Problems of Irrigation Return Flows

Sheldon G. Boone 1/

The theme of this conference "Environmental Aspects of Irrigation and Drainage" while not necessarily positive or negative in itself has initiated presentations and discussions at this conference about problems. And so it is with the assigned topic of my paper. There are water quality problems with irrigation return flows as there are with the natural drainage of land areas. The quality of the receiving water is usually degraded by irrigation flow just as any use of our natural water supply degrades or at least modifies the quality. After admitting this, one must ask how significant are the water quality problems and what can be done to reduce water pollution? What about future developments? What questions do we try to answer -- are there alternatives to new irrigation projects, do we in fact even need the old ones, what are the circumstances that would permit new development, how should resources be developed, can return flows be better managed as well as irrigation deliveries are planned and managed? And in the end, what choices does society have?

In the few minutes we have today I can only outline the problem, talk a little about the impact of irrigation return flows on water quality, propose measures for reducing irrigation return flows, and draw a few conclusions as to how this is likely to impact future actions.

The Dimensions of Irrigated Agriculture in U.S.

The major water user in the United States is irrigated agriculture. There are 195 million acre-feet diverted annually to irrigate 42 million acres. To identify the impact of irrigated agriculture on the nation's water resources, one must point out that irrigation accounts for (1) 47 percent of the total diversions, (2) 82 percent of the total water consumptively used, and (3) 32 percent of the total return flows. Irrigation operation under present water management efficiency returns 92 million acre-feet (30 trillion gallons) of the gross diversions to the stream system.

1/ Assistant Deputy Administrator - River Basins, Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C. 20250

Irrigation return flow in the nine western water resource regions is 87 million acre-feet. About 47 percent of the water diverted returns to the water supply. The range in irrigation return flow by water resource regions is 18 to 68 percent as shown in Table 1.

Table 1 -- Irrigation return flows for present condition (1)

Region	Irrigated area	Gross diversions	Net depletions	Return	Flow
	million acres	*million acre-feet*			%
Missouri	7.90	35.90	14.83	21.07	59
Arkansas-White Red	3.97	11.61	8.18	3.53	30
Texas-Gulf	4.53	13.47	11.05	2.42	18
Rio Grande	1.96	7.07	4.83	2.24	32
Upper Colorado	1.37	7.92	2.72	5.20	66
Lower Colorado	1.33	9.21	4.64	4.57	50
Great Basin	1.75	8.88	4.14	4.74	53
Columbia	5.75	45.36	14.36	31.00	68
California	8.95	41.88	29.27	12.61	30
West subtotal	37.51	181.30	94.02	87.38	48
Other regions	4.74	13.32	9.00	4.32	32
U.S.	42.25	194.62	103.02	91.70	47

Most of the irrigated land in the United States is in the 17 western states (not including Alaska and Hawaii). Table 2 shows 1975 irrigation water budget information for these states.

Other states that have more than 500,000 acres of irrigated land are Arkansas, Florida, and Louisiana.

Nationally, only about 52 percent of the water that is delivered to the farms is used by the growing crops; the remaining 48 percent is either returned to the stream system, evaporates from poorly drained areas, is used by plants that have a very low economic value, or percolates into non-recoverable ground water aquifers. Surface and subsurface return flows transport much of the sediment, salts, and other pollutants to the receiving waters. The irrigation water requirements for the United States in 1975 are illustrated in Figure 1.

