In: "Water Pollution and Disease," 6th Internatl. Water Qual. Symp., April 18-19, 1972 Proc., p. 47-50. Washington, D.C.

THE PROBLEMS OF IRRIGATION

By David Carter

Water is the "life blood" of the land. Without it, the land will not produce food and fiber for man and animals. The land receives abundant water through precipitation in many areas of the world, and the land produces. Other areas are barren because the land receives essentially no water. Still other areas produce a sparse vegetation because of inadequate water.

Irrigation is the practice of transferring water from areas of plenty to areas of need to make larger areas of land produce food and fiber. In the Western U.S. snow accumulates in the high mountains on rocky peaks where there is no soil. It also accumulates on timbered slopes and on mountain meadows in amounts excessive to need. During the spring and summer this snow melts, continually feeding streams and rivers that transfer the water towards the ocean. En route the water passes through areas where the land needs water to produce. Man diverts part of this water to the land – the process of irrigation.

The transfer of water from natural streams, and the application of water to the land changes the environment. Most of these environmental changes are beneficial and represent progress. Some of them are problems that illustrate a lack of knowledge during development of early irrigation systems. Many errors have been made, both in system design and water application. Through research we have learned how to avoid many errors and how to correct others, but it is difficult and costly to redesign and reconstruct irrigation distribution systems. It is even more difficult to change attitudes and practices of irrigation farmers and to change water rights and legal codes associated with these attitudes and practices.

The environmental quality problems associated with irrigation must be kept in proper perspective. The growing world population requires more food each year, and irrigation is necessary to produce that food. We cannot eliminate irrigation to solve the environmental problems. We can, through research, minimize these problems and enhance the already tremendous benefits of irrigation.

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Water is not toxic. It has no unpleasant odor. It does not produce harmful gases. In fact, water itself presents no problems except where there is too much of it and flooding results. Thus, the environmental problems associated with irrigation differ from those associated with toxic pesticides and feedlot and human wastes. But, water is the universal solvent and transports many materials that can be problems. Most problems associated with irrigation involve materials transported by water. The five most important materials transported by water that can cause environmental problems are sediment, soluble salts, organic residues, nutrients, and pesticides.

An estimated 4-billion tons of sediment wash into U.S. waterways each year, and as much as 75% of it is believed to come from forested and agricultural land. Most of this sediment results from erosion of forest and agricultural lands during and following natural precipitation and during spring runoff from snowmelt. However, irrigation return flows sometimes contain two or more tons of sediment per acre-foot. Sediment eroded from farmlands by irrigation can clog canals, drains, and diversion systems and return to rivers and streams to combine with sediment from other sources to be deposited in reservoirs. Sediment causes undue wear on sprinkler nozzles and pumps, clogs screens, and adversely affects water as a habitat for aquatic life and for domestic and industrial use. Pesticides and nutrients attached to sediments are carried into waterways as a result of erosion. Most of the pesticides and phosphorus that enter U.S. surface waters from agricultural land are attached to sediment.

The amount of sediment returning to our waterways can be greatly reduced. Research is underway at the Snake River Conservation Research Center on the design and function of sediment ponds to remove sediment from irrigation return flows before the water returns to the Snake River. Research and development of irrigation practices that will not erode the land are underway in several countries. As a result of this research and development, the sediment problem associated with irrigation should be at least partially solved.

Nearly all water contains dissolved salts -- sodium chloride or common table salt, calcium chloride, sodium sulfate, magnesium chloride, and others. If the salt concentration is too high, the water is unsuitable for irrigation. Water that has passed through the soil generally has a higher salt concentration than when it was first applied to the surface of the land. The increase in salt concentration degrades water quality. If drainage is not adequate, excess water accumulates in the soil and evaporates, leaving the soluble salts behind to further concentrate in the remaining water. This process causes the land to become saline and nonproductive. Thousands of acres of the best farm land in the mountain valleys in the Western U.S. became salt affected because as irrigation was expanded to include higher elevation soils, drainage water accumulated in the deep, rich soils of the valley bottoms. Salt accumulations as water evaporated turned these previously productive soils into wastelands.

Archaeological studies indicate that the combined effects of sediment and soluble salts caused the downfall of the fabulous cities built by the Sumerians over 5,000 years ago in the Tigris-Euphrates valley. The Sumerians brilliantly engineered a system of irrigation canals, but had no concept of the need for drainage to cope with the dissolved salts in the irrigation water. They required a continuing source of slaves to remove the tremendous silt deposits from their canals, but did nothing to prevent erosion on the contributing watershed. It was necessary for them to develop new lands further from the cities because of salt accumulations and sediment deposits. The inability of the Sumerians to cope with the sediment and salinity problems eventually destroyed agricultural production and thence brought about the downfall of the cities.

Most organic residues in irrigation return flow waters arise from feedlot waste runoff. It is common in the western U.S. for the irrigation canal or drainage ditch to pass through small feedlots or animal pens, and animal wastes readily drain into these streams. Very little organic residue enters irrigation water during irrigation processes.

