Hydro-Economic Models
- Insights for Integrated Management and Adaptation to Climate Change

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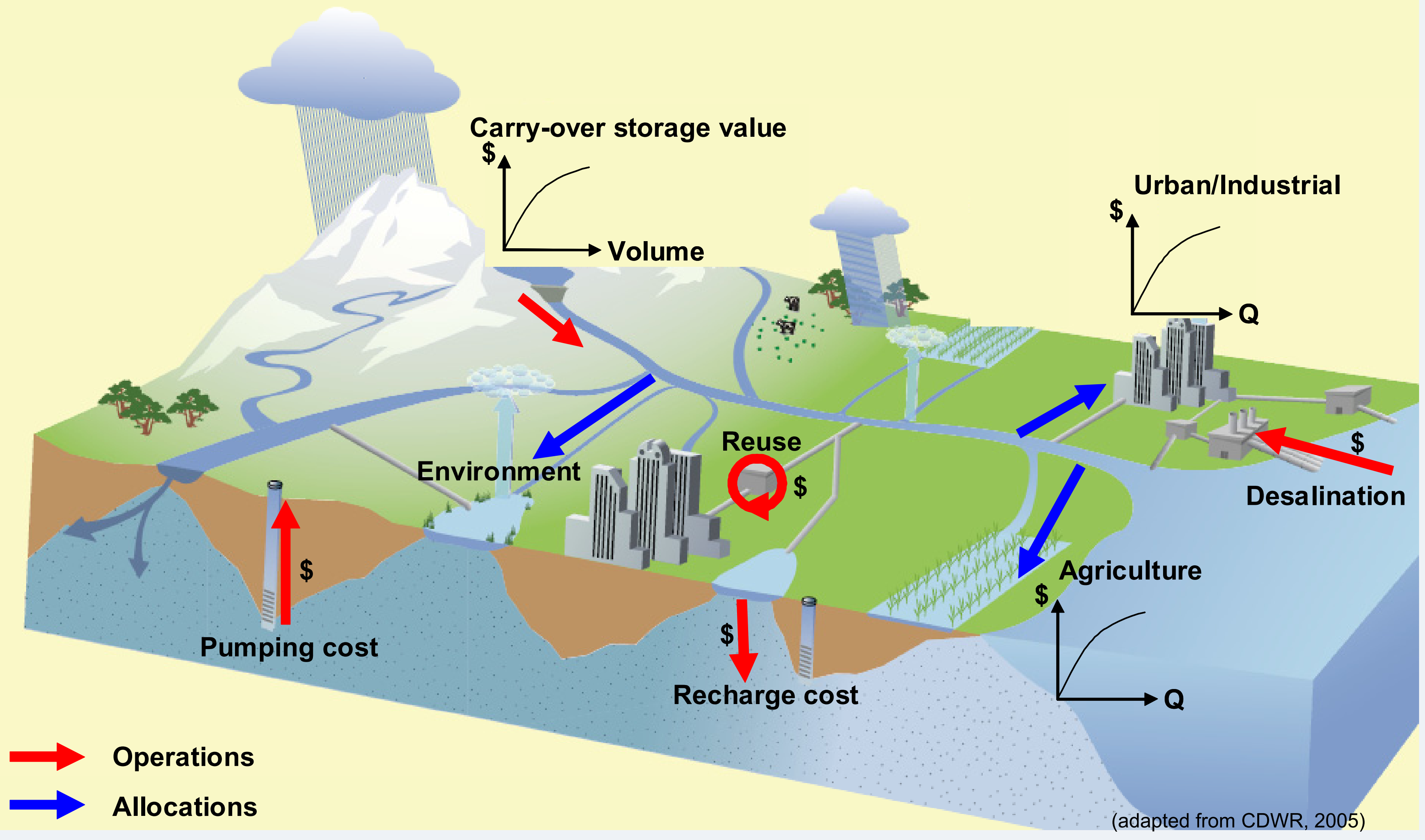
Introduction to Hydro-economic Models

Using economic concepts and parameters can help water managers design, operate and expand water resource systems efficiently and in accord with societal values and priorities. The cross-fertilization of engineering and economics allows both fields to represent more realistically within mathematical models how water is managed in practice and how management could be improved.

Hydroeconomic models are distinguished by a solution-oriented and integrated approach. A central idea is that water demands are not fixed but rather functions where different quantities of water at different times have varying total and marginal values to distinct users. In this approach water allocation and management is driven by the economic value of water and/or evaluated by that measure. Representing in a single framework a wide array of hydrologic and economic processes and water management options reveals both opportunities for improvement and policy insights. Hydroeconomic models are built with diverse aims, formulations, levels of integration, spatial and temporal scales, and solution techniques. Both simulation and optimization approaches are used.