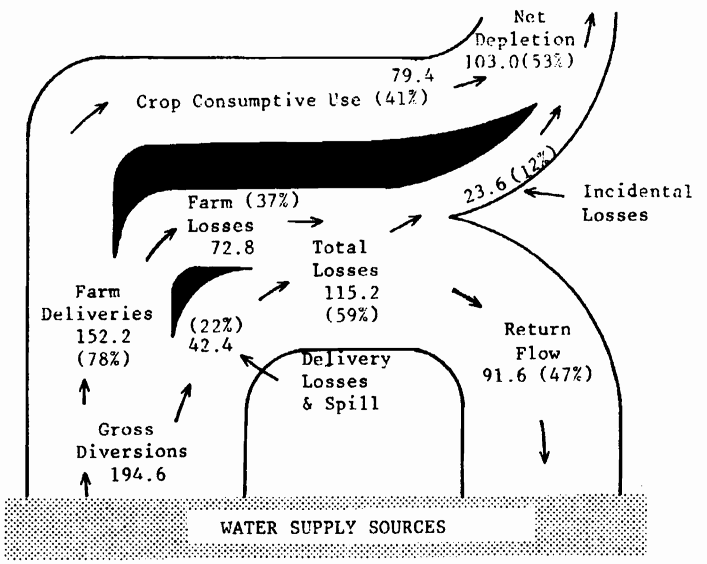
Table 2 -- Irrigation water requirements for 1975, by state.

State	1975 Irrigated land	Withdrawals or diversions	Off-Farm conveyance loss	Farm delivery	Consumptive use: Crop and pasture	Consumptive use: Associated losses1/	Return flow
	1,000 acres	thousand acre-feet					
Arizona	1,250	8,690	1,910	6,780	3,840	570	4,280
California	8,730	40,520	7,980	32,540	21,280	7,590	11,650
Colorado	2,910	12,970	3,760	9,210	4,320	980	7,670
Idaho	2,900	28,690	7,780	20,910	5,530	1,390	21,770
Kansas	1,590	3,850	80	3,770	1,890	490	1,470
Montana	1,900	13,530	6,780	6,750	2,890	790	9,850
Nebraska	3,330	10,170	1,440	8,730	5,020	1,460	3,690
Nevada	830	4,000	270	3,730	1,670	610	1,720
New Mexico	870	4,250	850	3,400	1,680	690	1,880
North Dakota	80	280	90	190	100	40	140
Oklahoma	530	1,680	100	1,580	860	460	960
Oregon	1,600	9,730	3,290	6,440	2,580	790	6,360
South Dakota	150	450	60	390	190	150	110
Texas	6,930	20,160	810	19,350	12,870	4,000	3,290
Utah	1,070	5,750	1,280	4,470	1,940	460	3,350
Washington	1,220	6,710	1,930	4,780	2,760	1,240	2,710
Wyoming	1,550	9,650	2,990	6,660	2,310	430	6,910
TOTAL	37,440	181,080	41,400	139,680	71,730	22,140	87,210

1/ Includes consumptive use by evaporation and wildlife habitat and ground water buildup from deep percolation not "readily recoverable." Associated wildlife habitat and phreatophyte vegetation within irrigated areas generally does not include more than 14 million acre-feet of use by phreatophyte and hydrophyte vegetation outside irrigated areas.

Source: Developed by SCS Special Projects Division staff from Soil Conservation Service field office data and used in 1975 National Water Assessment.

Figure 1 -- U.S. 1975 water requirements 1/



1/ For 42.2 million acres and showing values in million acre-feet and in percentage of the gross diversion (1).

Significance of Irrigation Return Flows

A question can now be asked about the significance of irrigation return flows. Why should drainage flow from irrigated land be discussed or treated separately from drainage flow from any other agricultural land? Rainfall provides most of the water for intensively cropped lands in the humid east while man must apply the water to the lands of the arid west to produce crops. Perhaps the answers can be found in part in several ways. First, because man's development is responsible for irrigation return flows, he may be able to make changes and improvements. Second, areas where irrigation is required for crop production are normally more arid and water supplies are in relatively short supply. Irrigation in arid areas uses a much higher proportion of the total available water supply than does crop growth in the humid areas. Third, the soils developed for irrigation in arid areas are relatively unleached and contain much more soluble salt than soils used for agriculture in humid areas. These three factors are enough to focus special attention on irrigation return flows.

The judicious management of water applied to irrigated crops is the most important action affecting the amount and quality of return flows. This management is expressed as "irrigation efficiency." This term

can be easily misunderstood as it can be computed in a number of different ways. Table 3 illustrates one way by which irrigation efficiency can be computed, as a percentage of total withdrawal. Yet another efficiency often computed or cited is the onfarm or field efficiency. The average onfarm efficiency for the tabular data presented can be computed by dividing the percentage farm delivery into the percentage crop consumptive use. For example, for Arizona the average onfarm efficiency would be 44 ÷ 78= 54.4% using data in Table 3.

