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NORMAN J. DUDLEY*

Water Allocation by Markets, Common Property and Capacity Sharing: Companions or Competitors?

ABSTRACT

Capacity Sharing is a new way of defining and allocating rights to flowing and stored surface water in a river valley. It is as if each user of water, or group of users, has their own small reservoir on their own small stream to manage independently from others. Hence it provides a very sound basis for the market allocation of private property rights, about which there has been a recent surge in the literature, especially with respect to the western United States. A similar surge, although spread more widely both in its geographic emphasis and across academic disciplines, is in the literature on common property approaches to resource management. Whereas the common property approach may work well for small water resource systems, it is inappropriate for the management of large systems. However, because capacity sharing minimizes the interdependence of behavior between users of system water, it provides a very good basis for dividing up such large systems among a number of independent, multi-purpose groups each operating their sub-system as a common property resource. Similarly, capacity sharing allows a harmonious mix of private property and common property resource management of the sub-systems within river valley systems.

The world is amazed at the speed and extent of the recent rightward movement away from centralized economic planning in favor of market-based approaches, especially in eastern Europe. Water has been caught up in this swing, particularly in England and Wales, with the privatization of the water supply industry. But that privatization is not to be confused with the recent surge in the literature on the market allocation of water as a resource, especially on the maturing water economy of the western United States.

Water resources usually exist as state property, private property, or common property. The ground swell of interest in the market allocation

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in the western United States and elsewhere implies institutional arrangements which treat water as a private property resource, even though the state may continue to 'own' the resource in some cases. Also, there has been a surge of interest in common property resource management, although spread over a broader literature. It involves the treatment of natural resources, especially commonly held land resources, as common property so their management and allocation is achieved by group cooperation and community action rather than by individuals influenced by the invisible hand of the market.

This author has been involved in another recent development in the water resources literature—the concept of Capacity Sharing (CS). It grants individual users, or groups of users, rights to both streamflows and reservoir storage space in such a way that each can manage their individual subsystems with almost no interference from others. It is as if each user has his own small reservoir on his own small stream. The purpose of this paper is to demonstrate that CS has an important potential role as an institutional arrangement for improving the management and allocation of water where surface reservoir storage is an important component of the water supply system, in conjunction with private property, common property, or both.

This paper begins by briefly and selectively surveying the recent literature on the market-based approach, followed by a similar survey of the common property literature. The evolving concept and features of CS are then presented before discussing its potential role as a facilitator of the market and common property approaches, whether operated in separate systems or both in the same system. Hence the subjects of the two recent surges in the literature, the market based approach and the common property approach, are not incompatible with respect to water—both may function very well even when operating together with CS in the same river basin water supply system.

A BRIEF INTRODUCTION TO THE WATER MARKET LITERATURE

Although a number of well known authors were concerned with water markets in the western United States prior to the 1980s,¹ the litera-

1. See, e.g., R. Anderson, *The Irrigation Water Rental Market: A Case Study*, 13 Agric. Econ. Res. 54 (1961); R. Anderson, *Windfall Gains From Transfer of Water Allotments Within the Colorado-Big Thompson Project*, 43 Land Econ. 265 (1967); C. Dittwiler, *Water Problems and Property Rights—An Economic Perspective*, 15 Nat. Res. J. 663 (1975); L. Hartman & D. Seastone, *Water Transfers: Economic Efficiency and Alternative Institutions* (1970); J. Hirshleifer et al., *Water Supply: Economics, Technology, and Policy* (1960); C. Howe and K. Easter, *Interbasin Transfers of Water: Economic Issues and Impacts* (1971); D. Johnson, *An Optimal State Water Law: Fixed Water Rights and Flexible Market Prices*, 57 Va. L. Rev. 345 (1971); M. Kelso, et al., *Water Supplies and Economic Growth in an Arid Environment* (1973); A. Maass & R. Anderson, . . . and the Desert Shall Rejoice (1978); F. Trelease, *Water Law and Economic Transfers of Water*, 43 J. Farm Econ. 1147 (1961).

ture has burgeoned in the 1980s. It ranges from the advocating² to the pessimistic.³ Victor Brajer, Al Church, Ronald Cummings and Phillip Farah discuss general strengths and weaknesses of water markets;⁴ Richard Gardner considers winners and losers.⁵

As would be expected, many authors—both economists and lawyers—focus on property rights to surface water, especially under the doctrine of prior appropriation.⁶ H. Stuart Burness and James P. Quirk argue that inefficiencies can arise under the doctrine of prior appropriation due to unequal risk sharing among water users.⁷ Other authors stress the need for security of tenure in water rights to encourage investment coupled with flexibility to allow adaptation to change.⁸

The important effect of water transfers on return flows and other factors which impact on third parties is considered by many authors. The attempt to reduce these impacts is seen as an important reason for high transaction costs which inhibit market transfers.⁹ In particular, Robert A.

2. See e.g., T. Anderson, *Water Crisis: Ending the Policy Drought* (1983); T. Anderson, *The Market Alternative for Hawaiian Water*, 25 Nat. Res. J. 893 (1985); R. Young, *Market Versus Non-market Management of Irrigation Water: A Review of the Issues*, Presented at the Water and Water Policy in World Food Supplies Conference (May 26-30, 1985).

3. See, e.g., A. Chan, *To Market or Not to Market: Allocation of Interstate Waters*, 29 Nat. Res. J. 529 (1989).

4. See V. Brajer et al., *The Strengths and Weaknesses of Water Markets as They Affect Water Scarcity and Sovereignty Interests in the West*, 29 Nat. Res. J. 489 (1989).

5. See R. Gardner, *Water Marketing—Idaho Style*, Presented at the Meeting of the American Water Resource Ass'n (1985).

6. See, e.g., W. Balleau, *Water Appropriation and Transfer in a General Hydrologic System*, 28 Nat. Res. J. 269 (1988); K. Boulding, *The Implications of Improved Water Policy*, Presented at Western Water Resources: Coming Problems and the Policy Alternatives Symposium (Sept. 1979); S. Ciracy-Wantrup & R. Bishop, *'Common Property' as a Concept in Natural Resources Policy*, 15 Nat. Res. J. 713 (1975); S. Clyde, *Adapting to the Changing Demand for Water Use Through Continued Refinement of the Prior Appropriation Doctrine: An Alternative Approach to Wholesale Reallocation*, 29 Nat. Res. J. 435 (1989); Ditwiler, *supra* note 1; N. Johnson & C. DuMars, *A Survey of the Evolution of Western Water Law in Response to Changing Economic and Public Interest Demands*, 29 Nat. Res. J. 347 (1989); R. Johnson et al., *The Definition of a Surface Water Right and Transferability*, 24 J. Law and Econ. 273 (1981); W. Schaab, *Prior Appropriation, Impairment, Replacements, Models and Markets*, 23 Nat. Res. J. 25 (1983); F. Trelease, *Alternatives to Appropriation Law*, in *Water Needs for the Future* (V. Nanda ed., 1977); J. Westcoat, Jr., *On Water Conservation and Reform of the Prior Appropriation Doctrine in Colorado*, 61 Econ. Geography 3 (1985).

