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DIVISION S-6—SOIL AND WATER MANAGEMENT AND CONSERVATION

Water-soluble NO_3 -Nitrogen, PO_4 -Phosphorus, and Total Salt Balances on a Large Irrigation Tract¹

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ABSTRACT

Return flow from a 82,030-ha (202,700-acre) tract of calcareous silt loam soils irrigated with water diverted from the Snake River in southern Idaho increased the downstream total soluble salt and NO_3 -N loads, but decreased the downstream PO_4 -P load. Under the existing water management practice, 50% of the total input water returned to the Snake River as subsurface drainage. Net total soluble salt output was 2.4 metric tons/ha (1.0 English ton/acre) and, on the average, was considerably greater than necessary to maintain a salt balance. Net NO_3 -N output was 33 kg/ha (30 lb/acre). Only about 30% as much PO_4 -P left the tract via drainage water as entered the tract in irrigation water. As water passed through the soil, PO_4 -P was removed by chemical reactions in the soil, thus decreasing the concentration in the subsurface drainage water and decreasing the downstream PO_4 -P load. Applied P fertilizer was not leached into the drainage water.

Additional Key Words for Indexing: pollution, nutrients in water, salt load, nutrient load, water balance, evapotranspiration (ET).

THE GROWING concern for the quality of man's environment has directed much attention to water quality. Public interest in environmental quality has aroused speculation about the effects of irrigation and the application of fertilizers on the quality of surface and ground waters. The Environmental Pollution Panel of the President's Science Advisory Committee (14) recommended that high priority be given to investigations of the relative contribution of nutrients and total salts from various sources that enter our surface and ground waters. Other groups have recom-

mended that the contribution of fertilizers to the concentration of nitrogen and phosphorus in surface and ground waters be determined under various management systems, climatic environments, and on representative soil types (11, 15, 19, 21, 22).

A pressing need in irrigation agriculture is the development and evaluation of procedures to improve the quality of irrigation return flows. The factors controlling this quality of return flows are the quantity and quality of diverted water, evapotranspiration for the irrigated area, the proportions of the water that return as surface and subsurface drainage, and direct contributions of quality-degrading components from industry, municipalities, etc. A certain amount of leaching is required for maintaining a salt balance for sustained productivity of any irrigation project (1, 11, 21, 24, 25), but excessive leaching may dissolve more soil minerals and remove more soluble salts than necessary for a salt balance. The relationships between the amount of water passing through the soil and the salt concentration in return flows have not been investigated sufficiently on many projects. These relationships must be investigated under present irrigation practices to provide basic information for use in determining practices to improve the quality of return flows and in planning new irrigation projects.

There is much speculation that increased use of P fertilizers has greatly increased the PO_4 -P concentration in surface waters, and that this concentration increase is the key to algal blooms and stimulated growth of aquatic plants (11, 14, 15, 19, 21, 22). PO_4 -P concentrations ranging from 0.02 to 0.05 ppm have been reported as minimal for supporting algal blooms. Certainly algae require phosphorus for growth and reproduction. Unfortunately, many writers have considered only phosphorus as the key to water pollution and have ignored other possible key factors. Recently Kuentzel (8) presented convincing evidence that C is more

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likely the key to algal blooms than is P. Certainly, more research is needed to definitely establish factors controlling algal blooms.

Information on the P concentration in irrigation return flows is extremely limited. Chemical reactions of P in the soil indicate that $PO_4\text{-P}$ concentrations in subsurface drainage waters should be very low (3, 4, 10, 12, 21). These concentrations should not exceed the solubility of the various phosphorus compounds found in the soil. Johnston and others (7) reported that the amount of phosphorus removed from an irrigated area through the subsurface drainage water was insignificant. More field information is needed. If irrigation return flows contain insignificant $PO_4\text{-P}$ concentrations, we need to know about it. If they contain important quantities, we need to change practices to decrease the $PO_4\text{-P}$ outputs from irrigated lands.

