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Probably one of the most difficult areas to resolve in water law is the right to appropriate and put to beneficial use underground water. Because of the short and seasonal supply of surface water in many parts of the world, including the state of Colorado, we have no alternative but to cope with the problem. If existing economies are to be enhanced, or even preserved, underground water is probably the last frontier for water resource conservation and development in the vast arid and semiarid areas of the world. The ever-increasing population growth, need for food, fiber, and essential exploitation of natural resources, and the preservation of the environment for a decent quality of life are dependent on adequate water supplies. The impetus for maximization of the beneficial use of available supplies demands treatment of underground water by imaginative and innovative legislation designed to provide the framework for sound development.

Promulgating and implementing laws on the use of underground water is a relatively new and extremely challenging field. Without a thorough knowledge of the physical characteristics and ramifications of effect, an ill-advised groundwater law can be a total disaster.

The first step in devising a groundwater law must be to categorize this water into one or more of the several types and deal with each category as a separate entity when and if applicable. Underground water can be considered under two broad general categories: tributary to a surface stream and nontributary.

Even this broad categorization must be approached with caution. Judgment based on policy and on local situations must be made, because from a purist's viewpoint there is no such animal as non-tributary groundwater. The purist maintains, and rightly so, that there is no magic source of groundwater. It all derives from surface sources, whether it be precipitation, stream percolation, or recharge from surface application.

In Colorado, considerable work is still necessary on the

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groundwater law. In the area of non-tributary groundwater, further dissection is necessary for proper definition and treatment, as follows: (1) transient water—groundwater with little or no hydraulic connection to surface streams and/or little or no utilization of surface water; (2) water in bedrock aquifers—not hydraulically connected to surface streams; (3) perched aquifers; (4) closed basins—isolated by geological formation from either surface or other groundwater; and (5) water trapped in solid rock zones. Generally speaking, these non-tributary waters are being or soon will be mined, causing the withdrawal of water in excess of the natural recharge rate. The policy of the State is to exploit these waters, realizing that at some future date we will reach a point of no return. The solution to this seemingly short-sighted policy would be a rather nebulous hope that technology might provide economically-justifiable recharge programs before the axe falls.

Transient water with little or no hydraulic connections to surface streams was given special consideration in the statute, under the title, "Designated Groundwater." Seven basins now exist which have been designated in eastern Colorado by the Colorado Groundwater Commission and are under the jurisdiction of the Commission rather than the courts. Although appellate recourse from any decision of the Commission is provided for in the district courts, I would call your attention to the policy of the Commission on mining groundwater. Each application for a well permit is analyzed on the basis of permitting 40 percent depletion of the saturated thickness of the aquifer within a circle three miles in radius and a time period of 25 years.

Groundwater, as defined in (2), (3), (4), and (5) above, might be recategorized as static rather than transient water, although each has its own peculiarities and its own unique problems. Some bedrock aquifers are considered as non-tributary because historic depletion has caused declines in the static water tables which would take centuries of natural recharge to restore to their past hydraulic connection with surface water. These bedrock aquifers were treated separately in the statutes, with the proviso that the State Engineer may grant a well permit to an applicant if the annual withdrawal of water did not exceed 1/100 of the recoverable water underlying his property: a 100 year aquifer. This was designed to an-

swer the question of adequacy of the water supply for subdivision development dependent on these aquifers. Although this may not be in strict compliance with the constitutional doctrine of prior appropriation, expedience often dictates policy, and this may be a good example.

Numbers (3), (4), and (5) above would probably be best defined as static aquifers which are "a little bit" tributary, since natural recharge does occur, but at a rate less than the rate of withdrawal. I suppose if there is a condition being "a little bit pregnant," then we can have aquifers which are "a little bit tributary." But again, expediency dictates the terms. The hazards involved in applying the doctrine of prior appropriation and the right to divert unappropriated water to these conditions are obvious, especially for subdivision development. The ramifications of circulation of water in a closed system by well withdrawal and recharge with sewage effluent boggles the mind. Our legislature has not addressed this rather nauseous problem as yet.

The general category of tributary water superficially presents fewer problems than non-tributary groundwater if one were to adopt a simplistic approach under the priority system and order all tributary wells to cease and desist diverting, because of injury to senior vested rights. Unfortunately, the realization that diversions of tributary groundwater eventually diminish surface flows, to the injury of prior vested rights, was recognized only after the fact. In the interim, a substantial economy has developed around the use of this groundwater. The legislative body is thus faced with closing the barn door after the horses have been stolen.

In Colorado, this sin of omission was thought to have been atoned for by declaring a policy to integrate surface and tributary groundwater, *i.e.*, conjunctive use. The more knowledgeable legislators recognized the fallacy of this atonement because there simply was not enough water available without some innovative management plan. The policy statement further proclaimed that the doctrine of prior appropriation would be honored and the economy dependent on groundwater would be preserved. This was to be accomplished, despite the over-appropriated water supply, through the provisions requiring plans of augmentation to be reviewed by the State Engineer for approval or help in devising a viable plan, and through another

statute granting the State Engineer authority to adopt rules and regulations.