(adapted from CDWR, 2005)

Figure 1: Hydro-economic perspective of a managed water resource system. Allocation can be driven by agricultural and urban economic benefit functions, carry-over storage value and constrained by environmental flows. Operating costs are incurred by managing flows (e.g. groundwater pumping, artificial groundwater recharge, desalination, water reuse, water treatment, …).

California Water Management

California faces population growth, possible dry climatic change and increased demands for water and environmental quality. Agricultural (80% of use), urban, industrial and environmental sectors compete for finite supplies within a complex natural and engineered system. The state has moved from centralized control of large reservoir systems to encouraging local implementation of innovative solutions such as water banking (conjunctive use), water transfers (figure 2), and water reuse.

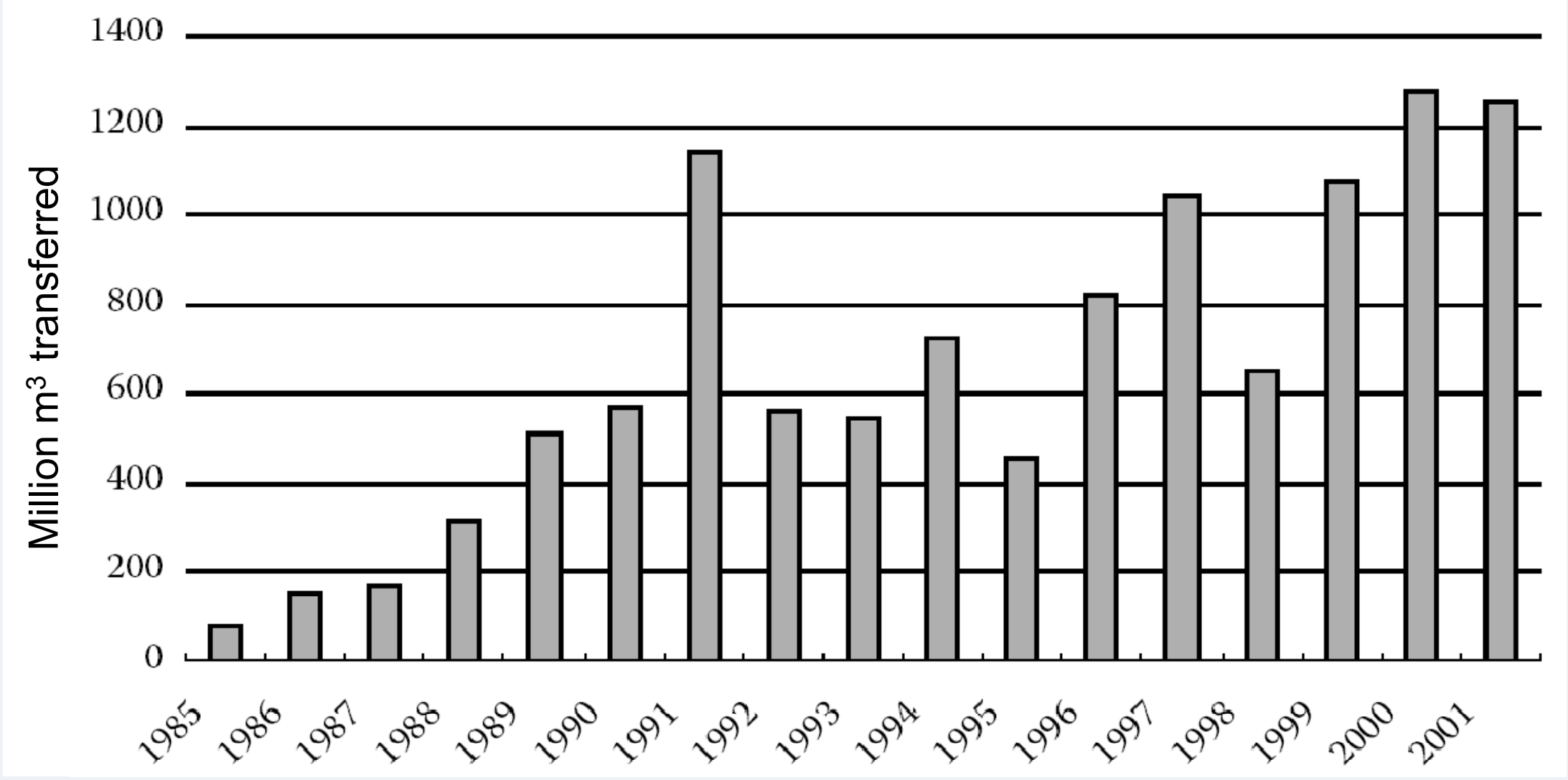


Figure 2: Total water transfers in California (Howitt and Sunding 2004). 75% of water is sold by Central Valley farmers; 25% from rural counties. Purchases since 1995: 20% environmental flows, 50% farmers, 30% municipal.