There are some myths now circulating in the literature that warrant attention. One is that it is possible to use water for irrigation from a stream and not increase the concentrations of minerals in the stream when drainage flow is returned. Two, increased efficiency in the use of water for irrigation will not improve water quality in the stream system. The section that follows should dispel such misconceptions.

Impacts on Water Quality

Irrigation return flows normally degrade the quality of receiving waters in a number of ways. Probable changes in quality as a result of irrigation are indicated in Table 4. It has been said that irrigation-related pollution is equal in importance to municipal and industrial waste in terms of degradation of receiving waters (2). Detriments include increases in suspended and dissolved solids, nutrients, pesticides, and temperature.

Salinity

Dissolved mineral content, more commonly known as salinity, is a problem that is becoming increasingly serious in surface waters throughout Western United States. As a higher percentage of the water supply is required for irrigation, energy or other municipal and industrial use, salinity problems are expected to become even more serious. Only the Columbia River system of the major drainage systems in the West is not faced with high levels of salinity. Many streams in the arid and semiarid regions of the West display a progressive increase in salinity between their headwaters and outlets. This is especially true where a large part of the total water is consumptively used by irrigated agriculture and where there are intervening natural sources of salt. The streams and rivers most adversely affected by salinity increases from irrigation return flows are located in the arid and semi-arid portions of Western United States.

These include, of course, the Colorado River, which serves a portion of seven states and some areas of Mexico; the Rio Grande and Pecos River in New Mexico and Texas; the San Joaquin River in California; the closed system of the Great Basin; the South Platte in Colorado; the Arkansas and Red Rivers in Colorado, Kansas, Oklahoma, and Texas; the Brazos and Colorado Rivers in Texas; and other small streams.

In most instances, the water quality is excellent in the headwaters of these streams. These areas are located in high altitude forest and mountainous areas, and most of the runoff comes from snowmelt. All these streams I have mentioned display progressive increase in salinity levels as the water flows to the lower reaches of the drainage basins; the exceptions are streams that flow east from the Great Plains area of the United States and on into the downstream areas of the Missouri and Mississippi Rivers. Rainfall increases as we move east in the United States and runoff likewise increases, diluting the salt concentrations in stream flow that come from the drier plains area east of the Rocky Mountains. In these arid and semiarid regions, the soils at the lower altitudes contain large amounts of salts, and the surface waters originating from these areas generally have high concentrations of salt and sediments.

Of course, salinity is not a new problem. It has been a problem for a long time in many areas of Western United States as well as throughout the world. Ancient civilizations flourished with irrigation of fertile valley lands, but dwindled as high water tables combined with salt accumulations forced much of the land out of production. In the world today, about 550,000 acres of irrigated land is going out of production annually because of salt accumulation and poor drainage. This loss of irrigated land can be reduced by better soil and water management practices. In the 17 western states in the United States where about 37 million acres of land are being irrigated, nearly all the irrigation farmers need to be concerned with the salinity problem. They have long been concerned about the maintenance of a salt level in the root zone suitable for the crops they are growing. Today, they are concerned about the quality of the return flows to the streams and rivers; and, in these more arid river basins where mineral quality of water is a problem, the users of all the land either affect or are affected by the salt problem. However, like sediment, salinity in water is a result of interaction of water with the soil and other geologic formations and, as such, can be influenced by man's action only to a degree. Maintaining high standards in the use and management of land and water resources appears to be the best long-range solution to water quality problems originating on land areas.

High salt concentrations in water not only affect the use of water for crop production but limit its use for municipal and industrial processes without costly treatment. The reduced agricultural production and increased operation cost, both in agricultural and nonagricultural activities, as a result of increased salt concentrations in water make salinity a significant economic, as well as environmental, problem.

Table 3 -- Relative irrigation water rates and efficiencies for 1975, by state.

