The AMERICAN JOURNAL *of* ECONOMICS *and* SOCIOLOGY

Published QUARTERLY in the interest of constructive synthesis in the social sciences, under grants from the FRANCIS NEILSON FUND and the ROBERT SCHALKENBACH FOUNDATION.

VOLUME 51 | January, 1992 | NUMBER 1

Third Party Effects of Groundwater Law in the United States:

Private Versus Common Property

By THOMAS H. BRUGGINK*

ABSTRACT. *Groundwater* is an increasingly important component in the nation's total *water supply*. Although groundwater is one of this nation's most abundant resources, falling *water tables* and contamination episodes have caused localized water shortages. This has led to news media accounts describing water supply as our nation's next *natural resource* crisis. The problem with groundwater supply can be attributed in part to the current system of incomplete *property rights*. This, in combination with the common pool characteristics of underground water and other third party effects, has resulted in technical and allocative inefficiency. Groundwater *hydrology*, common property, contamination, and other third party effects are examined in seeking the causes of the current *water crisis*.

I
Introduction

WATER SUPPLY is abundant and scarce at the same time: abundant because there are huge amounts of renewable water available in this country, scarce because under the current laws and pricing policies, the demand for water in many parts of this country cannot be met at all times. This paper, concerned

* [Thomas H. Bruggink, Ph.D., is associate professor in the Department of Economics and Business, Lafayette College, Easton, PA 18042.]

American Journal of Economics and Sociology, Vol. 51, No. 1 (January, 1992).

with economic effects of the nation's groundwater laws, discusses: 1) current state laws governing groundwater systems, 2) relationship between the hydrogeology of the underground water and pumping efficiency, 3) third party effects of common property, pollution, and public interest.

In the two decades after World War II, expanding economic activity and waste products of new technology depleted existing sources of water supply and also accelerated the deterioration of our nation's water quality. This led to the passage of the Water Quality Act of 1965, Water Pollution Act Amendments in 1972 and 1977, and the Safe Drinking Water Act of 1977. There have been concerted efforts to slow down or end the degradation of rivers, lakes, and reservoirs from the pollution attributed to industry wasteproducts and urban wastewater, but agricultural runoff and other sources of non-point pollution continue.

More recently public debate has centered on the groundwater supply and quality. Regional water scarcity and quality become public issues during dry weather patterns or after local contamination episodes. The problems, quantity and quality, will undoubtedly grow as economic development and population growth and migration proceed. Additionally, the demand for groundwater will increase as surface water systems meet increasing constraints.

Despite media reports of an impending water crisis,[1] water remains our nation's most abundant resource. It is also renewable, barring contamination, although generally not at the location of last use. Most economists would agree that the increasing scarcity is an allocation problem, not a supply problem. The common property characteristics of most water systems, combined with an incomplete system of property rights under a variety of state laws, provide little incentive for owners of water rights to make provisions for future use, invest in water reclamation, or transfer water rights to higher valued uses. Many state legal systems have adopted rules over the years that lock in historical patterns of use. This has resulted in some uses of water that are excessively wasteful or less productive compared to newer alternatives.

Groundwater is found in aquifers, underground layers of porous rock and rock particles saturated with vast amounts of water that are economically feasible water suppliers. Aquifers are usually bounded from below by impermeable rock strata that form large basins. They underlie most land in the United States and supply drinking water in every state. Aquifers are renewed by rainfall, snowmelts, river flows, lakes and other impoundments, as well as man-made discharge that percolate through the soil and upper layers of rock surfaces to recharge the basin. Withdrawals from an aquifer occur through a pumping well or natural flow into a stream, lake, underground stream, or another aquifer.

Part II of this paper looks at the current status of state water law and in Part III some of its undesirable consequences. In Part IV the confrontation of water law with the principles of water hydrology leads to the the troubling third party effects of groundwater use. Part V identifies for further examination several options to reduce the growing water scarcity problem.

II

State Groundwater Law

WATER LAW is mostly state property law, with the exception of some reserved federal land and Indian water rights. Usually there is a distinction made between surface water law and groundwater law, although this varies from state to state.

Groundwater law is covered by one or more of the four doctrines outlined below.[2] They follow a regional pattern (Eastern versus Western states), similar to surface water laws. The distribution of these practices is presented in Tables 1 and 2. In general, the property rights apply to the use of water, not to the water itself, and ownership initiates upon withdrawal (the capture rule).

The Eastern States

Absolute Ownership. This is based on English common law. The landowner can withdraw groundwater for any purpose (on site or off site) without liability to other users of the groundwater system (*e.g.*, without compensating other parties for lowering the water table and raising their pumping costs). This law resulted from the difficulty in establishing the guilty parties in any pumping interference case due to the 19th century ignorance of geohydrological principles.