There are several sources of nutrients in irrigation return flows. A source already mentioned is the sediment. Other sources include the soil leachates, decomposing plant materials, feedlot waste, domestic sewage, applied fertilizers, and even industrial wastes that enter drains. Approximately 30 pounds of nitrate-nitrogen per acre of irrigated land enters the Snake River in return flows from a 203,000-acre irrigation tract in southern Idaho. A similar per-acre amount was reported to be draining into the Yakima River from a 71,000-acre irrigation tract in central Washington in 1970-71. Compared to earlier work on the same Washington project, the amount of nitrate-nitrogen has markedly increased during the past 30 years. In contrast, studies along the Rio Grande River indicate that the nitrogen load in the river has not changed appreciably during the past 30 to 40 years during which fertilizer use on the adjacent lands has greatly increased.

Nearly all of the pesticide found in drainage water from irrigated areas is adsorbed on the sediment. Therefore, decreasing the sediment load in water will decrease the pesticide load.

The amount of water used for irrigation varies widely. In Idaho, some irrigation districts divert up to 10 acre-feet of water per acre each growing season. Adjacent districts or individual farmers divert or pump only 2 acre-feet per acre for irrigating the same crops on similar soils and produce similar or better yields. The amount of water used depends upon water rights, the amount of available water, cost, water quality, age and design of the irrigation distribution system, and the application method. Where water storage facilities are inadequate or do not exist, the time that water is available influences the amount of water used. I recall back in the ranching area where I grew up, all the ranchers tried to irrigate all of their cultivated land in the spring with water from the snowmelt runoff from the mountains. Sometimes these lands were already wet from winter and spring precipitation, but these ranchers still applied water every spring. They knew that if soils were irrigated in the spring, a hay or small grain crop could be produced. They also knew that there would be no water available for irrigation during the summer.

In recent years, we have learned much about the amount of water required by various crops, and have begun to irrigate according to consumptive use by crop. For example, we now know that alfalfa may require 23 inches of water in South Dakota, 40 inches at Fort Stockton, Texas, 39 inches in areas of Turkey, and 30 inches in parts of the Western U.S. In the Western U.S. wheat requires 14-22 inches, potatoes 10-23 inches, sugarbeets 22-26 inches, corn 12-30 inches, and cotton 25-30 inches, depending upon the particular location and the year. The amount of water required by a particular crop depends largely upon the climate where it is grown. The amount to apply depends upon the consumptive use, leaching requirement, and the application efficiency. Extensive research and development are being directed toward providing the quantity of water needed by each crop and for leaching at the time it is needed. Daily crop requirements vary, and this must be taken into account. A computer irrigation scheduling program developed largely at the Snake River conservation Research Center, Kimberly, Idaho, informs the farmer when to irrigate each of the crops on his farm. The program can tell the farmer how much water to apply if the leaching requirement and the efficiency of his irrigation system are known.

Some present irrigation systems are inefficient. The type of irrigating I first learned to do as a boy on the ranch is known as "wild flooding," and it is not very efficient. The efficiency of furrow irrigation varies widely. Generally, sprinkler irrigation is more efficient than surface methods, but it is not without problems. Recent development of "trickle irrigation" and subirrigation with plastic tubing shows promise of high efficiency.

The soil is a container for growing

plants. It contains the nutrients and holds the water needed for plant growth. When any of the required materials become insufficient to meet the needs of the growing plants, growth is limited or ceases. A continued, severe deficiency may kill the plants. Fertilizers are applied to provide adequate supplies of plant nutrients. Water is applied by irrigation to assure an adequate supply for plants. The soil will hold a certain amount, depending upon soil texture and depth of the plant rooting zone. When more than that amount is applied, the excess passes through the soil into groundwater reservoirs or makes its way to surface waters through natural or artificial drainage channels. This drainage water usually has a higher soluble salt concentration than the applied irrigation water or the surface water into which it drains.

There are several processes that increase the salt concentration in drainage waters. One process is an accumulation of salts left behind as water is used by plants and evaporated from the soil surface. For example, suppose a soil was filled to capacity with water and then half of the water was used by plants. All of the salt in the water initially present is left in the remaining water. Since only half of the water remains, each unit of water contains twice as much salt as it did initially. Now suppose that half of the remaining water is used by plants. This again doubles the salt concentration so that it is four times greater than in the irrigation water. The next irrigation will force part of the remaining water into drainage channels. Thus, the drainage water has a higher salt concentration than does the irrigation water.

Another process that increases the salt concentration in drainage water is the dissolution of naturally occurring soluble salts in soils of nonhumid climates. These salts are known as fossil salts and they readily dissolve when contacted by water.

Under certain conditions, some slightly soluble salts such as calcium carbonate ($CaCO_3$) and gypsum ($CaSO_4.2H_2O$) will precipitate from the water and remain in the soil without injury to most crops. For this precipitation to occur, the concentration of calcium, bicarbonate, and sulfate must exceed the solubility concentrations for these slightly soluble salts. If the salt concentration becomes high enough, however, some other more soluble salts will precipitate. When this occurs, the soils are becoming salinized, and plant growth and crop production will be limited.

