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Urban Capacity Sharing - An Innovative Property Right for Maturing Water Economies

Norman J. Dudley

NORMAN J. DUDLEY*

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ABSTRACT

Researchers have previously proposed an innovative property right structure for sharing reservoir catchment water between groups of users and, in the case of irrigation farmers, between individual users. The concept is being implemented for sharing between groups. An urban version for individual consumers—urban capacity sharing—has a number of attractive features as an alternative property rights structure. Its introduction would create decentralized demand management with consumers taking the opportunity cost of water into account. It would be as if each user had their own small reservoir on their own small stream. Urban capacity sharing would provide a sound basis for achieving high levels of short and long run economic efficiency of water use. Its introduction into urban water economies would be easier and more beneficial if completed early in the water economy maturing process.

INTRODUCTION

Many cities throughout the world face increasing demand for water over time and increasing marginal costs of obtaining good quality water.[1] This common phenomenon has been referred to as the "maturing water economy" in Australia;[2] as a movement of the water economy into a "mature phase" in the Western United States;[3] and more generally, as increasing water scarcity.[4]

In many places the early years of the immature water economy were characterized by residents collecting rain water from their roofs—an intermittent flow resource—and diverting it into private storage containers.

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*Dr. Dudley is currently University Fellow, Centre for Water Policy Research, University of New England, New South Wales, on secondment from the School of Economics, University of New South Wales, New South Wales, where this work was carried out. The author gratefully acknowledges comments from anonymous referees, with the usual caveat.

1. The increasing costs result from obtaining the extra water either from new sources or by displacing traditional users, or both.

2. W. Watson & R. Rose, Irrigation Issues for the Eighties: Focusing on Efficiency and Equity in the Management of Agricultural Water Supplies (Feb. 12-14, 1980) (Presented at 24th Annual Conference, Australian Agricultural Economics Society, Adelaide).

3. Young, *Local and Regional Economic Impacts*, in Water Scarcity: Impacts in Western Agriculture (E. Englebert & A. Scheuring eds. 1984).

4. Williams & Suh, *The Demand for Water by Customer Class*, 18 Applied Econ. 1275 (1986).

The resulting water supply had both flow and stock components. Each household became skilled in managing its demand so as to match it with supplies from its flow-stock resource according to its individual water consumption reliability or security requirements. They became tuned to their uncertain water-supply environments. These skills were largely lost in the later phase of the immature water economy as big headworks storages on rivers, and associated distribution and reticulation systems, gave users open access to an abundant common property flow-stock water resource.[5]

As demand grew, new facilities were added to maintain open access. But, as maturity approached, water shortages began to appear in some years, requiring the temporary loss of open access due to the implementation of centrally-imposed restrictions, such as garden sprinkler bans, on water use. Now as maturity increases and the interruptions to open access become more frequent, more appeals for demand management are made. But how is demand to be managed? Many economists favor moving away from common property-quantitative restriction demand management to water-unit pricing designed to limit scarce water to those who value it most in the sense that they have the greatest willingness (and ability) to pay for it.[6] Dales writes that:

> economists tend to assume implicitly that it is impossible to own water and therefore seek to devise artificial price systems that are identical to what prices "would be" if ownership were possible. . . . The purpose of this [Dales'] article is to suggest that there are very considerable advantages to attacking our water problems by means of a system of explicit ownership rather than by a system of shadow prices.[7]

Whereas Dales' primary concern is the increasing difficulty of maintaining water quality, the purpose of this article is to introduce a property rights structure for stream-based urban water supply systems which will achieve the advantages of such ownership when water quantity becomes increasingly scarce. Although a thorough review of pricing proposals is beyond the scope of this article, four main areas of relevance to water pricing are readily identifiable in the theoretical literature. They are:

a) peak-load pricing with known cycles of demand;[8]

5. Whether or not historical commons were subjected to open access, and became non-property resources, need not concern us here. *See* Ciriacy-Wantrup, *"Common Property" as a Concept in Natural Resources Policy*, 15 Nat. Res. J. 713 (1975). *See also* Quiggin, *Common Property, Private Property and Regulation: The Case of Dryland Salinity*, 30 Aust. J. Agric. Econ. 103 (1986).

6. For advantages of marginal opportunity cost pricing of water, see Hank & Davis, *Potential for Marginal Cost Pricing in Water Resource Management*, 9 Water Res. Research 808 (1973).

7. Dales, *Land, Water and Ownership*, 1 Canadian J. Econ. 791, 792 (1968).

8. Riley & Scherer, *Optimal Water Pricing and Storage With Cyclical Supply and Demand*, 15 Water Res. Research 233 (1979).

b) pricing and investment under uncertain demand;[9]
c) pricing under uncertain supply as well as uncertain demand;[10] and
d) congestion, which exists when the value of the supply service to users falls as the number of users increase.[11]

A closely related area is planning the best mix of price and quantity rationing when a planning authority faces uncertainty about the costs and benefits of producing a good.[12]

A premise of this article is that there are sufficient practical problems associated with reliance on water pricing for allocating urban water in a mature water economy to make examination of alternatives worthwhile. These problems are expanded by the uncertainty of urban water supplies and demands, and the interdependence of these supplies and demands between time periods. There are problems with estimating water demand functions;[13] problems with implementing appropriate prices for congestion-prone resources,[14] such as water in a mature water economy; problems with using prices without support from quantitative restrictions on consumption to achieve efficient allocation in the usual case of seasonal patterns in supply and demand;[15] problems with the feasibility of continuously variable prices under uncertain demand;[16] problems with the highly

9. For a recent discussion, see Hamlen & Jen, *An Alternative Model of Interruptible Service Pricing and Rationing*, 49 S. Econ. J. 1108 (1983). For earlier seminal discussions, see Brown & Johnson, *Public Utility Pricing and Output Under Risk*, 59 Am. Econ. Rev. 119 (1969); Meyer, *Monopoly Pricing and Capacity Choice Under Uncertainty*, 65 Am. Econ. Rev. 326 (1975).