Reasonable Use. This American rule was adopted in the late 1800s as an alternative to the rather severe doctrine of absolute ownership. Overlying landowners have co-equal rights to the groundwater, provided it is put to "reasonable use" on site. Reasonableness is determined by the courts after consideration of the various demands of adjacent landowners relative to supply. In general, any on site use that was not overtly wasteful[3] was deemed reasonable. Use of pumped water on non-overlying land was considered "unreasonable" if its removal interfered with water use by other landowners. "In this latter situation, the pumper may be enjoined from transporting groundwater, or must pay compensation to those landowners who demonstrate damages due to the transportation of groundwater."[4]

Correlative Rights. This doctrine is a further refinement of reasonable use. Water rights to an allowed amount are distributed in proportion to the ownership share of the overlying land. When there is a water shortage due to drought, the landowners share the burden by proportionately reducing their use. When there is excess supply, allocation to non-overlying areas is permitted.

Table 1

CLASSIFICATION OF EASTERN STATES BY GROUNDWATER DOCTRINE

REASONABLE USE	REASONABLE USE/PERMIT
Missouri	Minnesota
Michigan	Wisconsin
Ohio	Iowa
West Virginia	Tennessee
Pennsylvania	Virginia
New York	Maryland
New Hampshire	Delaware
Alabama	North Carolina
	New Jersey (permit required only in critical areas)

CORRELATIVE RIGHTS/REASONABLE USE - Arkansas
CORRELATIVE RIGHTS/PERMIT - Florida
ABSOLUTE OWNERSHIP - Connecticut, Illinois
LAW OF CAPTURE - Louisiana

ABSOLUTE OWNERSHIP (percolating waters)
REASONABLE USE (subterranean waters)
Maine, Vermont, Massachusetts

ABSOLUTE OWNERSHIP (percolating waters)
REASONABLE USE/PERMIT (subterranean waters)
Georgia, Kentucky

Indiana	permit required only in critical areas
Mississippi	" " "
South Carolina	" " "

SOURCE: Warren Viesmann, Jr. and Clair Welty, *Water Management and Institutions* (New York: Harper and Row, 1985), p.60

The Western States

In the West, the doctines of absolute ownership and reasonable use did not work well, because of the lower amount of precipitation. This was especially true when water demand and water supply were in different locations.

Appropriation Rights. The appropriation doctrine that originated from the mining and agricultural needs permits water withdrawals to be diverted to non-overlying land. Priority is established by time of application from the appropriate state agency ("first in time, first in right"). Permits are granted if the new use is "beneficial" (has economic value), and if it does not conflict with the rights of higher priority users or the public interest.[5] The required permits often define the amount of water use per time period. During times of shortage, the most senior right holders receive their full allocation while junior right holders might receive nothing. Owners of water rights must exercise those rights since they may be lost through non-use. The rights can be sold, but the new owner will have to apply for a permit if there is any change in the use of the water.

Table 2

CLASSIFICATION OF WESTERN STATES BY GROUNDWATER DOCTRINE

APPROPRIATION/PERMIT

Washington	Oregon
Colorado	New Mexico
Nevada	North Dakota
Kansas	South Dakota

Utah

Idaho (permits face less scrutiny in noncritical areas)
Wyoming " " "
Nevada " " "
Montana (permit not required for small consumptive use in noncritical areas)

ABSOLUTE OWNERSHIP - Texas

CORRELATIVE RIGHTS/APPROPRIATION/CONJUNCTIVE MANAGEMENT

California

REASONABLE USE/PERMIT

Nebraska, Oklahoma

REASONABLE USE (percolating waters)
APPROPRIATION/PERMIT (subterranean waters)
Arizona (permit only required for large consumptive uses)

SOURCE: Warren Viesmann, Jr. and Clair Welty, *Water Management and Institutions* (New York: Harper and Row, 1985), p.61

Allotment. This is generally used in new, large scale public water projects (such as the Central Arizona Project). It is a contractual agreement among various users according to a formula created by a multi-state compact, interagency agreement, or the governors of a water service organization. Since transfer of these rights might violate the original terms of the contract, it, or any amendments, involves a difficult process of obtaining consent among all affected parties.[6]

Mutual Stocks. Owning a share of stock in a private water company grants the holder a fixed proportion of the total water service under control by the company. Within the service area of the organization, this water right can be sold provided the transfer complies with the legal restrictions on use.

III

The Undesirable Consequences

DEVELOPMENT OF WATER RESOURCES with the greatest economic value to society requires the certainty of ownership and flexibility in their use. Without these two conditions there is little incentive for owners of water rights to make investments to conserve water and diminished opportunity to take water out of a lower valued use in favor of a higher valued use. What is needed are state laws that delineate the property rights associated with groundwater ownership. In particular, the laws must " . . . define the degree of exclusivity of water rights, protect those rights against impairment, and specify the terms under which water rights may be transferred."[7] By doing this the relationship between effort and reward is made more certain, and individuals will take into account the social consequences of their actions.

