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ECONOMIC FACTORS SHAPING
WESTERN WATER ALLOCATION

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Water supply -- California

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Although most of the continental United States west of the 100th meridian is classified as arid or semiarid, water resources in the region have historically been treated as if they were relatively abundant. The perception of abundant water has been fostered largely by policies and institutions developed in an earlier era to facilitate the settlement of the West. These policies and institutions have persisted to current times, in part, because of their ability to insulate water users from a portion of the real cost of water. However, the perception of abundance masks the fact that western water resources are subject to increasing physical scarcity.

Although somewhat outdated, the Second National Assessment of the U.S. Water Resources Council provides evidence of the depth and extent of this scarcity. Two crude measures of physical scarcity for the nine major hydrologic basins of the west are presented in Table 1. In the first column, the sum of consumptive and in-stream uses is reported as a percentage of average annual runoff from precipitation. In the second column, total use is reported as a percentage of dry year runoff, where dry years are defined by a hydrologic frequency of 1 in 5. The figures show that in an average year, use levels in five of the nine basins exceed renewable supplies. In dry years, use levels in all basins exceed renewable supplies. The differences between annual use and annual runoff are accounted for by pumping groundwater at rates which exceed the rate of recharge. While the mining of groundwater may be economically justifiable, it cannot be sustained over the long run. Thus, in many areas of the West, existing levels of water use cannot continue indefinitely without supplemental sources of supply.

The patterns of western water use are heavily dominated by irrigation, which accounts for a little over 90% of total consumptive use and 84% of total withdrawals. Municipal and industrial uses account for 6.6% of consumptive use

(9% of withdrawals) while mineral and energy production make up the remaining 3.4% of consumptive use (7% of withdrawals) (U.S. Water Resources Council). Irrigation's share of withdrawals has remained relatively constant over the last three decades despite an increase of almost 9 million acres of irrigated land. This is explained primarily by the fact that, during this period, water use in the non-agricultural sectors grew for the first time at rates comparable to the growth rate of irrigation uses (Frederick).

The current picture of western water resources, then, is one characterized by increasing physical scarcity and use patterns that are overwhelmingly dominated by the agricultural sector. In the remainder of this paper, some of the economic forces acting on western water resources are identified and analyzed and a case study is presented to illustrate that the intensifying water scarcity may be largely attributable to institutions which promote both allocative inflexibility and the perception of abundance.

THE WATER SUPPLY OUTLOOK

Historically, increases in the relative scarcity of water associated with the economic growth of the West have been ameliorated by developing additional supplies. Improvements in pumping and well-drilling technology during the early parts of this century made vast quantities of groundwater reserves available for exploitation. Federal flood control and reclamation programs, as well as some state-sponsored water supply development activities, provided impoundment and conveyance facilities to bring surface waters from areas of origin to lands deficient in water but otherwise ripe for development. In many of these latter instances, subsidies and generous pricing policies were used to keep the price of water well below its real cost, thereby signaling that the resource was relatively abundant. However, this evidence suggests that the era when water supply functions can be shifted outward with relative ease is nearing an end. The costs of some existing supplies are likely to escalate; the costs of new supplies, where available, will be sharply higher than the costs of existing supplies; and, deteriorating water quality threatens to reduce available supplies of good quality water.

Costs of Supply. Over time, the costs of some existing water supplies are likely to rise. Where groundwater is mined, the associated decline in water tables will lead to higher extraction costs. Groundwater mining accounts for about 22% of total consumptive use West-wide but is especially pronounced in the Arkansas, Texas Gulf, and Lower Colorado basins where it accounts for between half and three-quarters of all consumptive use. Although groundwater exhaustion is only imminent in certain regions of the High Plains, increased groundwater extraction costs will occur throughout the west and be especially pervasive in the three southwestern basins (U.S. Water Resources Council).

Future increases in the price of energy will increase the costs of all pumped groundwater as well as surface waters which must be lifted from places of origin to places where they are used. Although the timing and magnitude of energy price increases are difficult to forecast, it is likely that they will have a significant effect on the price of all pumped water prior to the turn of the century. Groundwater and pumped surface water account for at least 60% of existing supplies and water costs in all western basins would be sensitive to any increases in the price of energy.