10. *See* Chao, *Peak Load Pricing and Capacity Planning with Demand and Supply Uncertainty*, 14 Bell J. Econ. 170 (1983). For consumer behavior under supply uncertainty, see Turnovsky, *A Model of Consumer Behaviour Under Conditions of Uncertainty in Supply*, 12 Int'l Econ. Rev. 39 (1971). For firm response to input supply uncertainty, see Turnbull, *The Theory of the Firm Under the Threat of Input Supply Disruption*, 49 S. Econ. J. 807 (1984).

11. Mills, *Ownership Arrangements and Congestion-Prone Facilities*, 71 Am. Econ. Rev. 493 (1981); Tybout, *Quasi-Public Goods: Pricing the Commons*, in Economic Modeling for Water Policy Evaluation (R. Thrall, E. Heady, T. Schad, A. Schwartz & R. Thompson eds. 1976).

12. *See* Freixas, *Monopolistic Behaviour, Prices and Quantities*, 47 Rev. Econ. Stud. 747 (1980); Weitzman, *Free Access and Private Ownership as Alternative Systems for Managing Common Property*, 8 J. Econ. Theory 225 (1974). For optimal fixed pricing and variable seasonal quantitative rationing when demand is deterministic and each season's water supply is known but future season's supplies are stochastic, see Fakhraei, Narayanan & Hughes, *Price Rigidity and Quantity Rationing Rules Under Stochastic Water Supply*, 20 Water Res. Research 664 (1984).

13. Chicoine, Deller & Ramamurthy, *Water Demand Estimation Under Block Rate Pricing: A Simultaneous Equation Approach*, 6 Water Res. Research 859 (1986). *See generally*, Howe, *The Impact of Price on Residential Water Demand: Some New Insights*, 4 Water Res. Research 713 (1982); Shefter, *Increasing Block Rate Tariffs as Faulty Transmitters of Marginal Willingness to Pay*, 63 Land Econ. 21 (1978); Martin & Thomas, *Policy Relevance in Studies of Urban Water Demand*, 22 Water Res. Research 1735 (1986); D. Gallagher, J. Boland, P. LePlastrier & D. Howell, Methods for Forecasting Urban Water Demands (1981) (Aust. Water Res. Council Tech. Paper 59) (available from Aust. Gov. Publishing Service, Canberra, A.C.T. 2601); Deller, Chicoine & Ramamurthy, *Instrumental Variables Approach to Rural Water Service Demand*, 53 S. Econ. J. 333 (1986); Williams & Suh, *supra* note 4.

14. Mills, *supra* note 11, at 493.

15. Manning & Gallagher, *Optimal Water Pricing and Storage: The Effect of Discounting*, 18 Water Res. Research 65 (1982).

16. Hamlen & Jen, *supra* note 9.

fluctuating quantitative restrictions required to supplement prices under both uncertainty and seasonality of supply and demand, especially with inelastic demand;[17] problems with tailoring supply reliabilities to individual users to satisfy their different preferences when quantity rationing is used to supplement water pricing;[18] problems of equity between established users and new-development users;[19] problems in distinguishing between short- and long-run effects of price changes;[20] and problems with adequate public investment criteria unless marginal cost pricing is strictly followed.[21]

An alternative to rationing by price and quantity restrictions in times of shortage is to allocate saleable coupons to ration water in storage during droughts.[22] But pertinent questions concern the "when" and "why" of drought. When to initiate such demand management is a non-trivial issue, especially where users have high-water-loss private storage facilities, such as their garden soil. Consumers will tend to use higher-than-usual amounts of water, by converting it from a low-loss open-access common property resource, to a high-loss private property resource if they believe that the issuing of coupons, which will increase the value of water, is imminent. Thus, there is a tradeoff between introducing coupon rationing early to reduce such inefficiencies and increasing the likelihood because of unexpected rain, of unnecessarily incurring the transactions costs[23] associated with the allocation and sale of coupons.

More important is the "why" of drought, or at least why rationing on a particular scale is currently needed. It is due, at least in part, to previous demand management policies. For example, more restrictive previous policies would have increased current supplies unless inflows since those restrictions would have caused the reservoir to fill. This highlights one of the great difficulties with centralized demand management—how to choose the best water saving strategies, and thus the best reliability of

17. For practical limitations with quantitative rationing of water, see generally Moncur, *Urban Water Pricing and Drought Management*, 23 Water Res. Research 393 (1987). For a more theoretical discussion of efficient and inefficient non-price rationing, see Sherman & Visscher, *Second Best Pricing with Stochastic Demand*, 68 Am. Econ. Rev. 31 (1978).

18. Hamlen & Jen, *supra* note 9. For similar problems with optimizing reliability in produced goods such as electricity, see also Crew & Kleindorfer, *Reliability and Public Utility Pricing*, 68 Am. Econ. Rev. 31 (1978).

19. Moreau & Snyder, *Financial Burdens and Economic Costs in Expanding Urban Water Systems*, 23 Water Res. Research 1139 (1987).

20. Carver & Boland, *Short-and Long-Run Effects of Price on Municipal Water Use*, 16 Water Res. Research 609 (1980).

21. Mumy & Hanke, *Public Investment Criteria for Underpriced Public Goods*, 65 Am. Econ. Rev. 712 (1975).

22. P. Layard & A. Walters, Microeconomic Theory 200-01 (1978).

23. For a definition of transactions costs, see Randall, *Property Rights and Social Microeconomics*, 15 Nat. Res. J. 729, 734 (1975); Crouter, *Hedonic Estimation Applied to a Water Rights Market*, 63 Land Econ. 259, 262 (1987).

aggregate supplies, when individual users may have quite different supply-reliability preferences.