However, with the current system of state rights, which does not clearly guarantee the exclusive right to a specific quantity of water, uncertainty and misuse abound. Even worse, it creates incentives for waste and diminishes the security of investment necessary for economic development.

There are several reasons for these problems. First, because current right holders in nearly all states must put water to "beneficial" use, assurance of perpetual supply is not guaranteed. The "use it or lose it" doctrine encourages inefficient use and does not reward conservation or reclamation. Second, the sale and transfer of water rights to those with plans for new, higher valued uses is inhibited since the new owners are not assured that their plans will meet with approval for the quantities they need. Third, there is no guarantee that the physical capacity of the system will provide the necessary supply at the time it is needed. In those states under the correlative rights doctrine, the quantities available for users are not certain since water shortages will force reductions in use for all. For the prior appropriation states, the junior right holders face cutbacks during dry periods. Fourth, a latent source of uncertainty lies with holders of unexercised rights (such as those held by Native Americans). Should these dormant rights be exercised, junior owners may find their supply reduced, perhaps even to zero. Although under the appropriation doctrine any dormant rights may be lost through non-use, the uncertainty exists until the legality of the loss is settled.[8]

Without clearly defined property rights, water resource development is unduly constrained. In response the necessary legal reform is taking place slowly. However, the nature of groundwater also creates a another set of problems called third party effects, which is the subject of the next section.

IV

Third Party Effects

In addition to the lack of clearly defined property rights, state groundwater laws also fail to fully incorporate the hydrologic principles of groundwater storage and movement. This leads to private agreements between two parties for a water transaction that has effects on third parties. In order to explain these third party effects a more detailed explanation of the hydrology follows.[9]

Groundwater Hydrology

The earth's surface is normally porous to varying depths in a zone of rock fracture. The pores or openings may be partially or completely filled with water.

The upper strata (aereated zone) lies just below the soil moisture belt, and is only partially filled with water. In the lower strata (saturated zone), all openings are completely filled, forming a huge natural reservoir or series of reservoirs in the same or separate layers of strata.

The depth of the lower zone ranges from a few feet to several hundred, depending on such factors as geological characteristics, degree of porosity in the rock layers, and the effects of water movement within the saturated zone from areas of recharge to areas of discharge (wells or streams and lakes).

Groundwater basins, or aquifers, are formations in the saturated zone from which water can be economically obtained. There must be a large number and volume of spaces, and the rock openings must be large enough to permit water to move through them to a well at a rate that makes it a feasible source of water. Other underground water formations exist that would not be called aquifers because they are not economically feasible to develop.

An unconfined aquifer has no impermeable rock strata above it. The water table forms the upper surface of an unconfined aquifer, and its shape is determined in part by the shape of the land surface above it. When a well is drilled into an unconfined aquifer, the static (no pumping) water level stands at the same height as the water table. Both levels are subject to atmospheric pressure. The water table rises and falls depending on the amount of recharge and discharge.

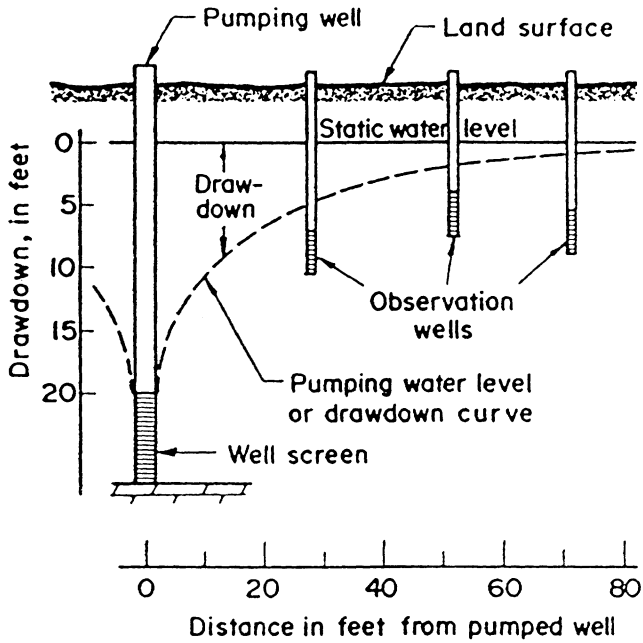
An aquifer serves both as storage and a network of transmission channels. Groundwater is constantly moving from areas of recharge to areas of discharge. The rate of movement depends on the rock strata's permeability (affected by the composition of the rock and the differences in pressure or water table level between any two points). In general, movement is very slow, with velocities ranging from a few feet per day to a few feet per year. As a consequence most of the water in an aquifer is in transient storage. This also explains how it is possible to pump water from a basin at a constant rate while recharging occurs intermittently. As such, they are more effective reservoirs than surface storage systems (which are more subject to seasonal shifts in volume and evaporation).