7. See H. Burness & J. Quirk, *Water Law, Water Transfers, and Economic Efficiency: The Colorado River*, 23 J. Law and Econ. 111 (1980).

8. See, e.g., D. Bromley et al., *Water Reform and Economic Development: Institutional Aspects of Water Management in the Developing Countries*, 28 J. Econ. Dev. and Cultural Change 365 (1980); E. Checchio & B. Colby, *Refining the Water Process: Innovations for Western States*, in *Water Marketing: The Move to Innovation* (S. Shupe ed., 1988); K. Frederick & J. Hanson, *Water for Western Agriculture* (1982); C. Howe et al., *Innovative Approaches to Water Allocation: The Potential for Water Markets*, 22 Water Res. Research 439 (1986); J. Quiggin, *Private and Common Property Rights in the Economics of the Environment*, 22 J. Econ. Issues 1071 (1988); Young, *supra* note 2.

9. See B. Colby, *Transactions Costs and Efficiency in Western Water Allocation*, 72 Am. J. Agric. Econ. 1184 (1990); B. Colby, *Enhancing Instream Flow Benefits in an Era of Water Marketing*, 26 Water Res. Research 1113 (1990); B. Saliba, *Do Water Markets 'Work'? Market Transfers and Trade-Offs in the Southwestern States*, 23 Water Res. Research 1113 (1987); Frederick & Hanson, *supra* note 8; R. Howitt & H. Vaux, Jr., *Water Trading and Efficiency Criteria in California in Transfer-*

Young notes that:

in spite of . . . measured optimism . . . it appears in too many cases that an overly large difference in the value in alternative uses is required in order to precipitate transactions as a solution to water supply problems.¹⁰

Micha Gisser and Ronald N. Johnson advocate the limitation of water transfers to consumptive use to minimize the third party impacts resulting from return flows.¹¹ The doctrine of beneficial use makes innovation difficult and results in inefficient water use.¹² Kathleen A. Miller argues from empirical evidence that restrictions by irrigation organizations on the transfer of water outside the organization by individual members, while the organizations per se engage in such transfers, may be consistent with efficient water use.¹³

The Northern Colorado Water Conservancy District has a large number of potential water traders including industrial, municipal and agricultural users. The district has some particular attributes which have facilitated the development of water rental and transfer markets within it.¹⁴

Other studies of the district and its markets include works by Raymond L. Anderson; Bonnie Colby Saliba and David Bush; Richard L. Gardner and Thomas A. Miller; L.M. Hartman and Don Seastone; and Arthur Maass and Raymond L. Anderson.¹⁵ Colby Saliba and Bush also explain the detailed workings, including the legal settings, of the northern Colorado water markets as well as others existing in the Southwest.¹⁶ They further address the valuation of water rights by those markets including their roles in mitigating risk and promoting economic growth, as well as the efficiency and equity of the market allocations. On her own,

ability of Water Entitlements Seminar and Workshop (J. Pigram & B. Hooper eds., 1990) (unpublished manuscript, on file with the University of New England Centre for Water Policy Research); L. MacDonnell, *Transferring Water to Higher Uses*, Presented at the American Ass'n of Civil Engineers Conference on Water Resources for the Future: The Management Challenge (May 1989).

10. R. Young, *Why Are There So Few Transactions among Water Uses?* 68 Am. J. Agric. Econ. 1143, 1150 (1986).

11. See M. Gisser & R. Johnson, *Institutional Restrictions on the Transfer of Water Rights and the Survival of an Agency*, in *Water Rights: Scarce Resource Allocation, Bureaucracy and the Environment* (T. Anderson ed., 1983).

12. See T. Tregarthen, *Water in Colorado: Fear and Loathing of the Market Place*, in *Water Rights: Scarce Resource Allocation, Bureaucracy and the Environment*, *supra* note 11.

13. K. Miller, *The Right to Use Versus the Right to Sell: Spillover Effects and Constraints on the Water Rights of Irrigation Organization Members*, 23 Water Res. Research 2166 (1987).

14. See Anderson, *supra* note 1; Frederick & Hanson, *supra* note 8; C. Howe et al., *Innovative Approaches to Water Management: Lessons from the Colorado-Big Thompson Project and Northern Colorado Water Conservancy District*, in *Scarce Water and Institutional Change* (K. Frederick ed., 1986).

15. See Anderson, *supra* note 1; B. Saliba & D. Bush, *Water Markets in Theory and Practice: Market Transfers, Water Values and Public Policy* ch. 5 (1987); R. Gardner & T. Miller, *Price Behavior in the Water Market of Northeastern Colorado*, 19 Water Res. Bull. 557 (1983); Hartman & Seastone, *supra* note 1, at ch. 5; Maass & Anderson, *supra* note 1, at ch. 7.

16. Saliba & Bush, *supra* note 15.

Colby Saliba covers similar ground before concluding:

This research indicates that we are a long way from being able to understand and quantify benefits and costs associated with water markets and alternative transfer policies in order to determine how and to what extent market outcomes should be governed and circumscribed by public policy.¹⁷

Concerning California specifically, Henry J. Vaux observes that:

[t]here is no direct evidence to indicate how much Kern County might benefit from marketlike institutions that facilitate trade. It can be argued inferentially from existing information that markets would result in more efficient use of water in Kern County and could make additional supplies of water available for agriculture. Whether such markets can be developed is another question, however, since there are a host of institutional barriers to market exchanges of water.¹⁸

Richard W. Wahl and Robert K. Davis consider whether or not property rights allow Colorado River water to be marketed between irrigation districts in southern California.¹⁹ Richard E. Howitt and Henry J. Vaux contend that regulations preventing water agencies from making profits on water sales substantially reduce the amount of water traded.²⁰

Extending the earlier work of John C. Flinn and John W.B. Guise,²¹ which in turn had modified the T. Takyama and George C. Judge approach,²² Vaux and Howitt demonstrate that interregional trade models can be used to assess the benefits from interregional water trading.²³ Vaux and Howitt distinguish their approach from the earlier interbasin work of Charles Howe and K. William Easter; Maurice M. Kelso, William E. Martin, and Lawrence E. Mack; and Ronald Cummings, which considered discrete transfers between basins and the alternative investments between them.²⁴

A number of other specific issues related to water marketing are addressed in the literature. The works of Sotirios Angelides and Eugene

17. B. Saliba, *supra* note 9.

18. H. Vaux, Jr., *Water Scarcity and Gains from Trade in Kern County, California*, in Scarce Water and Institutional Change, *supra* note 14.

19. R. Wahl & R. Davis, *Satisfying Southern California's Thirst for Water: Efficient Alternatives*, in Scarce Water and Institutional Change, *supra* note 14.

20. Howitt & Vaux, *supra* note 9.

21. J. Flinn & J. Guise, *An Application of Spatial Equilibrium Analysis to Water Resource Allocation*, 6 Water Res. Research 398 (1970).

22. T. Takyama & G. Judge, *Spatial Equilibrium and Quadratic Programming*, 46 J. Farm Econ. 67 (1964).

23. H. Vaux, Jr. & R. Howitt, *Managing Water Scarcity: An Evaluation of Interregional Transfers*, 20 Water Res. Research 785 (1984).