Perhaps there is some form of permanent privatization which will decentralize the "when" and "why" decisions of drought. Goetze[24] sought some way of privatizing the common pool, as did Dales[25] for environmental quality reasons, which follow from the earlier analysis of Hardin.[26]

Attempting to decentrally privatize, on a long-term basis, the flow-stock water in and entering storage among users with different supply-reliability preferences becomes very complex in the usual situation of both seasonality and uncertainty of water supply and demand.[27] A novel aspect of the property rights structure under focus in this article—capacity sharing—is that it *directly* attaches private property rights to the *capacity* of the headworks storage and *inflows* to the storage, and only *indirectly* attaches private property rights to the water stored at any time. It utilizes the fact that reservoir capacity, as distinct from fluctuating contents over time, is both divisible and immobile which makes it relatively "easy" to apply property rights to it.[28] In the terminology of Tybout,[29] capacity sharing converts water in storage from a quasi-public good, in which consumption by one interferes with that of others, into a private good free from such interference.[30]

Capacity sharing was proposed by Dudley and Musgrave[31] as a non-attenuated property right structure for multiple purpose reservoir users such as irrigation farmers, flood control authorities, bodies charged with maintaining downstream flows for instream and environmental purposes, as well as urban users. However, in that discussion it was assumed that urban consumers would hold the property rights as a group rather than as individual consumers.[32] The Victorian Department of Water Resources (Australia) has adopted this view when proposing the adoption of capacity sharing.[33] In contrast, this article proposes the idea of applying capacity

24. Goetze, *Identifying Appropriate Institutions for Efficient Use of Common Pools*, 27 Nat. Res. J. 187 (1987).

25. Dales, *supra* note 7.

26. Hardin, *The Tragedy of the Commons*, Science (Dec. 13, 1968) at 1243.

27. To "decentrally privatize" is to divide ownership among all users in contrast to the more usual private monopoly-public monopoly distinction. *See, e.g.*, Mills, *supra* note 11.

28. Dales, *supra* note 7. *See also*, Mills, *supra* note 11, for a discussion of the concept of "ownership."

29. Tybout, *supra* note 11, at 211.

30. This is not strictly correct, since some interference among consumptive users will still exist. However, this competition will be reduced greatly. *See* Dudley & Musgrave, *Capacity Sharing of Water Reservoirs*, 24 Water Res. Research 649 (1988). *See infra* notes 60-62 and accompanying text for discussion of possible interference between multiple purposes when some of them are non-consumptive.

31. Dudley & Musgrave, *supra* note 30.

32. *Id.*

33. Victoria Dep't of Water Resources, Water Resource Management Series Report No. 8, Security for Major Water Allocations, Victoria (1987).

sharing to individual urban consumers as Dudley and Musgrave have done for individual irrigation farmers.[34] Surveying the nature and attributes of property rights currently in existence is beyond the scope of this article. Rather it introduces the concept of capacity sharing as an urban water property rights structure, and leaves to readers the task of making comparisons with alternative systems with which they are familiar.

THE NATURE OF URBAN CAPACITY SHARING

The essential point of capacity sharing is that each user obtains a percentage share in the total capacity—not contents—of the surface reservoir and its inflows for their own exclusive use. It is as if each user owns a small reservoir on a little stream of their own, with the right to make withdrawals from their reservoir as they choose with a minimum of interference from other users or authorities, but the contents of each small reservoir can never exceed its capacity or become negative. To illustrate the concept of capacity sharing, assume an area of urban owner-occupied houses with gardens to which water is supplied through a piped distribution system from a single headworks reservoir. Each household or consumer would have secure title to a percentage share in the capacity of the headworks reservoir and its inflows. They would have exclusive right to whatever water is in their share of reservoir capacity at any time. The distribution system would always remain full of water which would always belong to the total system. Then a consumer would withdraw water from their own share of reservoir capacity by turning on one or more of their taps. The amount withdrawn would be recorded by a water meter at the user's property plus transmission losses. The meter would be read periodically and the result entered into the system computer, which would already contain data on the total inflow over the period as well as total reservoir evaporation and seepage losses. The computer would then calculate the new contents of the consumer's capacity share by adding that user's share of inflows to their previous contents, subtracting metered usage and share of losses and, if the resulting total for that user is in excess of the user's capacity share, allocating the overfill to a special fund.[35] Users would be able to obtain knowledge of their current contents at any time by reading their meter and reporting the reading to the authority for a computer update. Such interim calculations would be unofficial to guard against errors in meter readings by consumers and would serve only as a guide.

Penalties for using water from the system when a consumer's reservoir

34. Dudley & Musgrave, *supra* note 30.

35. Periodically, this special fund's contents would be allocated among users whose capacity shares are less than full at the time of the fund's allocation.

capacity share is empty would be sufficiently severe to prevent such practice.[36] Thus, as users empty their own capacity shares, their consumption would be restricted to current inflows and water obtained legally from other capacity shares.

Decentralized Demand Management

One of the attractive features of urban capacity sharing as introduced above, is that demand management would be performed by the final consumers themselves rather than by the water authority.[37] Users would consider the opportunity cost of using water currently before doing so. This would greatly reduce the need for the utility to maintain costly information, such as price and income elasticities of demand, and the factors which influence these elasticities through time in uncertain climatic and economic environments. Capacity sharing would also foster the fine tuning of demand by each individual consumer. Users would adjust their water use through time according to their supply-security preferences. Each user would take account of current reservoir inflows and storage in their own share of capacity as well as information on the probabilities of future inflows of varying quantity and timing. Some may choose to use water liberally in household appliances and on annual garden plants while the water lasts, being content to let the gardens die, hand-wash clothes and household utensils, and adopt other water conserving practices in times of water shortages. Others may plant low-water-using, drought resistant native perennials in their gardens and choose low-water-using appliances. But the choice would be theirs, and they would each reap the consequences of their actions.

Computer simulation models would probably be made available by the water authority or private consultants to assist users in making the choice which best suits their situations. The simulation models could use historical inflow data to produce graphs of fluctuations in the contents of a user's capacity share over time for different strategies of daily consumption. These could be supplemented with information on how such daily consumption might be constituted, such as rates of water use of various household appliances, showering with different types of shower heads(roses), watering gardens with different types of sprinklers, and so forth.

Some consumers would not be able to cope with managing their own shares; the management complexities would be too great for them. They

36. *See supra* text accompanying notes 39-40.