State	Withdrawals or diversions	Off-Farm conveyance loss	Farm delivery	Consumptive Use: Crop and pasture		Consumptive Use: Associated losses	Return Flow	
	acre-ft/acre	%1/	%1/	%1/	acre-ft/acre	%1/	%1/	acre-ft/acre
Arizona	7.0	22	78	44	3.1	7	49	3.9
California	4.6	20	80	53	2.4	19	29	2.2
Colorado	4.5	29	71	33	1.5	8	59	3.0
Idaho	9.9	27	73	19	1.9	5	76	8.0
Kansas	2.4	2	98	49	1.2	13	38	1.2
Montana	7.1	50	50	21	1.5	6	73	5.6
Nebraska	3.1	14	86	49	1.5	14	36	1.6
Nevada	4.9	7	93	42	2.0	15	43	2.9
New Mexico	4.9	20	80	40	1.9	16	44	3.0
North Dakota	3.6	33	67	34	1.2	15	50	2.4
Oklahoma	3.2	6	94	52	1.7	27	21	1.5
Oregon	6.1	34	66	27	1.6	8	65	4.5
South Dakota	3.0	14	86	43	1.3	33	25	1.7
Texas	2.9	4	96	64	1.9	20	16	1.0
Utah	5.4	22	78	34	1.8	8	58	3.6
Washington	5.5	29	71	41	2.3	18	40	3.2
Wyoming	6.2	31	69	24	1.5	4	72	4.7
Average	4.8	23	77	40	1.9	12	48	2.3
Range	2.4 to 9.9	2 to 50	50 to 98	19 to 64	1.2 to 3.1	4 to 33	16 to 76	1.0 to 8.0

1/ Percent of Withdrawals

Source: Developed by SCS Special Projects Division staff from Soil Conservation Service field office data and used in 1975 National Water Assessment.

Table 4 -- PROBABLE CHANGES IN QUALITY AS A RESULT OF IRRIGATION

Quality Factors	Irrigation Return Flow: Surface	Irrigation Return Flow: Subsurface Drainage
Salts (TDS)	Not greatly different from sources	Concentration increased usually 2-7 times. Depends on amount in the supply, number of times reused, the amount of residual salts being removed, and the amount from non-agricultural sources.
Sodium and chloride Ions	Relatively unchanged.	Both proportions and concentration likely to increase.
Nitrate	More likely a slight increase than a decrease and highly variable.	Likely to decrease if the content in irrigation water is high and increase if amounts are low. Greatest hazard from heavily fertilized porous soils over irrigated.
Phosphate	Content may increase, but closely correlated with erosion of fertile topsoil.	Decrease if considerable in source. Not likely to greatly increase.
Pesticides	Highly variable content. Surface waters subject to polluting. Likely associated with amount of erosion.	A reduction in many instances. Concentrations likely to be low.
Pathogens and other organisms	Variable and may increase or decrease.	Low content with a likely reduction in most all pathogens. Other organisms may increase or decrease.
Sediments and colloids Organics	Often more than in source but may be less--highly variable. Manures, debris, etc., likely to increase	Little or no sediment or colloidal materials in the flow. Most oxidizable and degradable materials to decrease.
Heavy metals	Kinds and amounts are variable. Likely to be greater than in subsurface flow.	More likely to decrease in concentration.
Sewage effluent	Not greatly changed except by filtering and oxidation effect of crops if sprinkled.	Concentration of all pollutants reduced except common soluble salts.

The chemical composition of the water is also a factor. For example, boron content in the lower Colorado River waters is now approaching the 0.33 ppm limit for sensitive crops, which include citrus (2).

There are two major factors that affect the salt content of irrigation return flows. First, that portion of the water supply that is consumed by the crop (evapotranspiration) is essentially salt free; therefore, the salts brought into an area with the water supply remain in the soil to be leached beyond the root zone and removed with the subsurface drainage. This accounts for the "concentrating" effect of irrigation on the salinity of drainage water. Second, as the water moves through the soil, it may pick up additional salts by dissolving weathered minerals or previously precipitated salts. These are natural results of the irrigation process and can be modified only in degree by system improvements and improved water management practices.

