UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

# IRRIGATION-WATER QUALITY IN THE SULPHUR CREEK BASIN, YAKIMA AND BENTON COUNTIES, WASHINGTON, APRIL 1976 THROUGH MARCH 1977

P. R. Boucher and M. O. Fretwell

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JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

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METRIC (SI) CONVERSION TABLE

| Multiply | By | To obtain |
|---|---|---|
| feet (ft) | 0.3048 | meters (m) |
| miles (mi) | 1.609 | kilometers (km) |
| acres | 0.0041 | square kilometers ($km^2$) |
| pounds (lb) | 0.4536 | kilograms (kg) |
| square miles ($mi^2$) | 2.590 | square kilometers ($km^2$) |
| acre-feet (acre-ft) | 1,233. | cubic meters ($m^3$) |
| tons | 0.9072 | tonnes |
| tons per acre (ton/acre) | 0.2242 | kilograms per square meter ($kg/m^2$) |
| pounds per acre (lb/acre) | 0.1121 | grams per square meter ($g/m^2$) |
| cubic feet per second ($ft^3/s$) | 0.02832 | cubic meters per ($m^3/s$) |

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level." NGVD of 1929 is referred to as sea level in this report.

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## ABSTRACT

Suspended sediment, total nitrogen, total nitrate-plus-nitrite, and total phosphorus concentrations, water temperatures, and water discharges were monitored in the irrigation water of the Sulphur Creek basin for the 1976 irrigation season and for the following nonirrigation season. The Sulphur Creek basin's net outflow of sediment during the study period was about 79,000 tons, which corresponds to a yield of 2.0 tons per acre of irrigated cropland. Only about 3 percent of the net sediment outflow occurred in the nonirrigation season of November to March. Of the subbasins, DID (Drainage Improvement District)-18 had the greatest net outflow of sediment (about 29,000 tons, or a yield of about 7.0 tons per acre), and DID-9 had the least net outflow (about 8,600 tons, or a yield of about 0.7 ton per acre). Differences in yield relate best to land slopes, but the lower yields from DID-9 subbasin are also partly attributable to a larger proportion of orchard land.

Net nutrient outflows from the Sulphur Creek basin were 1,200,000 pounds of nitrogen and 120,000 pounds of phosphorus. About one-third of the nitrogen and about one-sixth of the phosphorous outflow occurred during the nonirrigation season. Nitrate-plus-nitrite constituted 70 percent of the nitrogen outflow in the irrigation season and 84 percent in the nonirrigation season.

The monitoring network was discontinued at the end of 1 year, largely because few farmers participated in the demonstration pilot project the network was designed to monitor. Network sensitivity was adequate in the subbasins where the demonstration project was to have occurred, but was inadequate in the control subbasins. A reduction in sediment yields of 27, 23, and 10 percent, respectively, from DID-18 basin, Black Canyon Creek basin, and the entire Sulphur Creek basin would be necessary for the effects of improved agricultural practices to be reliably detected.

Harmonic analysis and fourth degree polynomial analysis indicated an annual cyclic pattern of constituent concentrations and discharges. Fourth degree polynomial analysis showed slight to no improvement over harmonic analysis in explaining the variations.

## INTRODUCTION

### Background

In 1972 Congress passed Public Law 92-500 (Sec. 208), the Federal Water Pollution Control Act Ammendments of 1972. Among the many nationwide objectives of this law is the restoration, by July 1983, of stream-water quality to what is commonly referred to as "fishable" and "swimmable." To meet this and other objectives, Congress prescribed goals and deadlines and the responsibilities of various government agencies. The U.S. Environmental Protection Agency (EPA) was designated as the Federal agency responsible for administering this law. Subsequently, the State of Washington Department of Ecology (DOE) requested that EPA delegate to them the authority for administering the law as it pertains to the introduction of point and nonpoint waste discharges into the State's waters. EPA granted DOE's request in November 1973.

The Department of Ecology formed a multi-agency Technical Advisory Committee for Water Quality Improvement to provide DOE with technical advice related to irrigated agriculture. Beginning with the first meeting on October 1, 1974, the committee has addressed itself specifically to irrigated agriculture in the Yakima River basin.

At about the same time (1974), in a study conducted for DOE, the consulting firm $CH_2M$ Hill identified Sulphur Creek subbasin (pl. 1) as having the greatest irrigation-water-quality problems of any subbasin in the Yakima River basin ($CH_2M$ Hill, 1975). They further ranked the subbasins of Sulphur Creek basin according to the severity of water-quality problems.

With the assistance of the Technical Advisory Committee, DOE and the U.S. Soil Conservation Service (SCS) developed a jointly funded demonstration project in the Sulphur Creek basin. The objective of the Sulphur Creek Demonstration Project was to develop and bring into operation a workable, voluntary program with the farmers to reduce soil erosion through application of best-management practices (BMP). Two subbasins in the Sulphur Creek basin, identified by $CH_2M$ Hill as having the most serious irrigation-water quality problems, were selected as the demonstration areas -- Black Canyon Creek basin and DID-18 basin.

Two additional programs were developed to evaluate the demonstration project's effectiveness in improving the quality of irrigation return-flow waters. The first program was to be pursued by Washington State University (WSU) on individual farm sites where BMP changes were to be applied. The second program was to be pursued by the U.S. Geological Survey, Water Resources Division (WRD), on a broader, basinwide scope.

The Washington State University program was funded by SCS from February 1976 through September 1976 and was thereafter approved as a 3-year research project, jointly funded by the WSU Agricultural Research Center and the Office of Water Research and Technology (OWRT), U.S. Department of Interior. The WRD program was funded jointly by WRD and DOE.

## Purpose and Scope

The purpose of the study was to design, implement, and evaluate a sampling network for observing changes in irrigation-water quality that were expected to result from improvement of agricultural practices in the Sulphur Creek basin. The monitoring program was designed to evaluate basinwide as well as subbasin changes in irrigation-water quality, as opposed to changes in water quality at individual farm sites. The water-quality characteristics selected for evaluation were sediment and nutrient yields, discharges and concentrations, and water temperature.

At the end of the first year the data would be evaluated to determine if the monitoring network used for the first year--or an alternative monitoring scheme--could measure the water-quality changes likely to occur when agricultural practices were improved. The evaluation would require the estimation of two factors: (1) What magnitude of change in a water-quality characteristic could be detected? (2) What magnitude of change in the water-quality characteristics could be anticipated from the implementation of BMP's, and would this change be large enough to be detected by the monitoring?

If the results of the first year's data-evaluation effort indicated that the monitoring could detect changes in water quality of the magnitude likely to occur, then the monitoring would continue for several years. If the prospect of success seemed small, the monitoring project would end with submission of the evaluation.

The Water Resources Division would determine what magnitude of change in a water-quality characteristic could be detected. The Department of Ecology and the Technical Advisory Committee would make the management decision about what magnitude of change could be reasonably anticipated as a result of BMPs, and whether the monitoring program continued or not.

The Water Resources Division monitoring effort terminated after the evaluation of data at the end of the first year, and this report presents the results of the network evaluation and the water-quality conditions observed during the period April 1976 through March 1977. Work on Sulphur Creek Demonstration Project was continued by the SCS, however, and WSU continued its evaluations of water-quality improvements at individual farm sites.

## Location and Extent

The Sulphur Creek basin occupies an area of about 155 $mi^2$ in the Yakima River basin in south-central Washington (pl. 1). About 75 percent of the Sulphur Creek basin is in Yakima County and 25 percent is in Benton County. The basin is 14 miles long from the crest of the Rattlesnake Hills on the north to the Yakima River on the south, and almost uniformly 12 miles wide from east to west.

## Previous Investigations

During the irrigation season of 1974, $CH_2M$ Hill, a private consulting corporation, conducted a study of the management of irrigation return flows in the Yakima River valley, with emphasis on the Sulphur Creek basin. $CH_2M$ Hill, in the first phase of their study, collected water-quality data at several sites in the Sulphur Creek basin--data that were useful in the design of the monitoring network for this study. The data ($CH_2M$ Hill, 1975, p. 43) indicated that the greatest suspended-sediment concentrations (refered to as "solids" on table 1) came from Black Canyon Creek (DID-5 Drain) and DID-18 Drain. Total-nitrogen and total-phosphorous concentrations were also greater in those drains than in the other drains. Average concentrations determined by $CH_2M$ Hill are summarized for six sites in table 1.

Another study of suspended-sediment transport in irrigation return flow in the Yakima River basin was made by Nelson (1979) during the 1975 and 1976 irrigation seasons. That study included estimation of sediment discharges of the major drains and of the Yakima River in the area from Selah to Kiona. Three sampling points established during Nelson's study were also sampled in this study - Roza Canal at Wilgus Road (site 13), Sunnyside Canal at Grandview (site 18), and Sulphur Creek at Holladay Road near Sunnyside (site 8). (See plate 1.)

The U.S. Bureau of Reclamation (USBR), has collected water-quality data in the Yakima River basin for many years, including data for various drains and for Sulphur Creek Wasteway. The USBR data are on file at their project office in Yakima.

Washington State University conducted a program of monitoring the quality of irrigation return flows at specific farm sites as part of the Sulphur Creek pilot program. The WSU program began with the 1976 irrigation season (about April 1, 1976), and the data collected are on file at WSU's Department of Agricultural Engineering in Pullman.

The soils of the Sulphur Creek basin have been described by the SCS in soil surveys of Yakima and Benton Counties (U.S. Soil Conservation Service, 1970, 1971).

## Acknowledgments

This study was made in cooperation with the State of Washington Department of Ecology under the general direction of Marc Horton, DOE's project officer, and of the Technical Advisory Committee for Water Quality Improvement.

The cooperation and assistance of Hank Vancik, manager of the Roza Irrigation District, and Gary Weston, manager of the Sunnyside Irrigation District, are acknowledged; they provided permits to establish sampling sites and structures on irrigation district rights-of-way, and furnished highly important streamflow data from various wasteways, canals, and laterals. Dr. Larry King of the WSU Department of Agricultural Engineering provided precipitation data and helpful technical advice.

TABLE 1.--Average values of selected constituents and characteristics in major drains of Sulphur Creek basin, April 17 through October 24, 1974

[Data from $CH_2M$ Hill, 1975, p. 43]

| USGS site no. (pl. 1) | Station name | Water discharge ($ft^3/s$) | Water Tempera-ture (°C) | Total nitrogen as N (mg/L) | Total phosphorus as P (mg/L) | Suspended sediment (mg/L) | Turbidity (JTU) |
|---|---|---|---|---|---|---|---|
| [a]7 | DID 3 Drain | 52 | 14 | 2.85 | 0.70 | 260 | 79 |
| 3 | Washout Drain | 10 | 14 | 3.38 | .56 | 438 | 106 |
| 2 | DID 18 Drain | 18 | 14 | 3.60 | .70 | 589 | 106 |
| [b]5 | Black Canyon Creek | 23 | 13 | 3.41 | .64 | 498 | 122 |
| 6 | DID 9 Drain | 38 | 13 | 3.14 | .38 | 198 | 37 |
| 8 | Sulphur Creek Wasteway | 310 | 13 | 2.39 | .45 | 229 | 73 |

[a] USGS site is 0.6 mi above mouth. $CH_2M$ Hill site is near mouth.

[b] USGS site is 1.0 mi above mouth. $CH_2M$ Hill site is near mouth, and is listed as DID-5-1.

## DESCRIPTION OF THE BASIN

### Geologic and Topographic Setting

The Sulphur Creek basin is on the southern limb of the Rattlesnake Hills anticline, an east-west trending upwarp of the Miocene Columbia River Basalt Group. Snipes Mountain and Grandview Butte represent minor uplifts of basalt in the southern part of the basin. The basalt is at, or near, land surface in the deeper canyons and on the higher hilltops in the Rattlesnake Hills.

Altitudes in the Sulphur Creek basin range from 3,630 ft above the National Geodetic Vertical Datum (NGVD) of 1929 in the Rattlesnake Hills to about 630 ft at the confluence of Sulphur Creek with the Yakima River in the southwestern part of the basin. Grandview Butte rises to an altitude of 1,100 ft; Snipes Mountain rises to an altitude of 1,300 ft. Land slope in the basin is generally downward in a southwesterly direction, and the steeper slopes are in the headwater areas along the northeastern divide.

Land slope is an important factor in the erosional susceptibility of the soil — soils in steeper areas are much more susceptible to erosion. Land slopes are generally 2 to 5 percent in the irrigated areas between Roza and Sunnyside Canals, and decrease to 0 to 2 percent downhill from Sunnyside Canal, the lower of the two canals. Local slopes in the irrigated areas range from steep to flat. Table 2 includes a summary of generalized land slopes for irrigated areas in the Sulphur Creek basin and major subbasins.

### Soils

The soils in the Sulphur Creek basin are generally loams of variable depth, formed from windblown silt (fig. 1). In the extreme southwestern part of the basin, immediately south of Sunnyside, the soils are formed of fine, windblown sand and are underlain by deposits of moderately permeable sediments in old former lakebeds. Because all soils in the basin are composed of fine, windlaid materials, they are highly susceptible to erosion.

### Climate

The Sulphur Creek basin has an arid to semiarid climate. Annual precipitation averages 6.8 inches at Sunnyside and 15 inches in the higher elevations of the Rattlesnake Hills. (All climatic data are from the U.S. National Oceanic and Atmospheric Administration, 1976, 1977.) Most precipitation falls in the form of rain, but in the winter snowfall is common. Table 3 lists the long-term precipitation and temperature averages for the weather station at Sunnyside, along with the averages and totals for the study period April 1976 to March 1977. Precipitation during the study period was 40 percent of normal, and average temperature was 99 percent of normal.

TABLE 2.--Selected characteristics of Sulphur Creek basin and its major subbasins

[Data from $CH_2M$ Hill, 1975]

| Subbasins | Drainage area (DA) mi² | Drainage area (DA) acres | Irrigated croplands[1] acres[2] | Irrigated croplands[1] Percent of total DA | Orchards acres | Orchards percent of irrigated DA | Percent of irrigated DA in each land-slope category: 0-2 percent | 3-5 percent | 6-10 percent | greater than 10 percent |
|---|---|---|---|---|---|---|---|---|---|---|
| DID-3 and Washout Drain | 45.0 | 28,800 | 12,000 | 42 | 1,080 | 9 | 59 | 30 | 9 | 2 |
| DID-18 Drain | 14.7 | 9,410 | 3,930 | 42 | 455 | 12 | 10 | 83 | 7 | -- |
| Black Canyon Creek | 35.8 | 22,900 | 5,870 | 26 | 1,120 | 19 | 25 | 63 | 12 | -- |
| DID-9 Drain | 27.1 | 17,300 | 13,500 | 78 | 4,000 | 30 | 60 | 35 | 5 | -- |
| Other land | 32.4 | 20,700 | 6,000 | 29 | 465 | 8 | 56 | 44 | -- | -- |
| Sulphur Creek Basin | 155 | 99,200 | 41,500 | 42 | 7,120 | 17 | 49 | 43 | 7 | 1 |

[1]Figures represent only cropland, excluding land in other use, for the 1973 irrigation season.