37. Some water users may prefer, at least initially, to continue to operate under the familiar centralized demand management, with its progressive restrictions, in times of shortage. *See supra* note 55 for a discussion of how the supply authority could continue to communicate such restrictions to users on an advisory basis in response to the contents of each individual's share of capacity, in contrast to the current mandatory restrictions based on total storage contents.

are likely to convert most of their management complexities into management fees by paying for the supply authority, or employing private consultants, to monitor their shares through time and to advise them on consumption reductions in times of anticipated shortages. These advisers would probably use the above computer models to present alternative supply reliability plans before consumers. For example, one plan might allow consumers to continue to use water as they have in the past if the initial allocation of shares is sufficient to give consumers the same reliability of consumption. The "past" may be a short period if demand has been expanding rapidly. The adviser would monitor a client's share contents and issue periodic instructions on water consumption—perhaps in terms of restrictions to which the client is accustomed such as limited hours of garden watering, hand-held hoses, shorter showers, and so forth. Other plans may be more or less conservative. Such advice may become integrated with other forms such as advising on types of garden plants and landscaping, automatic watering systems, and the like. Consumers with similar consumption patterns could also form collectives for management of their aggregate shares in common by either a consultant, an employed manager, or the storage manager as agent.

Markets

An integral part of capacity sharing would be the establishment of markets for water users to trade in water *per se* in the short-term or capacity shares in the long-term. Since each capacity share user would have secure title to water currently in their reservoir share, and could obtain estimates of the probability distributions of inflows, they would be in a position to decide on the quantity of water to buy or sell at any point in time. A water market spot price would reflect current supply and demand conditions while a possible futures market would allow users to further reduce future risk. Since participation in such markets would be voluntary, rational water users would only do so if they believed that it would increase their well-being. The computer models described above could be used to help users decide whether or not to buy or sell some water. Simulated water sales (or purchases) would result in increased (or decreased) probabilities of shortages. Such models would be unlikely to include the market value of water traded as that value would depend on the behavior of all users.

Furthermore, water users may be able to improve their welfare by trading in future flows separate from capacity shares with rights to inflows attached. For example, some may be prepared to contract now to sell all of their inflow in excess of some quantity in some future month, con-

ditional on such inflows eventuating, if the prices are high enough. Buyers might be prepared to gamble on such water becoming available if the price is low enough.

In the longer term, users may see advantages in increasing or reducing their security of water supply by buying or selling some share capacity. That is, by increasing or reducing their shareholding in the headworks reservoir and its inflows. For example, householders who derive pleasure from gardens which require large and highly reliable water supplies, such as those containing long-life exotic plants, may purchase title to reservoir space from households enjoying local native flora which use less water and are relatively drought tolerant. Water currently stored in the capacity share being traded may be part of a sale or may remain the property of the original owner for transfer to his/her remaining share, or for separate sale, by an agreed date. The non-attenuated nature of capacity sharing property rights[38] makes them ideal for market transfers.

Empty Shares and Compliance in Droughts

As noted above,[39] should some reservoir share holders empty their shares at any time, their consumption would be limited to future inflows plus water obtained legally from other share owners. But what are these legal sources, and what would be the penalty for using water from the system in excess of these consumption entitlements? Legal aquisitions would include purchases of water held in another user's share, and perhaps borrowings from another's share against future inflows. Following such exchanges the supply authority would need to be notified by both buyer and seller. The buyer's share contents would then be credited and the seller's debited by the agreed quantity.

There may be some consumers, however, who are unable or unwilling to buy water from other capacity share owners. Instead, they may ignore the fact that their capacity shares are empty and continue to turn on their taps (or fail to turn off automatic water using appliances) and take water from the system. How can the principle of exclusion be applied to them? To take care of the immediate problem that such water is being drawn from other user's capacity shares, a share of the reservoir could be set aside to hold water to cover such "overdraws." In the longer term, sufficiently harsh fines, or sufficiently high charges for the water used from the overdraw fund, could be imposed to prevent overdrawing by

38. Capacity share property rights are explicit, enforceable, transferable, and exclusive. *See* Randall, *supra* note 23.

39. *See supra* text accompanying note 36.

all but the most incorrigible. Perhaps charitable shares of capacity could be held by a public authority, or by private charitable organizations, and water supplied concessionally to those who cannot afford to pay market prices.[40]

Externalities

Externalities may exist, such as Households A and B suffering a loss in quality of lifestyle if neighboring Household C lets their garden die because they have sold water or capacity shares. It may be feasible to zone areas or streets such that each zone has a specific minimum size of capacity share per household and also limitations on their sales of water as such. Obviously this is a sensitive area. Education of consumers about landscaping with low-water-using flora may go a long way toward solving such problems.

Tenants

Capacity sharing may introduce extra potential conflict areas between landlords and tenants, but they would appear to be easily overcome. For example, the tendency for tenants to leave a household water capacity share almost empty could be reduced by requiring tenants to pay an initial deposit which would be refundable according to the share contents and garden status at the termination of the lease. That is, both empty capacity shares and dead gardens would attract penalties. For tenants with a long history of tenancy it may be simpler to have their water use habits included in their tenant-suitability references. However, many existing housing units or apartments do not have a separate water meter for each unit. In these cases, groups of units supplied through one meter would use a capacity share in common. This may result in problems of individual

40. To discourage abuse of the system, it would seem necessary that a last resort excludability mechanism, such as physically cutting off the water supply at the user's meter, would be necessary. However, in some communities both public health and compassionate grounds make it unlikely that a user's supply would be completely cut off because of exhaustion of entitlement. In such communities a feasible solution may be to restrict such a user's supply, leaving only a constant trickle available—enough to re-fill toilet systems slowly and allow the user to obtain sufficient water for cooking, minimal bathing, and hand laundry by letting a tap trickle into receptacles over time. The prospect of such inconvenience, high prices, and possible fines would likely cause most consumers to adopt water conserving measures before their shares are actually exhausted, thereby reducing the likelihood of exhaustion. To the extent such incentives fail to prevent exhaustion of water in shares, the overdraw fund would be drawn upon to furnish restricted supplies as required. Users would regain their normal supplies from their own capacity shares when their shares of inflows less losses return their storage to some pre-determined minimum level. Perhaps a minimum level greater than zero could be used to trigger the imposition of the restricted supply to a household, thus reducing the percentage of reservoir capacity needed to maintain the overdraw fund. Presumably the required size of the overdraw share would also depend on the severity of the fines and the degree of supply restrictions.

users failing to conserve water sufficiently in times of shortage. Whether or not this warrants the expense of installing individual water meters, so that the common capacity share could be divided and privatized amongst the units, would be up to the management of the block of units. However, problems with lack of meters is not limited to capacity sharing. Without individual metering, the tendency for some unit occupiers to fail to comply with restrictions and free ride on others in times of shortage would exist under most institutional arrangements. On the other hand, if the management of the group of tenants sharing a meter can elicit cooperation from them, there would be no need for individual meters under either capacity sharing or other systems.