The figures in Table 1 indicate that additional renewable supplies are available only in the Missouri, Upper Colorado, Pacific Northwest, and California basins. However, the costs of these new supplies will be significantly higher than the costs of existing supplies in all but a few isolated instances. The real costs of developing new surface supplies tends to increase with time as the more expensive and locationally disadvantageous sources are developed. This trend is illustrated in Table 2 where the capital costs per acre-foot of annual dependable yield for several existing and proposed water storage facilities in California are presented. The figures show that the real capital costs of proposed new storage facilities, Los Banos Grande and Los Vaqueros, would be two to six times as expensive as the main storage facilities for the Central Valley Project and the California Water Project. The estimated cost for a Cross Delta facility suggests similar increases in the costs of conveyance works. The figures also indicate that the quantities of water which could be developed with new projects are relatively modest. These patterns of costs and quantities, which are typical for both storage and conveyance projects throughout the West, suggest that long-run water supply functions are quite price inelastic. Moreover, evidence shows that except in very isolated instances, potential users would be unwilling to defray costs of this magnitude (Vaux and Howitt).

Water Quality Deterioration. At the same time that the costs of some existing water supplies are on the rise and most new supplies are not economical to develop, deteriorating water quality threatens to diminish, perhaps substantially, the available quantities of good quality water. Currently, toxic wastes and runoff from irrigated lands pose the greatest hazards to water quality. In general, toxic wastes pose significant threats to groundwater while runoff from irrigation threatens primarily surface water sources.

The Environmental Protection Agency estimates that there are between 1200 and 2000 hazardous waste sites nationwide which pose serious threats to high quality groundwater. Such sites, which have the potential to contaminate or degrade groundwater are found in virtually every region of the country, including the West. The ultimate extent of groundwater degradation from toxic wastes cannot be predicted. Uncertainty surrounds almost every feature of hazardous waste disposal. In many instances, the materials placed in waste disposal sites are unknown as are the geologic and hydrologic properties of the site itself. Transport processes are imperfectly understood so that the extent of contamination over time is difficult to predict and expensive to monitor. The size and extent of the populations which may be affected by any given contamination episode are also difficult to predict. Although there appears to be strong consensus among both physical scientists and economists who have studied groundwater contamination that it is cheaper to prevent contamination than it is to clean it up, the major threat to groundwater is posed by previous waste disposal practices (National Research Council; Shecter; Sharefkin, Shecter, and Kneese).

While the precise impacts of toxic wastes on groundwater resources cannot be foreseen, some domestic water supplies have already been contaminated and it is clear that others will suffer the same fate. Even if the federal government defrays the large costs of cleanup or replacement supplies, the availability of high quality domestic water will decline since it is unlikely that complete cleanup or complete substitution will be economically or physically possible. The implications of contamination of groundwater sources for irrigation are somewhat less clear because contaminants, which are toxic to humans, often have no effect on plants. In these instances, the presence of toxicants in runoff and drainage waters may pose a threat to adjacent surface supplies. Toxic wastes from groundwater used in irrigation are not the only potential cause of surface water quality deterioration, however.

Virtually all irrigation water sources carry some dissolved salts. When water is transpired by plants or evaporates from field surfaces, salts remain in the root zone. Beyond some threshold, the buildup of salts in the root zone causes yields to decline and ultimately renders the land completely unproductive for agriculture. All irrigated lands are potentially subject to salinization, but salt balances can be effectively managed by applying water in excess of crop evapotranspiration so that salts are leached below the root zone where they no longer affect crops. However, over time, this leaching strategy will be successful only if there is adequate drainage. Where natural drainage is poor, water tables, high in salt content, will tend to rise threatening crops when they reach the root zone. In these instances, artificial drainage systems must be installed and the saline drainage water disposed of. Usually it is returned to surface waters, thereby diminishing the quality of water available to downstream users and degrading wildlife habitat. Indications are that about one-third of the irrigated land in the West has some type of salinity problem and that salinity is already a serious problem in the lower Colorado River and Rio Grande basins and the San Joaquin River sub-basin of California.

Historically, the costs of disposing of drainage water have been borne by the public at large or the federal government, and were thus external to farm water use decisions. However, as these costs increase, state and federal water quality regulatory agencies are subject to pressures to require water users to eliminate or minimize drainage discharges. The effect of drainage regulation will be to require irrigation water users to bear drainage costs in the form of on-farm disposal facilities and more intensive management of irrigation water. As a consequence, the costs of utilizing irrigation water will rise in areas where drainage is necessary to preserve agricultural productivity.