A salt balance must be maintained for an irrigated area to remain productive. Such a salt balance is maintained when the total quantity of salt in the drainage water leaving an irrigated area is equal to the total quantity of salt in the irrigation water entering the area minus the quantity of slightly soluble salts precipitated in the soil. Maintaining a salt balance requires that more water be applied (combined irrigation and precipitation) than is needed by crops so that there will be drainage water to transport the excess salts from the soil. The Imperial Valley of California is one of the few places in the world where a close salt balance is being maintained.

To maintain a salt balance, adequate drainage is a must. If natural drainage is inadequate, artificial drainage must be installed. Many irrigated areas were improperly planned and designed because the emphasis was placed on the distribution system without proper consideration of drainage needs. Many such areas developed salinity and drainage problems. In some cases these problems have been solved by installation of artificial drains, but in other cases the solution was not that simple. Through research and experience, we now know that both water distribution and drainage systems must be considered when designing a new irrigation project. Unfortunately, projects are still being proposed and developed without proper consideration for drainage.

A true salt balance is not being maintained on most irrigation tracts. Soluble salts are accumulating in many tracts because of inadequate drainage and improper water management. Too much water is applied to many areas, resulting in a net leaching of fossil salts and dissolving of soil minerals with a net salt output. Practicing the knowledge gained through recent research will help solve many of these problems and prevent such problems from developing in the future.

The leaching necessary to maintain a salt balance depends upon the irrigation water quality. The poorer the quality, the greater will be the amount of water needed for leaching the excess salts from the soil so that crops will not suffer salt injury. The amount of water to apply at each irrigation depends upon (1) the crop requirement, (2) the soil capacity, (3) the leaching requirement, and (4) an application efficiency factor.

Drainage water from irrigation usually contains a greater nitrate-nitrogen concentration than does the irrigation water. Nitrate-nitrogen is very soluble and therefore it moves readily with water. Excessive irrigation can leach nitrate-nitrogen into the drainage water, provided it is present in the soil. Sources of nitrate-nitrogen in the soil include fertilizer, mineralization of symbiotically fixed nitrogen, decomposing plant residues and organic matter, and the irrigation water which may contain nitrate-nitrogen from industrial wastes and sewage as well as drainage water from upstream irrigation projects.

Phosphorus compounds react with the soil and do not move through the soil with water except at extremely low concentrations. Research in southern Idaho showed that only 30% of the phosphate-phosphorus entering a 203,000-acre irrigation tract in the irrigation water was returned to the Snake River in drainage water. Most of the phosphate-phosphorus in the irrigation water for this tract was from industrial wastes and domestic sewage. Furthermore, the applied phosphorus fertilizers remained on the land and did not appear as phosphate-phosphorus in the drainage water. Irrigation can reduce the quantity of phosphorus in water and lower the phosphorus load in surface waters.

Irrigation changes the environment. It transforms barren deserts to fertile lands for producing food and fiber for man and animals. It changes nearly uninhabitable areas to pleasant places to live. It can change an area that produces only enough food on 10 acres for one cow and calf to an area where the same 10 acres will produce enough food for 10 or more cows and calves. Irrigation can cause environmental problems by adding salts, sediment, and sometimes nitrage-nitrogen to surface waters. Research and technology have developed and will continue to develop practices to reduce the impact of these environmental problems. One of the greatest needs is to change attitudes and practices of irrigation farmers. Such a change is needed so that water rights and legal codes can be changed to allow application of available technology to reduce environmental problems. Irrigation decreases the soluble phosphorus load in our surface waters and deposits that phosphorus in the soil. Irrigation makes it possible to feed a hungry world — without it, mass starvation would result.

Questions from the Audience

QUESTION: Please comment on the salinity problem in the Colorado River Basin.

CARTER: The Colorado River Basin is somewhat of a closed system and there are problems in some areas where there are quite large deposits of salts. From the use of water, rather large quantities of these salts are getting into the Colorado system. In irrigation, whenever four or five feet of water are applied to an acre of land in a year, and half of it goes into the air through evaporation, transpiration, or crop uses, the salt concentrates in the remaining water and ultimately gets back into the river. There are some things that can be done, management-wise, to improve the water quality situation. I believe the studies being done under contract by Utah State University and others are making real headway towards a solution of this problem.

QUESTION: Is salt a problem in the major rice-growing countries of the world, such as in Hawaii where you have large irrigation projects?

CARTER: Generally speaking, rice growing countries have sufficient rainfall, or pure water, so there is considerable leaching and the accumulation of salt that exists in the inner-mountain west does not occur. Here in the eastern part of the U.S., the rainfall is sufficient and the soil characteristics are such that there seldom are signs of salt accumulation. Wherever drainage is adequate and precipitation is adequate, so we don't have to reuse the water for irrigation, salt is seldom a problem.

QUESTION: What disease control measures are being taken in U.S. irrigation systems?

CARTER: This is rather a new area. There is a problem of spreading of crop diseases through the irrigation system occuring from reuse. Nematodes, in particular, are a serious problem. This is something that is being given consideration in the research studies on irrigation at the present time.