24. Howe & Easter, *supra* note 1; Kelso et al., *supra* note 1; R. Cummings, *Interbasin Water Transfers: A Case Study in Mexico* (1974).

Bardach; Kenneth Frederick and James Hanson; and Richard L. Gardner²⁵ all discuss water banking, which is a means of trading water through a government agency—a water bank—on a short-term basis without renters forfeiting water under the prior appropriation doctrine. The works of Ari Michelsen and Robert A. Young; and Steven J. Schupe, Gary D. Weatherford and Elizabeth Checchio²⁶ both consider 'dry-year options' which are long-term arrangements allowing cities to use irrigators' water during droughts. An article written by Robert A. Young, John T. Faubert and J. Morel-Seytoux²⁷ considers alternatives before favoring a quasi-market system of stream-aquifer interrelationships, but its workability requires an adequate supply of upstream reservoir water to which groundwater users have market access. The works of Terry L. Anderson and Ronald N. Johnson; and Marie Leigh Livingston and Thomas A. Miller²⁸ are concerned with the effect of general instream rights on the transfer of water between traditional users whereas Walter Butcher, Philip R. Wandschneider and Norman K. Whittlesey; and Kathleen A. Miller²⁹ focus on hydropower generation as the instream use in the Pacific Northwest. Others are concerned with market transfers of water between hydropower generation and irrigation in that area.³⁰ Elizabeth Checchio and Bonnie Colby³¹ believe that both private and state agencies should be allowed to acquire water rights for instream flow maintenance. Focusing on subsidized Bureau of Reclamation water, Richard W. Wahl recommends that efficiency be promoted by making rights more secure and fostering water marketing with existing subsidies in place, rather than pursuing the historically unsuccessful task of removing the subsidies from water charges.³² Two recent developments with the potential to impact dramat-

25. S. Angelides & E. Bardach, *Water Banking: How to Stop Wasting Agricultural Water* (1978); Frederick & Hanson, *supra* note 8; R. Gardner, *A Beginning for a Water Market*, in *Water Values and Markets: Emerging Management Tools* (1986) (special report of the Freshwater Foundation).

26. A. Michelson & R. Young, *Economics of Optioning Agricultural Water Rights for Urban Water Supplies During Droughts*, in *Transferability of Water Entitlements Seminar and Workshop*, *supra* note 9; S. Schupe et al., *Western Water Rights: The Era of Reallocation*, 29 *Nat. Res. J.* 413 (1989).

27. R. Young et al., *Evaluating Institutional Alternatives for Managing an Interrelated Stream-Aquifer System*, 69 *Am. J. Agric. Econ.* 787 (1986).

28. T. Anderson & R. Johnson, *The Problem of Instream Flows*, 24 *Econ. Inquiry* 535 (1986); M. Livingston and T. Miller, *A Framework for Analyzing the Impact of Western Instream Water Rights on Choice Domains: Transferability, Externalities, and Consumptive Use*, 62 *Land Econ.* 269 (1986).

29. W. Butcher et al., *Competition between Irrigation and Hydropower in the Pacific Northwest*, in *Scarce Water and Institutional Change*, *supra* note 14; K. Miller, *Climate Change: Water Rights and Electric Utilities*, 1989 *Energy Pol'y* 420; K. Miller, *Water, Electricity, and Institutional Innovation*, in *Climate Change and U.S. Water Resources* (P. Waggoner ed., 1990).

30. See, e.g., J. Hamilton et al., *Interruptible Water Markets in the Pacific Northwest*, 71 *Am. J. Agric. Econ.* 63 (1989); N. Whittlesey and J. Houston, *Water Markets for Stream Flow Augmentation*, Presented to the Symposium for the American Water Resource Ass'n (June 1984).

31. Checchio & Colby, *supra* note 8.

32. R. Wahl, *Markets for Federal Water: Subsidies, Property Rights and the Bureau of Reclamation* (1989).

ically on water transfers in the western United States relate to groundwater and Indian reservation water rights.³³

In Australia, Bruce Davidson and Allan J. Randall each consider water marketing,³⁴ as do the more recent papers of John J. Pigram and Warren F. Musgrave; and Andrew K. Dragun and Victor Gleeson.³⁵ In Israel, Ezra Sadan and Ruth Ben-Zvi indicate the low cost of market and marketlike institutional alternatives relative to new resource development.³⁶ The works of Ronald Hide; and Walter Moore and Murray Arthur-Worsop discuss aspects of the move toward water marketing in New Zealand.³⁷ The long history of water marketing in Spain is detailed by Arthur Maass and Raymond L. Anderson.³⁸

Terry L. Anderson, Oscar R. Burt and David T. Fractor discuss, and illustrate with a case study, the concept of privatizing groundwater by granting individual users rights to both stocks and flows, and making such rights transferable.³⁹ Hence private users incur the full opportunity costs of their actions. This is privatizing the resource, which is distinct from privatizing previously public water supply authorities as done in England and Wales⁴⁰ and being considered in Australia.⁴¹

33. See D. Brookshire et al., *Current Issues in the Quantification of Federal Reserved Water Rights*, 21 Water Res. Research 1777 (1985); R. Cummings, *The Contemporary Setting for Water Management in the West: An Overview*, 21 Water Res. Research 1749 (1985); S. Deloria, *A Native American View of Western Water Development*, 21 Water Res. Research 1785 (1985); C. DuMars, *The State as a Participant in Water Markets: Appropriate Roles for Congress and the Courts*, 21 Water Res. Research 1771 (1985); C. DuMars & A. Tarlock, *Symposium Introduction: New Challenges to State Water Allocation Sovereignty*, 29 Nat. Res. J. 331 (1989); M. Moore, *The Bureau of Reclamation's New Mandate for Irrigation Water Conservation: Purposes and Policy Alternatives*, 27 Water Res. Research 145 (1991); A. Tarlock, *An Overview of the Law of Groundwater Management*, 21 Water Res. Research 1751 (1985); A. Utton, *Alternatives and Uncertainties in Interstate Groundwater Law*, 21 Water Res. Research 1767 (1985).

34. B. Davidson, *Australia: Wet or Dry?* (1969); A. Randall, *Property Entitlements and Pricing Policies for a Maturing Water Economy*, 25 Austl. J. Agric. Econ. 195 (1981).

35. J. Pigram & W. Musgrave, *Transferability of Water Entitlements in Australia*, Presented at the Annual Meeting of Universities Council on Water Resources (Aug. 1989); A. Dragun & V. Gleeson, *From Water Law to Transferability in New South Wales*, 29 Nat. Res. J. 645 (1989).

36. E. Sadan & R. Ben-Zvi, *The Value of Institutional Change in Israel's Water Economy*, 23 Water Res. Research 1 (1987).

37. R. Hide, *Property Rights and Natural Resource Policy*, Lincoln University Centre for Resource Management Studies in Resource Management (Canterbury, New Zealand) No. 3, 1987; W. Moore & M. Arthur-Worsop, *Privatizing Water: An Analysis of Initiatives to Sell Community Irrigation Schemes and to Create Water Markets*, Presented at the Annual Conference of the New Zealand Branch of the Australian Agricultural Economics Society (June 1989).