Although the depth and extent of future water quality degradation in the west cannot be clearly forecast, it is clear that there will be some degradation of both surface and ground waters. At a minimum, past toxic waste disposal practices threaten to reduce the quality of domestic water supplies below what is necessary to meet drinking water standards while salinity and problems related to drainage threaten the productivity of irrigated agriculture. Irrespective of what steps are taken to control and mitigate water quality degradation, the real costs of good quality water will almost certainly rise. If mitigation measures are widely practiced, the costs of maintaining relatively large quantities of high quality water will be high. If little is done to mitigate water quality deterioration, the competition for high quality water will intensify and, at a minimum, impose higher opportunity costs on the use of that water.

The major trends affecting water supply in the West suggest that the real costs of supplies will increase over time. In regions where groundwater mining is prominent, the costs of existing supplies will rise. In addition, these trends will be reinforced by the need to make complimentary expenditures to avoid water quality deterioration from drainage. The potential of toxic waste to degrade existing water supplies will make some deterioration in water quality inevitable. The decline in high quality water supplies cannot be inexpensively offset by developing new sources of supply because such sources are increasingly costly to develop. While supply trends suggest higher costs and perhaps an absolute reduction in the quantities of high quality water available for use, there is evidence that the demand for water, particularly high quality water for domestic uses, will continue to grow.

THE WATER DEMAND OUTLOOK

Historically, the major determinants of water demand in the West have been population growth and agricultural development. More recently, demands have been influenced by public desires to preserve and enhance many of the recreational and amenity values associated with instream flows. Future changes in demand are likely to be dominated by population growth, particularly in the southwestern Sun Belt. Agricultural demands are more difficult to forecast but appear unlikely to grow in the absence of significant changes in world markets for food and fiber.

The Bureau of the Census projects that between 1980 and 2000, population in the West will grow by 44.8%. The projections show that the populations of Arizona, Nevada, Utah and Wyoming will double while all of the remaining states will experience substantial, but lesser, rates of growth. The effects of this growth on water demand will depend very much on future water pricing policies. If real prices remain constant in the future, and other things are equal, projected population growth would cause domestic consumptive use West-wide to increase by approximately 2.8 million acre-feet by the year 2000. The associated increase in withdrawals would total 3.7 million acre-feet.

The elasticity of demand for domestic water in the west is thought to be quite low, with estimates ranging between -0.2 and -0.6. Assuming provisionally that the elasticity of demand is equal to -0.3, a doubling of the current real price of domestic water to new users would reduce the growth in domestic consumptive use to 2.0 m.a.f. On the other hand, if the real price of <u>all</u> domestic water were to double, total consumptive use West-wide would grow by only 0.1 m.a.f. in the face of the projected population growth. On a region-wide basis, then, domestic water pricing policies will play an important role in determining the levels of domestic consumptive use.

Nearly one-third of the increase in demand would occur in the Lower Colorado and Great basins, with the remainder spread in rough proportion to existing levels of use among the other seven basins. The problems of servicing this demand will be most severe in the Lower Colorado and Great basins both because additional sources of renewable supply are not available and because population growth is skewed toward those basins. However, all western basins will face some difficulty either because of the absence of additional supplies or because the expense of developing new supplies is likely to exceed the willingness to pay for them.

The demand for water in the agricultural sector will be primarily a function of crop prices. Current trends, both domestic and international, suggest that there will be little, if any, growth in the demand for agricultural water in the immediate future unless there are unexpected changes in world markets for food and fiber. Increased production abroad, protectionism, and the relatively high value of the dollar have all served to reduce the demand for exports substantially. The shrinkage in export demand, together with excess productive capacity in U.S. agriculture, have reduced the profitability of irrigated agriculture. In the absence of increases in world demand for western produce or other events which might increase crop prices, the problems of excess capacity are likely to remain beyond the immediate short run. This could result in a modest reduction in the capacity of irrigated agriculture which would, in turn, translate into a similar reduction in the derived demand for agricultural water. Even in the event that export markets rebound somewhat, it currently appears that the demand for agricultural water will remain relatively static over the next 10 or 15 years. Should demand grow, it is likely that new acreage would be brought into irrigation only in isolated areas such as western Nebraska where some additional groundwater suppplies are available. No growth in irrigated acreage is forecast for basins where renewable supplies are being fully utilized.

Demands for water by the energy and mineral industries currently account for only about 3.4% of total consumptive use in the West. Although these demands have been projected to increase by as much as 6% between 1980 and

2000 (U.S. Water Resources Council), the increases will occur in specific localities particularly within the Texas Gulf, Upper Colorado, and Pacific Northwest basins. The projected increases will be difficult to serve only in certain localities within the Texas Gulf and Upper Colorado basins where additional renewable supplies are not available.