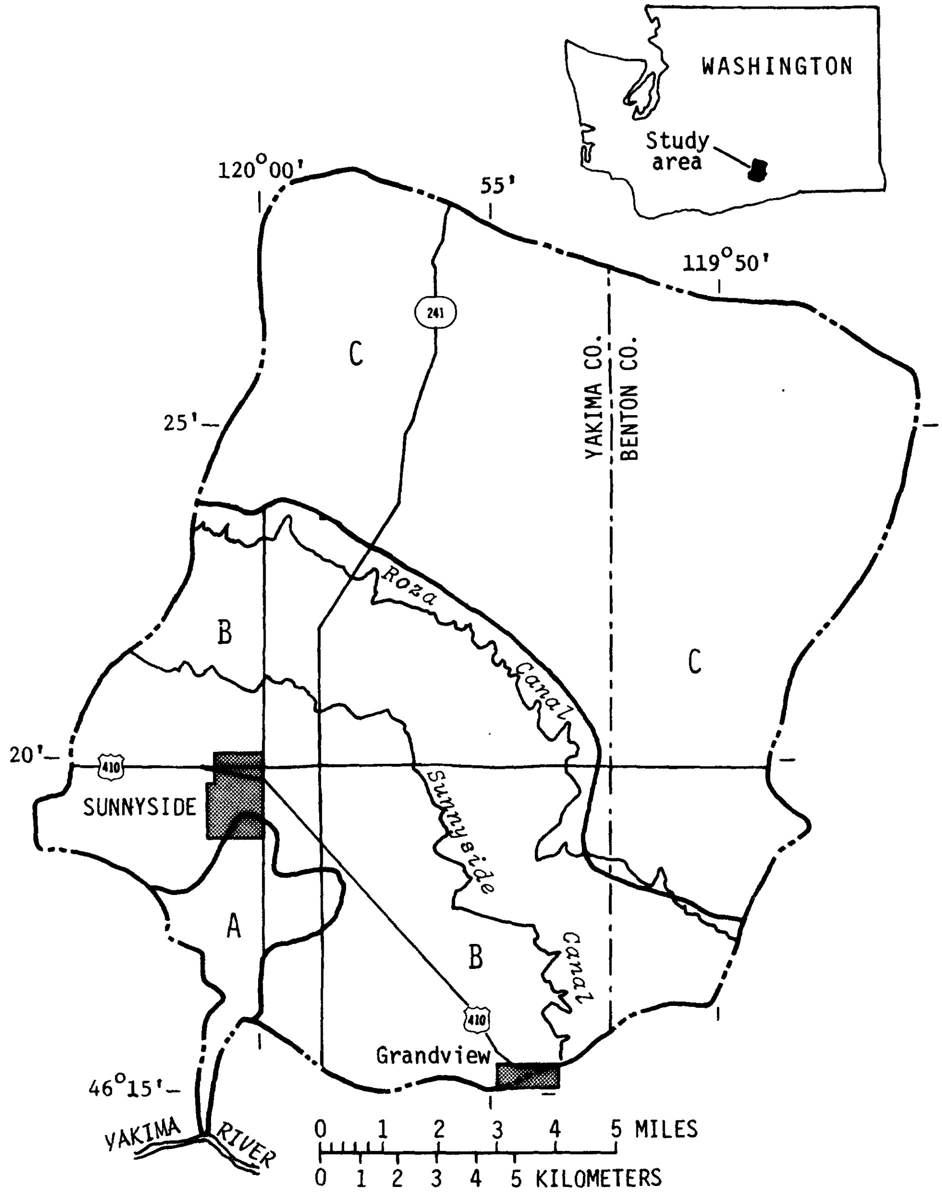
[2]Includes orchards.

TABLE 3.--Long-term average precipitation and temperature at Sunnyside, Wash., and averages and totals during the period April 1976 to March 1977

[U.S. National Oceanic and Atmospheric Administration, 1976, 1977)]

| | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Total for period |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Long-term aver. precip. (in.) | 0.49 | 0.56 | 0.68 | 0.19 | 0.24 | 0.34 | 0.67 | 0.85 | 0.86 | 0.93 | 0.61 | 0.39 | 6.81 |
| Study period precip. (in.) | .60 | .05 | Tr | .19 | .65 | .05 | .05 | Tr | .10 | .08 | .64 | .34 | 2.75 |
| Long-term aver. temp. (°F) | 51.9 | 60.0 | 66.5 | 72.0 | 70.0 | 63.2 | 52.0 | 40.6 | 33.8 | 30.5 | 37.9 | 44.0 | 51.9 |
| Study period aver. temp. (°F) | 50.7 | 59.9 | 62.9 | 70.5 | 68.2 | 65.7 | 51.7 | 42.0 | 30.3 | 25.8 | 40.7 | 45.1 | 51.2 |

(Tr = trace)




EXPLANATION

A Deep soils formed in fine windlaid sand

B Deep soils formed in windlaid silt

C Shallow soils formed in windlaid silt

Source: U.S. Soil Conservation Service 1970, 1971

FIGURE 1.--Generalized soil types in the Sulphur Creek basin.

Wind is an important erosion factor in the Sulphur Creek basin. Observations of dry canals during the non-irrigation seasons indicated that significant amounts of windblown sediment were trapped in the canals; sediment drifts as deep as 1 foot were common.

## Land Use

Land use in the basin is predominantly agricultural, and most of the rural population is dispersed in farmsteads situated below Roza and Sunnyside Canals, the principal sources of the irrigation water used extensively to sustain crops during the growing season. Except for some land irrigated by pump-supplied laterals uphill from Roza Canal, the basin uphill from the canal is primarily grazing land.

The major population centers are at Sunnyside and Grandview (pl. 1). Sunnyside had a 1977 population of about 6,700 and Grandview about 4,300.

A wide range of crops is grown in the basin. Seventeen percent of the irrigated land is planted with orchards, and the rest mostly annual crops. Table 2 lists the percentages of cropland and the total number of acres irrigated in the basin during 1973. According to $CH_2M$ Hill (1975), there were 48,765 acres in the irrigated part of the basin (outlined in pl. 1); however, 7,270 acres of this land were not in crops, but include fallow, urban, and industrial land and roadways. Some of the fallow land was occupied by mint stills and by dairies and feedlots that accommodate several thousand head of cattle. Total acreage of dryland (nonirrigated) crops grown in the basin was not determined for this report.

## Streams, Canals, and Drains

Many streams in the Sulphur Creek basin were formerly ephemeral, but are now perennial due to augmentation from irrigation waste water and seepage of ground water that, in turn, has been increased by seepage from canals, laterals, and irrigated areas. Photographs in figure 2 show some typical drains in the Sulphur Creek basin.

The basin has many points of outflow and inflow. There are several minor canals that flow into or out of the basin, or both. The major canals, Roza and Sunnyside, flow across the basin and furnish the surface water to the basin. Figure 3, an extrapolation from plate 1, is a schematic of the major (and most minor) inflows and outflows in the Sulphur Creek basin.

Diversions from the Yakima River provide almost all the irrigation water in the Sulphur Creek basin. Water delivered to the Sulphur Creek basin by Roza Canal is diverted at Roza Dam on the Yakima River, 54 canal miles upstream from the basin. Water in Sunnyside Canal is diverted at Sunnyside Dam on the Yakima River, 33 canal miles upstream from the basin. Distances are measured from points of diversion on the Yakima River to the west boundary of Sulphur Creek basin.

WASHOUT DRAIN AT SUNNYSIDE

DID-18 DRAIN DISCHARGING
INTO SULPHUR CREEK WASTEWAY

SULPHUR CREEK WASTEWAY AT HOLLADAY ROAD

FIGURE 2.--Typical drains in the Sulphur Creek basin.

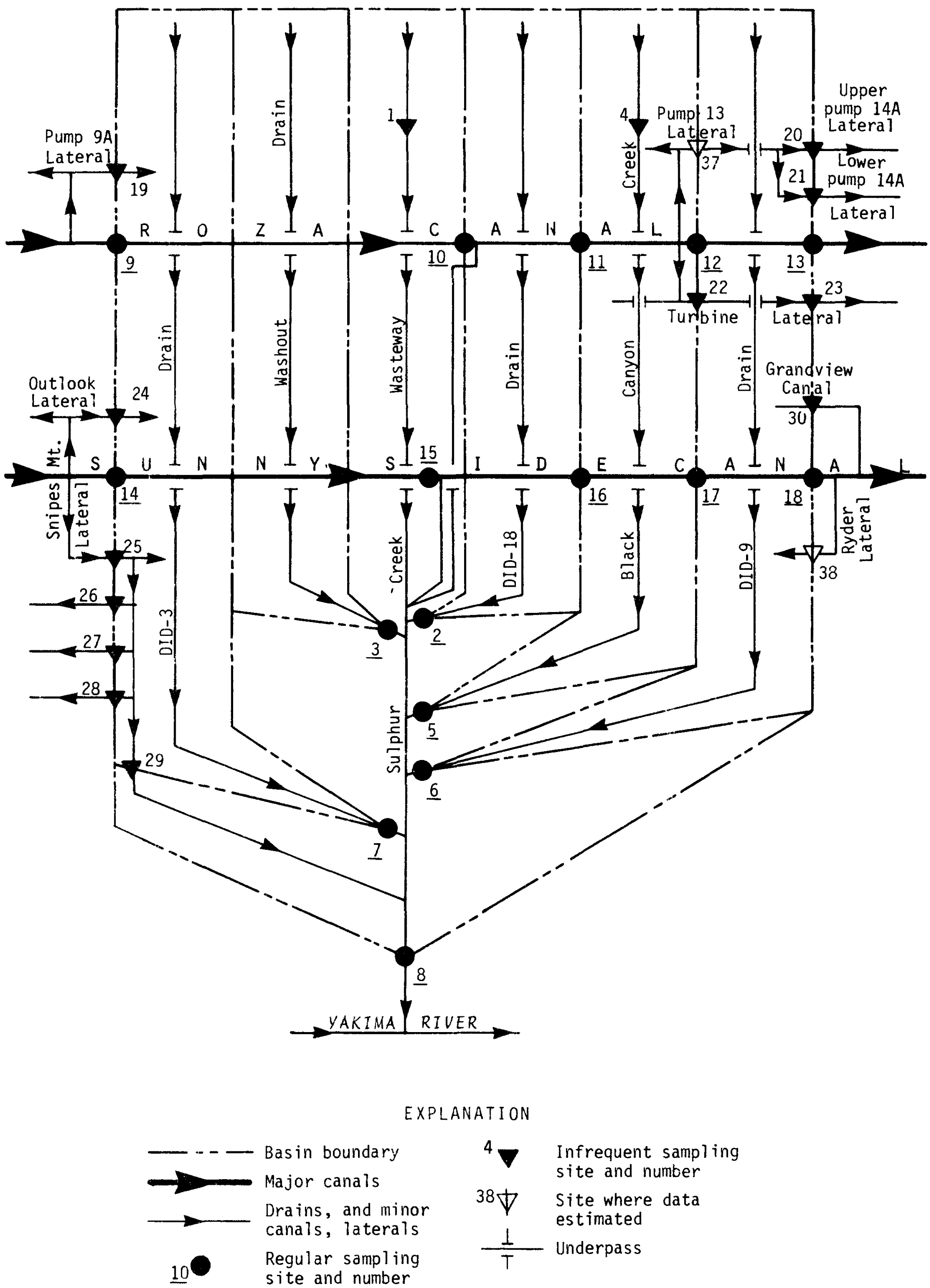



FIGURE 3.--Irrigation-water system in the Sulphur Creek basin showing sampling sites.

Few data are available for natural surface-water runoff in the basin, but some have been obtained by the WRD at a crest-stage gage site (site 39) that records peak flows on a tributary to Washout Drain (pl. 1). The drainage area above this site is 1.91 $mi^2$. During the period of record, 1954-73, maximum recorded peak flow was 264 $ft^3/s$ (138 $ft^3/s/mi^2$), in 1954. According to Cummans, Collings, and Nassar (1975, p. 31), a discharge of that magnitude would have a recurrence interval of about 50 years. During the years 1955, 1958-60, 1964, and 1966-68, there was no flow indicated at this site. The area above the crest gage is composed of nonirrigated cropland and natural rangeland, and the peak runoff at this gage is, therefore, generally indicative of what might be expected from nonirrigated lands.

## THE STUDY APPROACH

A water-quality-monitoring network was established, with stations at the major surface-water inflow and outflow points of Sulphur Creek basin (see pl. 1 and fig. 3), so that both net constituent outflows and yields could be calculated. For this study, it was not necessary to do a detailed water budget accounting; it was sufficient to know water inflow and outflow by surface-water conveyances and the concentrations of constituent these waters carry. From this, the deposition or removal of a constituent from a basin by surface-water conveyances can be calculated according to the mass-balance equation,

$$S = L_{out} - L_{in} , \qquad (1)$$

where S is change in constituent storage in the basin and will hereafter be called net inflow if S is negative and net outflow if S is positive; $L_{out}$ is the sum of all constituent outflows from the basin; and $L_{in}$ is the sum of all constituent inflows to the basin.

Black Canyon Creek and DID-18 subbasins would receive the major thrust of the demonstration project efforts. The other subbasins would be control basins. The meaning and value of control basins is briefly explained below.

If the water-quality-monitoring network is sensitive enough for the purpose intended, then changes produced as a result of modified farming practices in the demonstration-project test basins will be reliably detected. Unfortunately, changes might be the result of other factors besides the demonstration- project efforts. Variations in climatic conditions, such as unusually frequent rainstorms, drought, extended hot or cold periods, and many other factors, might conceivably produce changes as large as or larger than those produced by the demonstration project. Using control basins is one option for detecting the effects of uncontrollable variables. The basic assumption is that if a control basin is sufficiently similar to a test basin, and if both basins are acted upon by the same general factors, then both basins will produce nearly the same response. Hence, changes that occur in both the control basins and the test basins should not be attributed to the effects of the demonstration project.