Confined aquifers are bounded from above by another layer of impermeable rock and are not recharged by the the hydrologic cycle. They hold their water under pressure and, if a well is tapped into such an aquifer, the water will rise to the height determined by the amount of pressure in the aquifer. If this height, known as the piezometric surface, is above the land surface there is the possibility of an artesian well. Confined aquifers were once glaciers that were covered with rock layers over the years. They may be located below unconfined aquifers and have an entirely different shape.

When a well begins pumping, the water level around the well and in its vicinity is lowered. The drawdown is greatest at the shaft, and diminishes with

Figure 1

CONE OF DEPRESSION



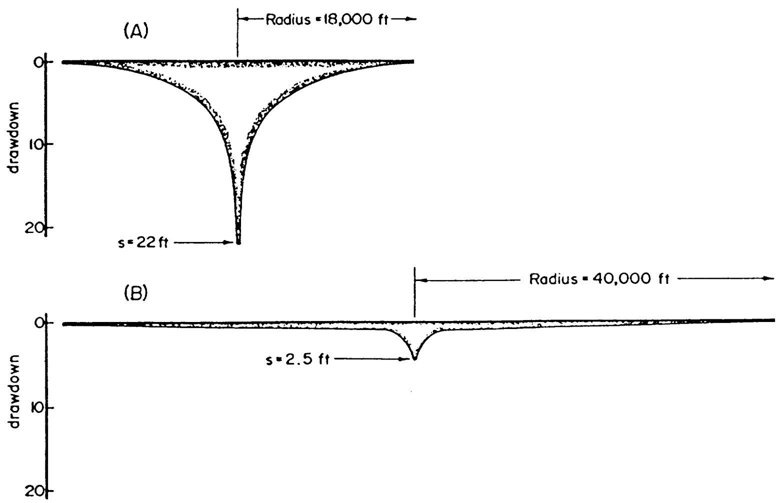
Source: G. F. Briggs, "Developing Ground-water Resources," in *Handbook of Water Resources and Pollution Control*, ed. Harry W. Gehm and Jacob I. Bregman (New York: Van Nostrand Reinhold Company, 1976), p. 308.

distance from the well. The shape of this falling water level forms an inverted cone of depression. The shape of the cone of depression depends on the pumping rate and the rock permeability (which affects the conductivity of the rock formations and the rate of transmissivity of the water). As pumping from a new well continues, the cone expands and deepens. However, the amount of drawdown decreases from the center because each additional foot of horizontal expansion of the cone brings forth a larger volume of available stored water.

A cone of depression is in equilibrium (no further drawdown) when aquifer recharge equals the pumping. This occurs when the cone enlarges to the point where 1) it intercepts sufficient natural recharge and/or precipitation equal to the pumping rate, 2) intercepts a body of surface water from which sufficient water enters the aquifer to equal the pumping rate, or 3) receives sufficient leakage from overlying or underlying water formations equal to the pumping rate.

Figure 2

DIFFERING RADII FOR CONES OF DEPRESSION



Source: G. F. Briggs, "Developing Groundwater Resources," *Handbook of Water Resources and Pollution Control*, ed. Harry W. Gehm and Jacob I. Bregman (New York: Van Nostrand Reinhold Company, 1976), p. 308.

At this point the water level is no longer drawn down. Equilibrium in the shape of the cone of depression may occur within a few hours or it may take several years.

The distance from the well to the point where the water table is unaffected is called the radius of influence. Its length varies for different wells and for the same well with different pumping rates and different time periods of pumping. Figure 1 shows the cone of depression caused by pumping action of a well. The static water level shows the highest level of water in the aquifer (the water table) in the absence of a pumping well. This water level falls (drawdown) when pumping commences. Figure 2 show different cones of depression based on different conductivities of the rock structures (pumping rate and other factors held constant). This figure suggests that the radius of influence for the cone can extend quite far.

Common Property Problems

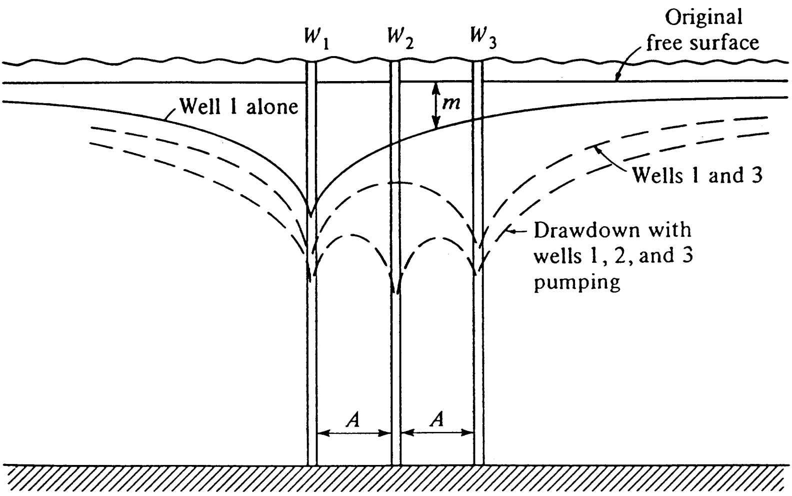
There are common property problems with underground waters because most are located below numerous, independently owned plots of land. A landowner doesn't begin to obtain ownership of the economic value from the water until it is pumped. Given the migratory nature of water, the more the owner pumps the greater the amount he receives at any time. Location, well depth, pipe diameter, and pumping rates of the wells have effects on all owners withdrawing water from an aquifer. These production decisions are affected by and can affect the hydrogeologic characteristics of the basin.