The broad picture of western water demands suggests that those demands will continue to grow. While agricultural demands will remain relatively stable, demands for domestic use will grow throughout the region. In addition, water demands for production of energy and minerals will also grow but that growth will be limited to certain specific localities. This forecasted growth in water demands cannot be easily accommodated, however, given the difficulties of augmenting supplies and the prospective deteroiration in water quality. The impact of these growing demands on future levels of water use in the different sectors may depend importantly on how water is priced.

THE IMPLICATIONS FOR USE AND ALLOCATION

The trends of increase supply costs and growing domestic and industrial demands imply higher real opportunity costs for water in virtually all sectors. Yet, western water institutions characteristically insulate water users from both the magnitude of cost increases and from changes in the relative prices that prevail in different sectors. Early water purveying activities were characterized by decreasing average costs and this led to the widespread adoption of average cost pricing policies. Such policies have persisted, although it is generally accepted that the average costs of water supplies now rise as capacity expands. In addition, reclamation subsidies and federal cost sharing policies serve to keep the price of some water supplies below even average costs.

Western water institutions also tend to impede market-like exchanges of water largely because the circumstances of an earlier era required extraordinary assurances of security in water rights in order to facilitate settlement. While free water markets may be untenable because of their inherent failure to account for the interdependency of water use, quasi-markets, in which exchange is limited to quantities consumptively used, have the potential to ameliorate the intensifying water scarcity. An analysis of the impact of different pricing rules and the introduction of limited water markets in California suggests that the intensifying western water scarcity may be more attributable to outmoded institutions than to a physical scarcity of water.

To examine the impact of prices and markets, the California basin was divided into three agricultural regions and two urban regions (see Vaux and Howitt). Demand and supply functions were estimated for each region for 1980 and 2000. All supply functions were assumed to change over time in time in response to projected changes in the cost of energy needed to pump water (a substantial portion of which have already occurred). The separately estimated groundwater supply functions encompassed the decline in groundwater tables for areas where groundwater mining occurs. A supply function for new sources was based on the costs and yields of six new projects and included to assess the extent to which new supplies might be developed in response to increased willingness to pay for water. Urban demand functions were assumed to grow in direct response to the projected population increase. Agricultural demand functions were assumed to grow very modestly although current forecasts suggest that this may be optimistic.

Two cases were examined. In the first case, existing water institutions are preserved but marginal cost pricing practices are assumed to prevail. In this case, the results approximate efficient outcomes within each region though not necessarily between regions. The results, which are displayed in

Table 3, show that between 1980 and 2000 water use for an average year declines in all subregions since the higher supply costs embodied in the marginal cost pricing rule outweigh the growth in demands. Basin-wide, use would decline by 9.1% and, not surprisingly, no new supplies would be developed.

These results illustrate that changes in pricing policies which result in more efficient water use within existing sectors lead to levels of use which are significantly below average year supplies. That is, in each sector, it would not be efficient to use some proportion of existing supplies by the year 2000 as the economic scarcity becomes more constraining than the abso lute availability of water. Price increases, particularly in the urban sectors, would be substantial and, as Martin et al. have documented, could be extremely difficult to implement. However, the disparity between agricultural and urban water prices at the margin suggests that a reallocation of water between regions through market-like exchange might confer substantial benefits on all participating sectors. In the second case, the potential of water markets was analyzed assuming that: 1) trade could occur between regions but not within regions, and 2) that groundwater could not be directly exchanged, as required by California law, although it could substitute for surface supplies sold or leased through markets. The analysis incorporated the regional supply and demand functions in a spatial equilibrium model together with estimates of interregional transport costs and the costs of treatment for agricultural supplies acquired by urban regions.

The results of this limited trade case are presented in Table 4 and show that each of the agricultural regions would sell or lease water to a counterpart urban region, with the southern agricultural and Imperial Valley regions selling to the San Francisco region. For 2000, total water use statewide declines by 13.6% over 1980 levels and this reduction would be 4.4% larger than that which would occur in response to pricing reform alone. These figures show that in the absence of provisions which permit the reallocation of water between sectors, pricing reform alone is not sufficient to guarantee efficient water use.

The pattern of prices and quantities that emerge for the various regions show that for the northern and southern agricultural regions, prices would be modestly higher and quantities used modestly lower when compared with the no trade case. For the Imperial Valley, the opportunity cost would be significantly higher and the quantities substantially lower, indicating the relative inefficiency of some water use by agriculture in that location. For the urban regions, prices would be lower, by 66% for San Francisco and 40% for Los Angeles, than if reallocation were prohibited. On the other hand, quantities would be approximately 23% larger in both basins and, as a result, current levels of per capita use would be sustained over time, even with population growth.