38. Maass & Anderson, *supra* note 1.

39. T. Anderson et al., *Privatizing Groundwater Basins: A Model and its Applications*, in *Water Rights: Scarce Resource Allocation, Bureaucracy and the Environment* (T. Anderson ed., 1983).

40. See D. Parker & W. Sewell, *Evolving Water Institutions in England and Wales: An Assessment of Two Decades of Experience*, 28 Nat. Res. J. 751 (1988).

41. See H. Mulligan, *Private Sector Involvement in the Irrigation Industry*, (University of New England Centre for Water Policy Research Occasional Paper. No. 6, 1990).

A BRIEF INTRODUCTION TO THE COMMON PROPERTY LITERATURE

Quite a large body of literature has arisen on the desirability of common property instead of private or state property in natural resource management. The economic discussion is led by writings which would fit Allan J. Randall's institutional/land economics (I/LE) classification.⁴² Conception Cruz; Christopher Gibbs and Daniel W. Bromley; and John Quiggin provide further examples of such writings.⁴³ Other prominent contributors in the wider literature are anthropologists and human ecologists as well as geographers, and political and environmental scientists.

There are a number of reasons for this renewed interest. A chief reason among economists is the dissatisfaction with the belief that common property is synonymous with open access, as further discussed below. Some economists also see common property as a way of promoting community and reducing conflict in some complex systems,⁴⁴ and as an equitable and efficient way of achieving sustainable resource use, especially under uncertainty.⁴⁵ Scholars from other disciplines are interested in common property for a number of reasons including the breakdown of traditional common property resource management as a factor in environmental degradation in developing countries;⁴⁶ as a means of nurturing degraded ecosystems back to productive states;⁴⁷ because of the "new-found pride in traditional values and institutions, both in the Third World and in the West,"⁴⁸ and because of the increasing realization that common property has been the means by which many natural resources have been traditionally maintained on a sustainable basis for a very long time.⁴⁹

42. See A. Randall, *Methodology, Ideology, and the Economics of Policy: Why Resource Economists Disagree*, 67 Am. J. Agric. Econ. 1022 (1985).

43. C. Cruz, *Water as Common Property: The Case of Irrigation Water Rights in the Philippines*, in *Common Property Resources: Ecology and Community-based Sustainable Development* (F. Berkes ed., 1989); C. Gibbs & D. Bromley, *Institutional Arrangements for Management of Rural Resources: Common-Property Regimes*, in *Common Property Resources: Ecology and Community-based Sustainable Development*, *id.*; Quiggin, *supra* note 8.

44. Quiggin, *supra* note 8.

45. Gibbs & Bromley, *supra* note 43.

46. See R. Goodland et al., *Meeting Environmental Concerns Caused by Common-Property Mismanagement in Economic Development Projects*, in *Common Property Resources: Ecology and Community-based Sustainable Development* 150, *supra* note 43.

47. See H. Regier et al., *Reforming the Use of Natural Resources*, in *Common Property Resources: Ecology and Community-based Sustainable Development* 110, *supra* note 43.

48. See F. Berkes & M. Farvar, *Introduction and Overview to Common Property Resources: Ecology and Community-based Sustainable Development* 3, *supra* note 43; see also B. McCay & J. Acheson, *Human Ecology of the Commons*, in *The Question of the Commons: The Culture and Ecology of Common Resources* 25 (B. McCay & J. Acheson eds., 1987).

49. See, e.g., A. Grima & F. Berkes, *Natural Resources: Access, Rights-to-Use and Management*, in *Common Property Resources: Ecology and Community-based Sustainable Development* 51, *supra* note 43; McCay & Acheson, *supra* note 48, at 14-15; S. Sutton, *The Falaj—A Traditional Co-operative System of Water Management*, in *Community Water Development* 268 (C. Kerr ed., 1989).

The literature can be divided broadly into concerns with international, global commons and concerns with local, regional and national commons. The World Conservation Strategy, a report of the World Commission on Environment and Development, and the work of Boulding address the former concern,⁵⁰ while this paper more closely addresses the latter. A recurring theme in this literature on common property is that mainstream 'property rights economists' have made a fundamental error by confusing common property with open access.⁵¹ In other words, they have followed Garrett Hardin's "tragedy of the commons" approach⁵² and paid too little attention to S.V. Ciriacy-Wantrup and Richard Bishop's observation that "common property . . . implies that potential resource users who are not members of a group of co-equal owners are excluded."⁵³ This recurring theme implies that too much has been made of the tendency for common property resource management to fail under external pressures,⁵⁴ as well as abuses from within,⁵⁵ and too little consideration has been given to factors resulting in their sustainability. Robert Wade discusses factors which increase the likelihood of successful collective action.⁵⁶ The above cited literature examines a range of specific types of natural resources being managed as common property. The authors do not see common property as a panacea. Some hope to develop a theory of why and under what conditions common property management continues, fails, occurs and re-occurs, replaces and is replaced by state and pri-

50. See World Commission on Environment and Development, *Our Common Future* (1987); see also K. Boulding, *Commons and Community: The Idea of a Public*, in *Managing the Commons* (G. Hardin & J. Baden eds., 1977).

51. See e.g., D. Bromley, *Common Property Issues In International Development*, 5 *Devs.* 12 (1985); C. Dahlman, *The Open Field System and Beyond: A Property Rights Analysis of an Economic Institution* (1980); McCay & Acheson, *supra* note 48, at ch. 1; Quiggin, *supra* note 8; C. Runge, *Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context*, 63 *Am. J. Agric. Econ.* 595 (1981); M. Taylor, *The Possibility of Cooperation* 26 (1987). However, just what constitutes closed or reduced access, in contrast to open access, is not abundantly clear, at least in the case of water resources. Presumably it means no access to new users without acquiring rights. Quiggin, *supra* note 8, makes the point, implicit in Ciriacy-Wantrup & Bishop, *supra* note 6, that it also implies upper bounds on access by existing users. But such upper bounds would need to be flexible in water resources subject to fluctuating supplies and demands, especially when private water storage facilities are available to users at their point of use. If, instead of such flexibility, users had constant upper limits on quantity used in, say, each week of a season, in droughts each user would seek access to the limited supplies to convert water from a common property resource in the headworks reservoir to a private property resource in their soil and, in the case of many irrigators in the uncertain Australian environment, in their large on-farm water storage facilities. This is wasteful because it converts water from low-loss to high-loss storage.

52. G. Hardin, *The Tragedy of the Commons*, 162 *Sci.* 1243 (1968).

53. Ciriacy-Wantrup & Bishop, *supra* note 6, at 715.

54. F. Berkes, *Cooperation from the Perspective of Human Ecology*, in *Common Property Resources: Ecology and Community-based Sustainable Development*, *supra* note 43.