The $NO_3\text{-N}$ concentration in subsurface drainage waters from irrigation generally exceeds that in the irrigation water (21). Several investigators have concluded that much of the $NO_3\text{-N}$ in subsurface drainage waters originated from applied N fertilizer (7, 18). In contrast, Bower and Wilcox (2) concluded that the use of N fertilizer on adjacent irrigated land has not increased the $NO_3\text{-N}$ concentration in the upper Rio Grande River. More information is needed from other irrigation projects to validly assess the importance of $NO_3\text{-N}$ in irrigation return flows.

This paper reports results of an investigation of the water-soluble salt, $PO_4\text{-P}$, and $NO_3\text{-N}$ balances for a 82,030-ha (202,700-acre) irrigation tract in southern Idaho. Inputs and outputs of these constituents were determined under existing water management practices.

MATERIALS AND METHODS

The study area (Fig. 1) was developed by the Twin Falls Canal Co. and has been under irrigation for about 65 years. Water is diverted from the Snake River and allocated to farmers at the rate of approximately 14 liters/sec for each 16 ha (0.5 cubic feet/sec for each 40 acres) continuously. Water is in the canal system from about April 1 to November 15 each year. Canal-flows in the early spring and late fall are considerably lower than during the peak irrigation season of June, July, and August because some crops do not require early spring and late fall irrigation.

Soils of the study area are wind deposited, calcareous, silt loams, ranging from 0 to 15 m (0-50 feet) deep. A caliche and silica cemented hardpan layer is found from 0.30 to 0.45 m (12 to 18 in.) below the surface over most of the area. The soils are underlain by fractured basalt to depths of several hundred meters. Water infiltration rates are fairly high and most crops are irrigated by small furrows.

The most important crops are alfalfa (*Medicago sativa* L.), dry beans (*Phaseolus* spp), sugarbeets (*Beta vulgaris* L.), small grain, corn (*Zea mays* L.), and pasture (Table 1). The row crops are normally seeded in April and May, and normally the last crop harvested is sugarbeets, which is generally in October. Mean annual precipitation for the area is approximately 210 mm (8.5 in.).

High water tables appeared in localized areas throughout the tract soon after irrigation was initiated in 1905. To alleviate this problem, the Canal Company excavated tunnels 1.3 m wide by 2.3 m high (4 by 7 feet), into the basalt underlying the high water table areas. Tunnels were terminated when fractures in the basalt carrying significant amounts of water were intercepted. The tunnels then served effectively as drain-

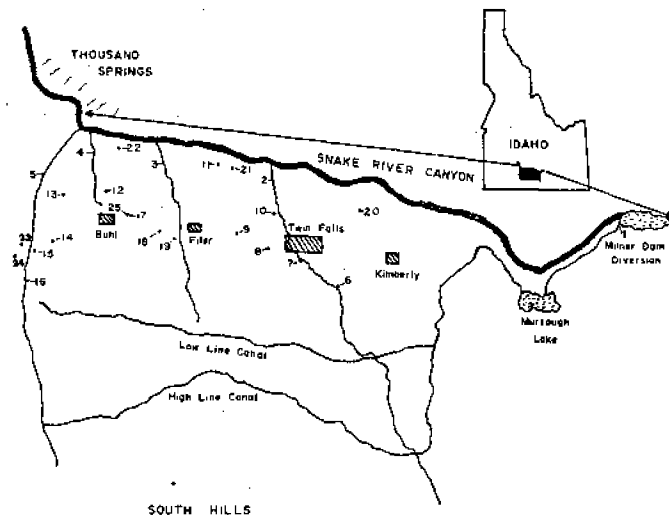


Fig. 1.—The study area illustrating sampling sites and important features.