Common property problems develop when 1) the pumping drawdown at any particular well lowers the water table and adversely affects the pumping efficiencies for neighboring wells, 2) decisions on current rates of pumping do not include the effects on future supply, 3) incentives are lowered for conservation and reclamation efforts, 4) the drawdown creates interchange with a surface water source or another underlying formation, or 5) drawdown causes ground subsidence (which will permanently reduce the recharge capacity and pumping efficiency of the aquifer). Each of these will be discussed below.

As adjacent wells try to capture water from the same general location, the cones of depression intersect, reducing the flow of water to each well (see Figure 3). This reduces the efficiency of existing wells. In particular, well number 2 has a very limited water source because of the adjacent wells. In the worst

Figure 3

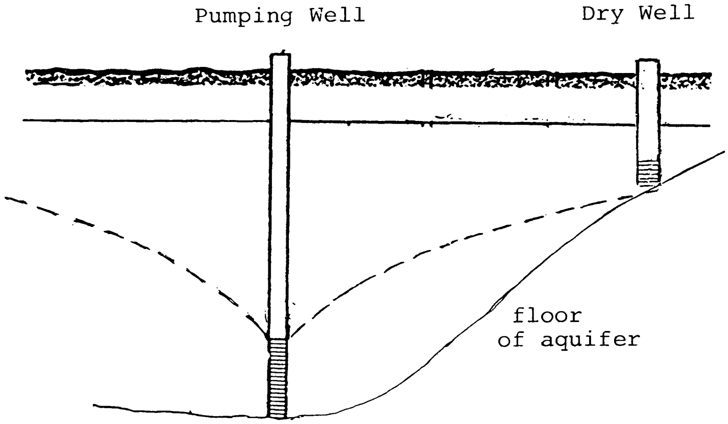
INTERFERING CONES OF DEPRESSION



Source: Warren Viessman, Jr., John W. Knaff, Gary L. Lewis, and Terence E. Harbaugh, *Introduction to Hydrology* (New York: Harper and Row, 1977), p. 325.

Figure 4

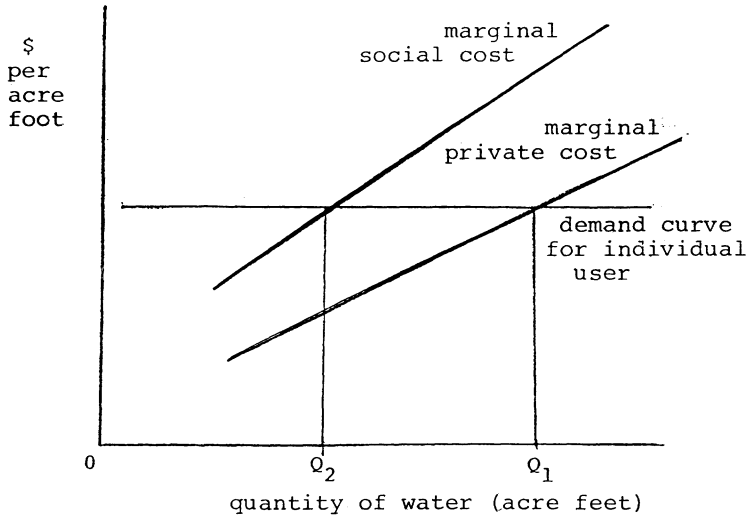
CREATION OF A DRY WELL



case it may cause shallow wells or wells located along the perimeter of the basin to go dry as the water table falls (see Figure 4). Well number 2 could become productive if well number 1 would discontinue pumping, but if the

Figure 5

COMMON PROPERTY PROBLEM



water table has been permanently lowered (due to pumping rates that exceed recharge rates), well number 2 may remain dry even if well number 1 is shut down. For dry wells along the perimeter, drilling deeper wells is not feasible. Only recharge will make them productive again.