55. Quiggin, *supra* note 8.

56. R. Wade, *Village Republics: Economic Conditions for Collective Action in South India* (1988); R. Wade, *The Management of Common Property Resources: Finding a Cooperative Solution*, 2 *World Bank Res. Observer* 219 (1987).

vate property. But most examine single natural resources in particular historical, cultural and geographical settings.⁵⁷ Perhaps the best overview of the literature is given in the following quote from Bonnie McCay and James M. Acheson:

By equating common property with open access, the tragedy-of-the-commons approach ignores important social institutions and their roles in managing the commons. Moreover, its policy solutions—government intervention and privatization—can weaken or demolish existing institutions and worsen or even create tragedies of the commons.⁵⁸

57. One of the most cited works is that of R. Netting, *Balancing On an Alp: Ecological Change and Community in a Swiss Mountain Community* (1981), who left anthropological research in Africa in favor of a Swiss alpine community, largely because of the detailed historical data available. He writes "By 1473 the community was regulating its affairs by written statute An important regulation of alp rights in 1517 . . . laid down the principle that 'no one is permitted to send more cows to the alps than he can winter.' This made the number of animals sent to the communal summer pasture directly dependent on the amount of hay and thus the meadow area possessed by each cattle owner The alp could not, in theory, be overgrazed, because stocking was limited to the fixed number of animals that could be provided from a bounded village territory. At one stroke this simple rule overturns the economic logic of the 'tragedy of the commons.' The Torbel rule was given teeth by the provision for one official . . . to be chosen yearly. . . [with the] . . . authority to fine anyone who exceeded his quota at the high rate of two pounds per horse, one pound per cow, and five shillings per sheep Half the fine was kept by the official 'for his work'. In 1971 similar penalties were exacted. The most detailed rules for internal order were those in 24 statutes written on parchment and dated April 17, 1531." Netting, *supra*, at 60-62. After closing the community to immigration, the population was controlled by strict mores. "The closed community of Torbel maintained a level of vigilance on its members that militated against any clandestine sexual activity. From the small windows of the black log houses there . . . is no movement on the paths or across the meadows that cannot be identified both as to who it is and what they are doing. It is instantly known whether or not the person can possibly have business in that place at that time of day. . . . In this sense privacy is the enemy of the moral community, and the Torbel of times past trusted its members no farther than it could see them." *Id.* at 134. For recent comprehensive case studies by economists, see N. Jodha, *Rural Common Property Resources: Contribution and Crisis*, 25 *Econ. & Pol. Wkly* A65 (1990); and Wade, *supra* note 56.

58. McCay & Acheson, *supra* note 48, at 34. The language used by McCay and Acheson refers to G. Hardin's classic article "The Tragedy of the Commons," *supra* note 52. It may appear that Hardin was inferring that all common property resources will end up in tragic open-access situations. However, the title of his article, "The Tragedy of the Commons," and the use of that phrase in his paper, is really an abbreviation for "The Tragedy of Freedom in a Commons," which is the title of a key section in his paper. He wrote, "Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all." Hardin, *supra* note 52, at 1244. Hence he was writing about tragedy in those commons free from effective rules governing behavior, including entry, rather than claiming that all common property resources are destined for the tragedy which such freedom brings. For a discussion of those types of collective action to which limit such freedom, see E. Ostrom, *The Origins of Institutions for Collective Action in Commonpool Resource Situations* (Indiana University-Bloomington, Workshop in Political Theory and Policy Analysis Working Paper No. 14, 1985).

CAPACITY SHARING (CS)

At the outset it is useful to distinguish between the development of property rights to water in Australia, where the concept of CS originated, and in the western United States which is prominent in the movement toward water marketing. In the western United States, a large and viable irrigation industry, holding property rights to unregulated streamflows, was firmly established before large dams were built to increase usable supplies. The generally more arid climate in Australia made it obvious that major headwork dams would have to precede significant irrigation. Hence, in Australia water rights grew up around regulated water supplies; in the western United States the construction of large dams caused relatively minor adjustments to existing rights. Australian water rights are mostly defined in terms of stored water whereas in the western United States they are mostly defined in terms of pre-regulated streamflows. Thus Capacity Sharing is developing in Australia to aid in the management of water systems in which the operation of water storage is paramount.

In terms of irrigation system decisionmaking, there are really two Australias; one lies in the predominantly winter rainfall zone in the higher latitudes, and one covers the predominantly uniform and summer rainfall zones in the lower latitudes.⁵⁹ Given the usual 'summer drought' in the winter rainfall zone, once the pre-planting irrigation is applied, there is virtually no uncertainty about either demand or supply for the immediate year. Uncertainty is essentially limited to supply in later years. Known supply and demand for the immediate season permits the use of deterministic, season-long, computer-based operations research methods, such as simulation or linear programming models, with a high degree of confidence.

In great contrast, in the summer and uniform rainfall zones of the lower latitudes, both supply and demand for irrigation water remain highly stochastic or uncertain at the time water use decisions are made. This means that stochastic, short time-step decision models for water users are required in place of the deterministic, season-long time-step models sufficient for the higher latitudes. Decisionmaking is further complicated in this environment by serial correlation in both supply and demand, and cross-correlation between them.

Although these complications add considerably to the complexity of the models and data required in the lower latitudes, further complexity arises because supply-side and demand-side subsystems should not be

59. N. Dudley, *Alternative Institutional Arrangements for Water Supply Probabilities and Transfers*, in *Transferability of Water Entitlements Seminar and Workshop* (J. Pigram & B. Hooper eds., 1990) (unpublished manuscript, available from the University of New England Centre for Water Policy Research).

modeled separately. There is a great deal of interaction between supply-side and demand-side decisions in the lower latitudes. Demand for water is conditioned by the users' perceptions of the reliability with which supplies fluctuating through time will match their fluctuating demands. For example, users may respond to a perception of unreliable supply by modifying crops planted and maintained under irrigation in times of shortage; modifying construction and operation of on-farm water storage facilities which are commonplace in the lower latitudes in Australia; and modifying areas and methods of leveling land, or channeling or recirculating water.

Each of these modifications in turn affects the demand-reliability preferences of users which the supply authority tries to accommodate by changing reservoir storage carryover strategies. That is, supply management, and the resulting probability that supplies will be sufficient for demands, is conditioned by the supplier's perception of the users' reliability preferences.⁶⁰ This means that there are difficulties or problems of coordination and communication between the supply-side and demand-side decisionmakers. These problems apply both in real life and when modeling to aid decisionmaking.

One approach to overcome these coordination and communication problems, and to indicate what is optimally achievable using the water resources of a river valley, is to assume that one decisionmaker controls both supply-side and demand-side decisions in a system with a non-limiting distribution system capacity. This approach internalizes the coordination and communication decisions and jointly optimizes the reservoir and farm management and planning decisions to maximize expected regional net revenue from water use. Even so, a hierarchy of decisions remain: within-season and beginning season system operation decisions need to be optimized before long-term planning decisions about reservoir and distribution system capacities, and size of area to be serviced, can be optimized. At first, a suite of computer simulation and dynamic programming models was used⁶¹ to develop this approach before it was simplified by using a larger-dimension dynamic programming model.⁶²

60. G. Kaine-Jones & Y. Simpson, A Cluster Analysis of Cotton Planting Strategies in the Namoi Valley, Presented at the 34th Annual Conference of the Australian Agricultural Economics Society (Feb. 12-15, 1989); N. Dudley, *Volume Sharing of Reservoir Water*, 24 Water Res. Research 641 (1988).