Beyond Residential Use

Only residential use has been considered so far in the explanation of urban capacity sharing because it is one with which readers are most likely to be familiar. Other users may gain as much or more from the increased security of future water supplies due to capacity sharing. Under capacity sharing, all present users of water who own or lease real estate property, as well as public service bodies who service the property of others, such as fire control and sewage authorities, would have shares in the capacity of the reservoir. Commercial and industrial users could also change their initial distribution of capacity shares by entering the markets and choosing the combination of (i) controlling a "large" capacity share and selling water at times, and (ii) controlling a "small" capacity share and buying water at times, which best suits their water supply and financial needs. Again the water trading may involve current spot and future water contracts. Users such as educational institutions, parks, and sporting grounds would operate similarly. Those providing emergency services, such as hospitals and fire departments, may satisfy their requirements for extreme security of supply with a "small" capacity share while standing ready to buy high-priced water or call for donations of water in times of shortage, or by controlling a larger share and reducing their dependence on purchased or donated water, perhaps to zero. The combination which best suits their situation would be influenced by the anticipated prices of capacity shares and water as well as political considerations.[41] The amount used by emergency users would be metered or estimated. For example, the quantity of hydrant water used at a fire could apparently be approximated by a combination of water pumped by fire engines plus an estimate of losses and gravity usage. Presumably all public bodies would be accountable to the public for water used.

41. *See infra* note 43 and accompanying text for discussion of initial allocation of capacity share size.

Attachment to Property with Maxima and Minima

A possible concern of urban capacity sharing as introduced so far is that some persons or groups may be able to exercise control over "too much" of the resource whereas others would control "too little." Privately owned shares may need to be tied to real estate parcels[42] with bounds placed on the size of the capacity shareholding owned per real estate parcel. The maximum constraint would prevent an individual economic entity from gaining monopoly power over reservoir capacity and inflows unless they also control a very large proportion of the real estate. The minimum would prevent those who underestimate the likelihood and/or cost of droughts from selling their share of capacity for short-term gain to the point where they would be reduced to a restricted supply status too often to be socially acceptable.

Initial Allocation of Capacity Shares

The introduction of capacity sharing requires some method for initially allocating the reservoir capacity and inflow shares among users. Market transactions would subsequently alter the allocation, so financial fairness is likely to be a major factor in the attractiveness of changing capacity sharing to users. Perhaps allocating capacity shares to real estate properties in proportion to historical usage would be most favored as being financially equitable, as well as allowing users to approximate their current consumption reliability positions without needing to buy or sell capacity shares.[43]

User Charges

Changing an urban water supply system from a conventional property rights structure to capacity sharing is not expected to cause important cost increases in the long-term. Accurate water metering of all users will be required for conventional systems when increased population results in the need for demand management as shortages become more frequent. The computational effort required to monitor the contents of each user's capacity share would probably not add much to the cost of service to each user above that required for conventional consumption recording and billing.

There are a variety of ways in which the costs of supplying water could be apportioned among users. One way would be to allocate headworks

42. For example, a house, a housing unit or group thereof, a factory, an office, or a vacant building lot approved for building by the relevant authority.

43. Those who have only recently purchased a property may be advantaged or disadvantaged if their planned consumption differs from that of the previous owners. Perhaps processes could be established to allow appeals in such cases.

reservoir capital and operating costs across users according to the size of the capacity share held. The distribution system costs could be split into fixed and variable costs, with the latter including pumping and quality treatment costs. The fixed component could be spread equally across all users or could be apportioned according to size of capacity shares held. Either way, the revenue received by the water supply authority would closely match their capital and operating cost commitments through time, regardless of fluctuations in reservoir inflows and desired consumption; an apparent advantage to most supply authorities. Also, constant costs would not appear to disadvantage users except perhaps those industrialists whose output, and hence revenue, fluctuates with the availability of water. Indeed, household consumers may prefer water charges levied to cover supply system fixed costs to be a constant rather than fluctuating component of their budgets.[44]

It is apparent that the introduction of capacity sharing would allow a high degree of separation between the allocative and revenue raising roles of water pricing. The allocative role would be performed largely by the markets discussed above.

Some Possible Scenarios

To clarify the issues involved in the initial allocation of capacity shares, as well as likely advantages and disadvantages, a number of hypothetical cities or towns are considered. Suppose that each town has its own developed reservoir and reticulation system with all properties metered.

Town A has not been growing, has no prospects for future growth, has no vacant lots, and does not experience water shortages. Shares would be allocated initially in proportion to each user's (real estate owner's) historical proportion of total consumption. For example, if a consumer has historically consumed one percent of the total town consumption, their capacity share would be one percent of capacity of the headworks reservoir and its inflows. In this case, capacity sharing would be easy to implement but is unlikely to have significant advantages over most alternative water supply institutions.

Town B is the same as Town A except that the storage capacity and its inflows are smaller relative to average demand which, coupled with highly fluctuating climatic conditions, results in frequent water shortages which may be severe in drought times. These shortages result from a simultaneous reduction in supply and increase in demand.[45] Conventional

44. Of course, although unlikely, such expenditure and revenue stability could be achieved under flexibly administered prices if the individual and aggregate price elasticities of demand happened to be unity over the relevant range.