With an ideal spatial distribution of wells the pumping costs would be minimized, but unlike perfect competition, the market will not provide an efficient outcome. Each water user will make pumping decisions to maximize his own net benefits, and his decision-making does not include the third party effects that he imposes on neighboring wells. The result is higher costs for the group. In many parts of the West, the water table falls every year, raising the lift costs continuously. The expenses can be very high. For example, one farm in Arizona has 15 electric pumps for lifting groundwater, each costing $4,000 a month to run.[10]

Another common property problem involves the provision of water for future use. With no property rights to the unpumped water, the decision to pump now or pump later is heavily biased toward the present. The benefits of postponing consumption (greater supply in the future) are shared by all. And the costs of a reduced water supply in the future (greater lift costs) are also shared by all. Therefore there is an incentive to overpump in the present. This is compounded by the state laws that require the exercise of the water rights in order to maintain those rights (use it or lose it). This encourages high pumping rates so that water users can protect their rights to a high water flow. This divergence between private and social benefits results in a nonoptimal time path of water withdrawals. These consequences are shown in Figure 5. The private costs of pumping water are lower than the social costs because a private pumper only compares his or her marginal cost of pumping an extra acre-foot of water with the extra revenue it will immediately provide. This person does not include the extra pumping costs imposed on other pumpers, both now and in the future. As a consequence this individual removes Q_1 amount of water from the aquifer instead of the preferred Q_2. This overpumping causes the less than optimal outcome, although some economists do not believe this problem is as great as it was originally feared to be.[11]

A very similar common property problem involves the conservation and reclamation efforts. Conservation and reclamation (i.e., enhancing recharge) result in higher water tables and provision for a larger future water supply than would be the case without such efforts. However, with no property rights to the unpumped water, conservation of X acre feet in period 1 does not guarantee X acre feet of additional water for that individual in period 2. This reduces the incentive to conserve water. The conserved water will be available to all wells.

Another source of common property problems occurs when the underground basin is physically connected to a surface water system such as an ocean, lake, or river. In an average year groundwater provides 30% of this country's instream flow.[12] Interchange of water supplies can result in third party effects. More rapid rate of groundwater withdrawal will lower the flow from the aquifer to the stream, reducing the inland river flow and affecting the surface water users and the ecology of the inland stream.

Another severe situation occurs when the interchange goes in the other direction. Drawdown from groundwater wells near oceans and estuaries can cause saltwater to become a source of recharge to the aquifer. This can contaminate the underground water and adversely affect the plant life on the overlying land. Saltwater intrusion is a problem along the coasts of Texas and California, on Long Island, and along certain coastal rivers.[13] Prevention of the interchange involves the costly construction of deep underground walls at the shoreline to separate the two systems.

The final common property problem in this section is ground subsidence. An extreme consequence of overpumping is structural change in the aquifer. Overpumping in certain areas of the West and in Florida has caused the surface area of the land to fall by as much as 28 feet.[14] Beside the third party potential for physical damage to surface structures and reduced property values, the new permanently lower ceiling of the water table will never again be fully recharged.

Contamination of Groundwater

Scientists now investigating groundwater supplies are reporting measurements of many different kinds of contaminants at concentrations far higher than have ever been found in the nation's lakes and rivers. The U.S. Water Resources Council[15] has identified groundwater pollution problems in all but four states (Washington, Oregon, Idaho, and Montana). More active enforcement of air and surface water quality standards is likely to increase the disposal of contaminants to landfills, and thereby increase the number of groundwater contamination episodes.

The sources of groundwater contamination include leaks from industrial landfills and surface disposal pits, subsurface percolation from septic tanks and cesspools, runoff of fertilizers and pesticides, leaks from oil wells and underground oil and gasoline storage tanks, chemical spills, and leaks from sewer pipelines.

Groundwater pollution is extremely difficult to control. Although historically groundwater has been cleaner than surface water (the soil filters out some of the bacteria and most of the suspended solids), the soil is not effective in removing the newer synthetic organic chemicals. Furthermore, it is difficult to monitor the movement of the pollutants. Once they enter the aquifer they spread out in a plume whose shape and movement depend on the conductivity of the rock mixture and the pumping rate of the wells. Because the rate of movement is slow (anywhere from a few feet to a fraction of an inch per day), groundwater may be safe in one location but unsafe a few hundred feet away.[16]

The most serious sources of groundwater contamination are the surface impoundments and underground storage tanks. According to the Environmental Protection Agency, there are over 200,000 active disposal pits, ponds, and lagoons holding industrial, agricultural, mining, and municipal wastes, or oil and gas wastes.[17] Particularly troublesome are the approximately 26,000 *unlined* impoundments that may be leaking a variety of toxins into underground water supplies. The director of the Office of Solid Waste Programs of the EPA testified that 95% of all operating impoundments are within one-fourth mile of drinking water sources.[18] Underground storage tanks pose an equally frightening prospect. Gasoline leakage from corroded tanks is releasing 11 million gallons into the ground from over 75,000 tanks across the country. One gallon of gasoline per day is sufficient to pollute the water of a 50,000 person community to a level of 100 parts per billion.[19]