61. N. Dudley, *A Single Decision-Maker Approach to Irrigation Reservoir and Farm Management Decision Making*, 24 Water Res. Research 633 (1988); N. Dudley, *Irrigation Planning 4: Optimal Interseasonal Water Allocation*, 8 Water Res. Research 586 (1972); N. Dudley et al., *Optimal Intra-seasonal Water Allocation*, 7 Water Res. Research 770 (1971); N. Dudley, *Irrigation Planning 2: Choosing Optimal Acreages within a Season*, 7 Water Res. Research 1051 (1971); N. Dudley et al., *Irrigation Planning 3: The Best Size of Irrigation Area for a Reservoir*, 8 Water Res. Research 7 (1972).

62. N. Dudley & O. Burt, *Stochastic Reservoir Management and System Design for Irrigation*, 9 Water Res. Research 507 (1973).

The first attempt to progress from one to multiple decisionmakers involved one reservoir manager interacting with multiple but identical irrigation decisionmakers, each trying to maximize expected net revenue. However, under this scheme, the regional expected net revenue fell below that of the single decisionmaker system because communication and coordination problems existed between the reservoir managers and the irrigators.⁶³

CS provides for multiple decisionmakers while keeping coordination and communication problems internalized within one decision-making entity. Each user has secure, long-term title to a percentage share in the capacity or empty space of the reservoir and a percentage share of its inflows as well as reservoir losses. As noted above, it is as though each user has their own small reservoir on their own small stream. This gives users with varying degrees of risk aversion the flexibility to manage their individual sub-systems in accordance with their specific income stability requirements with much less interference from the behavior of other water users and reservoir managers than exists with centralized reservoir management.⁶⁴ The extent to which there are non-market interactions between the users under CS could depend on the climatic environment in which the system is located, although this interaction was found to be negligible in the environmental setting of Dudley and Musgrave.⁶⁵

CS was developed so irrigators could allocate their own water through time so as to satisfy their individual supply sufficiency requirements in a highly uncertain environment without interference from other water users or reservoir managers. Allowing water stored in the users' shares of reservoir capacity to be transferred through the market confronts users with the full opportunity costs of water.

Dudley and Musgrave⁶⁶ illustrate CS with an example in which 25 percent of the water users are risk neutral whereas each of three other

63. Dudley, *supra* note 61.

64. N. Dudley & W. Musgrave, *Capacity Sharing of Water Reservoirs*, 24 *Water Res. Research* 649 (1988).

65. Under CS, there is no reservoir inflow interaction between shareholders unless voluntary exchange of inflows is engaged in; there is no reservoir storage interaction between shareholders, apart from very minor storage loss interaction depending on the total volume stored in the reservoir, until (a) shareholders exchange storage or (b) one shareholder gains stored water unexpectedly because other shareholders do not sell enough of their stored water in time to prevent their share of storage 'overflowing' into the storage space of others; there may or may not be distribution system interactions between shareholders depending on the nature and capacity of the distribution system. *Id.* See also N. Dudley, *Urban Capacity Sharing—An Innovative Property Right for Maturing Water Economies*, 30 *Nat. Res. J.* 381 (1990). Bringing the distribution system into the models complicates them greatly, but this is currently being pursued by this author. A daily time step simulation model, and a corresponding dynamic, stochastic optimization model, is being developed to incorporate delivery time lags of some three weeks, irrigation frequencies of about ten days and on-farm storages in which to store currently unusable tributary flow water and unwanted reservoir release water (unwanted because of local rain while the reservoir release is traveling to the point of use).

66. Dudley & Musgrave, *supra* note 64.

user groups had different levels of risk aversion. The authors also note that the CS concept readily extends to multiple purposes such as instream recreation and environmental uses, flood control and urban uses as well as irrigation. Each of these purposes could be represented by a user group controlling a share of reservoir capacity and inflows. This represents 'first level' CS. Some user groups, such as flood control, may always operate their shares as a single unit. But, for other users, there are many ways in which each group's inflows and stored water can be suballocated to group users. Final users, those who use water as a private or rival good, such as irrigators and urban users, may in turn control shares in the reservoir capacity and inflows allocated to the larger group to which they belong. This represents 'second level' CS. Not all members of the group would be required to control individual shares themselves. For example, half of the irrigators may continue to use half the group's share in the traditional way while the other members would engage in (second level) CS and control their own shares. Similarly, only some industrial users may choose to be final shareholders while the rest receive water in the traditional way, and many private urban consumers would receive water allocated to them from the remainder of the urban share of reservoir capacity and inflows in the traditional way.⁶⁷

There could be more than two levels of CS. For example, the total urban share of a multi-purpose system (first level) could be subdivided into a number of shares, each controlled by a smaller urban authority (second level), who could then retail water to final consumers in a traditional way or by final user (third level) CS.⁶⁸ The number of users wishing to be final shareholders could expand over time as familiarity with the concept grows, although details of how existing group storage contents would be allocated at the time would need to be worked out. Note that the long-term rights held by CS users may not amount to private ownership of the resource, but may be a perpetual or long-term lease with sufficient security of tenure to result in efficient resource allocation.

To conclude this introduction to CS, note that it was developed to integrate supply and demand management in highly uncertain environments, and thus promote economically efficient resource allocation. The stochastic supply/stochastic demand was seen as the general case; short-term deterministic supply and demand situations are seen as special cases. But the first fertile ground for CS at an applied level was a special case area, as discussed in the following.

67. Dudley, *supra* note 65.

68. *Id.*

TAKING ROOT IN VICTORIA

Even before the first publication on CS, the concept was conveyed to the Director General of the Department of Water Resources in Victoria, Australia, economist Dr. John Paterson.⁶⁹ He quickly appreciated that CS provides a non-attenuated property right for water by a necessary "exhaustive partitioning of the resource among title holders . . . [which] . . . can be achieved only at the [resource] source."⁷⁰ He and his staff examined the feasibility of the concept for Victoria.⁷¹ They generally favored CS over the existing alternative—release sharing. Paterson distinguished between them as follows:

Release sharing defines entitlements in terms of delivered water with a given volume and reliability. The owner/operator of the storage decides what amount is available for release in the light of circumstances, and what prudent carry-over is required to meet the obligation of the operator. *Capacity-sharing* allocates explicit shares of storage capacity, inflow, losses, and hence stored water, to end users, each of whom decides, in regard to their own respective shares, what amount is available for release, and what to carry over.⁷²

Warren M. Musgrave, Chris Alaoze, and Norman J. Dudley⁷³ show algebraically that CS is at least as good as release sharing in achieving an efficiency objective in the predominantly winter rainfall environment where 'supply reliability' remains a useful concept, and does not need to be replaced by 'supply sufficiency reliability' which is relevant in the lower latitudes, as indicated above and discussed in Dudley.⁷⁴

69. N. Dudley & W. Musgrave, Property Rights and Capacity Sharing of Water Resources, Presented at the 30th Annual Conference of the Australian Agricultural Economics Society (Feb. 1986).

70. J. Paterson, *Rationalized Law and Well-Defined Water Rights for Improved Water Resource Management*, in Renewable Natural Resources: Economic Incentives for Improved Management 48 (OECD, ed., 1989).