The network as designed included a total of 42 stations, of which 35 were water-quality stations, 6 were rain-gage stations, and 1 was a crest-stage gage station for determining peak floodflows. Plate 1 shows station locations, station names, identification numbers, latitude-longitude locations, and methods of obtaining streamflow at each water-quality station. At 10 stations on the two major canals (Roza and Sunnyside) and at 6 stations on the major drains, water samples were obtained twice weekly to measure total or suspended-sediment concentration, temperature, specific conductance, and turbidity, and twice monthly to measure total phosphorus, total nitrogen, and total nitrate-plus-nitrite. At 12 other sites, water samples were obtained at random frequency to determine the same constituents and characteristics, and at five other sites concentrations and constituent discharges were estimated. To evaluate sediment production from the dryland part of the basin, two additional sites were established, one on the main stem of Sulphur Creek and one on the main stem of Black Canyon Creek.

For this study, it was necessary to know total concentration and discharge of constituents; that is, to know both the suspended portion and the portion moving along the streambed. However, total discharges and concentrations could not be measured (except by expensive and time-consuming means) at some stations because the suspended-sediment samplers used in this project sample to only 3 to 5 inches above a streambed, except at drop structures such as wiers or culvert outflows where the body of the sampler can be lowered sufficiently to allow the nozzle to reach bottom. The two situations are illustrated in figure 4.

Whenever possible, stations were placed where both total concentrations and discharges of constituents could be measured. For those stations where only the suspended portion could be measured, an estimated quantity was added to the suspended portion to provide an estimated total concentration and discharge. Estimation procedures are described in the section Unmeasured Sediment Discharge, page 49.

Total constituent concentrations could be measured in samples collected at DID-18, DID-9, and DID-3 Drains because the samples were collected at road culverts. Samples collected at Black Canyon Creek, Washout Drain, and Sulphur Creek Wasteway were taken in turbulent riffles over a cobble-and-boulder bottom and closely approximated total concentrations there. Samples collected from the major canals contained suspended concentrations only.

Samples from the minor canals and laterals were generally collected at drop structures or where constrictions caused turbulent flow. At stations where there was an unmeasured zone, either it was too small to affect the mass-balance calculations, or the unmeasured concentration was estimated for the site.

The sampling frequencies selected were the estimated minimum frequencies needed to adequately describe temporal variations in constituent concentrations and discharges. Intensive sampling was carried out during two 48-hour periods, in June and August 1976, to estimate the daily variability of constituent discharges and to provide a better basis for establishing sampling frequencies in future networks.

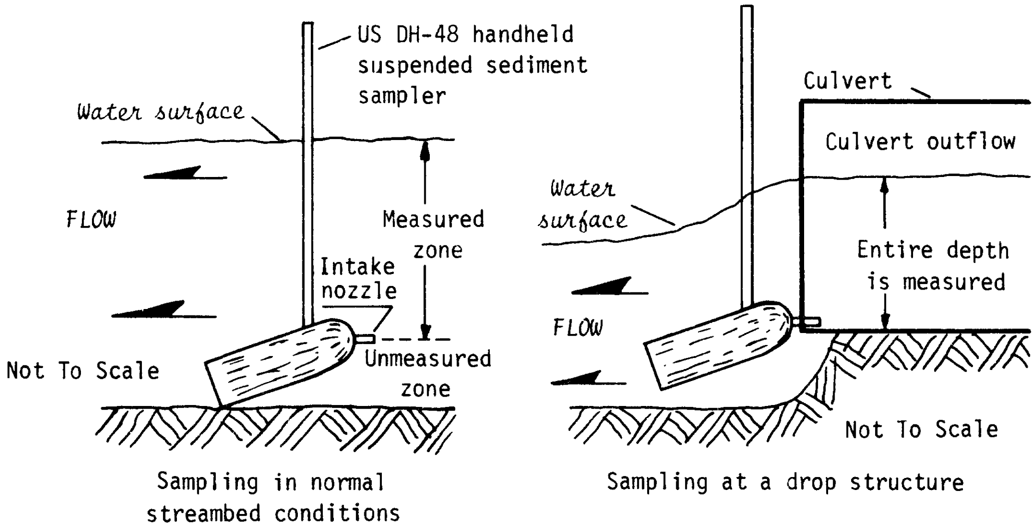



FIGURE 4.--Suspended-sediment sampler measurements in a stream and at a culvert outflow.

## METHODS OF COMPUTING CONSTITUENT DISCHARGES AND MEAN CONCENTRATIONS

Five methods of obtaining the total discharges and mean concentrations of constituents from periodic data were examined, because no single method is presently accepted as best for all situations, and because it was not initially known which method might be best for this study. The methods were:

1) Sediment-transport, flow-duration curve
2) Time-weighted averaging
3) Discharge-weighted averaging
4) Harmonic analysis
5) Fourth-degree-polynomial analysis

The results of all five methods were comparable within 0 to 5 percent at the several sites for which they were all examined. Methods 3, 4, and 5 are discussed in this report because their results were used in the network evaluation. The discharge-weighted averaging method was used for this report because of simplicity of application, and it is the basis for all concentration and discharge values in the main text of the report. Harmonic analysis was used to determine median monthly and mean irrigation-season water temperatures in the major canals and drains, and both harmonic analysis and polynomial analysis were used to provide comparative data and to demonstrate that the data fit annually repetitive theoretical time distributions, all of which are explained in the following subsections.

### Discharge-Weighted Averaging

The mean constituent concentration is calculated by using the equation:

$$\bar{C} = \frac{\sum_{i=1}^{i=N} C_i Q_i}{\sum_{i=1}^{i=N} Q_i}, \qquad (2)$$

where $\bar{C}$ is the discharge-weighted mean concentration; $C_i$ is the observed instantaneous concentration on sampling day i; $Q_i$ is the observed instantaneous streamflow at the time of sampling on day i; and N is the last sampling day during the period of interest.

The quantity of a constituent discharged during the period of interest is calculated using the equation:

$$L = \bar{C}Q_t(0.0027) \qquad (3)$$

where $Q_t$ is total volume of flow during the period, in cubic feet per second-days, and 0.0027 is a unit conversion factor.

## Harmonic Analysis

The methods for computing discharges and mean concentrations by harmonic analysis and fourth-degree-polynomial analysis are explained in this section because the results obtained by these two methods are compared with results obtained by the discharge-weighted averaging method in the section Two Mathematical Approximation Methods of Data Analysis, beginning on page 51. The potential usefulness of these alternative methods of data analysis is also discussed in that section. Both of these methods are regression techniques of fitting theoretical time distributions to the data, and both assume that the data follow some pattern of variation in time, as the data from this study appear to do.

The harmonic analysis used to determine mean constituent concentrations and discharges is an adaptation of the method developed by Ward (1963) and refined by Collings (1969) and Steele (1974) for analyzing stream-temperature data. The temporal variations of constituent concentrations, constituent discharges, and water temperature are described by the equations,

$$C_x = A \cdot \sin(Bx+\emptyset) + M_C \qquad (4)$$
$$L_x = A \cdot \sin(Bx+\emptyset) + M_L \qquad (5)$$
and $$T_x = A \cdot \sin(Bx+\emptyset) + M_t \qquad (6)$$

where $C_x$ is the computed daily mean concentration on day x;

$L_x$ is the computed daily mean constituent discharge on day x;

$T_x$ is the computed daily mean water temperature on day x;

A is the amplitude, or one-half the computed variation for the period;

B is a constant (0.0172 radian/day) used to convert the day of the year to an angle, in radians. The constant derives from the expression $2\pi \div 365$ or 366;

x is the number of days, starting with the first day of the calendar year (January 1), inclusive;

$\emptyset$ is phase angle, in radians; and

$M_C$ is the computed mean concentration for a period of 365 or 366 days;

$M_L$ is the computed mean daily constituent discharge for a period of 365 or 366 days; and

$M_t$ is the computed mean water temperature for a period of 365 or 366 days.

For any time period less than a year, such as the 204-day irrigation season of 1976, the mean concentration, total constituent discharge, and mean temperature for the period are obtained by use of the equations,

$$\bar{C} = \sum_{x=n}^{x=m} C_x \div (m-n+1) \tag{7}$$

$$L_T = \sum_{x=n}^{x=m} L_x \tag{8}$$

$$\bar{T} = \sum_{x=n}^{x=m} T_x \div (m-n+1) \tag{9}$$

where $\bar{C}$ = the mean concentration for the period of interest;

$L_T$ = the total constituent discharge for the period of interest;

$\bar{T}$ = the mean temperature for the period of interest;

n = number of days — January 1 to the beginning day of the period of interest (inclusive); and

m = number of days — January 1 to the last day of the period of interest (inclusive).

## Fourth-Degree-Polynomial Analysis

Fourth-degree-polynomial analysis was also performed to describe the temporal variation of the data by an equation of the generalized form,

$$L_x \text{ or } C_x = c + ex + fx^2 + gx^3 + hx^4 \qquad (10)$$

where c, e, f, g, and h are regression coefficients. Constituent discharge for the period is obtained by integration according to the equation

$$L = \int_n^m (c+ex+fx^2+gx^3+hx^4)dx = \left[ cx+\frac{ex^2}{2}+\frac{fx^3}{3}+\frac{gx^4}{4}+\frac{hx^5}{5} \right]_n^m$$

Mean concentration ($M_c$) is calculated similarly, but the integral is divided by m-n+1 (total number of days in the period of interest) to obtain the mean for that period.

## Confidence Limits

To ascertain the amount of change that must take place to be detected, the confidence limits of the computed constituent concentrations and discharges must be determined.

The estimated confidence limits for the values obtained from the discharge-weighted-averaging computations were arrived at by calculating the daily variability in the constituent discharges and combining that with other sources of uncertainty--such as sampling error, laboratory error, water discharge error--using principles of propagation of uncertainty (Baird, 1962), into a single estimated confidence limit for the data.

The estimated confidence limits of constituent yields and net outflows from a basin were obtained using standard statistical methods for determining the uncertainty of sums and differences (Arkin and Colton, 1970).

Confidence limits for values obtained from the two theoretical time-distribution equations were calculated from the standard error of estimate. The standard error of estimate is a measure of the departure of the observed values from computed values obtained by a particular equation, and is thus indicative of the uncertainty of the equation. The confidence limits are statistically reliable.

## IRRIGATION-WATER QUALITY

In this section, the constituent concentrations and discharges and the water discharges of the canals and drains are discussed from two perspectives, (1) concentrations and discharges at a single point on the canal or drain; that is, at the station; and (2) changes in concentrations and discharges between stations, and the addition of constituents to the basin or subbasin by individual canals or drains. Because the net outflow and yield of the basin or a subbasin (as opposed to outflow of an individual drain or canal) is the sum of several net inflows and outflows, basin and subbasin yields and net outflows will be discussed in the section Net Constituent Outflows and Yields, pages 40-42.

### Roza Canal

#### Water Discharge

The 1976 irrigation-season water discharge past five sites on Roza and Sunnyside Canals as they traverse the Sulphur Creek basin is given in table 4. Hydrographs showing the flow in Roza Canal at site 10 and in Sunnyside Canal at site 15 are presented in figure 5. These hydrographs are also representative of the flow at the other sites on the canals, and in fact the hydrographs were used, along with miscellaneous discharge measurements, to determine seasonal flow at the other eight sites.

Roza Canal delivered about 110,000 (221,000 acre-ft at Scoon Road, site 9 minus 111,000 acre-ft at Wilgus Road, site 13) acre-ft of water to the Sulphur Creek basin during the 1976 irrigation season. Of this, about 13,000 acre-ft was unused and was discharged to Roza Canal Wasteway and into Sulphur Creek Wasteway.

#### Constituent Concentrations and Discharges

Because Roza Canal is at a higher elevation than Sunnyside Canal, it receives less irrigation return flow, and, as may be expected, average nutrient and suspended-sediment concentrations are lower than in the Sunnyside Canal. However, Roza Canal plays an important role in the suspended-sediment and nutrient discharges in the Sulphur Creek basin. Although concentrations in general are low, the large water discharge of Roza Canal results in a nutrient input to the basin from the canal that is nearly as large as output from the basin by some of the irrigation return-flow drains. For example, during the 1976 irrigation season the input to the basin from Roza Canal of nitrate-plus-nitrite, total nitrogen, and total phosphorus was about 19, 42, and 7 tons, respectively, as compared with output from the basin of 15, 26, and 3.7 tons, respectively, by Washout Drain, and 34, 51, and 9.9 tons, respectively, by DID-18 drain.

TABLE 4.--Water discharge in Roza and Sunnyside Canals in the Sulphur Creek basin during the 1976 irrigation season

| Site no. (pl. 1) | Station name | Water discharge (acre-ft) |
|---|---|---|
| | Roza Canal | |
| 9 | At Scoon Rd | 221,000 ± 22,000 |
| 10* | Below Sulphur Cr | 182,000 ± 9,000 |
| 11 | At Black Canyon Cr | 162,000 ± 16,000 |
| 12 | At Factory Rd | 139,000 ± 14,000 |
| 13 | At Wilgus Rd | 111,000 ± 11,000 |
| | Sunnyside Canal | |
| 14 | At Maple Grove Rd | 299,000 ± 30,000 |
| 15* | Below Sulphur Cr | 256,000 ± 13,000 |
| 16 | At Edison Rd | 249,000 ± 25,000 |
| 17 | At Bethany Rd | 231,000 ± 23,000 |
| 18 | At Grandview | 212,000 ± 21,000 |

* Site for which daily flows were computed and used to estimate the flows at the other sites on the same canal.