age channels to convey excess water into natural surface drains. Approximately 50 tunnels ranging from 400 to 2,400 m (0.25 to 1.5 miles) long were excavated before the practice was discontinued in the 1930's and replaced by relief wells connected by tile lines. These relief wells were 10 to 20 m (35 to 70 feet) deep, and the tile lines connecting them were 1 to 3 m (3.5 to 10 feet) below the ground surface. These wells flow from hydrostatic pressure, and water is conveyed to natural surface drains by the tile lines. This practice also has proved effective in lowering the water table and is still used today. Flow records for the drainage tunnels and tile-relief well networks, maintained by the Canal Company until the mid-1940's, were made available for review. All surface and subsurface drainage returns to the Snake River, which flows through a canyon 165 m (500 feet) deep, forming the northern boundary of the project.

Sampling sites selected throughout the area included the project diversion at Milner Dam on the Snake River, 15 drainage tunnel outlets, five tile-relief well network outlets, four main natural surface drains (Rock Creek, Cedar Draw, Mud Creek, and Deep Creek), and approximately 15 small natural surface drains returning water to the Snake River. These sites, except the small surface drains, are shown in Fig. 1 by number, and the numbers identify the data in Table 3. Samples from each site, except the 15 small natural surface drains, were collected at 2-week intervals for the Canal Company water year, October 1, 1968 through September 30, 1969. Surface runoff water samples were collected at irregular intervals during the study year. Weirs, flumes, and current meters were used to measure water flow at the sampling sites. The record of water diverted was provided by the Twin Falls Canal Co. in cooperation with US Geological Survey.

Water samples were analyzed for total soluble salt concentration and the usual salinity constituents (20), water-soluble $PO_4\text{-P}$ (23) and water-soluble $NO_3\text{-N}$ (20). In addition, some measurements were made of water-soluble polyphosphates by standard methods (16, 20) and of $NH_4\text{-N}$ and $NO_2\text{-N}$ by microdiffusion.

The total inputs and outputs of water-soluble salts, $PO_4\text{-P}$, and $NO_3\text{-N}$ were based on the concentrations found in diverted waters, surface runoff water, and subsurface drainage water. To make these computations, it was necessary to compute a water balance for the system as described below. Total soluble salts, $PO_4\text{-P}$, and $NO_3\text{-N}$ in the irrigation water were considered the primary inputs for the balance. The N input from precipitation was considered negligible in this study. Applied fertilizers were considered as factors affecting $PO_4\text{-P}$ and $NO_3\text{-N}$ outputs. Amounts of fertilizers applied were estimated by inter-

viewing major fertilizer dealers in the area. Estimated yearly application rates for P and N, respectively, were 30 and 60 kg/ha (27 and 53 lb/acre).

A water balance based upon the following equation (5), was computed for the irrigation district:

$$D + P = ET + G + Q \pm \Delta S$$

where:

- D = all water diverted into the tract
 P = precipitation
 ET = evapotranspiration
 G = subsurface drainage or deep percolation
 Q = direct surface runoff.
 ΔS = change in soil water content.

Most of the diverted water, D , was measured at the Milner Dam diversion. The contribution from the South Hills watershed was estimated from US Geological Survey records, and the small contribution from the city of Twin Falls was estimated from city records. Evapotranspiration, ET , was determined using a modified Penman approach (6, 13) and crop growth-by-season curves for the various crops grown in the irrigation district. This technique has been shown to be valid in southern Idaho. Surface runoff was determined by measuring the flow of natural surface drains throughout the period of sampling. The proportions of surface runoff and subsurface drainage water in natural surface drains conveying both were estimated by standard hydrograph separation techniques (9). Normal flow in these drains from December through March consisted of only subsurface drainage water from tunnels and tile-relief well networks. Canal company records and flow measurements showed that the subsurface drainage flows from these sources cycle yearly, with maximums in the fall and minimums in the spring. The flows in the surface drains and the contributing tunnels and tile-relief well networks were measured from December 1 through March 30. This procedure provided part of the yearly flow cycle for the subsurface water in these natural surface drains. The remaining portion of the yearly cycle was projected from the cycles for the contributing tunnels and tile-relief well networks. Thus, yearly flow cycles for the subsurface drainage water in these natural surface drains were computed. Measured flows in excess of the estimated subsurface drainage portion during the year were considered surface runoff. The change in soil water content, ΔS , was considered negligible because soils generally are low in water content at the beginning of each water year. The subsurface drainage or water that passed through the soil was computed by difference after measuring or estimating the other components in the equation. More than one-half of this subsurface drainage water was measured and sampled at the various tunnel and tile-relief well outlets.