45. Moncur, *supra* note 17.

approaches to water shortage management of surface reservoir systems is for the supply authorities to initiate policies to reduce water consumption. As noted above,[46] the formulation and implementation of such policies is complicated by the common property or common pool nature of the water in surface reservoirs under conventional property rights structures for such water. This common pool nature combines the public good characteristic of non-excludability (reservoir water available to one is available to all) with the private good characteristic of subtractibility (units of water consumed by one cannot be consumed by another).[47] Urban water usually has the private good characteristic of subtractibility,[48] since water used by one consumer is not available for use by others in the town. These characteristics make such water a quasi-public good.[49] Many commonly used consumption restrictions invoked during shortages, such as hours of watering and sprinkler bans, do not reduce the non-excludability characteristics of reservoir water and "often encourage consumers to inform on violating neighbours, generating all sorts of ill-will in the community."[50] Thus, consumption restrictions have equity problems as well as inefficiency problems—the latter arising because it is unlikely that consumer's marginal rates of substitution would be equated. Excludability in such a town's water supply system could be achieved by allocating quotas—perhaps ration coupons as indicated above[51]—for remaining reservoir contents during a prolonged shortage, with efficiency requiring that they be marketable. But, as well as the difficulties noted above,[52] there may be equity problems with quotas invoked during a drought because "consumers who have already gone to some expense and care to conserve water complain of unfairness in being asked to cut back further along with their less conservation-minded neighbours."[53]

Similarly, as indicated above, the tasks of deriving and implementing the best strategies or rules for combinations of prices and restrictions over time, under changing circumstances and an uncertain environment, are very difficult. Capacity sharing overcomes most of these problems associated with conventional property rights. Essentially, it privatizes the reservoir water and inflows. Goetze notes "[i]f a way can be found to divide up the commons then the various parts of the commons can be treated as private goods with each part or good allocated to a separate

46. *See* text accompanying notes 24-26.
47. Goetze, *supra* note 24.
48. *See* Randall, *The Problem of Market Failure*, 23 Nat. Res. J. 131 (1983), for the use of the term "Rivalry."
49. Tybout, *supra* note 11, at 211.
50. Moncur, *supra* note 17, at 393-98.
51. *See supra* text accompanying note 22.
52. *Id.*
53. Moncur, *supra* note 17, at 393-98.

owner. Owner-users would then have legal backing to exclude others from using their portion of the pool."[54] Capacity sharing is a means of dividing up reservoirs and their inflows to this effect, allowing owners to use water at their own discretion. In the short-term, some consumers in Town B would want the reservoir authority to continue very much as before with advice on how to restrict consumption in times of shortage;[55] some would manage their own shares by consuming and trading in water so as to maintain relatively high storages in their shares; whereas others may consume and trade water less conservatively, maintaining lower average balances, as discussed above. In the long-term, some will expand their initial capacity share allocation to increase their reliability of supply. These purchases would be made from other owners who are prepared to sell portions of their capacity share at the current market price, reducing their long-term reliability of supply. The price of water *per se* would fluctuate greatly depending on seasonal conditions, whereas the price of the long-term asset—share of reservoir capacity—would be much less influenced by short-term climatic fluctuations. Thus, demand management is decentralized and privatized under capacity sharing. Also, capacity sharing allows the stabilization of consumers expenditures and the authorities' revenue, as discussed above.[56]

Capacity sharing is concluded to be likely to have significant advantages over most alternative water supply institutions for Town B. However, there may be political difficulties in implementing it because of problems with initially allocating capacity shares in a seemingly equitable way when shortages are frequent.

Town C is also the same as Town A (zero present and future growth,

54. Goetze, *supra* note 24, at 199.

55. After the introduction of capacity sharing, the reservoir authority could still derive and communicate demand management restrictions to individual consumers who feel unable to cope with the management of their shares. These restrictions would be based on the quantity of water in those user's individual reservoir shares and inflow probabilities, rather than the quantity of water in, and probability of inflows into the total reservoir, as was done previously. This could increase costs, and those users requiring it could be charged. There would be no compulsion to follow such advice—advice in a later time period would again depend on the water volume in their share which would reflect the degree to which they followed the earlier advice. Thus, users would have two basic choices about the management of their shares when capacity sharing is introduced. First, they could elect to have the water authority manage their shares as indicated above. Second, they could elect to manage their shares, including buying and selling water in the short-term, or a portion of their share capacity in the longer term, with or without expert help. The first option could be maintained indefinitely without loss of water supply reliability to the user. However, the value of capacity shares would grow through time as demand for water increased, which would be likely to encourage transfer from the first to second category over time. That is, as scarcity and the value of shares increase, larger numbers of users will believe that the revenue from the sale of portions of their capacity shares would be sufficient to compensate them for the resulting increased water management burdens, reduced mean water consumption, and increased likelihood of water shortages. The increased management burdens could be consultants fees and/or the user's own efforts.

56. *See supra* text accompanying note 44.

no vacant lots, and does not experience water shortages) except that it has high growth potential. New land is available to accommodate the growth. Town C is also subject to fluctuating climatic conditions with no scope for expanding the headworks storage. Hence it will, in time, become like Town B. This implies falling average annual consumption per user over time. This, in turn, means that users would lose, usually without compensation which they would regard as adequate, what they may perceive as a right to the amounts and reliability of water supplies to which they have become accustomed. If a user-pays water pricing policy is used, poor consumers are likely to suffer a greater reduction than the rich in average annual consumption.