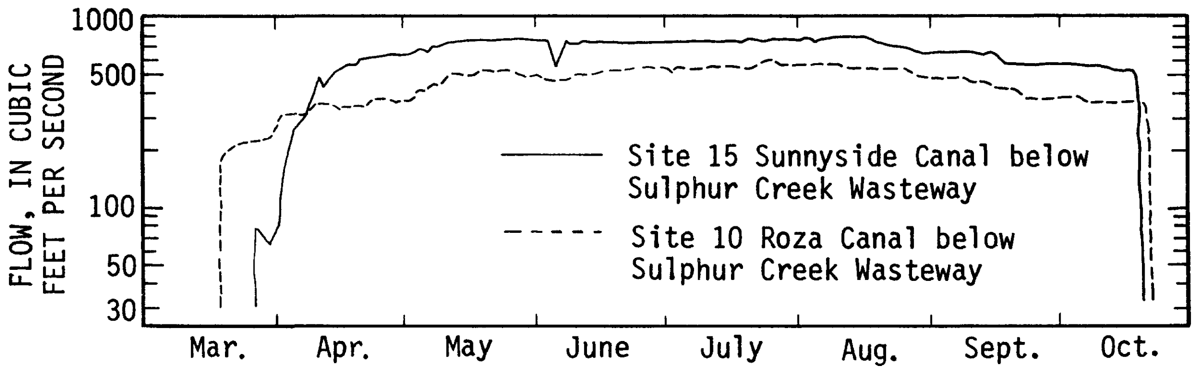



FIGURE 5.--Daily mean flow at selected sites on Roza and Sunnyside Canals for the 1976 irrigation season.

Figure 6 illustrates the variation in mean concentrations and discharges of the constituents past the five monitoring sites on Roza Canal. Table 5 includes the seasonal discharge-weighted mean concentrations and discharges of each constituent at each site on both Roza and Sunnyside Canals. Nutrient concentrations changed only slightly, but nutrient discharges all decreased considerably in a downstream direction.

Nitrate-plus-nitrite discharges decreased faster than can be accounted for by water diversions. This decrease may be attributable in part to the assimilation of nitrate and nitrite by rooted aquatic plants along the canal. Nitrate-plus-nitrite averaged about 25 percent of the total nitrogen, and that proportion remained constant from site to site.

Suspended-sediment concentration generally increased in a downstream direction, due in part to sediment-laden return flow and in part to the canal's diversion gates, which may have excluded some sand particles from the laterals and left the sand in the main canal to be deposited or transported as total-sediment discharge. Estimated total-sediment discharge increased by 7,000 tons between Scoon Road (site 9) and Factory Road (site 12) and decreased by 4,000 tons between Factory Road and Wilgus Road (site 13), for a net estimated increase of about 3,000 tons in the entire reach in Sulphur Creek basin. The decrease between the two lower-most sites may be attributable to diversions, or also in part to channel deposition.

## Sunnyside Canal

### Water Discharge

The seasonal water discharge past five sites on Sunnyside Canal, which may be compared with that of the Roza Canal, is given in table 4 and figure 5. Sunnyside Canal delivered about 110,000 acre-ft of water to the Sulphur Creek basin during the 1976 irrigation season, or about the same quantity as that delivered by Roza Canal. The figures cited for Sunnyside Canal include about 24,000 acre-ft of water delivered to the basin by Ryder Lateral. This lateral diverts water from Sunnyside Canal downstream of and outside of the basin and returns it to the basin. About 28,000 acre-ft of water in Sunnyside Canal was passed unused down Sunnyside Canal Wasteway and into Sulphur Creek Wasteway. Both this 28,000 acre-ft and the 13,000 acre-ft passed by Roza Canal Wasteway diluted the irrigation return flows to Sulphur Creek Wasteway. Comparing the actual irrigation deliveries of the two canals after subtracting water lost to the canal wasteways, Roza Canal delivered about 97,000 acre-ft and Sunnyside Canal about 82,000 acre-ft.

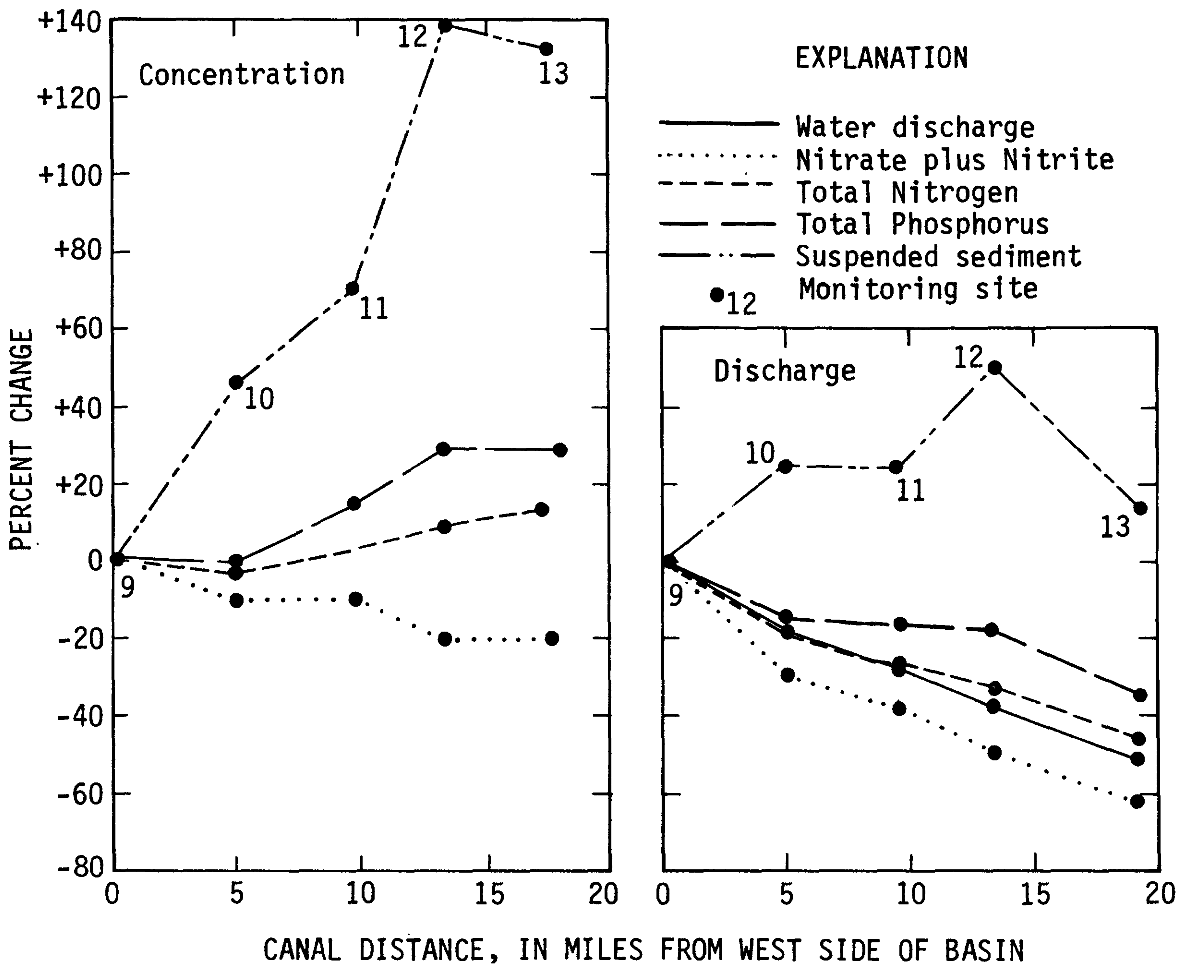



FIGURE 6.--Changes in constituent concentrations and discharges in Roza Canal, in the Sulphur Creek basin.

TABLE 5.--Constituent discharges and concentrations in Roza and Sunnyside Canals in Sulphur Creek basin during the 1976 irrigation season

| Site no. (pl. 1) | Location | Nitrate-plus-nitrite (as N) | | Total nitrogen (as N) | | Total phosphorus (as P) | | Suspended sediment* | |
|---|---|---|---|---|---|---|---|---|---|
| | | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) |
| | Roza Canal | | | | | | | | |
| 9 | At Scoon Road | 0.10 | 31 | 0.34 | 100 | 0.07 | 21 | 37 | 11,000 |
| 10 | Below Sulphur Creek | .09 | 22 | .33 | 82 | .07 | 18 | 55 | 14,000 |
| 11 | At Black Canyon Road | .09 | 19 | .35 | 77 | .08 | 18 | 63 | 14,000 |
| 12 | At Factory Road | .08 | 16 | .37 | 71 | .09 | 17 | 88 | 17,000 |
| 13 | At Wilgus Road | .08 | 12 | .39 | 58 | .09 | 14 | 86 | 13,000 |
| | Sunnyside Canal | | | | | | | | |
| 14 | At Maple Grove Road | .11 | 46 | .41 | 170 | .13 | 52 | 120 | 48,000 |
| 15 | Below Sulphur Creek | .17 | 58 | .48 | 170 | .14 | 50 | 140 | 48,000 |
| 16 | At Edison Road | .15 | 51 | .51 | 170 | .16 | 53 | 180 | 61,000 |
| 17 | At Bethany Road | .16 | 51 | .54 | 170 | .16 | 50 | 180 | 57,000 |
| 18 | At Grandview | .19 | 55 | .57 | 160 | .18 | 51 | 210 | 62,000 |

*Suspended sediment is less than total sediment as explained on pages 14,49.

## Constituent Concentrations and Discharges

Although Sunnyside Canal delivered slightly less water to the Sulphur Creek basin than did the Roza Canal, on the average, water discharges were greater in Sunnyside Canal than in Roza Canal. Also, because it is below the irrigated land served by Roza Canal, Sunnyside Canal received irrigation return flows that had greater concentrations of nutrient and sediment.

Concentrations of various constituents in Sunnyside Canal all generally increased in the downstream direction. Constituent discharges, except total nitrogen at the lowermost site and total phosphorus in general, increased similarly. Nitrate-plus-nitrite concentrations of the water entering the basin via Sunnyside Canal averaged about the same as those for water entering via Roza Canal; however, in the water leaving the basin, nitrate-plus-nitrite concentrations in Sunnyside Canal were nearly 2½ times greater than in Roza Canal. Nitrate-plus-nitrite represents about 30 percent of the total nitrogen in Sunnyside Canal, and the proportion is not significantly different from site to site. The larger proportion of total nitrogen as nitrate-plus-nitrite in Sunnyside Canal is probably attributable to subsurface tile drains, which add water to Sunnyside Canal. Subsurface drains have characteristically higher nitrate-plus-nitrite concentrations than surficial drains. As will be discussed more fully in the section Major Drains, page 28, the trend of increasing nitrate-plus-nitrite concentration as water passes through the basin is even more noticeable in the surface drains than in the canals; nitrate-plus-nitrite concentrations averaged about 60 to 70 percent of the total nitrogen in the drains. Like Roza Canal, Sunnyside Canal discharged more sediment out of the basin than it delivered to the basin. Phosphorus discharges in Sunnyside Canal remained fairly constant from site to site. For comparison, approximate net irrigation-season outflows from the basin via Sunnyside Canal and Roza Canal were as follows:

| | Net change in constituents (tons) | | | |
|---|---|---|---|---|
| | Sunnyside Canal | | Roza Canal | |
| | Inflow | Outflow | Inflow | Outflow |
| Nitrate-plus-nitrite (as N) | | 9 | 19 | |
| Total nitrogen (as N) | 10 | | 42 | |
| Total phosphorus (as P) | 1 | | 7 | |
| Total sediment | | 18,000 | | 3,000 |

The net sediment outflow from the basin by way of Sunnyside Canal was greater than the sediment discharge of any of the drains except Sulphur Creek Wasteway. Total sediment is all the sediment transported in the stream, whereas suspended sediment is only that measured by the samples used in this project. For further explanation the reader is referred to page 49.

Figure 7 illustrates the variation in concentrations and discharges of the four constituents past the five monitoring sites on Sunnyside Canal, and table 5 gives the seasonal discharge-weighted mean concentrations and seasonal discharges of each constituent at each site.

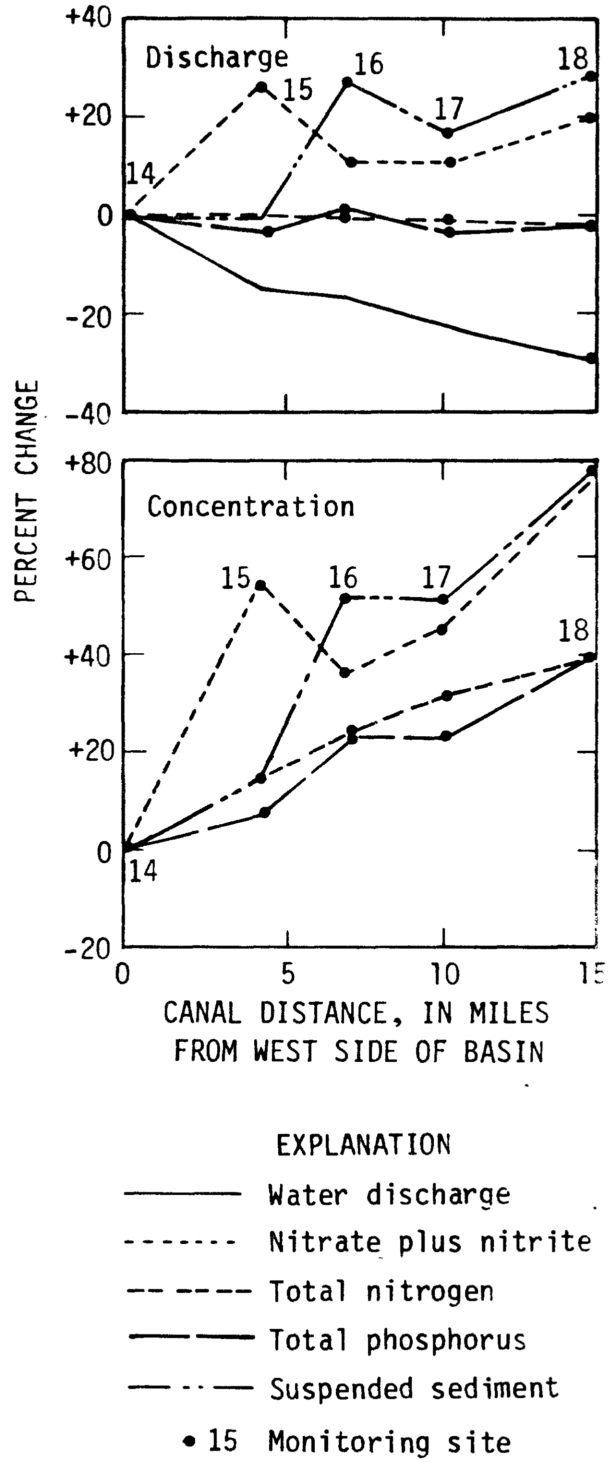



FIGURE 7.--Changes in constituent concentrations and discharges in Sunnyside Canal, in the Sulphur Creek basin.