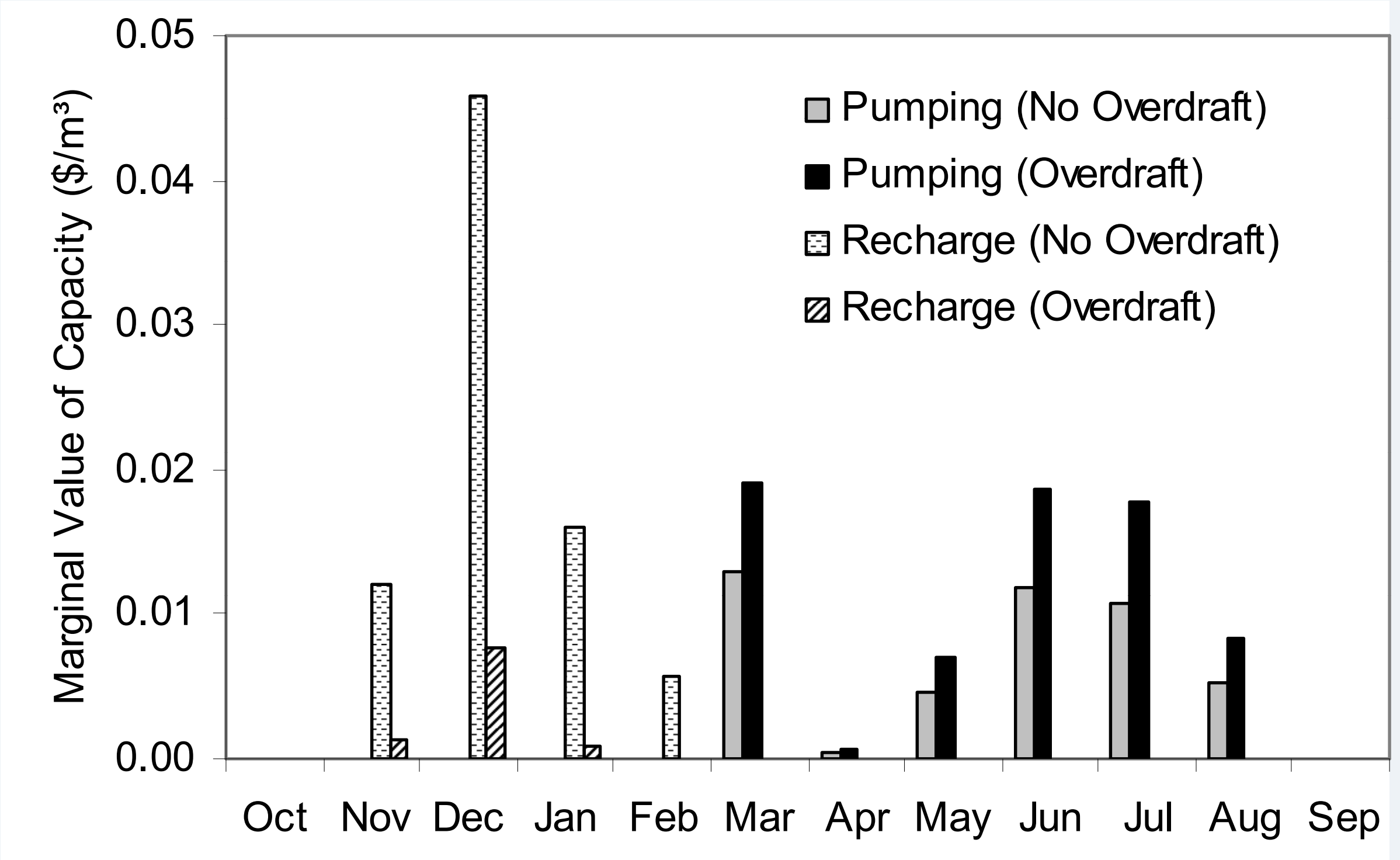


Figure 3: Shadow values showing the monthly economic value of more artificial groundwater recharge and pumping capacity in groundwater banks. Both overdrafting and sustainable aquifer management scenarios are considered (Harou and Lund, *in press*).

