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Ground Water—The Problems of Conservation and Interferences

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GROUND WATER—THE PROBLEMS OF CONSERVATION AND INTERFERENCES

Philip C. Sorensen*

I. INTRODUCTION

"Too long we have reckoned our resources in terms of illusion. Money, even gold, is but a metrical device. It is not the substance of wealth. Soil, water, minerals, vegetation and animal life—these are the basis of our existence and the measure of our future."[1] In Nebraska, our measure of wealth is primarily in terms of water and soil, and the proper use and conservation of these resources is certain to assure us of prosperity now and for the future.

This article is concerned with but one part of these resources—ground water. It can hardly be called, in the legal sense, a legal article, but it is hoped that that portion of the article setting forth a layman's explanation of the existing hydrologic and geologic conditions in Nebraska will be pertinent to the lawyer or legislator who is concerned with any aspect of the law dealing with ground water, and that that portion dealing with the experiences of other states will be pertinent to any person concerned with laws regulating ground water.

II. THE HYDROLOGIC CYCLE AND GEOLOGIC CONDITIONS IN NEBRASKA

A. Hydrologic and Geologic Conditions and Conservation

For many years, our assets of water were measured only by our income—rainfall and streamflow. We later learned to build up reserves for the future by trapping this income and storing it by means of dams. Recently it has been discovered that a vast water account long trapped and stored beneath the surface of the ground could be put to use. In years when income of water is insufficient to support soils and vegetation, we draw from these reserves to supplement income, or where income is perpetually insufficient, we can continually supplement it by drawing from these ground water accounts. Annual deposits to underground accounts remain fairly

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[1] Dr. Paul Sears, Conservationist, as quoted in UNIVERSITY REPORT, Univ. of Neb. p. 31 (Summer Issue, 1956).

constant through the years. However, withdrawals have increased tremendously, especially in the last ten years. The number of irrigation wells in the state on January 1, 1940 was about 3,000; on January 1, 1950 about 7,500; on January 1, 1955 about 11,800; on January 1, 1958 about 22,000; and on April 1, 1963 about 24,500. It is forseeable that withdrawals will continue to increase in amount, and accordingly it becomes obvious that there exists an upper limit to the amount of withdrawals that may be made if these accounts for the future are to be preserved. A fuller understanding of the creation and conditions of these ground water reserves should aid in our plans of conservation, and it is this writer's hope that the following few pages might be of some help to such understanding.[2]

Water beneath the earth's surface is categorized into two zones —the zone of aeration and the zone of saturation. The zone of aeration holds water by molecular attraction or capillary force, and will not yield water to wells. It is nevertheless significant. The soil water in this zone directly feeds water to the plant life on the surface and protects topsoil against wind erosion. Lower stages in the zone of aeration are significant in that water cannot percolate

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[2] The author must disclaim any expertise in the fields of hydrology or geology, but in studies of ground water law made for the United States Dep't of Agriculture in conjunction with the Univ. of Neb., Project No. 621, in 1958 and 1959, an attempt was made to gain an understanding of the physical conditions of ground water. It is that layman's understanding that is set forth here. While gratitude is expressed to a number of individuals for their help, special thanks must go to Mr. Oliver J. Scherer, Geologist with the United States Dep't of Agriculture Soil Conservation Service, and Dr. E. C. Reed, Director, Conservation and Survey Division, Univ. of Neb., for their time and advice.

Sources for the information contained herein, other than the abovenamed individuals, include the following publications or reports: Conservation of Land and Water Resources of Nebraska, Bull. 14, Conservation Dep't, Univ. of Neb.; PROCEEDINGS OF THE NEBRASKA WATER CONFERENCE, Feb. 28 to March 1, 1957, sponsored by the Univ. of Neb.; United States Dep't of Agriculture, THE YEARBOOK OF AGRICULTURE (1955); Interior & Insular Affairs Comm., House of Rep., U.S. Cong., *The Physical Basis of Water Supply and Its Principal Uses*, PHYSICAL & ECONOMIC FOUNDATION OF NATURAL RESOURCES; PART II (1952); Univ. Report, Univ. of Neb. (Summer Issue 1956); Tomek, *Some Economic Consequences of Groundwater Mining*, an unpublished report for the Dep't of Ag. Econ., Univ. of Neb. (Aug. 15, 1958); Nebraska Farm and Ranch Economics, No. 128, Univ. of Neb. Extension Service and College of Agriculture (Oct. 1958); Theis, *The Source of Water Derived from Wells—Essential Factors Controlling the Response of an Aquifer to Development*, Civil Engineering, Vol. 10, No. 5, pp. 277-80 (May 1940); Reed, *Nebraska on the March*, Vol. IX, No. 1, 13, & Vol. X, No. 9, Division of Nebraska Resources, State of Nebraska (1956, 1957, & 1958).