Groundwater pollution is extremely difficult to clean up since the aquifer is recharged very slowly. A major episode of contamination can be irreversible. Two methods of cleanup do exist: 1) pumping an aquifer out and disposing of the contaminated water, and 2) enhancing the activity of the microbial community in the groundwater to alter the toxicity. The first method is expensive and the second method is still being tested. Pumping out an aquifer will reverse the underground flow toward public wells. High pumping rates allow a more rapid cleanup than natural recharging, but water flow is still governed by the permeability of the rock surfaces. Microbe activity, long thought to exist only in surface water systems, can either intensify or degrade the toxicity in the groundwater. Enhancement of the microbe's natural activity is achieved by supplying them with limiting nutrients and oxygen. Experiments involving genetically engineered organisms are still in the experimental stage.

There is only a limited governmental commitment to clean up contaminated aquifers. If the contamination is from a toxic waste dump on the Superfund list, then the federal government will provide cleanup financing. Otherwise the government is involved only through its enforcement of drinking water quality standards and regulations on solid-waste disposal. The 1986 Clean Water Act requires the states to draw up groundwater protection plans, but little progress has been made since its passage. A coherent approach to groundwater contamination would involve a policy based on the benefit/cost framework. But this is not likely to occur in the near future due to enormous measurement problems:

> Benefit analysis of controlling groundwater contamination requires, as usual, quantification of several links between sources and receptors. One must know the location and strength of actual or potential sources of contamination, and must be able to model the spread of the contaminant plume in the aquifer. One must know the number of persons exposed to contaminated groundwater and the extent and timing of their exposures. One must know the

"dose-response relationship," the nature and extent of health effects on the population at risk. And finally, one needs a way of converting health effects into monetary, or dollar, values.[20]

A landowner responsible for a toxic leak into the ground may eventually be responsible for damage to the whole aquifer. Given the numerous potential sources of contamination and the potentially long lags between contamination, detection, and health consequences, it may be difficult to pinpoint the responsible parties, and more importantly, to link a specific contamination to the health and economic consequences of the victims.

Public Interest

If a water transfer has a high probability of adversely affecting the wildlife in an ecosystem, or the cultural heritage of a community, or the ability of a region to sustain agricultural activity, legitimate objections can be raised in court. New arguments are now being made regarding broad "public interest" impacts of water transfers.[21] Three cases illustrate this emerging doctrine.

First, when the city of Los Angeles attempted to increase its water supplies [Audubon versus Los Angeles, 1985],[22] it was determined that the city's proposed withdrawals would lower the water level in Mono Lake to such an extent that the resulting changes in the ecosystem would significantly reduce the migratory and native bird populations.

Second, in a New Mexico case, the court denied an application to sell water rights from an old Hispanic irrigation area on the grounds that it interfered with the cultural heritage of the area. "[I]t is clearly not so . . . that greater economic benefits are more desirable than the preservation of a cultural identity."[23]

Third, in a Rocky Ford Ditch transfer case, the several third party impacts were investigated during the court litigation to determine the water transfer's potential effects on neighboring groundwater and surface water supplies. The removal of irrigation was linked to less moisture in the soil and reduced economic activity in the region. The effects that were investigated were: 1) soil erosion and dust storms, 2) spread of weeds from abandoned farms to neighboring farms, 3) higher level of contamination and salinity due to lower level of water, 4) greater seepage losses from irrigation ditches due to reduced flow, 5) reduction in tax collection on economic activity, 6) loss of "critical mass" of farmers necessary to maintain a rural community, and 7) adverse effects on recreation activities (rafting and fishing).[24]

V

Possible Solutions

Several possible solutions to the problems presented are: 1) piece-by-piece, state-by-state legal reform, 2) an increased role for central management (state regulation administered through a state water agency), 3) an increased role for private enterprise in the form of the complete privatization of aquifers, or 4) a new cooperative arrangement between state government and private water utilities.

Different states will choose different routes to reform based on their legistlative patterns and the necessity of action. Certainly the most radical proposal is the privatization of aquifers. The goal is to resolve the problems with common property and other third party effects while providing an improvement in water use over the old regime. The various merits and drawbacks of each of these proposals is the subject of another study to appear in the next issue of the *American Journal of Economics and Sociology* under the title "Privatization versus Groundwater Central Management: Public Policy Choices to Prevent a Water Crisis in the 1990s."

Notes

1. For example, "California Painfully Faces Grim Truths of Drought," *New York Times* Feb. 26, 1991; "The Big Thirst," *New York Times Magazine* Oct. 28, 1990; "Drought," *Forbes* 146 July 23, 1990; "On the Great Plains, Life Becomes a Fight for Water and Survival," *Wall Street Journal* Aug. 16, 1989; "Iowans Struggle Against Rising Water Pollution," *New York Times* Nov. 11, 1987; "Rapid Use and Pollution Threaten Long Island Water Supply," *New York Times* Dec. 12, 1986; "Troubled Waters in Atlantic City," *Discover* Vol. 3 (Mar., 1982); "The Browning of America," *Newsweek* Feb. 23, 1981.