Excessive salinity in drinking water can create a sodium hazard to heart patients. It results in high water-softening and other treatment costs for domestic users; growth-retarding and plant-killing effects in irrigation use, requiring changes in crop varieties and soil management; and boiler scale and chemical interferences in industrial applications. Total dissolved solids (TDS) concentrations in the lower Colorado River now approach and at times exceed 1,000 parts per million (ppm). Levels are much higher in some other basins.

Nutrients

Irrigation return flows transport nutrients to receiving waters. In some areas of the Northwest, phosphate levels are sufficient to stimulate nuisance aquatic growth when combined with the nitrogen discharged by irrigation drains. Enrichment of streams can cause accelerated eutrophication of lakes and reservoirs, impairment of fisheries, depressed oxygen concentrations, impairment of navigation, taste and odor in drinking water supplies, and interference with water treatment processes. Enrichment has reached problem proportions in receiving water bodies in some basins of the West. The more notable are the Snake River and the San Joaquin River (2). Nutrients from natural sources can be a major contributor to enrichment problems also.

Pesticides

Pesticides enter receiving waters as drift and overspray from aerial applications on and into canals, drains, and streams; in storm runoff from fields; in subsurface drainage and tailwater from irrigated fields; from dumping of excess mixes and equipment cleanup solutions into waterways; and by direct application to control aquatic weeds, rough fish, and aquatic insect pests. Pesticide pollution from irrigated areas occurs with random localized events, frequently manifested as fish kills caused by organo-phosphorus and organo-chlorine pesticides. Long-term general uptake of organo-chlorines by exposed organisms also occur. Environmental Protection Agency and state regulations prohibit the release of pesticides in toxic amounts but accidental releases can occur. Organo-chlorine pesticides are highly persistent in the environment but their use is banned in most locations. They are toxic to fish and warm-blooded animals and tend to concentrate through the aquatic food chain (2).

Organo-phosphorus pesticides are much more toxic and, generally, less persistent in the environment than are the organo-chlorines. The carbamates are also highly toxic, but since most are shortlived, they are generally considered a lesser hazard than chlorinated and phosphorus compunds (2).

Temperature

Changes in receiving water temperatures attributable to irrigation return flow are not well defined. Unquestionably, some increases occur when excess applied irrigation water is exposed to elevated ambient temperatures and is discharged as tailwater. Temperature of subsurface return flow is normally not raised enough to cause serious problems in receiving waters (2).

Solids

Suspended and settleable solids in irrigation return flows result from the presence of the solids in the applied water; sediment from erosion of fields, canals and drains; and sediment from erosion associated with storm runoff. Aside from loss in soil productivity, sediments and other suspended and settleable solids cause silting of streambeds, reservoirs, and estuarines.

Measures for Reducing Return Flows

Water Delivery

Within this framework, let's look into the opportunities for improving the use of water in irrigated agriculture. First of all, about 20 to 25 percent of all the water withdrawn from streams and reservoirs for irrigation does not reach the farm. It is lost in conveyance. Some of this water, of course, is not lost from the stream system, as it may return to the stream or river from which it came. However, it frequently picks up sediment and salts as it returns to the stream. Some of the off-stream conveyance loss is caused by noncrop plant growth, evaporation, and deep percolation. The rehabilitation of these conveyance systems is needed in many of our older irrigation projects in the West. The lining or piping of canals is an important part of improving the overall water use efficiency in irrigated agriculture. Off-farm conveyance losses are small in areas where onfarm wells provide a high percent of the water supply.

Farm Water Management

Improvement of onfarm irrigation systems and reduction in the application of water levels more in line with the actual crop requirement through proper management and scheduling are being emphasized to improve irrigation efficiency.