and seep down to the zone of saturation, which does yield water to wells, unless these stages through which the water must percolate contain their full potential of molecularly held water.

The saturation zone, lying beneath the zone of aeration, extends from the bottom of the zone of aeration—where there is a stage called the capillary fringe—to bedrock and in many cases into bedrock. Here, in the openings between the sand, gravel and rock, the water completely saturates all available space. This zone will usually yield water when pumped. The top level of the saturation zone is referred to as the water table. The amount of water yield depends upon *porosity* (the space between the sand, gravel, or rocks in a given area) and *permeability* (the rate of flow possible through the materials) of the materials in this zone. Ground water, or underground water, when used herein, refers to the water in this zone.

Where did this water originate? Obviously, at one time it was in the form of precipitation falling on the land. But of the 97,000,000 acre-feet that fall on Nebraska during an average year, only a small percentage reaches the ground water reservoirs (sometimes referred to as aquifiers). That percentage of precipitation which does reach these reservoirs comes in part by means of direct percolation through the ground above—the zone of aeration, in part from the filtering off of ephemeral streams (streams which flow only in direct response to precipitation), and in part from irrigation water being used or transported above. It is estimated that the average amount of the total precipitation for Nebraska which reaches the water table and thus enters the zone of saturation is 8%. But this statewide figure can be misleading when water use problems are considered, as in many instances the amount of infiltration is high in areas of low demand, and low in areas of high demand. It has been estimated that in the tableland area of the western part of the state, 4% of the total precipitation percolates down to the zone of saturation. In the south central portion, the amount is only 2-3%, and in the eastern sector of the state these percentages drop to a mere 1%. Of course, precipitation increases from west to east, so in total amounts, the replenishment may be equal or greater outside the western part of the state. In the sandhills, with soil permitting a high degree of percolation, as much as 25% of the total precipitation infiltrates down to the water table, and finally, in the terraces of the Platte Valley, the percentage of percolation is approximately 15%. Even within these areas, recharge varies greatly from uplands to bottom lands.

Where, if anywhere, does this water go once it reaches the zone of saturation? This depends upon a great number of factors.

But as to horizontal movement, the water doesn't go anywhere, at least not very rapidly. Depending upon the materials through which the water must move and the slope of the bedrock, ground water moves horizontally an average of only two or three feet per day. It ultimately reaches a drainage basin (in Nebraska, the Republican River is an example), and reappears on the surface as streamflow. There is a posibility that this ground water might be confined and prevented from its slow, horizontal flow, which in this state is generally in a northwest to southeasterly direction. The evidence, however, indicates that this is not the case in Nebraska, with almost all of the ground water being unconfined, and most of the reservoirs evidently being hydraulically interconnected. Another loss of ground water may occur when the water table begins to approach the land surface, subjecting the water to loss through evapo-transpiration (evaporation and plant transpiration). The third major loss of ground water is through wells. When used for irrigation, a portion of the water yielded by a well will of course percolate back to the water table, but most of it is lost to the reservoir through consumption, evaporation, transpiration, and runoff.

At this point it is convenient to borrow an illustration from a 1956 University of Nebraska publication which illustrates where Nebraska's precipitation goes.[3] It should be kept in mind that except for the 2,000,000 acre-feet of water entering the state by means of the North Platte, South Platte, Republican and Niobrara Rivers, and a few small streams, Nebraska's water supply income depends wholly upon precipitation falling in Nebraska. There is no significant horizontal groundwater flow *into* Nebraska.