## Major Drains

### Water Discharge

Water discharges from the five major drains and Sulphur Creek Wasteway (plate 1, fig. 3) are given in table 6. Hydrographs showing discharges at each of the indicated sites are presented in figure 8. There is a greater day-to-day variation in flow in the drains than in the canals. Between October 20 and 25 there was a marked decrease in flow in each drain, corresponding to the end of the irrigation season and the closing of the canals.

Flow in the five major drains above Sulphur Creek Wasteway totaled about 52,000 acre-ft during the 1976 irrigation season, and flow in Sulphur Creek Wasteway totaled 121,900 acre-ft -- about 230 percent of the sum of the flow in the five major drains. About 41,000 acre-ft of the excess in Sulphur Creek Wasteway is accounted for as spillage from the wasteways of Roza and Sunnyside Canals. The remaining 29,000 acre-ft is attributable to return flow from other lands in Sulphur Creek basin, exclusive of the five subbasins monitored, and to ground-water seepage directly entering Sulphur Creek Wasteway.

During the nonirrigation season when the canals were dry, about 18,200 acre-ft of water flowed from the five major drains above Sulphur Creek Wasteway, and 24,400 acre-ft flowed in Sulphur Creek Wasteway. The 6,200 acre-ft difference comes from return flow from land outside the five subbasins monitored and from ground-water seepage, which flows directly into Sulphur Creek Wasteway.

The average daily flows past four of the six sites during the 1976 irrigation season were nearly the same as those reported for 1974 by $CH_2M$ Hill (1975). Comparative flows in the DID-3 and DID-9 drains were quite different, but it is uncertain whether the differences are real or reflect differences in data-acquisition and computational methods. The comparisons are listed below:

| | | Average daily water discharge, $ft^3/s$ | |
|---|---|---|---|
| Site | Drain | 1974 irrigation season ($CH_2M$ Hill, 1975) | 1976 irrigation season |
| 7 | DID-3 Drain | 52 | 34 |
| 3 | Washout Drain | 10 | 11 |
| 2 | DID-18 Drain | 18 | 17 |
| 5 | Black Canyon Creek | 23 | 23 |
| 6 | DID-9 Drain | 38 | 45 |
| 8 | Sulphur Creek Wasteway | 310 | 303 |

Little or no flow occurred at sites 1, 4, and 39 (see pl. 1), which were established to monitor flows from the dryland-farming portion of the basin.

TABLE 6.--Water discharge from the major drains in Sulphur Creek basin during the 1976 irrigation and the 1976-77 nonirrigation seasons

| Site | Drain | Water discharge (acre-ft) | |
|---|---|---|---|
| | | Irrigation season | Nonirrigation season |
| 7 | DID-3 | 13,500 ± 680 | 5,190 ± 300 |
| 3 | Washout | 4,600 ± 500 | 750 ± 80 |
| 2 | DID-18 | 7,040 ± 350 | 2,130 ± 110 |
| 5 | Black Canyon Creek | 9,240 ± 460 | 3,070 ± 150 |
| 6 | DID-9 | 18,100 ± 900 | 7,060 ± 350 |
| 8 | Sulphur Creek Wasteway | 121,900 ± 6,100 | 24,400 ± 1,200 |

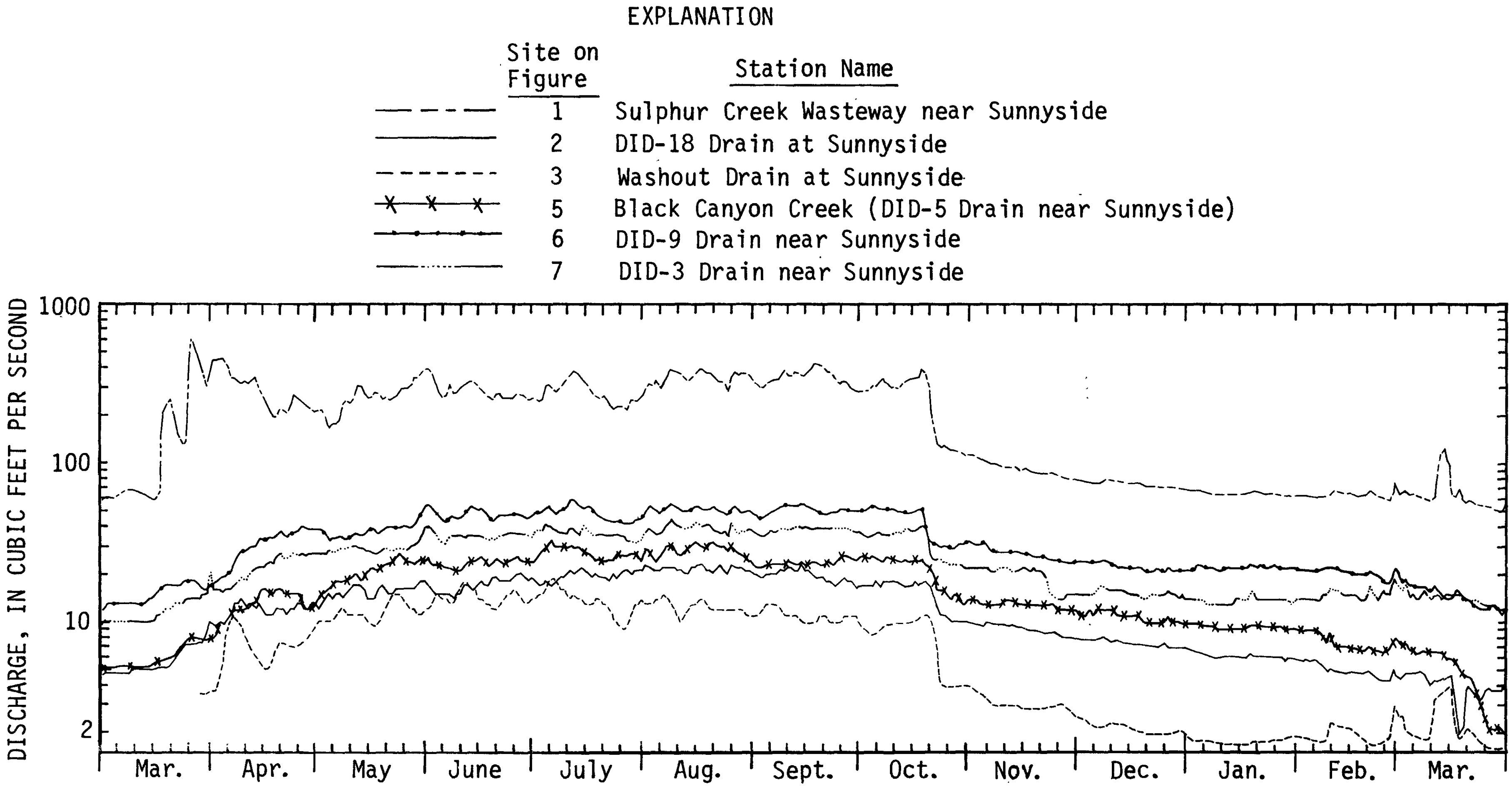



FIGURE 8.--Daily mean water discharges from the major drains in the Sulphur Creek basin, for the period March 1976 through March 1977.

## Constituent Concentrations and Discharges

To avoid confusion, it is worthwhile to state again the nature of this section of the report. The following discussion is concerned with constituent concentrations and discharges passing specific sites near the mouths of the major drains. The concentrations and discharges are not representative of the net outflow or yield of the subbasin or basin from which a drain flows, because inflow and outflow from the major and minor canals and minor drains must also be considered when obtaining net outflows and yield. Net outflows and yields of the subbasins and of Sulphur Creek basin will be discussed in the section Net Constituent Outflows and Yields, page 40.

Figures 9 and 10 illustrate the differences between constituent concentrations and discharges of the major drains. Average suspended-sediment concentrations in all major drains were greater during the 1976 irrigation season than during the 1976-77 nonirrigation season. Phosphorus concentrations also were greater during the irrigation season, except in DID-3 Drain, where the average nonirrigation-season concentrations slightly exceeded irrigation-season concentrations. In all major basins, nitrate-plus-nitrite and total-nitrogen concentrations were greater in the nonirrigation season, and discharges were greater in the irrigation season. Table 7 gives the seasonal mean concentrations and discharges of each constituent at each site. Constituent concentration generally ranged from 5 to 20 times greater in the drains than in the canals. However, constituent discharges in the drains were not greatly different from those in the canals because of lesser flows in the canals.

Nitrate-plus-nitrite was a considerably greater fraction of the total nitrogen in the drains than in the canals, and in the nonirrigation season than in the irrigation season (table 8). Fretwell (1979) found similar nitrogen distribution shifts between canals (or supply streams) and drains in the Toppenish, Satus, and Ahtanum Creek basins, which are also irrigated subbasins draining to the Yakima River (west of the area shown on pl. 1). Nutrient concentrations were generally greater in the Sulphur Creek basin than in nearby irrigated subbasins draining to the Yakima River ($CH_2M$ Hill, 1975; Fretwell, 1979).

Comparisons between data collected during the 1974 irrigation season by $CH_2M$ Hill (1975), shown in table 1, and the 1976 data collected for this report show that average sediment and total nitrogen concentrations were all lower in 1974. Total nitrogen, suspended-sediment, and total phosphorus concentrations in 1974 averaged about 70, 50, and 85 percent, respectively, of those observed in 1976. Nelson (1979) sampled at site 8 on Sulphur Creek Wasteway in 1975; suspended-sediment concentrations in the 1975 irrigation season averaged 86 percent of those observed in this study during the 1976 irrigation season. Nelson collected no nutrient data.

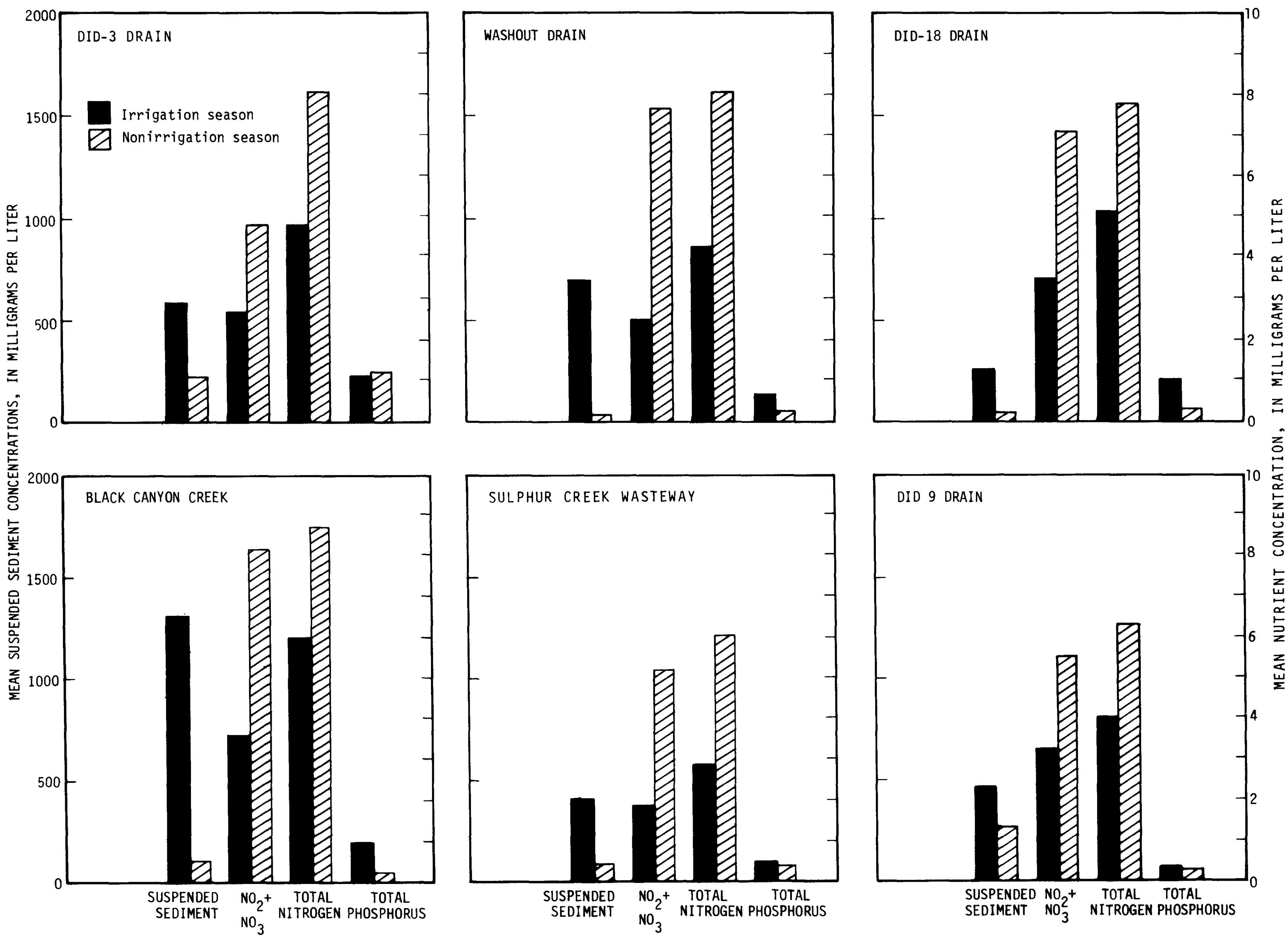



FIGURE 9.--Seasonal differences in constituent concentrations in the major drains in Sulphur Creek basin.