2. For more details on groundwater law see Norman K. Johnson and Charles T. DuMars, "A Survey of the Evolution of Western Water Law in Response to Changing Economic and Public Interest Demands," *Natural Resources Journal* 29(2) Spring, 1989; Warren Viesmann, Jr. and Clair Welty, *Water Management and Institutions* (New York: Harper, 1985); David Fractor, "Property Rights and Groundwater Management" in *Natural Resouces: Bureaucratic Myths and Enviromental Management*, Richard L. Stroup and John A. Baden, eds., (Cambridge, MA: Ballinger Publishing Company, 1983); Rodney T. Smith, *Trading Water: An Economic and Legal Framework for Water Marketing* (Washington: The Council of State Policy and Planning Agencies, 1988); Zachary A. Smith, *Groundwater in the West* (San Diego: Academic Press, 1989).

3. In practice, however, ". . . in spite of glowing constitutional damage language about the beneficial uses and the prevention of waste, economic and political realities make it beneficial for farmers and others to waste a great deal of water." Zachary A. Smith, 11.

4. Rodney T. Smith, 47.

5. In the pure form of the appropriation doctrine, the pumper who first puts groundwater to a beneficial use can demand compensation for *any* damages caused by the lowering of the water table by other pumpers. But in practice most states ". . . allow pumping by junior appropriators if it does not 'unreasonably' impair the groundwater rights enjoyed by others." Rodney T. Smith, 47.

6. Saiba and Bush, 58.

7. Rodney T. Smith, 12.

8. Fractor, 75.

9. The material for this section is taken from *Water Management and Institutions* by Warren Viesmann, Jr. and Clair Welty, (New York: Harper, 1985); *Introduction to Hydrology* by Warren

Viessman, Jr., John W. Knaff, Gary L. Lewis, and Terence E. Harbaugh, (New York: Harper, 1977); *Applied Principles of Hydrology* by John C. Manning, (Columbus, Ohio: Merrill Publishing Company, 1987); and "Developing Groundwater Resources" by G. F. Briggs, in *Handbook of Water Resources and Pollution Control*, Harry W. Gehm and Jacob I. Bregman, eds., (New York: Van Nostrand Reinhold Company, 1976).

10. James R. Udall, "Losing Our Liquid Assets," *National Wildlife* Vol. 24 (Dec./Jan. 1986): 50–55.

11. Michael Gisser, "Groundwater: Focusing on the Real Issue," *Journal of Political Economy* 91(6) 1983: 1001–27, and David T. Fractor, "Privatizing the Ground Water Resource: Individual Use and Alternative Specifications," *Water Resources Bulletin* Vol. 24 (Apr. 1988) 405–412.

12. U.S. Water Resources Council, *The Nation's Water Resources 1975–2000* (Washington, DC: U.S. Government Printing Office, 1978).

13. Kenneth D. Frederick, "Water Supplies," in *Current Issues in Natural Resource Policy*, Paul R. Portney, editor (Baltimore: Johns Hopkins UP, 1982) and "Rapid Use and Pollution Threaten Long Island Water Supply," *New York Times* Dec. 12, 1986, B1 and B-7.

14. Zachary A. Smith, 55.

15. Water Resources Council.

16. Laura Tangley, "Local Problems Become National Issue," *Bioscience* Vol. 34 (Mar. 1984), 143.

17. *Ibid.*, 146.

18. *Ibid.*, 146.

19. *Ibid.*, 146.

20. Allen Kneese, *Measuring the Benefits of Clean Air and Water* (Washington, DC: Resources for the Future, 1984), 115.

21. Victor Brajer and Wade E. Martin, "Water Rights Markets: Social and Legal Considerations," *American Journal of Economics and Sociology* Vol. 49 (Jan. 1990), 35–44.

22. *National Audubon Society* v. *Superior Court of Alpine County* 33 Cal.3d 419 (1983). For a summary of the decision, see Ellen Sullivan Casey, "Water Law—Public Trust Doctrine" *Natural Resources Journal* Vol. 14 (1984), 809.

23. Philip C. Metzger, "Protecting Social Values in Western Water Transfers," *Journal of American Water Works Association* (Mar. 1988), 58–68.

24. Kevin B. Pratt, "Mitigating Third-Party Effects," *Journal of American Water Works Association* (Mar. 1988), 51–57.

On Human Understanding

There are four classes of Idols which beset men's minds. To these for distinction's sake I have assigned names,—calling the first class *Idols of the Tribe*; the second, *Idols of the Cave*; the third, *Idols of the Market-place*; the fourth, *Idols of the Theatre*.

Francis Bacon