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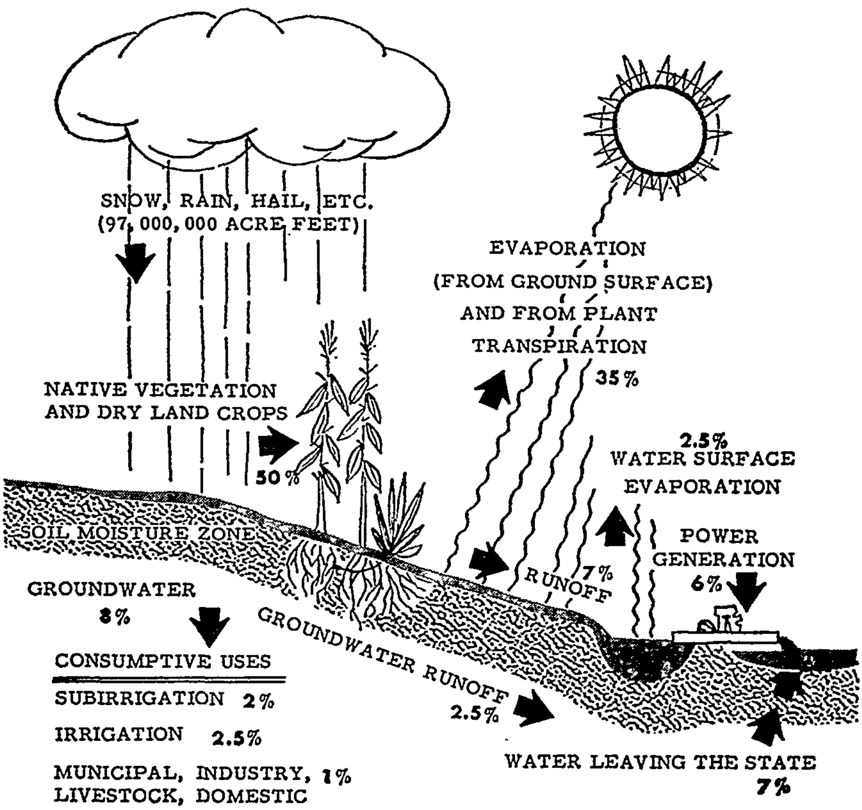
[3] Univ. Report, Univ. of Neb., p. 12 (Summer Issue 1956).

WHERE DOES NEBRASKA PRECIPITATION GO?



Most of Nebraska's water resource is lost as evaporation, transpiration, and runoff. But before this takes place the water is often used and re-used.

It might also be pointed out that all of the ground water in Nebraska is in a state of percolation. There are no underground streams in the state. It has often been said that the Todd Valley is an underground stream, but this geologically is not the situation. The Todd Valley was once the bed of the Platte River, and deposited therein are materials more permeable than those in the surrounding region, but the ground water percolating through this valley is not separate nor unconnected with the rest of the zone of saturation in the area.

Geologically, Nebraska is a most favored state in terms of ground water potential. There are unconsolidated and semiconsolidated aquifers underlying practically all of the state, less the eastern one-sixth. Practically all of this water is unconfined by either horizontal or vertical impervious strata, again excepting the eastern one-sixth of the state where some aquifers are confined from above by horizontal, impervious strata.[4] The ground water reservoirs for most of Nebraska are not small, individual aquifers, but are rather interconnected reservoirs extending beneath almost the whole of the state. This is not to say that the depths of the reservoirs, or to the reservoirs, are the same, nor that the reservoirs are made up of the same types of materials. Beginning at the western border of the state and proceeding eastward, the depths to the water table (200 feet average) and the depths to the bottom of the reservoirs (400 to 500 feet average from the surface) decrease. Further, the permeability of the materials becomes greater in the east. In the eastern one-sixth of the state, ground water aquifers appear only sporadically, and often are under artesian conditions. Many of these aquifers in the eastern one-sixth are limited, lens-shaped reservoirs unconnected with others.