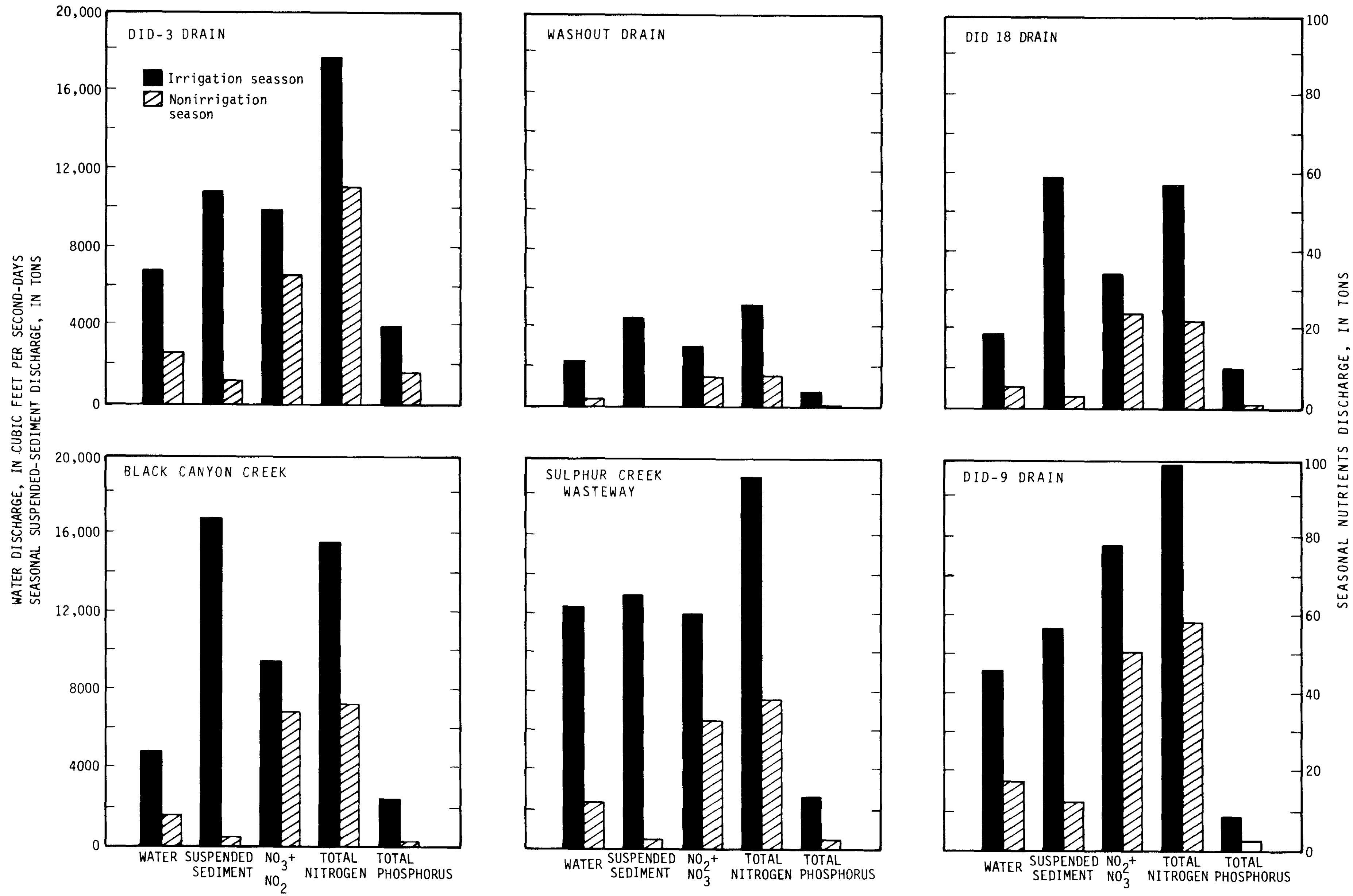



FIGURE 10.--Seasonal differences in constituent discharges in the major drains in Sulphur Creek basin.

TABLE 7.--Constituent discharges and concentrations in the major drains in Sulphur Creek basin during the 1976 irrigation and the 1976-77 nonirrigation seasons

| Site no. (pl. 1) | Location | Nitrate-plus-nitrite (as N): Discharge-weighted mean concentration (mg/L) | Nitrate-plus-nitrite (as N): Seasonal discharge (tons) | Total nitrogen (as N): Discharge-weighted mean concentration (mg/L) | Total nitrogen (as N): Seasonal discharge (tons) | Total phosphorus (as P): Discharge-weighted mean concentration (mg/L) | Total phosphorus (as P): Seasonal discharge (tons) | Suspended sediment: Discharge-weighted mean concentration (mg/L) | Suspended sediment: Seasonal discharge (tons) |
|---|---|---|---|---|---|---|---|---|---|
| | (Irrigation season) | | | | | | | | |
| 7 | DID-3 Drain | 2.7 | 49 | 4.8 | 89 | 1.1 | 20 | 580 | 11,000 |
| 3 | Washout Drain | 2.4 | 15 | 4.2 | 26 | .59 | 3.7 | 680 | 4,300 |
| 2 | DID-18 Drain | 3.5 | 34 | 5.2 | 51 | 1.0 | 9.9 | 1,200 | 11,000 |
| 5 | Black Canyon Creek | 3.6 | 46 | 6.0 | 76 | .94 | 12 | 1,300 | 17,000 |
| 6 | DID-9 Drain | 3.2 | 79 | 4.0 | 99 | .34 | 8.5 | 450 | 11,000 |
| 8 | Sulphur Creek Wasteway | 1.8 | 300 | 2.8 | 470 | .41 | 68 | 380 | 64,000 |
| | (Nonirrigation season)[1] | | | | | | | | |
| 7 | DID-3 Drain | 4.8 | 33 | 8.0 | 56 | 1.2 | 8.1 | 180 | 1,200 |
| 3 | Washout Drain | 7.9 | 8.1 | 8.3 | 8.5 | .14 | .14 | 15 | 15 |
| 2 | DID-18 Drain | 7.2 | 20 | 7.9 | 22 | .26 | .75 | 210 | 610 |
| 5 | Black Canyon Creek | 8.2 | 34 | 8.7 | 36 | .16 | .64 | 100 | 410 |
| 6 | DID-9 Drain | 5.5 | 51 | 6.3 | 59 | .24 | 2.2 | 260 | 2,400 |
| 8 | Sulphur Creek Wasteway | 5.1 | 160 | 5.9 | 190 | .32 | 10 | 66 | 2,100 |

[1]For the nonirrigation season the discharge from each drain is also the total surficial outflow of the respective drains because the canals are dry.

TABLE 8.--Percentage of total nitrogen present as nitrate-plus-nitrite, during the 1976 irrigation and 1976-77 nonirrigation seasons

| Site | Station name | Percent of total nitrogen that is nitrate-plus-nitrite: Irrigation season | Percent of total nitrogen that is nitrate-plus-nitrite: Nonirrigation season[1] |
|---|---|---|---|
| | Canals | | |
| 9 | Roza Canal at Scoon Road | 30 | -- |
| 10 | Roza Canal below Sulphur Creek | 27 | -- |
| 11 | Roza Canal at Black Canyon Road | 25 | -- |
| 12 | Roza Canal at Factory Road | 22 | -- |
| 13 | Roza Canal at Wilgus Road | 20 | -- |
| 14 | Sunnyside Canal at Maple Grove Road | 28 | -- |
| 15 | Sunnyside Canal below Sulphur Creek | 34 | -- |
| 16 | Sunnyside Canal at Edison Road | 30 | -- |
| 17 | Sunnyside Canal at Bethany Road | 30 | -- |
| 18 | Sunnyside Canal at Grandview | 34 | -- |
| | Drains | | |
| 7 | DID-3 Drain | 56 | 60 |
| 3 | Washout Drain | 57 | 95 |
| 2 | DID-18 Drain | 67 | 91 |
| 5 | Black Canyon Creek | 60 | 94 |
| 6 | DID-9 Drain | 80 | 87 |
| 8 | Sulphur Creek Wasteway | 64 | 86 |

[1]Water supply to canals is shut off during the nonirrigation season.

The large differences between the 1974 suspended-sediment concentrations and the 1975 and 1976 concentrations are more probably due to the differences in methodology than to actual year-to-year variation. $CH_2M$ Hill (1975) reported their data as suspended solids, which is differentiated from suspended-sediment concentration by method of collection. Suspended-solids samples are usually collected as a dip sample from the centroid of discharge. R. Gatton, of $CH_2M$ Hill, confirmed that this was the method used in 1974 (oral commun., 1977). However, suspended-sediment concentrations are normally determined from a sample collected in multiple vertical passes throughout the cross section of a stream, using a sampler that collects at a rate equal to the stream velocity (see fig. 4). Characteristically, the discharge-integrated sample thus collected is more representative of the sediment distribution in the entire stream cross section and normally has a greater concentration of sediment than does the suspended-solids sample.

## Water Temperature in Major Canals and Drains

Because water temperature is an important factor (sometimes the controlling factor) in stream ecosystems, periodic temperature data were collected to determine general temporal distributions and to provide an indication of the temperature differences between delivered water and the irrigation return flow.

Temperature records at five sites each on Roza and Sunnyside Canals, five sites on the major drains, and one site on Sulphur Creek Wasteway were studied by harmonic analysis (see p. 17-18) to estimate the median monthly and the mean irrigation-season water temperatures. Figure 11 shows an example of the analysis for site 10 and illustrates that water temperature does follow a harmonically cyclic pattern. Median monthly temperatures and mean irrigation-season temperatures calculated from harmonic analysis are presented in table 9.

Temperature data collected by Nelson (1979) on Roza Canal at Wilgis Road and Sunnyside Canal at Grandview during the 1975 irrigation season correspond closely to the 1976 data. Median monthly temperatures calculated from Nelson's data are shown in the following table:

| | Median monthly temperatures (°C) | | | | | | | Mean irrigation season* temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| | Apr. | May | June | July | Aug. | Sept. | Oct. | |
| Roza Canal at Wilgus Road (site 13) | 9.3 | 13.7 | 16.9 | 18.7 | 18.3 | 15.7 | 11.8 | 15.0 |
| Sunnyside Canal at Grandview (site 18) | 9.0 | 12.8 | 15.9 | 18.2 | 18.7 | 17.2 | 14.2 | 15.2 |
| Sulphur Creek Wasteway (site 8) | 10.6 | 15.2 | 18.2 | 19.6 | 18.6 | 15.5 | 11.2 | 15.8 |

*1976 irrigation season.

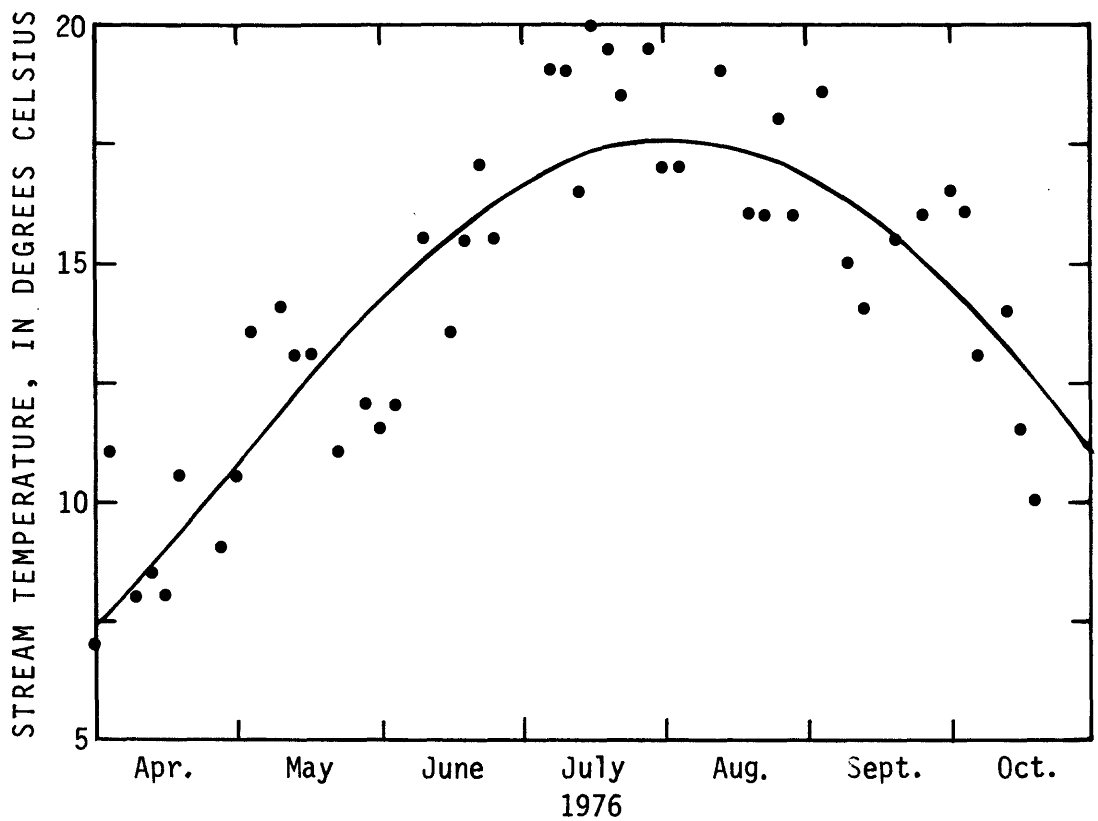



FIGURE 11.--Harmonic analysis of water temperatures in Roza Canal below Sulphur Creek Wasteway (site 10), for the 1976 irrigation season.