While most gravity-flow irrigation systems used in the United States have potential for high efficiencies, pressurized systems are generally managed at higher efficiencies. However, many onfarm irrigation systems in the West require physical improvement before they can be managed efficiently. In many areas where we need to minimize the amount of return flows, pressure systems seem best adapted to achieve this end. However, many crops are grown quite successfully at high irrigation efficiencies by gravity systems, and it would be very costly to change to pressurized systems. This is particularly true of the close-grown deep-rooted crops such as alfalfa and some of the row crops such as cotton or sorghum. Sprinkler irrigation systems are being used for these types of crops in many areas of the West, but they are not always more advantageous than good gravity systems when all things are considered.

More and more, the drip or trickle irrigation systems are being utilized on vegetable and citrus crops, and these systems appear to be the best suited for high efficiency installations, where water supplies are limited. Return flows are greatly reduced through the use of pressurized systems even though efficiencies may be low for some sprinkler systems where water is lost through evaporation and drift in the application process.

As high efficiencies are approached through the use of improved systems and better water management practices, we need to be more concerned about the salt balance in the root zone of the plants being grown. It has been known for generations that for irrigated agriculture to remain workable over time, sufficient drainage must be provided to avoid an adverse salt buildup in the soil. This necessity has led to the "leaching requirement, "which is defined as the fraction of applied irrigation water that must move through the soil to leach salts from the root zone (3).

The obvious consequence of meeting the leaching requirement is that the drainage water from the irrigation enterprise will have a higher salt concentration than the irrigation water. However, a combination of reevaluation of crop salt tolerance data, recent advances in understanding of soil chemistry, and application of soil physics principles lead to a possible management system for irrigation that can result in significant reductions in the amounts of salt discharge from an irrigation project (3).

In the past the leaching requirement concept has been based on the principle of salt balance. If the total salt input exceeds the salt output, the salt balance is considered adverse, and the accumulation of salts in the root zone was thought to be highly undesirable. Many irrigation projects and drainage systems have been designed according to this principle. However, irrigated agriculture can operate successfully without the attainment of a salt balance by irrigating with the lowest leaching fraction values possible that are commensurate with satisfactory crop growth. Research and modeling studies of the U.S. Salinity Laboratory have verified that minimizing the leaching fraction reduces the return of applied salts in the return flow and minimizes river and ground water pollution. It maximizes the precipitation of carbonate and gypsum materials in the soil, it minimizes soil mineral weathering and dissolution of salt previously deposited in the soil, and it reduces the salt pickup from the underground sources (3).

The Wellton-Mohawk Project in Arizona and its contributions of salt to the Colorado River system and the role in which improved irrigation efficiency can play in the solutions to these problems is a good example for brief discussion. Several agencies of the United States Government made a study (4) on irrigation efficiency improvement in the Wellton-Mohawk Project and improvement programs have been initiated. The object of the study was to determine ways to reduce the amount of return flows to the Colorado River system. Before they are returned, they are to be treated by a desalting plant to improve the quality of water delivered to Mexico.

Deep percolation from the irrigation applications enters the ground water aquifer under the project lands. The level of the aquifer is maintained below the root zone by pumping the ground water into lined channels for transport back to the river.

The major off-farm irrigation distribution systems in the Wellton-Mohawk Project are some of the latest and best to be built in the United States. Because seepage from the distribution system is limited, most of the emphasis for improved efficiency has been in regard to onfarm irrigation systems and water management.

In comparison with other projects in the United States, the Wellton-Mohawk is already one of the more efficient projects. Currently, the average onfarm efficiency is about 56 percent, resulting in approximately 214,000 acre-feet of return flow annually. The study showed that a realistic improvement might be expected to increase the average onfarm efficiency to about 72 percent, which would reduce the return flow to 136,000 acre-feet annually. If this is achieved, there would be about 78,000 acre-feet less water to treat at the desalting plant. About 500,000 tons less salt pickup will result. On the basis of the cost difference of handling these two flows at the desalting plant and the cost of the onfarm improvement measures, the cost effectiveness of the onfarm improvements is about six to one (4).

The method of irrigation in the Wellton-Mohawk is primarily basin flooding. The basins are leveled with little or no gradient and water is released through a high discharge of about 15 feet per second so that these areas are uniformly covered quickly with the required amount of water. As much as 3 to 5 inches are applied in one irrigation.