As mentioned, most of the ground water reservoirs are hydraulically interconnected with each other. Similarly, these reservoirs are hydraulically interconnected with the rivers of the state, although the extent and manner of interconnection varies greatly. The rivers originating in the sandhills, *e.g.*, the Loup, Dismal and Snake Rivers, are supplied by some 800,000,000 acre-feet of underground water lying beneath the surface (or in some places upon the surface) in that area. The Republican River acts as a drain on ground water, with its river bottom cutting into bedrock beneath the bottom level of the ground water reservoirs of that region. Conversely, the North Platte River loses some of its water to the ground water reservoirs—while the Platte is more or less in equilibrium with the water table, feeding the reservoirs or extracting therefrom, depending on its flow and the heighth of the water table. And so it goes, with innumerable variations in relationships between the streams and rivers and the ground water reservoirs.

Although the rate of fill of underground water reservoirs is slow, the passage of years while they lay untapped resulted in cumulation of large amounts of water. It would be misleading to give figures for the amount of this storage, for much of it underlies areas where there is little or no demand for such great quantities, *e.g.*, in the sandhills. Additionally, much of this water lies below depths from which it cannot be economically brought to the surface.

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[4] This upper confinement often creates pressures on ground water (called artesian pressures) which will result in the water in wells which puncture the strata to rise above the water table, sometimes even to the surface, thus causing what are commonly called artesian wells.

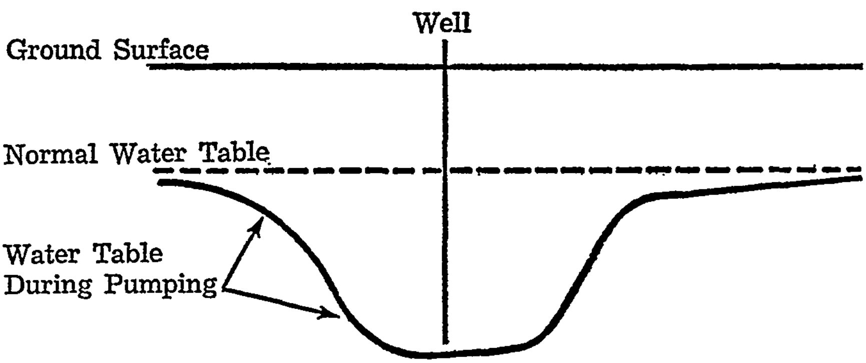
Although the reservoirs are interconnected, it cannot be anticipated that one area where the ground water is not in high demand might be able to supply another area of high demand for the slow lateral flow would take years to replenish a depleted area, if in fact it could at all.

Nebraska's ground water reservoirs are recharged each year by an average of 8 million acre-feet of water. This means that withdrawals exceeding that amount per year will result in a depletion or "mining" of ground water reservoirs for the state as a whole. We are not yet withdrawing at such a rate. But, as has been noted, recharge varies in different areas of the state, and specific or local conditions must be considered. Localities where the average withdrawals exceed the average recharge have already appeared, with other locales expected to encounter such a situation shortly. The immediate problem of conservation cannot be spoken of as "state-wide," but the localized problems are of state-wide concern and, in the opinion of this writer, call for a study of conservation measures in order to effectuate the ground water policy of Nebraska, (as expressed by the legislature) namely that of conservation.[5]

B. Hydrologic and Geologic Conditions and Individual Interferences

The hydrologic cycle and geologic conditions discussed up to this point were primarily pertinent to the question of conservation. Many problems, which often result in litigation, involve interferences between individual well users. Geologic and hydrologic forces relevant to these issues are now discussed.

A well which is drawing water will cause the water table to look something like this:



[5] The 1957 session of the Nebraska legislature passed a resolution calling for a study of conservation measures, stating that "the conservation of this important resource is vital to the economy of this state."

This bell-shaped depression will expand until it attains an equilibrium with the recharge of the area being pumped. However, the distance of significant drawdown is limited. This distance may vary greatly depending upon the materials from which the water is being drawn, the depth of the well, the amount of draw, and whether or not the water table is under artesian conditions. Under nonartesian conditions, which is the situation for most of the state, the radius of significant drawdown rarely extends beyond 1,000 feet, with 300 to 500 feet being typical. When the water table is under artesian conditions, this radius of drawdown may extend for a mile or more. As a result of these depressions, a well drilled within the area of significant drawdown of another well would be affected in its yield, and would also affect the yield of the other well if both were pumping at the same time. A further possibility is that one well might be shut off altogether as the result of the second well's drawdown.