TABLE 9.--Water temperatures at selected sites in the Sulphur Creek basin for the period April 1976 through March 1977

| Site | Location | Median monthly temperature, in degrees Celsius | | | | | | | | | | | | Mean irrigation-season temperature (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | |
| | Roza Canal | | | | | | | | | | | | | |
| 9 | At Scoon Road | 8.6 | 12.2 | 15.1 | 17.0 | 17.1 | 15.4 | 12.4 | -- | -- | -- | -- | -- | 14.1 |
| 10 | Below Sulphur Creek Wasteway | 9.0 | 12.7 | 15.5 | 17.4 | 17.5 | 15.8 | 12.8 | -- | -- | -- | -- | -- | 14.4 |
| 11 | At Black Canyon Road | 9.2 | 13.2 | 16.2 | 18.2 | 18.1 | 16.1 | 12.8 | -- | -- | -- | -- | -- | 14.9 |
| 12 | At Factory Road | 9.0 | 13.0 | 16.2 | 18.2 | 18.2 | 16.1 | 12.7 | -- | -- | -- | -- | -- | 14.9 |
| 13 | At Wilgus | 9.0 | 13.3 | 16.6 | 18.6 | 18.4 | 16.1 | 12.4 | -- | -- | -- | -- | -- | 15.0 |
| | Sunnyside Canal | | | | | | | | | | | | | |
| 14 | At Maple Grove Road | 9.1 | 12.5 | 15.3 | 17.3 | 17.6 | 16.3 | 13.6 | -- | -- | -- | -- | -- | 14.6 |
| 15 | Below Sulphur Creek Wasteway | 9.3 | 12.6 | 15.4 | 17.4 | 17.8 | 16.4 | 13.8 | -- | -- | -- | -- | -- | 14.7 |
| 16 | At Edison Road | 9.3 | 12.6 | 15.3 | 17.4 | 17.8 | 16.6 | 14.0 | -- | -- | -- | -- | -- | 14.7 |
| 17 | At Bethany Road | 9.4 | 12.8 | 15.6 | 17.6 | 18.0 | 16.7 | 14.0 | -- | -- | -- | -- | -- | 14.9 |
| 18 | At Grandview | 9.5 | 13.3 | 16.3 | 18.4 | 18.6 | 16.8 | 13.8 | -- | -- | -- | -- | -- | 15.3 |
| | Drain | | | | | | | | | | | | | |
| 7 | DID-3 | 13.7 | 16.8 | 18.9 | 19.8 | 19.0 | 16.8 | 13.7 | 10.6 | 8.2 | 7.4 | 8.3 | 10.6 | 17.1 |
| 3 | Washout | 13.6 | 7.0 | 19.2 | 20.1 | 19.3 | 16.8 | 13.5 | 10.1 | 7.6 | 6.8 | 7.7 | 10.2 | 17.2 |
| 2 | DID-18 | 13.6 | 16.6 | 18.5 | 19.3 | 18.5 | 16.3 | 13.3 | 10.3 | 8.2 | 7.4 | 8.3 | 10.5 | 16.7 |
| 5 | Black Canyon Creek | 13.4 | 16.6 | 18.7 | 19.5 | 18.6 | 16.2 | 13.0 | 9.8 | 7.5 | 6.8 | 7.8 | 10.2 | 16.7 |
| 6 | DIO-9 | 12.9 | 15.9 | 17.9 | 18.7 | 17.8 | 15.5 | 12.4 | 9.4 | 7.2 | 6.5 | 7.5 | 9.8 | 16.0 |
| 8 | Sulphur Creek Wasteway | 12.2 | 15.4 | 17.7 | 18.8 | 18.3 | 16.3 | 13.3 | 10.1 | 7.6 | 6.5 | 7.1 | 9.2 | 16.1 |

For the Roza Canal site, the computed mean temperature during both the 1975 and 1976 irrigation seasons was 15.0°C For the Sunnyside Canal site, the computed mean for the 1975 irrigation season was 15.2°C, and for the 1976 irrigation season the computed mean was 15.3°C.

Temperature data were collected by Nelson (1979) on Sulphur Creek Wasteway (site 8) during the 1975 irrigation season. These data compare slightly less favorably with the 1976 data than do Nelson's temperature data for the two Canal sites, 13 and 18. The differences between the two seasons are probably due to different spilling practices from the canals.

Median monthly temperatures in Sulphur Creek Wasteway during the 1975 irrigation season are also shown in the table above. The mean temperature for the 1975 irrigation season was 15.8°C, compared with 16.1°C in the 1976 irrigation season.

Table 10 lists the harmonic-analysis regression coefficients for all sites where water temperature was available. DID-9 Drain had significantly cooler temperatures (mean annual temperature, $M_t$, of about 12.6°C), probably as a result of greater shading (greater percentage of area in orchards) and possibly because of a greater subsurface return flow than occurs in the other subbasins. Similarly, Sulphur Creek Wasteway was also cooler (mean annual temperature of about 12.7°C) than all the other drains except DID-9, probably because of spillage from Roza and Sunnyside Canal Wasteways and a greater percentage of subsurface return flow.

The mean irrigation-season water temperatures in the drains are about 1 to 2°C warmer than those of the water delivered to the basin by the canals.

## Minor Canals and Laterals

The Sulphur Creek basin has numerous minor distributary canals and laterals. Those that cross subbasin or basin divides can in some cases cause a small error in basin discharge and yield computations unless they are accounted for in the mass balance computations. The minor canals and laterals generally were diverted from major canals at points near established sampling sites. Because of the proximity, constituent concentrations in the minor canals and laterals were estimated by correlating miscellaneous samples collected from them with the concentrations at the nearest station upstream from their diversion. Table 11 presents a summary of estimated water discharges and estimated constituent discharges in the minor canals and laterals.

TABLE 10.--Harmonic-analysis-regression coefficients for water-temperature data from major canals and drains in the Sulphur Creek basin for the period April 1976 to March 1977

| Site | Station name | A (°C) | Ø (radians) | $M_t$ (°C) | CI[a] (°C) |
|---|---|---|---|---|---|
| | Roza Canal | | | | |
| 9 | At Scoon Road | 6.88 | 4.18 | 10.43 | ± 0.34 |
| 10 | Below Sulphur Creek Wasteway | 6.84 | 4.17 | 10.85 | ± .33 |
| 11 | At Black Canyon Road | 7.47 | 4.22 | 10.91 | ± .33 |
| 12 | At Factory Road | 7.72 | 4.21 | 10.74 | ± .34 |
| 13 | At Wilgus Road | 8.15 | 4.25 | 10.60 | ± .38 |
| | --do-- (b) | 8.36 | 4.31 | 10.44 | ± .43 |
| | Sunnyside Canal | | | | |
| 14 | At Maple Grove Road | 6.41 | 4.09 | 11.29 | ± .33 |
| 15 | Below Sulphur Creek Wasteway | 6.38 | 4.09 | 11.48 | ± .32 |
| 16 | At Edison Road | 6.28 | 4.07 | 11.57 | ± .33 |
| 17 | At Bethany Road | 6.45 | 4.09 | 11.64 | ± .34 |
| 18 | At Grandview | 7.20 | 4.15 | 11.53 | ± .38 |
| | --do-- (b) | 7.20 | 4.09 | 11.52 | ± .44 |
| | Drains | | | | |
| 7 | DID-3 | 6.18 | 4.45 | 13.63 | ± .33 |
| 3 | Washout | 6.68 | 4.46 | 13.46 | ± .38 |
| 2 | DID-18 | 5.93 | 4.48 | 13.38 | ± .33 |
| 5 | Black Canyon Creek | 6.36 | 4.49 | 13.16 | ± .35 |
| 6 | DID-9 | 6.09 | 4.49 | 12.58 | ± .31 |
| 8 | Sulphur Creek Wasteway | 6.20 | 4.37 | 12.68 | ± .33 |
| | --do-- (b) | 8.80 | 4.42 | 10.82 | ± .47 |

[a] 90-percent confidence interval for the mean ($M_t$).
[b] 1975 irrigation season (Nelson, 1979).

TABLE 11.--Estimated water and constituent discharges from selected minor canals and laterals in the Sulphur Creek basin during the 1976 irrigation season

| Site | Station name | Total water discharge (acre-ft) | Suspended-sediment discharge (tons) | Nutrient discharges: Total phosphorus (as P) (tons) | Nutrient discharges: Total nitrogen (as N) (tons) | Nutrient discharges: Nitrate-plus-nitrite (as N) (tons) |
|---|---|---|---|---|---|---|
| 19 | Pump 9-A Lateral blw Scoon Rd | [f]5,200 | [a]200 | [a]0.5 | [a]2.7 | [a]0.9 |
| 20 | Upper Pump 14-A Lateral abv Missimer Rd | [f]4,800 | [a]300 | [a].5 | [a]2.6 | [a].9 |
| 21 | Lower Pump 14-A Lateral blw Wilgus Rd | [f]5,200 | [a]1,200 | [a].9 | [a]3.1 | [a].7 |
| 22 | Turbine Lateral nr Grandview | [f]10,000 | [a]600 | [a]1.0 | [a]5.6 | [a]1.6 |
| 23 | Turbine Lateral abv Griffin Rd | [f]4,800 | [a]300 | [a].9 | [a]4.7 | [a]1.7 |
| 24 | Outlook Canal blw Independence Rd | [f]7,500 | [a]3,100 | [a]3.5 | [a]8.9 | [a]2.0 |
| 25 | Snipes Mt. Lateral blw Drop 4 | [g]59,000 | [a]11,000 | [a]12 | [a]32 | [a]12 |
| 26 | Snipes Mt. Lateral at Mile 9.06 | [g]7,900 | [a]1,700 | [a]1.7 | [a]5.4 | [a]1.5 |
| 28 | Snipes Mt. Lateral at Drop 8 | [g]11,000 | [a]3,000 | [a]2.8 | [a]7.2 | [a]2.0 |
| 29 | Snipes Mt. Wasteway abv DID-3 Drain | [g]8,300 | [a]2,300 | [a]3.0 | [a]7.0 | [a]2.0 |
| 30 | Grandview Canal blw County Line Rd | [f]1,600 | [a]400 | [a].4 | [a]2.3 | [a]1.4 |
| 37 | Pump 14 Lateral on Boundary of DID-5 and DID-9 | [b]12,000 | [b]400 | [b].6 | [b]3.0 | [b]1.0 |
| 41 | Roza Canal Wasteway to Sulphur Cr Wasteway | [h]13,000 | [c]1,000 | [c]1.3 | [c]6.1 | [c]1.6 |
| 42 | Sunnyside Canal Wasteway to Sulphur Cr Wasteway | [g]28,000 | [d]5,200 | [d]6.3 | [d]18 | [d]5.5 |
| 27 | Snipes Mt. Lateral at Mile 10.21 | [g]19,000 | [b]5,400 | [b]5.0 | [b]13 | [b]3.6 |
| 38 | Ryder Lateral blw Rocky Ford Lateral | [g]24,000 | [e]6,900 | [e]5.7 | [e]18 | [e]6.2 |

[a]Estimated from 2-3 samples.
[b]Estimated.
[c]Calculated using concentration data from Roza Canal below Sulphur Cr Wasteway (site 10).
[d]Calculated using concentration data from Sunnyside Canal below Sulphur Cr Wasteway (site 15).
[e]Calculated using concentration data from Sunnyside Canal at Grandview (site 18).
[f]Estimated on basis of 2-3 discharge measurements.
[g]Estimated from records furnished by Sunnyside Irrigation District.
[h]Estimated from records furnished by Roza Irrigation District.

## NET CONSTITUENT OUTFLOWS AND YIELDS

In addition to examining constituent concentrations and discharges at a single point on each major drain and at several points on each canal, it is also useful to examine net constituent outflows and yields (net outflow per unit area) from individual subbasins and from the entire Sulphur Creek basin. To do this, use of the mass-balance equation (eq. 1) presented on page 13 is necessary. Table 12 presents the results of mass-balance computations. For this discussion, the data from DID-3 and Washout subbasins have been combined.

From table 12, it is apparent that Black Canyon Creek and DID-18 subbasins have greater yields of nitrogen and sediment than do the other subbasins, and that DID-18 subbasin and DID-3 subbasin have the greatest phosphorous yields. The order, by subbasin, of increasing sediment yields coincides with the order of increasing percentage of land slopes greater than 2 percent. DID-9 subbasin produced the lowest yield of all constituents during the irrigation season, probably in part due to having had the lowest average land slopes of all the subbasins and the greatest percentage of orchard land.

During the 1976 irrigation season the estimated net outflow of sediment from the entire Sulphur Creek basin was about 3,800 tons greater than that from the five monitored subbasins (table 12).

However, during the nonirrigation season the net outflow of sediment from the entire basin was about 2,400 tons less than that from the five subbasins. The reason for this is not known, but three possibilities are given: (1) the excess 2,400 tons may have been stored temporarily during the nonirrigation season as channel deposits along Sulphur Creek Wasteway; (2) the excess sediment may have passed down Sulphur Creek Wasteway as unmeasured sediment discharge; (3) the difference may be the result of uncertainties in the net-outflow values.

The first possibility, that of channel deposition and the presumed subsequent removal when the canals are reopened, is supported by data showing evidence of minor channel scour in Sulphur Creek during the first few days of canal priming. On March 26, 1976, alone, about 900 tons of suspended sediment passed site 8 near the mouth of Sulphur Creek. This is a far greater amount than can be accounted for from the drains or canal wasteways, and is the largest water discharge and also the largest suspended-sediment concentration and discharge recorded at this site during the study. The large sediment discharge on March 26 thus appears to have been caused by bank and mid-channel scour in Sulphur Creek Wasteway as a result of canal-wasteway spillage. This was also suggested by data collected on March 17 and 20, 1975, by Nelson (1975). The large sediment discharge was not evident in the data of March 1977 because in 1977 a drought caused an extremely low supply of water, and canal priming was later than normal; thus, all wasteway spillage occurred after the discontinuance of this study (March 31, 1977).

TABLE 12.--Net constituent outflows and yields of Sulphur Creek basin and four subbasins during the 1976 irrigation and the 1976-77 nonirrigation seasons

| Basin or subbasin | Net outflow (tons) | Sediment yield[a] (tons/acre) | Nitrate-plus-nitrite (N) Net outflow (lbs) | Nitrate-plus-nitrite (N) Yield (lbs/acre) | Total nitrogen (N) Net outflow (lbs) | Total nitrogen (N) Yield (lbs/acre) | Total phosphorus (P) Net outflow (lbs) | Total phosphorus (P) Yield (lbs/acre) |
|---|---|---|---|---|---|---|---|---|
| Irrigation season | | | | | | | | |
| Subbasin: | | | | | | | | |
| DID-3 and Washout | 23,000 | 1.9 | 140,000 | 12 | 220,000 | 18 | 46,000 | 3.8 |
| DID-18 | 28,000 | 7.1 | 50,000 | 13 | 99,000 | 25 | 26,000 | 6.6 |
| Black Canyon Creek | 16,000 | 2.7 | 90,000 | 15 | 150,000 | 16 | 20,000 | 3.4 |
| DID-9 | 6,200 | .5 | 150,000 | 11 | [b]120,000 | [b]9 | 1,200 | .1 |
| Sulphur Creek basin | 77,000 | 1.9 | 560,000 | 14 | 800,000 | 19 | 100,000 | 2.4 |
| Nonirrigation season | | | | | | | | |
| Subbasin: | | | | | | | | |
| DID-3 and Washout | 1,200 | .10 | 82,000 | 7 | 130,000 | 11 | 16,000 | 1.3 |
| DID-18 | 610 | .16 | 40,000 | 10 | 44,000 | 11 | 1,500 | .1 |
| Black Canyon Creek | 430 | .07 | 68,000 | 12 | 72,000 | 12 | 1,300 | .2 |
| DID-9 | 2,400 | .18 | 100,000 | 7 | 120,000 | 9 | 4,400 | .3 |
| Sulphur Creek basin | 2,200 | .05 | 320,000 | 8 | 380,000 | 9 | 20,000 | .5 |

[a]Yield is calculated using cropland acreage, not total acreage, in the irrigated portions of the basin.

