phase is to land a high proportion of the iceberg mass as fresh water. Unless the iceberg is totally enclosed with an impermeable wrapping, sea water will melt ice from the berg and mix with the melt water. An important function of the harvesting scheme then is to separate melting ice from sea water.

Some of the proposed (Husseiny, 1977) processing methods are

- Skirt collection
- Mechanical cutting
  - saws
  - high pressure jets
  - dredging
  - blasting
- Electrothermal cutting
  - heated cables
  - laser beam

and these will now be briefly discussed.

Skirt entrapment of fresh water does not seem feasible (Huppert and Turner, 1978) due to the substantial mixing of saline and melt water during the iceberg melting process.

Mechanical methods of harvesting are efficient from an energy expenditure viewpoint but all suffer from the problems of the transfer of mechanical power to the cutting face. It would be undesirable to instal large equipment on an iceberg to be processed and therefore dredging and high pressure jets are not favoured methods. Blasting is energetically efficient but control and secondary processing of the blasted ice would be difficult. Sawing appears to be the most attractive of the mechanical methods. A type of bladeless chain saw that cut over the entire width of the iceberg could probably be developed.

Electrothermal methods are not as energetically efficient as mechanical ones but they do possess the ability to easily transfer power to the cutting face. Laser methods offer the possibility of transferring energy without physical contact with the iceberg, however their overall thermal efficiency is only about 10%. Cutting with heated cables is probably the processing method easiest to implement and is the one we have adopted for costing purposes in this paper.

4 ICEBERG WATER COSTS

The cost of iceberg water is the sum of the acquisition and processing costs. We shall use the results of other studies for an estimation of acquisition costs. A processing method will be described and costed.

4.1 Acquisition Costs

Weeks and Campbell (1973) have provided costs of towed ice delivered to offshore processing sites. Table 2, applying to Western Australia, was derived from their analysis.

Initial volume 10^6 m^3	Delivered volume 10^6 m^3	1972 cost cents m^{-1}	1982 cost cents m^{-1}
1200	840	0.3	2.1
600	390	0.5	3.5
300	180	0.8	5.6
150	75	1.5	10.5

Table 2. Cost in A$ of delivering icebergs to Western Australia.

The 1972 costs have been increased by a factor of seven to update to 1982 A$. Allowances have been made for inflation, increases in oil prices and, on the other hand, improvements in towing technology.

4.2 Processing Costs

The processing system that is costed here contains six functional elements:

iceberg + MOOR + SLICE + TUG + LOCK + POND = POWER + water

The moored iceberg is cut by heated electrical cables into slices which are towed into a lock. The lock serves to separate the ice from sea water and to pass it into a freshwater cooling pond used by a power station. The lower condenser temperature provided by the ice melting in the pond increases the thermal efficiency of the power station and thus provides some offset to the other costs. Table 3 provides a breakdown of the indicative costs.

The unit costs of mooring, slicing and tugging are independent of iceberg volume as is the return from power generation. The largest costs are for the provision of a lock and pond. The unit cost of locking is proportional to the throughput of ice and so it could be reduced if more than one iceberg per year were processed. The unit cost of providing a pond to accommodate the processed ice reduces with increasing volume.

Further discussion on the details of the cutting process, block sizes, locking and ponding schemes, as well as a consideration of the environmental impact of the presence of a large low-temperature heat sink, is to be the subject of a further paper.

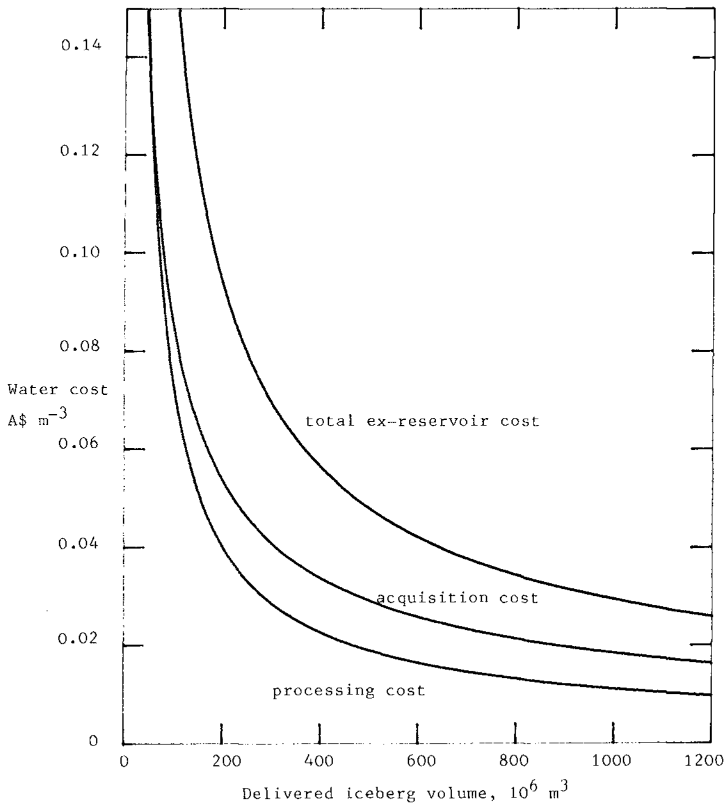

Figure 2. Ex-reservoir iceberg water costs for Western Australia.

Iceberg size 10^6 m^3	Moor	Slice	Tug	COSTS (cents kl^{-1}) Lock	Pond	Power	Water
1000	0.01	0.17	0.22	0.57	0.53	-0.45	1.0
500	0.01	0.17	0.22	1.13	0.76	-0.45	1.8
200	0.01	0.17	0.22	2.84	1.20	-0.45	4.0
100	0.01	0.17	0.22	5.67	1.69	-0.45	7.3

Table 3. Indicative costs of iceberg processing (1982 A$ prices).

4.3 Total Costs

The sum of the harvesting and processing costs are shown in Figure 2. For a yearly augmentation demand of 2 x 10^8 m^3 or more, the indicative ex-reservoir unit cost is less than 14 cents kl^{-1}.

5 CONCLUSIONS

A generalized estimate of an iceberg water augmentation scheme for the Perth region of Western Australia has been given in this paper. The costs of processing icebergs through the coastal zone appear to be about half the cost of bringing an iceberg to the offshore site. There are economies of scale applicable to both the acquisition and processing phases of iceberg water augmentation and it seems that the augmentation demand perceived by the water authorities in south western Australia may be economically fulfilled by iceberg water.

At this stage it seems that a system can be implemented using fairly conventional technology and that the cost may not be prohibitive. The use of icebergs as a supply of urban water is a concept that warrants further serious enquiry.

6 ACKNOWLEDGEMENTS

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Observing Ship Motions of Ship leaving Richards Bay Harbour

PART V

Ship Motions

Observed Ship Motions, Ship leaving Richards Bay Harbour