Closely related to drawdown of an individual well is the phenomenon of drawdown created by a large number of wells in a specific area. Simultaneous pumping by all these wells can create a bell-shaped depression in the water table covering a large area, similar in shape to that of a single well, and resulting in a lessened yield for each of the wells. This then becomes a problem of multiple interference.

Another problem falling within the classification of multiple individual interferences is the long range impact on users of surface streams caused by a lowering of the water table. Many streams and their tributaries are fed by ground water either totally (except for runoff following heavy precipitation), or supplementarily in the case of large streams flowing at all times from aggregations of runoff over wide areas.

On every stream there is a point of effluency; a point above which the stream does not flow except sporadically when there is sufficient runoff from precipitation. Below this point, the stream flows continually. In many instances, this point of effluency is established and maintained fairly constant by ground water reservoirs. Suppose, therefore, a stream with a gradient of eight feet per mile. If the stream's point of effluency is at point X and the water table is lowered twenty feet by heavy pumping in the area, the point of effluency will move downstream 2½ miles from point X. This will mean that users of the surface stream along this 2½ mile stretch will be pre-empted of their constant water supply.

It is not only at the point of effluency that such interference may occur. Heavy pumping and the resultant lowering of the water table in an area may change a stream from one with constant flow into one that flows for a distance, is dry for a distance, and then begins flowing again. Further, a stream, although not completely shut off in flow, may have its flow reduced in amount by a lowering of the water table, if such stream depends partially or wholly on ground water for its supply, or if a lowered water table will cause diversion of the stream's water to the underground reservoir.

What has been said as to the effect of the lowering of the water table on surface stream users may be conversely applied as to the effect of surface stream users on the ground water reservoirs in the area. Our rivers and streams and underground reservoirs, although in differing hydraulic connections, strike a balance of a sort with the effect that the use of one creates an undoubted impact on the other.[6]

A final problem is that a lowering of the water table resulting from heavy pumping by numerous wells can result in the loss of subirrigation (a condition where the water table is right at or just below the surface of the ground), which is now being used to irrigate more than one million acres in the state.

The laws or regulations dealing with these individual or multiple-individual interferences are practically nonexistent in Nebraska. The interferences, although limited in scope and number, are now occurring. An increase in both scope and number is fairly predictable.

III. GROUND WATER PROBLEMS IN OTHER STATES

In the summer of 1958, this writer made a survey of the State Geologists or Engineers of fourteen western states to determine their ground water problems and their experiences in attempting to solve them.[7] The states were Arizona, Colorado, Idaho, Kansas,

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[6] For a more detailed study of the interrelationship of stream flow and underground water, see Tolman & Stipp, *Analysis of Legal Concepts of Subflow and Percolating Waters*, 21 ORE. L. REV. 113 (1942).

[7] The questionnaire was as follows:

1. Is ground water conservation a problem in your State?
   Presently ______ In the future ______ Neither ______
   - A. Is ground water presently being "mined" in any areas?
     Yes ______ No ______
   - B. If ground water is being "mined," what action is being taken?
     Regulation to stop mining altogether ______ Regulation to

Missouri, Montana, Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah and Wyoming. The specific answers of any particular state were to be kept confidential, although the general results of the survey could be used. Many of these states have already met a number of the problems of conservation and individual interferences that have not yet arisen in Nebraska, and it is hoped that their experiences and attitudes might be helpful

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slow the mining so as to extend the ground water supply over a greater number of years ______ No regulation whatsoever to control the mining ______