By consulting Mr. Webster's published works, I renewed my understanding of augmentation as meaning increasing, especially in size or amount. I knew I should have been more attentive in advanced mathematics because with an over-appropriated river I kept adding zero to not enough and coming up with not enough.

The best answer had to be better management of the resource. That included converting the root of the problem—tributary aquifers—from a culprit to an asset. Starting with the general concept that underground storage is far superior to surface storage, the solution seemed to be to divert water from this underground reservoir during times of deficient surface supplies and to recharge that reservoir during times of surplus surface supplies.

The next question was who would pay the bill for recharge projects and pumping back to the river? Quite obviously the beneficiaries of the project are the underground water appropriators who are junior to injured vested rights. Probably the most Herculean task of the entire exercise was to convince well owners, especially those most remote from the river, that (1) their pumping affected the surface flow, (2) they did not own the water underlying their property, (3) they were injuring senior vested surface rights, and (4) they had to finance remedial measures for that injury.

The difficulty of this public relations task was aggravated by procrastination of previous legislatures and polarization of diametrically opposed positions by well owners and surface appropriators, almost to the point of anarchy. We then organized a task force of experts in the fields of geology, hydrology, and administration to conduct a series of well-advertised informational meetings along the entire reach of the South Platte River Basin. Hostility was the name of the game at the earlier meetings. However, our bullet-proof vests received nary a dent after the well owners understood: (1) the interaction between surface and groundwater, (2) the constitutional doctrine of prior appropriation, (3) the new law, (4) our mutual problems, and (5) our willingness to help them devise ways to remedy injury at a reasonable cost. Their cooperation since that time

has been remarkable. It certainly brought home to me the adage that a person's greatest fear is that of the unknown.

The culmination of our meetings in the South Platte River Basin was a general meeting to discuss ways and means of organizing some kind of legal entity to implement the plans for remedying the injury to prior rights. The result was a non-profit corporation under the name, "Groundwater Appropriatiors of the South Platte, Inc.," G.A.S.P. for short. Membership in the corporation is voluntary with a board of directors elected by members from the several districts. The board has done an outstanding job of furnishing replacement water to the river at a price to the members of about 25-35 cents per acre-foot of diversion. How can the corporation provide water at such a low rate, when the price of water in the South Platte in particular is inflated beyond all comprehension? A careful analysis of the law will answer that question. Groundwater appropriators are required by law to remedy any injury only during times that an injured senior right is demanding water and only in the amount of the injury occurring at that time. The first function in determining injury is consumptive use derived from, in the case of irrigated agriculture, irrigation efficiency. That water which is not consumed percolates back to the aquifer and does not constitute injury. The next function is timing of effect, which varies with the distance from the extreme channel, among other parameters. Given the physical characteristics of the aquifer, distance from the stream, and rate of pumping the lifetime and amount of effect can be determined by computer programming for any number of wells. This injury, at that given point in time, must be remedied when and if a downstream senior is demanding water. With the time frame of demand narrowed down to a small percentage of the year, the total injury is again reduced by that percentage factor. The end result is that an acre-foot of replacement water goes a long way toward remedying the net injury of considerable groundwater diversions.

Two projects have been completed that demonstrate the capability of utilizing groundwater storage for replacement water, one in the South Platte River and one in the Arkansas River, both of which have been very successful. The lower reaches of the South Platte ditch had been abandoned for some time because of excessive seepage losses, and a small

holding pond was also abandoned for the same reason. That was the very thing we were looking for, the means to recharge the aquifer during times water not demanded by a senior was available in the river. In cooperation with other agencies the lower reach of the ditch was rehabilitated and water was diverted into the pitch and pond during periods when there was no call on the river. Instrumentation of the recharge area recorded the effect on the water table to ascertain the amount of recharge attributable to the project. The cost accounting indicated that this water in storage, and available for diversion during the following irrigation season, cost about $1.00 per acre-foot when the minor capital cost for culverts, and so forth, was disregarded.

In the lower Arkansas, wells were constructed along the Buffalo Canal to pump replacement water into the canal during times when the canal would have demanded curtailment of upstream junior rights, namely, wells. The first year of operation happened to be one of the driest on record. These wells provided water to the Buffalo Canal during the most critical part of the season, saving crops along the canal estimated to be worth about $225,000.00. This benefit was accrued in one year. With a construction cost of some $70,000.00, it more than paid for the project in the first year of operation. Further, the member wells of the Lower Arkansas Water Management Association, which was the sponsoring entity, were permitted to pump without restriction and grew crops also valued at many times the cost of the project. I had to contract as State Engineer with the Four Corners region in order to get this project built as a demonstration project, and the State of Colorado owns it for five years, at which time it will revert to the ownership of the association.

Other proven means of remedying injury include the purchase of reliable surface water rights and storage water, transmountain diversions for release to the streams, changes in points or alternate points of diversion with the replaced surface right released to the stream, and use of non-tributary developed water augmenting the stream.

In summary, good management planning solves many of the problems of the State of Colorado and other arid and semi-

arid areas of the world. Good management must include maximum utilization of groundwater in conjunction with surface water.