If capacity sharing is introduced in Town C before the growth begins, existing residents will receive a capacity share which is sufficient to maintain their historical no-shortage consumption if they choose not to sell a portion of their capacity share to incoming consumers. Under capacity sharing as envisaged here, new consumers would have to buy capacity shares (including the attached inflow shares) to satisfy their demand for water. Some may choose to buy rather small capacity shares and rely on short-term purchases of water or future inflows to supplement the inflows to their own capacity shares, but presumably most would prefer to buy capacity shares and reduce uncertainty. Of course, the relative prices would be an important factor.[57]

Simply allocating the total reservoir capacity on the basis of historical proportions of total consumption by existing users may result in such large capacity shares that each user's share would be far larger than necessary to maintain historical consumption. This would be the case if a recently constructed reservoir had been designed to accommodate considerable future population growth. In such cases, population expansion would result in new consumers purchasing portions of the capacity sharing reservoir space and inflows held by existing users. Given the finite nature of such shares, especially the inflow component, speculation may cause their price to rise rapidly if current holders expect large future population increases. In such cases the political acceptability of capacity sharing may be enhanced if the current "excess" reservoir capacity is held in common by the urban unit through its local government. The price charged for shares in capacity over time, and thus the rate of population immigration to some extent, would be controlled in common. This may be especially important in communities where the rate of future urban growth

57. If no one in an urban area would accept the offers made by those wishing to move into the area, then that urban area would not grow. But this is an extreme case in which the value of capacity shares to all existing residents exceeds the value of capacity shares (in that area) to all potential newcomers, regardless of their planned use of water.

is an important political issue. Existing users who place a high value on the reliability of supply would be under no compulsion to sell portions of their shares. Similarly, those who do not wish to incur the increased management complexities or management fees associated with operating reduced, less reliable capacity shares (which would result from the sale of some of their capacity shares) would not have to do so. Hence they could preserve their historical reliability level, and maintain very low management complexities, for as long as they choose. However, the opportunity cost of doing so would increase over time as development takes place and the market price of capacity shares rises.[58]

Hence capacity sharing prevents the erosion of the water supply quantities and reliabilities to which consumers have become accustomed without the compensation which they consider adequate. Compared to alternatives which may allow such erosion to occur without compensation, capacity sharing may be considered equitable with respect to existing consumers of water from a system, but inequitable with respect to new and old consumers combined. Which is preferable from a social welfare viewpoint appears difficult to determine on equity grounds. However, efficiency considerations would indicate that incoming consumers should pay the marginal costs of their entry.[59] If the latter path were taken, it would mean that existing consumers would not have to incur the increased management complexities of managing reduced capacity share sizes in a fluctuating environment until the capacity share price has risen sufficiently for the benefit from the sale to offset the increased management complexities to that consumer. On the other hand, incoming consumers would buy shares in capacity until the advantages of holding extra shares, in terms of increased reliability and reduced management complexities, is offset by the cost of the shares.

Hence it is concluded that the management complexities due to capacity sharing incurred by existing users would be essentially non-existent if capacity sharing is introduced before demand grows to the point where the capacity shareholding of at least some users is too small to prevent shortages.

Town D is like Town C except that vacant building lots exist in the town. Their owners have not yet become consumers but would probably expect to do so on the same basis as existing consumers under most existing property rights systems. That is, they would expect to incur the

58. This, of course, is similar to the case in Town B except that in that case the historical reliability level would be much lower and the initial allocations would have to be chosen more carefully to enable users to approximate the reliabilities they had before the introduction of capacity sharing.

59. I am indebted to Professor Warren Musgrave for noting that, given the likely concentration of power in the hands of the existing consumers (storage owners), this outcome is also not likely in terms of political reality.

same charges and enjoy the same conditions of supply as existing users or, if many of them become consumers simultaneously, for both new and old consumers to share equally in the reduced average supply and reliability. If there are many owners of vacant blocks, the initial allocation of capacity shares would be made more complicated. Since they have no historical consumption, on what basis is the size of their initial allocation to be determined? Would it match the water supply expectations which they had in mind when purchasing the land? Again, such questions become increasingly important as the likelihood of water shortages increase. The best solutions would probably vary from situation to situation depending on past institutional arrangements and the likely frequency of water shortages with and without the new consumers.

Timing of Transition to Capacity Sharing

The foregoing discussion indicates that it would be much easier to begin capacity sharing in an urban center when water supplies are still plentiful in relation to desired consumption. First, the initial allocation of shares would appear to be much easier if all users could get capacity shares of sufficient size to give a very low probability of water shortage. The lower the probability of water shortage to anyone, the easier to satisfy users with an initial allocation, or so it would seem.

Second, changing to capacity sharing when the probability of water shortages is low allows time for users to learn how to manage their existing capacity shares at any point in time (short run management) and how to expand or contract the size of their capacity shareholdings as water and share prices change over time (long run management).

Thus it would seem to be important for urban centers to change to capacity sharing early in the maturing process of their water economies. However, given the short-term bias in most political decisionmaking, perhaps the greatest factor limiting the adoption of urban capacity sharing will prove to be the political cost of upsetting the status quo by making the change when there is little immediate advantage from doing so.

Toward Multiple Reservoirs and Multiple Purposes

To simplify the introduction of urban capacity sharing the assumptions of one reservoir and one purpose have been maintained so far. Although a complete analysis of the implications of relaxing these assumptions is beyond the scope of this paper, some possible situations and indications of how capacity sharing might then function are introduced below.[60]

Turning first to multiple reservoirs, one case could involve reservoirs

60. For similar implications for the irrigation case, see Dudley & Musgrave, *supra* note 30.

in different hydrologic regions, each having the same ratio of inflows to capacity, with highly correlated inflows. Under capacity sharing users could have a percentage share in any one of the reservoirs. A more complicated situation might include reservoirs in different hydrologic regions, each having different inflow/capacity ratios and uncorrelated inflows. In this case various options are possible. One would be for users to have their percentage of total capacities of all reservoirs spread proportionately across the reservoirs initially. For example, if they are to have one percent of the total of all reservoirs before modification by trading shares, they would be allocated a one percent share of each. They would then have a share in each of the individual reservoirs, as a household may have deposits in many individual bank accounts. This would add to the management complexities, probably increasing the compensation (share price) needed to encourage a user to sell some capacity which would further increase the complexities.