71. C. Alaoze, A Dynamic Programming Demonstration of the Optimality of Capacity Sharing over Release Sharing as a Method of Allocating Entitlements to Bulk Water in Shared Reservoir Systems (Victorian Dep't of Water Resources Staff Paper No. 8, 1988) (unpublished manuscript, available from Victorian Dep't of Water Resources, Australia); Dep't of Water Resources, Security for Major Water Allocations: Background Report (Water Resources Management Series Report No. 8., 1987) (unpublished manuscript, available from Victorian Government Printing Office, Melbourne).

72. J. Paterson, *supra* note 70, at 51.

73. W. Musgrave et al., *Capacity Sharing and its Implications for System Reliability*, in Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability (G. Dandy & A. Simpson, eds., 1989) (Australian Water Resources Council Series No. 17) (unpublished manuscript, available from Australian Gov't Publication Service, Canberra). See also Alaoze, *supra* note 71.

74. Dudley, *supra* note 59.

After discussing the complexities that arise in introducing CS, John Paterson concludes:

In Victoria, Australia, we hope to obtain enabling legislation which permits the old and debased coinage of releases to be translated into the new currency of transferable capacity shares. Statutory safeguards and saving provisions are proposed to confirm the negotiating base of existing right holders. The rate of (voluntary) uptake of the new instrument of allocation can only be guessed at. There are currently enough supply authorities with exposed positions to offer a high probability that some immediate use will be made of the new provisions.⁷⁵

This hope has since become a reality with the passing of a new act governing the use of water by the Victorian state parliament.⁷⁶

DISTINGUISHING FEATURES OF CAPACITY SHARING

Although aspects of the nature and implementation of CS are still evolving, such as the recent addition of percentage sharing of below-dam tributary flows to the river when it serves as delivery channel,⁷⁷ CS possesses some distinguishing characteristics. The term *Capacity Sharing* is really an abbreviation chosen to highlight the proportional sharing of one or more reservoirs in a water resources supply system among users or groups of users who store their share of inflows according to their aversion to risk. To preserve the analogy that CS allows each shareholder to have their own small reservoir on their own small stream to operate as they choose with a minimum of interference, streamflows above and below the reservoir are also shared proportionately. Hence, a more descriptive but cumbersome term would be "proportional sharing of streamflows (reservoir inflows and downstream tributary flows) and proportional sharing of active reservoir storage capacity in which share holders can store their share of inflows according to their risk preferences."

POTENTIAL ROLE OF CAPACITY SHARING WITH PRIVATE AND COMMON PROPERTY

This section discusses 1) the compatibility of CS and private property in water resource systems; 2) the compatibility of CS and common property in water resource systems; and 3) the compatibility of CS, private

75. Paterson, *supra* note 70, at 60.

76. Water Act of 1989, Vict. Acts No. 80.

77. Dudley, *supra* note 59.

and common property in water resource systems. Private property is equated in the following discussion with the market allocation of resources.

COMPATIBILITY OF CAPACITY SHARING AND MARKET ALLOCATION

To make efficient short- and intermediate-term management decisions, including decisions about trading water, users must have confidence in their information on the probabilities of supply. Users match the probability of supply with the probability of demand in a decisionmaking process to determine the likelihood of going broke, the suitability of their cash flow path over time, and other eventualities. Other things being equal, the greater the uncertainty about the probabilities of supply and demand, the less likely efficient decisions will emerge. Ronald Heiner argues that increasing the uncertainty and complexity of problems will lead decisionmakers to resort to rules which restrict their behavior to a "limited repertoire of actions" instead of optimizing decisions from the total set of options available.⁷⁸ For efficient long-term decisions, including decisions about trading in water rights, users need secure tenure to rights for which the probabilities of supply will be unaffected by human intervention throughout the users' planning horizons without sufficient compensation.⁷⁹

CS satisfies these security requirements by granting shareholders, whether individuals or groups, secure long-term rights to a known percentage of inflows into a known percentage of active reservoir storage capacity, plus a known proportion of downstream tributary flows, if relevant. Using only reservoir inflow probabilities, shareholders can determine the probabilities of receiving their supplies since there is virtually no interference from others.⁸⁰

Thus CS gives both buyers and sellers a high degree of confidence in what is being traded. Water may be traded in the short term as a fixed quantity already in storage or as a future probable streamflow, or a combination of both.⁸¹ Similarly, CS provides an excellent basis for trading long term water rights of known probabilities because of the long-term title security. Dudley⁸² argues that other institutional arrangements for allocat-

78. R. Heiner, *The Origin of Predictable Behavior*, 73 Am. Econ. Rev. 560 (1983); R. Heiner, *The Origin of Predictable Behavior: Further Modeling and Applications*, 75 Am. Econ. Rev. 391 (1985).

79. Dudley, *supra* note 59.

80. Dudley & Musgrave, *supra* note 64.

81. An individual shareholder would, *ceteris paribus*, value water less as their reservoir share contents approaches its maximum level (i.e. the capacity of their reservoir share) since any water in excess of the maximum is lost to that individual shareholder unless sold beforehand or some extra storage can be obtained temporarily. Dudley, *supra* note 59.

82. *Id.*

ing water require information in addition to streamflow probabilities, and that the nature of the extra information reduces the shareholders confidence in their water supply probabilities and leads to less satisfactory market outcomes.

Since all distinct water uses from a supply system—including environmental, flood control and recreation uses—are represented by shareholdings, market transferability ensures that each use is confronted with market-generated opportunity costs. Adjustments may be made to reflect social opportunity costs, but the tradeoffs associated with allocating water to the various uses would be manifest. No one, including governments, could obtain shares of capacity and streamflows without entering the market and purchasing them from whoever values them least.⁸³

Instream user groups are likely to order releases from their reservoir shares only when the sum of other releases traveling the river reach of concern falls below their target rate. Free-rider problems may emerge if two or more downstream uses, such as recreation and environmental, required minimum flows at the same time. This suggests that one shareholder group could provide water for both purposes. Flood controllers, normally aiming to keep their reservoir share close to empty, may accumulate some water in times of low flood probabilities to sell to other users before the flood probability increases, thereby providing some revenue to offset their portion of reservoir operating costs.⁸⁴

Hence, CS is highly compatible with both short- and long-term market reallocations of water. Constraints may be needed to protect third parties, as with other market allocation institutional arrangements. The nonattenuated (explicit, enforceable, exclusive, transferable) nature of the property rights under CS make it an appropriate institutional arrangement for allocating water rights by market in a new system.⁸⁵ Moreover, CS establishes a basis for the operation of common property subsystems within large water resource systems, as discussed in the following section.

83. *Id.*

84. Dudley & Musgrave, *supra* note 64.

85. On the other hand, an initial nonmarket allocation of shares in reservoir capacity and streamflows could reflect equity concerns with subsequent marketing being a tool for economically efficient reallocation. In any case, under CS capital recovery, maintenance and most operating costs of the reservoir and associated works would be levied on users according to their size of shareholdings, rather than volume of water used, which would stabilize their annual costs and revenue to the dam builder. Dudley, *supra* note 65.