The total quantities of water reallocated between regions as a consequence of trade amounts to 8.3% of the total used in 1980 and less than 10% of the water used in agriculture statewide during that year. These results emphasize the fact that only a small percentage of existing agricultural water would be required to service urban growth and suggest that concerns over large trade-induced contractions in the agriculture sector may be exaggerated. The benefits from trade would amount to $168.9 million annually by 2000. This figure probably represents a lower bound insasmuch as it does not include the potential gains from trades within regions. It should also be noted that these benefits also represent the opportunity cost of failing to modify existing water institutions in ways which will promote more economically efficient use of scarce western water supplies. Markets have the additional advantage of providing a means for internalizing the costs of water quality degradation and allowing western water users to respond to unforeseen water problems in a flexible fashion.

CONCLUSION

With some exceptions, this lesson from the California basin can be broadly applied throughout the West. Howe, for example, shows that for offer prices not exceeding $72/acre-foot, as much as 1.6 million acre-feet might be forthcoming from agricultural uses in the upper Colorado River basin while Butcher et al. document the need for freer transfer of water in the Columbia River basin. The evidence suggests that the water problems which loom in the West are caused more by outmoded institutions than they are by a true physical scarcity of water. There are exceptions. The High Plains of Texas and other localities which rely exclusively on groundwater mining and are remote in terms of alternative sources of supply will have to make the transition to an economy which is far less dependent on water. For the rest of the West, however, the problem appears to be one of altering institutions which promote the underpricing of water and tend to lock water into existing uses.

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TABLE 1

ANNUAL WATER USE AS A PERCENT OF RUNOFF
IN NINE WESTERN RIVER BASINS

Region	Average year	Dry year
Misouri[1]	95.7	124.3
Arkansas, White Red[1]	120.9	225.3
Texas-Gulf[1]	132.7	259.9
Rio Grande	135.6	180.6
Upper Colorado	83.5	112.3
Lower Colorado	225.3	238.3
Great Basin	124.7	158.1
Pacific N.W.	84.7	101.8
California	82.5	112.7

[1]Includes only subregions where average annual precipitation in less than 20 inches.

Source: U.S. Water Resources Council

TABLE 2

COSTS PER ACRE-FOOT OF YIELD FOR EXISTING AND PROPOSED CALIFORNIA WATER PROJECTS

Project	Annual dependable yield	Capital cost per acre-foot of annual dependable yield	Date completed (proposed)
Shasta Dam[a]	1.5	$415	1949
Oroville Dam[a]	1.0	$835	1968
Cross Delta Facility[b]	0.7	{$850}*	(1992)
Los Banos Grande[c]	0.21	{$1734}	(1998)
Los Vaqueros[c]	0.09	{$2477}	(1998)

Costs in 1980 dollars and quantities in millions of acre-feet.

*May not include costs to mitigate fishery damage.

{ } = estimated costs

Sources: [1]Meral
[b]California Department of Water Resources, 1983
[c]California Department of Water Resources, 1984

TABLE 3

WATER PRICES AND QUANTITIES FOR FIVE REGIONS OF CALIFORNIA WITH MARGINAL COST PRICING

Region	1980 Prices ($/a.f.)	1980 Quantities (m.a.f.)	2000 Prices ($/a.f.)	2000 Quantities (m.a.f.)
North Agriculture	$20.92	13.78	$31.36	12.51
South Agriculture	$29.90	11.65	$39.50	10.46
Imperial Valley	$6.47	2.91	$17.80	2.91
Northern Metro	$154.18	1.41	$284.94	1.27
Southern Metro	$187.32	3.25	$349.45	2.85
TOTALS:		33.00		30.00

Prices in 1980 constant dollars

TABLE 4

WATER PRICES AND QUANTITIES FOR FIVE REGIONS OF CALIFORNIA WITH INTERREGIONAL TRADE

	1980 (trade)		2000 (no trade)	
Region	Prices ($/a.f.)	Quantities (m.a.f.)	Prices ($/a.f.)	Quantities (m.a.f.)
North Agriculture	$20.92	13.78	$33.55	11.73
South Agriculture	$29.90	11.65	$40.87	10.05
Imperial Valley	$6.47	2.91	$40.87	1.65
Northern Metro	$154.18	1.41	$154.51	1.58
Southern Metro	$187.32	3.25	$249.87	3.49
TOTALS:		33.00		28.50

Prices in 1980 constant dollars