Another case could comprise reservoirs in series in the same catchment, with no important tributaries between reservoirs. The system could be operated as one reservoir, shares being percentages of the aggregate capacity and inflow to the top reservoir. However, tributary inflows between the reservoirs would complicate operations somewhat. Water would then be stored as high up the system as possible to minimize spills of the bottom reservoir, but shares would be percentages of aggregate capacity and inflows. There may be times, perhaps after prolonged droughts, when tributary flows into the lowest reservoir would cause it to fill and spill while the upper ones remain unfilled until their tributaries flow sufficiently. The spilled tributary flows could not be included as part of users' supply even though their reservoir share would be less than full. This would somewhat complicate the derivation of probabilities of inflows to shares.

Turning now to multiple purposes, the basic point is that it is in keeping with the spirit of capacity sharing that reservoir capacity and inflow shares be allocated to each of the purposes. These include flood control, below-reservoir instream uses (environmental and recreational), hydro-power, irrigation, as well as urban purposes. The apparent feasibility of capacity sharing under multiple purposes is briefly discussed elsewhere[61] and will not be repeated here. However, these authors are rather pessimistic about capacity sharing's ability to contribute to the resolution of conflicts between the desire for maintenance of high storage volumes to increase pressure for hydropower generation and the desire for releases by other users. They express similar concerns with regard to recreation on the reservoir surface with its preference for constant volumes. But more recent

61. *Id.*

work indicates that the property right structure of capacity sharing gives a better basis for market allocations of water between reservoir recreational, hydro-power, and consumptive uses than conventional alternatives.[62]

Some Alternative Situations and Implications for Capacity Sharing

Although there is a great variety of water resource system configurations for which the implications of capacity sharing could be examined, only a few are briefly mentioned here. In some cases reservoirs and distribution systems are connected by an existing river channel with instream flow requirements, rather than by closed pipe. If reservoir authorities operate so as to keep the distribution system fully supplied under capacity sharing, users would still have their reservoir shares debited every time they turn on a tap. Calculating the efficiency losses may be more complex, but the principles would be the same as with piped water. If instream uses between reservoir and distribution offtake sometimes require more water than that released for the urban area, the instream use would also require a share of capacity and inflows from which to make up the differences. If instream flow maintenance below the urban offtake is also required, a larger capacity share may be needed for instream flow maintenance.

Situations also exist in which there is a wholesaler between the source and the distribution agency. In this case, the wholesaler would have a large capacity share in the reservoir(s) and inflows from which the retail water would come. Perhaps only wholesalers would have capacity shares, as is being introduced for some multi-purpose reservoirs in Victoria.[63] A variety of methods could be used by the wholesalers to allocate water at the retail level, including capacity sharing.

In other cases, both groundwater and surface water contribute to the urban water supply. Many possibilities exist for using capacity sharing, depending on the nature and relative importance of the two sources. But a rather generally applicable arrangement could be to divide the surface reservoir capacity and inflow shares in the usual way (that is, based on past consumption patterns for existing surface reservoirs and auctions for new ones) with it being understood that, as consumers use water, it comes from their individual surface reservoir shares, until exhausted, before drawing on groundwater. Groundwater could be centrally priced to reflect

62. Manuscript in progress by the author.

63. For a discussion of wholesale capacity sharing and comparison to release sharing, see Paterson, *Rationalized Law and Well-Defined Water Rights for Improved Water Resource Management*, in Renewable Natural Resources: Economic Incentives for Improved Management 43 (1989) (OECD Publication).

its long-term opportunity cost. The time profile of that price would largely determine the prices paid for surface water and capacity shares, as well as the degree of water conservation practiced. Alternatively, quantitative restrictions could apply to groundwater use, their nature and severity influencing prices for surface water and capacity shares as well as conservation. As with conventional allocation methods, some complications would arise if groundwater recharge is influenced by surface water use or delivery.

SUMMARY OF FEATURES OF URBAN CAPACITY SHARING

1. Water in the reservoir would become a private property resource rather than a common property resource. Therefore users would have an incentive to conserve water when it is in short supply relative to requirements, and to use it freely when it is plentiful. They would take its opportunity cost into account.

2. Capacity sharing would provide equitable rationing in times of shortage. Because each user owns the water they use, how they "waste" it is of little concern to other users. When rationing becomes severe under a conventional property rights system, antagonism is likely to develop between consumers as they comply differently to the requested restrictions on use.

3. Capacity sharing would have the consumption-reducing advantages of highly fluctuating water prices without producing a destabilizing effect on the consumers' finances.

4. Capacity sharing would stabilize net revenue to supply authorities. The "user pays" principle would apply to water collection and distribution facilities rather than water use as such. Capacity sharing would allow a high degree of separation between the allocative and revenue raising roles of water pricing.

5. Under many conventional property right structures for water, consumers face uncertainty about the probabilities of supply and costs of water over time. They have limited means of expressing preferences for water supplies of different likelihoods and an inadequate basis for making efficient decisions about installing water using equipment and gardens. Capacity sharing would virtually eliminate these problems.

6. The sound non-attenuated (that is, explicit, enforceable, exclusive, and transferable) property rights nature of urban capacity sharing would provide an ideal basis for water markets as such and for reservoir capacity and inflow shares. These markets would facilitate efficient water use in both the short and long runs. Furthermore, the initial allocation of capacity shares could be varied according to what is considered to be financially equitable.

7. Although average water consumption per consumer will fall as water economies mature, under capacity sharing existing consumers would not experience water supply quantities and reliability reduction without compensation which they judge to be adequate. Similarly, consumers would not decide to incur increased management complexities until they believe compensation to be adequate.

8. A market for capacity shares separate from inflow shares would provide a measure of the value of marginal units of reservoir capacity, which in turn could be used to indicate the best time to expand reservoir size. The capacity share market price would have the market value of water built into it, including the manner in which water value is expected to fluctuate over time.

CONCLUSION

This preliminary survey of urban capacity sharing indicates a number of attractive features as a potential property rights structure for maturing water economies. Transition to capacity sharing would be administratively easier and more beneficial if carried out earlier rather than later in the maturing process. However, the lack of short-term gain from introducing it early may be the greatest obstacle against its acceptance—given the short-term bias in most political decisionmaking. The concept of capacity sharing for urban systems is worthy of further investigation.