RESULTS AND DISCUSSION

Estimated annual ET ranged from 1,072 mm (42.2 in.) for irrigated pasture to 584 mm (23 in.) for spring grain (Table 1). Values for the actual crop season are lower than those for the entire year because of evaporation from the soil during the period when no crop is growing. The weighted mean annual ET was 787 mm (31.0 in.).

The water balance (Table 2) showed that 50% of the total input water passed through the soil and became subsurface drainage. Evapotranspiration accounted for 36%, and the remaining 14% was surface runoff. Thus, 64% of the total water input became irrigation return flow into the Snake River.

The mean electrical conductivity (EC) of water di-

Table 1—Crops grown on the Twin Falls Canal Co. tract and the estimated evapotranspiration (ET) for each

| Crop | Hectares | ET | | Acres | ET | |
|--|----------|-------------|-------------|---------|-------------|-------------|
| | | Entire year | Crop season | | Entire year | Crop season |
| | | mm | | | Inches | |
| Alfalfa (<i>Medicago sativa</i> L.) | 15,301 | 1,054 | 993 | 37,811 | 41.4 | 39.1 |
| Dry beans (<i>Phaseolus</i> spp.) | 14,299 | 630 | 498 | 35,333 | 24.8 | 19.6 |
| Spring grain | 9,835 | 584 | 480 | 24,302 | 23.0 | 18.9 |
| Irrigated pasture | 8,750 | 1,072 | 1,018 | 21,623 | 42.2 | 40.1 |
| Sugarbeets (<i>Beta vulgaris</i> L.) | 8,526 | 828 | 762 | 21,069 | 32.6 | 30.0 |
| Corn (<i>Zea mays</i> L.) | 6,380 | 706 | 597 | 15,765 | 27.8 | 23.5 |
| Fall grain | 3,278 | 612 | 498 | 8,100 | 24.1 | 19.6 |
| Potatoes (<i>Solanum tuberosum</i>) | 1,618 | 759 | 668 | 3,997 | 29.9 | 26.3 |
| Peas (<i>Pisum sativum</i>) | 862 | 617 | 516 | 2,130 | 24.3 | 20.3 |
| Towns, canals, etc.* | 8,094 | 1,072 | 1,018 | 20,000 | 42.2 | 40.1 |
| Nonirrigated area | 5,088 | 196 | - | 12,570 | 7.7 | -- |
| Total | 82,030 | - | - | 202,700 | -- | -- |
| Weighted mean | - | 787 | - | - | 31.0 | -- |

* Considered the same as for irrigated pasture.

Table 2—Water balance for the 82,030-ha (202,700-acre) Twin Falls Canal Co. tract for the water year, October 1, 1968 through September 30, 1969

| | Metric | | English | | % |
|---------------------------|----------------------------------|-------|-----------|--------|-----|
| | m ³ × 10 ⁴ | mm | acre-feet | Inches | |
| Input | | | | | |
| Diverted from Snake River | 159,134 | 1,941 | 1,290,000 | 76.4 | 89 |
| Runoff from South Hills | 3,948 | 48 | 32,000 | 1.9 | 2 |
| Precipitation | 16,049 | 195 | 130,000 | 7.7 | 9 |
| City of Twin Falls | 111 | -- | 900 | -- | 0 |
| Total | 179,242 | 2,184 | 1,453,000 | 86.0 | 100 |
| Output | | | | | |
| Evapotranspiration | 64,597 | 787 | 523,650 | 31.0 | 36 |
| Surface runoff | 25,151 | 307 | 203,880 | 12.1 | 14 |
| Subsurface drainage | 89,494 | 1,090 | 725,470 | 42.9 | 50 |
| Total | 179,242 | 2,184 | 1,453,000 | 86.0 | 100 |