The cropping pattern in the project area includes alfalfa, cotton, wheat, bermudagrass seed, citrus, sorghum, and several other crops. Because of the good farming practices followed, the long growing season, and the adequate amount of water available, crop yields are high; for example, alfalfa yield is around 8 tons per acre.

One of the problems is that some crops can be grown more efficiently than others under the current irrigation practices. Under the present situation, water use efficiency is low in the citrus orchards and the same is true for the shallow-rooted vegetable crops such as lettuce and mellons. Generally, alfalfa and other deep rooted crops such as cotton use a much higher percentage of the water applied. Under the type of irrigation used in the project, the sandy soils create a problem because of their high intake rate, and more deep percolation results than in soils that have a higher proportion of clays and silts.

There are many farms, particularly on the valley land, that are getting very high irrigation efficiencies. They have good systems, properly designed and installed; better soils; lined irrigation ditches; turnout structures with measuring devices to permit water to be delivered at the proper rate; and fields properly sized to permit uniform water application.

The recommended program that has been developed is to switch most of the citrus orchards on the sandy mesa lands to drip irrigation so that less water is diverted for use and a higher percentage used by the growing trees, resulting in much less deep percolation. For the other crops, improvements in the gravity flow systems are planned with consideration of the soil types and crops being grown. Information on water requirements of crops will be provided to landowners so they can better schedule water applications. Research and demonstration programs are being carried out under leadership of the Agricultural Research Service to provide more information about the techniques of drip irrigation and other practices to be installed in the project (4).

The scheduling and coordination of delivery of water in the Wellton-Mohawk project has been described in a paper presented by Gear et al at the April 1976 ASCE meeting in San Diego, California (5).

Another example of what improved irrigation efficiency might achieve in salinity reduction in the Colorado River Basin can be seen in reviewing the Grand Valley irrigated area in Colorado. This irrigated area is located at the junction of the Gunnison River and the Colorado River and covers about 72,000 acres. Farms are smaller than in the Wellton-Mohawk Project and have been in irrigation much longer. The primary problem in the Grand Valley area is the salt pickup from the soils and geologic materials.

The Mancos Shale Formation is prominent throughout the area. This is a marine shale, very high in salt content. The concentrations of salts returning to the Colorado River from the Grand Valley irrigated area do result, of course, from the consumption of water for plant growth, but the primary problem is the salt which is picked up from the underlying aquifers by ground water returning to the Colorado River from the irrigated area. The ground water in the aquifer has concentrations from 6,000 ppm to 36,000 ppm. The total salt pickup from the Grand Valley area is about 6 to 7 tons per acre per year. Unlike the Wellton-Mohawk area, the Grand Valley has need for improvement of the off-farm distribution systems. It has been estimated that about 30 percent of the salt pickup results from seepage from the main canal systems. However, the biggest problem, here again, results from farm ditch seepage and excessive deep percolation from the application of too much irrigation water. This can be solved through better onfarm systems, better management, and scheduling the water acutally needed for plant growth.

I submit that one of the most important overall programs that can be carried out in the water-short areas of Western United States is water conservation in all water uses, particularly in agriculture. Not only can we expect to reduce salinity levels in our streams and rivers--we can extend the use of our water supplies either to additional irrigated areas or to other beneficial uses. The overall quality of water will be improved, sediment loads will be reduced, and other transported pollutants reduced. These improvements in irrigated agriculture will (1) reduce pollutant loads to stream systems, (2) help stretch short water supplies, and (3) increase the productivity of agriculture.

To obtain higher efficiencies in all irrigated areas will require an accelerated program of improving irrigation systems and water management, using the best practical technology available; changes in water rights laws in some states to encourage conservation of water; state land use planning that would encourage the most efficient agricultural lands to remain in agriculture; acceleration of assistance programs that emphasize the development and implementation of improved technology, irrigation systems and cultural practices; and a modified water pricing policy that encourages good water management. On the basis of a field inventory of improvement opportunities in 11 western states for the Western U.S. Water Plan Study (6), treatment needs, costs, and impacts were estimated. About 28,300 miles of off-farm canals and laterals need lining or piping and 21 million acres of the total of 30 million acres need improved onfarm systems and water management. The one-time installation cost (1970 prices) is estimated to be $5.7 billion. This would require a very major investment in irrigated agriculture in the West.