Hydro-economic Modelling of California

Hydro-economic models can be used for climate change impact studies and for policy evaluation. Figures 3 and 4 show results of a hydro-economic model of the entire inter-tied California water resource system (see CALVIN in figure 5) (Draper et al. 2003). The model optimizes water allocation and operations over 72 years of historical or climate change perturbed hydrology.

Results bring insights to questions such as: how does trading affect water scarcity, what effect do markets have on agricultural water use, how will these answers shift under climate change? What solutions are most robust to adapt to climate change: new infrastructure or new institutions, policies and operating rules?

Climate scenario		Historical	Dry-warm
Delivery target (MCM)		51,904	51,792
Actual delivery (MCM)		47,344	43,773
Water scarcity (MCM)	Total[a]	4,561 (9%)	8,019 (15%)
	Agriculture	4,487 (12%)	7,919 (22%)
	Urban	74 (<1%)	100 (<1%)
Scarcity Cost ($M/year)	Total[a]	240	361
	Agriculture	195	312
	Urban	44	59
Operating Costs ($M/year)		3,896	4,265

Percentages in parenthesis represent scarcity relative to delivery target. MCM = million cubic meters.

Figure 4: Average annual statewide water scarcity, scarcity and operating costs for 2050 under a dry climate warming (GFDL CM2.1 A2) estimated by the CALVIN model (Medellin-Azuara et al. 2007). Operating costs include pumping, treatment, urban water quality, recharge, reuse, desalination, and other variable operating costs for the system. Scarcity costs represent how much users would be willing to pay for desired levels of water delivery.

Conclusions

Combining hydrology, engineering, and economics, hydro-economic models are ideally positioned to help manage water resources in an integrated manner. Such tools can serve as a guide in the policy making process, revealing where innovative policies and solutions can improve existing operating procedures and institutional arrangements.

As water scarcity and lack of new supplies increase, resource managers will increasingly turn to tools which reveal where greater efficiency in water use can be attained. Hydroeconomic models go beyond minimizing costs or maximizing profits, they provide a common framework through which the value of all water services can be considered and used to influence system planning and operation.

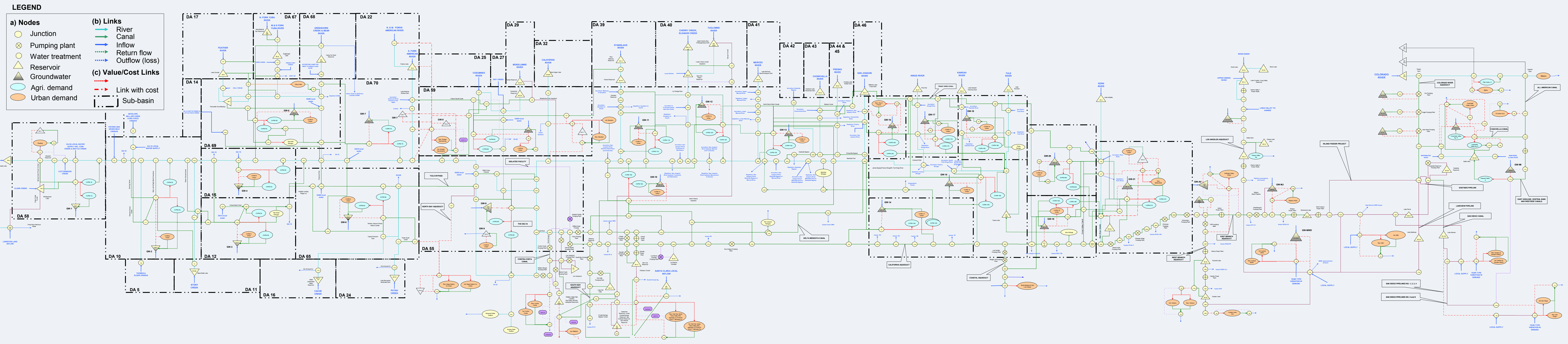


Figure 5: Node-Link network schematic of CALVIN hydro-economic model. The model optimizes water allocation and operations over 72 years of historical or climate change perturbed hydrology. The model uses an efficient network flow linear optimization formulation; it has 1.4 million decision variables and solves under 12 hours.

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