verted at Milner Dam averaged 460 $\mu\text{mhos/cm}$, with little variation (Table 3). This value was used for calculating the total salt input (Table 4), since variation was slight. Surface runoff water had the same EC value as did the diverted water. Hence, the mean value of 460 $\mu\text{mhos/cm}$ was also used for computing total salt outputs via surface runoff.

The total soluble salt concentration in subsurface drainage water was generally more than twice that in the irrigation water (Table 3). The concentration was nearly constant for each tunnel and tile-well network, but there was some variation among them. There was no particular pattern to the variation, and generally, differences were small. Thus, the mean EC value of 1,040 $\mu\text{mhos/cm}$ was used for computing the total soluble salt output via subsurface drainage water (Table 4).

$\text{PO}_4\text{-P}$ concentrations in water diverted from the Snake River ranged from 0.015 to 0.148 ppm. Concentrations were lowest during June and July during and immediately following peak river flow resulting from snowmelt. Because of the variation in $\text{PO}_4\text{-P}$ concentration over the year, monthly mean $\text{PO}_4\text{-P}$ concentrations were used with monthly water diversions to compute the total $\text{PO}_4\text{-P}$ input (Table 4). Using the mean concentration of 0.066 ppm for the year gave a slightly higher input of 105 metric tons (116 English tons).

Subsurface drainage waters were so low in $\text{PO}_4\text{-P}$ that it was necessary to concentrate samples to verify results by the sensitive method used (23) (Table 3). The mean concentrations for the various subsurface drainage effluents

Table 3—Mean concentrations of total salts, PO₄-P, and NO₃-N in irrigation and drainage waters of the Twin Falls Canal Co. irrigation tract

| | Site no. | Total salts | PO ₄ -P | NO ₃ -N |
|------------------------------------|----------|-------------|--------------------|--------------------|
| | | μmhos/cm | ppm | ppm |
| Milner Dam diversion | 1 | 460 | 0.066 | 0.12 |
| Surface runoff | 2-5* | 460 | 0.066 | 0.12 |
| <u>Tunnels</u> | | | | |
| Clear | 6 | 1,148 | 0.013 | 4.02 |
| Fish Hatchery | 7 | 867 | 0.013 | 2.24 |
| Grossman | 8 | 911 | 0.014 | 2.25 |
| Nye | 9 | 990 | 0.009 | 2.44 |
| Tolbert | 10 | 1,130 | 0.012 | 3.30 |
| Walters | 11 | 1,112 | 0.008 | 3.47 |
| Mendini | 12 | 1,106 | 0.009 | 3.97 |
| Neyman | 13 | 1,102 | 0.011 | 3.40 |
| Galloway | 14 | 982 | 0.014 | 3.58 |
| Cox | 15 | 973 | 0.015 | 3.44 |
| Herzman | 16 | 1,076 | 0.017 | 3.00 |
| Harvey | 17 | 965 | 0.008 | 3.39 |
| Peavy | 18 | 984 | 0.007 | 3.02 |
| Padgett | 19 | 1,000 | 0.008 | 3.01 |
| Hankins | 20 | 1,093 | 0.012 | 3.55 |
| <u>Tile-Well Complexes</u> | | | | |
| Brown | 21 | 1,121 | 0.009 | 3.01 |
| Hutchinson | 22 | 1,106 | 0.012 | 3.20 |
| Kaes | 23 | 1,044 | 0.023 | 3.40 |
| Molander | 24 | 1,088 | 0.009 | 3.79 |
| Harvey | 25 | 1,000 | 0.023 | 3.30 |
| Mean for subsurface drainage water | | 1,040 | 0.012 | 3.24 |