COMPATIBILITY OF CAPACITY SHARING AND COMMON PROPERTY

Cooperative decisions relating to common property are found to be more durable when the decision making group is relatively small.⁸⁶ Size per se is not important, but several conditions related to size do affect the durability of the decisions. McKay and Acheson capture most commentators' sentiments when, summarizing the work of Elinor Ostrom,⁸⁷ they observe that:

[s]mall-scale communities are more likely to have the formal conditions required for successful and enduring collective management of the commons. Among these are the visibility of common resources and behavior toward them; feedback on the effects of regulations; widespread understanding and acceptance of rules and their rationales; the values expressed in these rules (that is, equitable treatment of all and protection of the environment); and the backing of values by socialization, standards, and strict enforcement.⁸⁸

Incentives to cooperate can be negative as well as positive. Fikret Berkes notes that "small communities are not pleasant places for those who violate local rules and norms of cooperative behavior."⁸⁹ Michael Taylor believes that the most important size effect is the "increased difficulty of conditional cooperation in larger groups."⁹⁰

If effective common property resource management is restricted to relatively small groups, how are large, modern water resource systems to be managed? The world's major water resource systems typically cover large geographic areas, often drawing water from and supplying diverse political jurisdictions while attempting to satisfy multiple objectives across a range of multiple uses. Such large systems are often state owned

86. R. Bish, *Environmental Resource Management: Public or Private?* in Managing the Commons (G. Hardin & J. Baden eds., 1977); K. Bullock and J. Baden, *Communes and the Logic on the Commons*, in Managing the Commons, *supra*; Cruz, *supra* note 43; M. Gadgil & P. Iyer, *On the Diversification of Common-Property Resource Use by Indian Society*, in Common Property Resources: Ecology and Community-based Sustainable Development, *supra* note 44; M. Olson, *The Logic of Collective Action* 36 (1971); C. Runge, *supra* note 53; C. Runge, *Institutions and the Free Rider: The Assurance Problem in Collective Action*, 46 J. Pol. 154 (1984); R. Wade, *The Management of Common Property Resources: Finding a Cooperative Solution*, 2 World Bank Res. Observer 219 (1987).

87. McKay & Acheson, *supra* note 48, at 23.

88. Ostrom, *supra* note 58; M. Olson, *The Rudiments of a Revised Theory of the Origins, Survival, and Performance of Institutions for Collective Action* (Indiana University-Bloomington, Workshop in Political Theory and Policy Analysis Working Paper No. 32, 1985).

89. Berkes, *supra* note 54, at 85.

90. Taylor, *supra* note 51, at 12. Conditional cooperation exists where one's cooperation is conditional on that of other group members. It is required among at least some group members if collective action is to be sustained. *Id.*

with sub-systems operating under either private or common property. Conception Cruz provides an example of the latter from the Philippines.⁹¹ Water in the river is called *object* water and is subject to state control, whereas diverted water is a 'commodity' subject to a common property group's set of rules. As water becomes increasingly scarce in most of these large systems in the future, how is it to be allocated to the various sub-systems?

CS is an appropriate allocation method in these circumstances. To illustrate, consider a water resources system with a large headworks reservoir on a major river with some downstream tributaries. Water is supplied to a number of relatively small irrigation and village supply sub-systems operating under common property rules, and to a large urban area, downriver from the reservoir. Diversion weirs are in place where necessary to ensure that each of the groups can divert their portion of river flows regardless of the total flow. A variable-by-month minimum instream flow requirement exists for recreation and environmental purposes in the river beyond the furthest downriver diversion. Also, hydro-power is generated as a by-product of releases for other purposes. The reservoir is used for flood control as well.

Under CS, each of the irrigation/village communities, the urban water authority, the body responsible for instream flow maintenance and a flood control agency has long-term control of a percentage share in the active reservoir storage capacity. Although most of these CS shareholders control percentage shares of reservoir inflows and downstream tributary flows, the flood control agency may not share either inflows or tributary flows, thereby increasing shares to the other users. Diverters do not share in the flow of tributaries which enter the river downstream from their diversion points since such flows could only be used by them to barter for water upstream of their diversions.

The essential point is that, once the system is in place, the irrigation/village communities and the urban water center would be able to operate their shares of reservoir capacity as they choose, and allocate water within their groups by following their own common property rules without interference from others. Their behavior continues as long as their share title security is maintained. The minimum flow authority depends to some extent on return-to-river flows to maintain instream targets and save some of their reservoir water. This strategy may involve learning about quantities, qualities and lags of return flows, so long as the incentive exists to do so.⁹² Similarly, there is some dynamic interdependence between the releases of the flood control authority and other users, but CS

91. C. Cruz, *supra* note 43.

92. If the minimum flows apply to the river above the furthest downstream diversion, the instream maintenance authority would need to devote more attention to the releases of other users.

does not increase these interdependencies relative to alternative institutional arrangements.

Transfers of water and storage rights between shareholders over time can be by market or by political/administrative processes. Each common property group must arrive at a joint decision on quantities to buy or sell in the market, or quantities to ask for under political/administrative allocation. Procedures to protect third parties may be required in both cases. Market transfer forces each of the shareholders, including common property groups, to account directly for the opportunity cost of use by other shareholders, and to compensate the sellers to a degree satisfactory to them. However, considerable pressure may need to build up in more traditional societies before transfers of any kind are allowed.

The initial allocation of storage and water rights in an existing system could preserve the historical allocations as far as practical. This may result in emerging uses, such as instream flows, receiving a very small share of the allocated rights, and it may need to be modified to provide for the new uses. If market transactions are permitted, however, public funds can be budgeted to purchase water rights from the common property groups which value them least and to reallocate those rights to recently recognized water uses.

Regardless of the method of water transfers, or the extent to which they are permitted at all, CS provides a means of identifying the rights to water resources held by each of the common property groups, facilitating both the management of water by those groups and the transfer of water between them and other users.

COMPATIBILITY OF CAPACITY SHARING, PRIVATE PROPERTY AND COMMON PROPERTY

CS has attractive features for promoting efficient allocation and reallocation of water under either (a) private property, market transfer situations or (b) systems wherein rights to water are held as common property with either zero, market or nonmarket water rights transfers. However, CS has the added advantage that its non-attenuated property rights structure, with a clear delineation of who is entitled to what portions of stored and flowing water, promotes the efficient allocation of water when some water rights are privately held and some are held in common. Some shares of the reservoir and streamflow resources can be held and managed through time as common property while others can be held by private users. Still other shares can be managed by some mix of political and bureaucratic administration which would not affect the efficiency with which the private and commonly held shares are managed.

CS requires continuous accounting of each shareholders' streamflow and stored water volumes, so share holders know, at any time, the

location of the water to which they are entitled. One reason to have large, common property shareholdings, more common in less developed countries, is to allow for economies of size in monitoring and acting upon this information. On the other hand, the tendency toward greater water use efficiency when individual users directly confront the opportunity costs of the water they use, is an advantage gained when shares are held by final, private water users. Therefore, different economy-of-size situations may call for different balances of private and common control.

CONCLUSION

CS is an effective mechanism for allocating the water resources of large systems. It provides for a minimum amount of detrimental interaction between the beneficiaries, and a maximum amount of positive signals to promote efficient resource use, for any mix of public control, private property rights, and common property rights among water users.