2. Do the statutory and administrative regulations in your State promote ground water conservation? Yes ______ No ______ Incompletely______
   A. If not, or if incompletely, what general type of powers would you recommend to promote conservation? (Specify)
3. Is organized artificial recharging of aquifers being done? Yes ______ No ______
   A. If so, by whom? (Specify)
   B. If so, by what means? (Specify)
4. Do substantial problems of interference and conflicts of use exist among ground water users in your State? Yes ______ No ______
   A. If so, how are such problems now settled? (Percentage estimate). By the individuals themselves ______% By local administrators or administrative bodies ______% By a State administrative body or administrator ______% By the courts ______%
   B. What type agency do you feel is best suited to settle these disputes? State administrator ______ State administrative body ______ Local administrator ______ Local administrative body ______ Courts ______ Others (specify) ______
5. Do substantial interference problems exist between ground water and surface stream users in your State? Yes ______ No ______
   A. How are these conflicts now settled? (Specify)
6. Are there organized ground water irrigation and conservation districts within your State Yes ______ No ______
   A. If so, what generally are their powers? (Specify, unless their powers are set out in your statutes.)
7. Is there organized or strong general opposition to ground water regulation in your State? Yes ______ No ______
   A. If so, what does this opposition support? More regulation ______ Less regulation ______ Local control ______ State control ______ No regulation whatsoever ______
   B. In what group or groups is this opposition centered? (Specify)
8. In the past 5 years, has the legislature considered and rejected any general statutory scheme for ground water? Yes ______ No ______
9. Comments

in formulating solutions or controls of Nebraska's potential problems.

Eleven states replied that ground water conservation was then a problem. All fourteen indicated that it would be in the future. Thirteen of the fourteen stated that ground water was then being "mined," *i.e.*, being withdrawn at a higher rate than that of replenishment. In response to the inquiry of what general type of powers should be recommended to promote conservation, a state code which would create an administrative agency to investigate, make rules and regulations, and enforce conservation practices was most often mentioned. A number of states suggested regulations on casing of wells, waste, and requirements of proper use. Three states stressed the need for adequate enforcement powers.

Twelve of the fourteen respondents felt that their statutory and administrative regulations either completely or partially promoted ground water conservation. Five states had organized ground water irrigation and conservation districts.

Eight of the states were experiencing conflicts of uses and interferences between individual well users. Five states did not consider it a present or potential problem, while one state anticipated the problem in the near future. The respondents in those states with existing conflicts were questioned as to how such individual interferences were then being settled. The averages showed that 40% were being settled by the individuals themselves, 2% by local administrators, 28% by a state administrative body or state administrator, and 30% by the courts. These averages are, however, somewhat misleading in that in two states nearly all of the conflicts were settled by the individuals themselves, although in one of these states it was felt there was no serious problem with individual interferences; in two other states nearly all of the conflicts were settled by a state administrator or state administrative body. In all states, except where the problems were settled by individuals, the courts were used to a greater or lesser extent, either in the first instance or on appeal.

When queried as to what agency they felt best able to fairly settle these interference problems, the response was overwhelmingly in favor of a state administrative body or state administrator, with appeal to the courts. Only one state favored the use of the courts in the first instance, although it should be pointed out that it was not experiencing any problems with individual interference at that time. The only other agency mentioned was that of a local administrator, and this was favored by one state. One of the states which favored a state administrator conditioned it with the use of a local administrative body to be brought in for consultation and advice. This type of setup was then in actual use in that state, and its effectiveness was obviously strongly felt by the state engineer questioned.

Five states were experiencing substantial interference problems between ground water users and surface stream users. In three of these, the conflicts were settled by a state administrator, with appeal to the courts, and in the other two the conflicts were just not being settled.

Finally, it was asked whether there existed strong or organized opposition to ground water regulation. Nine states have experienced little or no such opposition, while five states have. The existing opposition arose primarily from farm groups indicating preference for local control and regulation—if not for less or no control and regulation whatsoever.

IV. CONCLUSION

The above presentation is hardly a comprehensive survey of either the geologic and hydrologic conditions in Nebraska or the experiences of other states. Its implications, if any, I leave to you. However, some matters of consideration are at least suggested in respect to Nebraska.

1. Although action, regulation or control for conservation purposes might be locally limited to critical areas, *i.e.*, areas where ground water is being mined, a statewide view must be preserved in light of the interconnection and interaction of our water resources. State administration seems desirable to accomplish this (which appears to be the general experience of other states).

2. Ground water cannot be considered or administered apart from surface waters, again in light of the interconnections and interactions of these resources.

3. Laws or regulations to adjust conflicts arising from individual interferences, especially multiple interferences arising from overdevelopment of a reservoir or basin, should be comprehensively developed, along with procedures for adjudication. A state administrative body with power to regulate, coupled with a procedure for judicial appeal seems to be suggested from the experiences of other states.