* Surface samples were collected throughout the tract where surface water ran off from fields. The small natural surface drains are not shown, but were sampled adjacent to the Snake River canyon.

did not differ widely. Hence, the mean value of 0.012 ppm was used for computing PO₄-P outputs. PO₄-P concentrations were generally lower than those reported by Johnston et al. (7) in subsurface drainage from California soils. The solubility of P compounds in calcareous soils at pH 8.2 is very low (3, 4, 10), and observed values are reasonable. Surface runoff water contained the same concentration of PO₄-P as did the irrigation water.

The NO₃-N concentration in water at Milner Dam was low, averaging only 0.12 ppm (Table 3). However, on two sampling dates during the winter when water was not being diverted, the concentration was about 1.50 ppm, indicating occasional increases in upstream inputs during low flows. The mean value of 0.12 ppm was used for computing NO₃-N inputs (Table 4).

Subsurface drainage water contained many times more NO₃-N than did the irrigation water, but concentrations were relatively low compared with Public Health Standards of 10 ppm as a maximum for drinking water. The mean value was 3.24 ppm, and variation within and among drainage effluents was small. Thus, the mean value was used for computing NO₃-N outputs. Surface runoff water contained the same concentration of NO₃-N as did the irrigation water.

Samples collected on several dates from all sampling sites were analyzed for NH₄-N and NO₂-N by microdiffusion techniques, but no detectable concentration of either was found.

The net output of 196,871 metric tons (217,100 English tons) of total soluble salts (Table 4) represents approximately 2.4 metric tons/ha (just over 1 English ton/acre). These salts arise largely from solubilization of soil minerals. Leaching occurs each year because 50% of the input water passes through the soil and becomes subsurface drainage. This high level of leaching assures against salt accumulations in the soil, but it also likely increases the

Table 4—Total water-soluble salts, PO₄-P, and NO₃-N balances for the 82,030-ha (202,700-acre) Twin Falls Canal Co. irrigation for the water year, October 1, 1968 through September 30, 1969

| | Metric tons* | | | English tons | | |
|-------------------------------|---------------|--------------------|--------------------|---------------|--------------------|--------------------|
| | Soluble salts | PO ₄ -P | NO ₃ -N | Soluble salts | PO ₄ -P | NO ₃ -N |
| <u>Inputs</u> | | | | | | |
| In diverted Snake River water | 467,584 | 84 | 190 | 515,414 | 93 | 210 |
| In runoff from South Hills | 5,128 | -- | -- | 5,563 | -- | -- |
| Total | 472,712 | 84 | 190 | 520,977 | 93 | 210 |
| <u>Outputs</u> | | | | | | |
| In surface runoff | 73,900 | 14 | 29 | 81,459 | 16 | 32 |
| In subsurface drainage | 595,648 | 11 | 2,898 | 656,618 | 12 | 3,194 |
| Total | 669,548 | 25 | 2,927 | 738,077 | 28 | 3,226 |
| Net input | -- | 59 | -- | -- | 65 | -- |
| Net output | 196,871 | -- | 2,737 | 217,100 | -- | 3,016 |

* Total salt concentrations were obtained by multiplying the μmhos/cm × 0.64 to give ppm. The total yearly quantities of all constituents measured were obtained by multiplying the concentration × total yearly flow on a weight basis.

salt output via subsurface return flows to the Snake River. Little or no precipitation of CaCO₃ or CaSO₄ occurs under these excessive leaching conditions. A salt balance is maintained in the sense that as much or more salt leaves the irrigation tract as enters it (24, 25), but such a balance probably could be maintained with less leaching. More efficient irrigation would probably decrease the total salt load in return flow and thus decrease the downstream salt load in the Snake River.