Implications of carrying out an accelerated water conservation program are:

1. Reduced withdrawals to leave greater volumes of water available for instream flow or downstream use.

2. Surplus flow or storage available to supplement present water shortages or for new irrigation needs.

3. Possible allocation of excess irrigation storage to fish and wildlife, recreation, energy, and municipal and industrial uses.

4. Reduced energy requirements in areas where irrigation water is pumped.

5. Helping obtain national goals of water quality improvement. Less seepage and deep percolation would reduce drainage needs and leaching of salts and nutrients.

6. Improved water and cultural management, resulting in greater crop production per unit of water used.

7. Loss of some wildlife habitat in phreatophyte and seeped areas.

Consideration for Water Resource Planning and Development in the Future

Where do problems with irrigation return flow lead us as far as meeting the food and fiber needs of future generations? There certainly is no one answer to this question. Today, we are spending many more resources on research, planning, and making impact evaluations relative to development work that is being undertaken than any time in recent years. Today's projects and programs that are undertaken should be those best alternatives available to us. But sometimes the projects remind us of a committee report -- it has a little something in it for everyone but not too much of any one thing to be objectionable to another. I'm not sure that this course of action will be the most desirable in the end. Sometime, we must "bite the bullet" on priorities.

But as we look ahead there are some basic principles I feel we must consider and address.

1. Planning must be done in an arena large enough to adequately consider the real alternatives for supplying the potential outputs of the project.

2. For the sake of water resource conservation, we must consider first the improvement of the irrigation facilities we have. Built-in obsolescence in resource development is not a workable alternative. For irrigated agriculture this means the rehabilitation of inadequate or deteriorated systems, development of additional water supplies to meet shortages, up-dated onfarm system and management measures to increase water use efficiency and land productivity, and full evaluation of alternative improvement programs to minimize adverse aspects of return flows.

3. The development of new irrigated areas should be carefully studied to (1) irrigate only the better soils, (2) provide water application systems which can be managed at a high level of efficiency, and (3) evaluate the effect of resulting drainage return flow on receiving waters, downstream water, land use, and environmental values.

4. All water resources planning should be carried out following the multiple objective approach with adequate displays of economic, environmental, and social values to facilitate public participation and decisionmaking. Single purpose water quality planning is as objectionable as single purpose water supply planning.

5. Institute in all future major water resource project and program undertakings a full evaluation of the energy requirements and impacts. Efficiency in the use of energy must be elevated as a major factor in water and related land resource decisionmaking.

REFERENCES

(1) Hedlund, John D., "Meeting Future Water Requirements by Water Conservation," Paper No. 75-2557, ASAE, December 1975.

(2) William C. Blackman, Jr., Carroll G. Wills, Esq., and Arnold C. Celnicker, Esq., "Application of PL 92-500 to the Control and Abatement of Pollution by Irrigation Return Flow," November 1975.

(3) van Schilfgaarde, Jan, Bernstein, Leon, Rhoades, James D. and Rawlins, Stephen L. "Irrigation Management for Salt Control," Journal of the Irrigation and Drainage Division, ASCE, September 1974.

(4) The Advisory Committee on Irrigation Efficiency, Wellton-Mohawk Irrigation and Drainage District, "Special Report on Measures for Reducing Return Flows from the Wellton-Mohawk Irrigation and Drainage District," September 1974.

(5) Gear, Roy D., Dransfield, Arnold S., and Campbell, Melvin D., "Effects of Irrigation Scheduling and Coordinated Delivery on Irrigation and Drainage Systems, Preprint 2720, ASCE, April 1976.

(6) Westwide Study Report on Critical Water Problems Facing the Eleven Western States, April 1975, U.S. Department of the Interior.