Irrigating the Twin Falls Canal Co. tract contributes to the total soluble salt load in the Snake River downstream. The contribution is not too serious because 579,792 × 10⁴ m³ (4.7 × 10⁶ acre-feet) of water enters the river each year from the Thousand Springs, adjacent to and downstream from the tract. This water has an EC of about 250 to 300 μmhos/cm and, thus, dilutes the salt load in irrigation return flows. Furthermore, the subsurface drainage water from the tract contains lower total salt concentrations than does the irrigation water diverted in many locations from the Colorado and Rio Grande Rivers (1, 2).

Using water for irrigation decreased the PO₄-P load in the downstream Snake River. Approximately 30% as much PO₄-P leaves the tract in the drainage water as enters in the irrigation water (Table 4). Hence, 70% of the input in the irrigation water remains in the soil or is taken up by plants. Furthermore, there is no evidence that applied P fertilizers leached into the drainage water as PO₄-P. The estimated yearly application of P fertilizer is 2,460 metric tons (2,735 English tons) and only 11 metric tons (12 English tons) of PO₄-P left the tract in the subsurface drainage water. At some sampling dates the irrigation water contained measurable polyphosphate concentrations, whereas the subsurface drainage waters did not. Also, the organic matter load of the irrigation water was appreciable, and it contains some organic phosphates. In contrast, the subsurface drainage waters were essentially free of organic matter. All these factors add to the total P input into the Twin Falls Canal Co. tract but have little or no effect on the P output in the drainage water from the tract.

The net NO₃-N output of 2,737 metric tons (3,016

English tons) amounts to about 33 kg/ha (30 lbs/acre) per year. The origin of the $\text{NO}_3\text{-N}$ is not definitely known, but possible sources are: (i) nitrification processes resulting from decomposition of plant residues including plowed alfalfa, (ii) applied N fertilizer, (iii) feedlots (18), (iv) farm-home sewer systems, (v) industrial wastes, (vi) leaching from semidesert soils, and (vii) precipitation. The relative importance of these $\text{NO}_3\text{-N}$ sources is not known.

Results from this investigation should be applicable in principle to much of the western USA where calcareous soils are irrigated. The variation among irrigation districts will depend primarily upon the water balance, land management, and geology of the areas. A lower net output of total soluble salts and $\text{NO}_3\text{-N}$ should be expected in districts where a smaller fraction of the applied water passes through the soil to become subsurface drainage. A higher net output of these components should be expected where a larger fraction of the input water becomes subsurface drainage. The $\text{PO}_4\text{-P}$ balance depends upon the input. Where irrigation waters contain essentially no $\text{PO}_4\text{-P}$, the balance would be quite different on a percentage basis than where they contain considerable amounts. If the irrigation water contains $\text{PO}_4\text{-P}$, most of it will be removed by the irrigation process, and subsurface drainage water will contain an extremely low $\text{PO}_4\text{-P}$ concentration.

Return flows from water diverted for irrigating calcareous soils in the West may contribute to the downstream total soluble salt and $\text{NO}_3\text{-N}$ loads of the source stream. The amounts contributed will depend primarily upon the water balance and the amount of leaching. Sufficient leaching to maintain a salt balance is necessary for continued productivity of any irrigation tract. More than that amount of leaching may contribute more soluble salt and $\text{NO}_3\text{-N}$ than necessary to the stream carrying away the drainage water—usually the source stream. The picture is different with $\text{PO}_4\text{-P}$. Irrigation decreases the downstream soluble $\text{PO}_4\text{-P}$ load if the irrigation water contains more than about 0.01 to 0.02 ppm. The $\text{PO}_4\text{-P}$ is precipitated as water passes through the soil. Of course if the irrigation water contains less than that concentration of $\text{PO}_4\text{-P}$, irrigation will have no effect on the downstream soluble $\text{PO}_4\text{-P}$ load. Under these latter conditions, $\text{PO}_4\text{-P}$ loads are unimportant.

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