[b]Total nitrogen discharge and yield can never be less than nitrate-plus-nitrite discharge and yield, because by definition total nitrogen = nitrate-plus-nitrite + ammonia + organic nitrogen. However, due to the uncertainty associated with these numbers, they are essentially the same.

The only other constituent indicating a similar deficit (net inflow exceeding net outflow) during the nonirrigation season is total phosphorus. Again, the reason for this deficit is not known, but the same three possibilities listed for sediment are applicable here. If temporary channel storage of sediment occurs, the phosphorus deficit may be attributable to phosphorus attachment (adsorption) to the sediments as they were deposited in Sulphur Creek Wasteway during the nonirrigation season. The 2,400-ton sediment deficit would have to retain less than 1 milligram of phosphorus per gram of sediment to achieve the approximately 3,200-pound phosphorus deficit.

Net constituent outflows from the Sulphur Creek basin for the non-irrigation season, expressed as percentages of the total year's net outflows, are as follows: sediment, 3 percent; nitrate-plus-nitrite, 36 percent; total nitrogen, 32 percent; and total phosphorus, 17 percent. Little error in the calculation of annual net-sediment outflows from the basin would be caused by using only the irrigation season data. A much larger error would result, however, if a similar assumption is made for nutrients.

Normal fertilizer application rates range from about 50 to 240 pounds of nitrogen per acre and about 50 to 100 pounds of phosphorus per acre, depending on crops and soil types. Data from table 12 show that about 30 pounds of nitrogen per acre of cropland leave the basin annually by surface-water conveyances. Phosphorus yield by surface-water conveyances is much less, being about 2 to 7 pounds per acre annually.

Of the basin characteristics measured in this study (table 2), land slope appears to have the most relation to sediment yield. As previously mentioned, the order, by subbasin, of increasing sediment production per unit area coincides with the order of increasing percentages of land slopes greater than 2 percent. The percentage of ditch and rill irrigation versus sprinkler irrigation for each basin may also be related to sediment production; however, these percentages were not available at the time of writing this report.

## NETWORK EVALUATION

The water-quality-monitoring network was discontinued at the end of the first full year of data collection, based on a joint management decision of all parties involved, including the Technial Advisory Committee for Water Quality. Farmer participation in the pilot program was only about 5 percent in the subbasins selected for the demonstration (Black Canyon Creek and DID-18). Because of the low level of participation, it is doubtful that sufficient reduction of sediment yield could have been achieved on the few participating farms to be detected in the monitoring of the basin or subbasins. This problem was compounded further in that participating farmers in the two demonstration subbasins also planned to implement the BMP improvements on some of their farm holdings that crossed the divides of the control subbasins. Because the control subbasins were an integral part of the network to help factor out natural variations, any BMP implemented in them could only reduce their effectiveness for comparison.

The amount of change in constituent discharge resulting from use of BMPs on individual farmsites is still being evaluated by WSU. WSU planned to continue the study through the 1980 irrigation season, and the SCS is continuing to work with the participating farmers, attempting to attain participation agreements with additional farmers. Beginning in 1979, the SCS, DOE, and the Conservation Districts implemented a program to test the available methods whereby different state and federal agencies could work together to improve water-quality programs. This project, called the Model Implementation Project (MIP), included an area in the Sulphur Creek basin between Sunnyside and Roza Canals.

Since 1979, DOE and the WRD have been involved in a project in the DID-18 Drain that includes 1,500 acres of irrigated land in the Sulphur Creek portion of the MIP project area. This project, part of the MIP project, samples sediment in four small subbasins to determine if changes in BMP can be detected and to test the validity of the Imhoff Cone, a sampling method used by DOE to monitor sediment in drains and on fields.

A decrease in sediment discharge from the DID-18 and Black Canyon Creek subbasins of about 27 percent and 23 percent, respectively, would be necessary to be detectable. For the entire Sulphur Creek basin, the magnitude of decrease that could be detected would be about 10 percent. These values were determined by the methods described on page 19.

The conclusion that the seasonal or annual discharge of one year is different than that of another could be made if these decreases in sediment discharges occurred; however, natural seasonal variations must also be considered before any valid conclusions about the effect of BMP can be made.

Automatic samplers that would produce composited daily samples would about halve the change in sediment discharge needed for detection--at a greatly increased cost. Even at this sensitivity level, however, the detection success of the network is doubtful.

Furthermore, changes in agricultural practices may result in a reduction of constituent yields during the irrigation season, but may also result in increased nutrient yields during the nonirrigation season, which would not be apparent in a monitoring scheme that operated only during the irrigation season.

The measurement of nutrient discharges and yields was less precise than that for sediment because nutrient samples were taken less frequently. To achieve smaller uncertainty levels similar to those attained for suspended sediment, nutrients would have to be collected at about four times the frequency of the 1976 sampling, or twice weekly--the same frequency as sediment data were collected.

The above conclusions are the major findings of the network evaluation. For those readers who may be interested in some of the more important sub-elements of the study that were necessary for the network evaluation, the following three subsections are included.

## Daily Variations of Constituent Concentrations and Streamflow

Two separate 48-hour studies were conducted on the major drains to assess the amount of daily variation of streamflow and of the various constituent concentrations. The resulting data were useful in assessing how well an instantaneous sampling, at a random time of day, represents daily mean streamflow, constituent concentrations, and constituent discharge. Figures 12 through 14 illustrate the findings.

Instantaneous sampling causes considerable uncertainty that the sample represents the daily mean values. This daily uncertainty is the major component of the total uncertainty of the seasonal or annual mean values. For example, for suspended-sediment discharge, the daily uncertainty ranged from 32 to 52 percent (at the 90-percent confidence level). Uncertainties of the constituent are summarized in table 13.

The effect that the daily uncertainty has on the total seasonal or annual uncertainty is considerably mitigated. For example, assuming a random 50-percent uncertainty in the daily suspended-sediment discharge, for 58 samples the mean seasonal uncertainty generated from the daily uncertainty component would be

$$\frac{50 \text{ percent}}{\sqrt{58}} = \text{about 7 percent.}^{1}$$

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[1]There are several statistical assumptions that must be satisfied before this is true; all assumptions have been satisfied for this monitoring. The major assumption is that the randon component of the discharges is normally distributed, or reasonably so. Such an assumption is clearly not met in most natural streams, but is met in this regulated system.

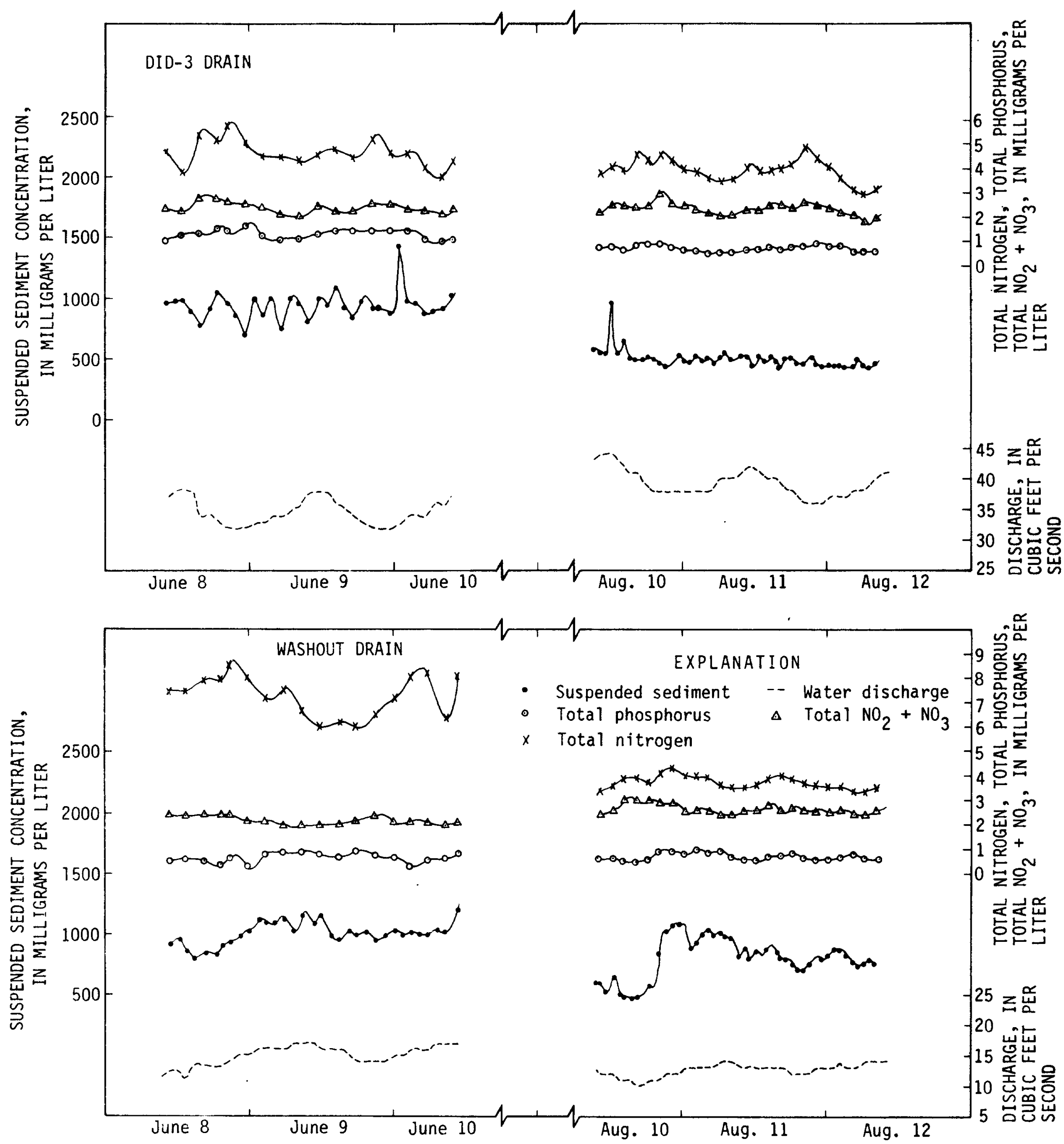


FIGURE 12.--Variations of water discharge and constituent concentrations during two 48-hour intensive studies at DID-3 Drain (site 7) and Washout Drain (site 3).

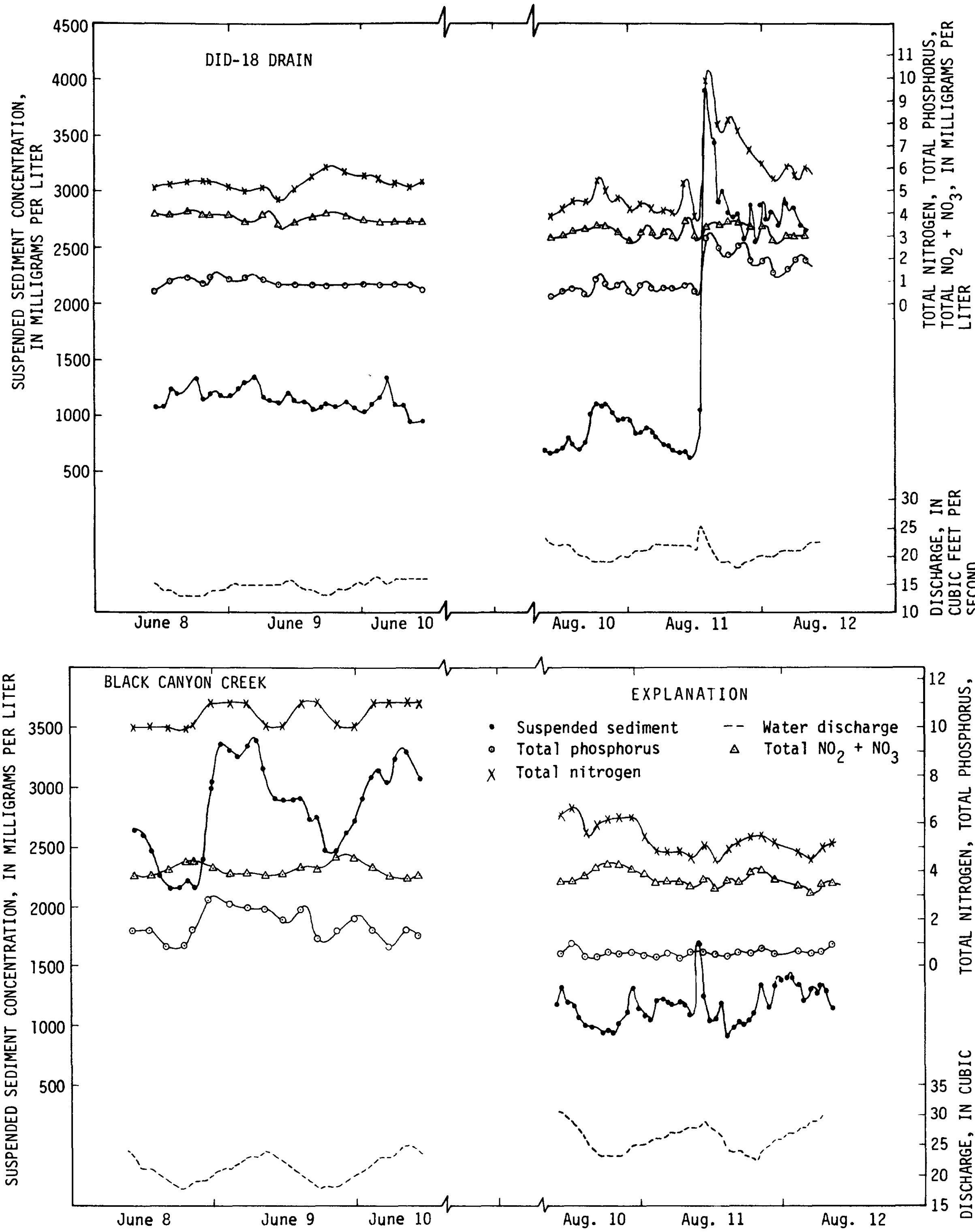


FIGURE 13.--Variations of water discharge and constituent concentrations during two 48-hour intensive studies at DID-18 Drain (site 2) and Black Canyon Creek (site 5).

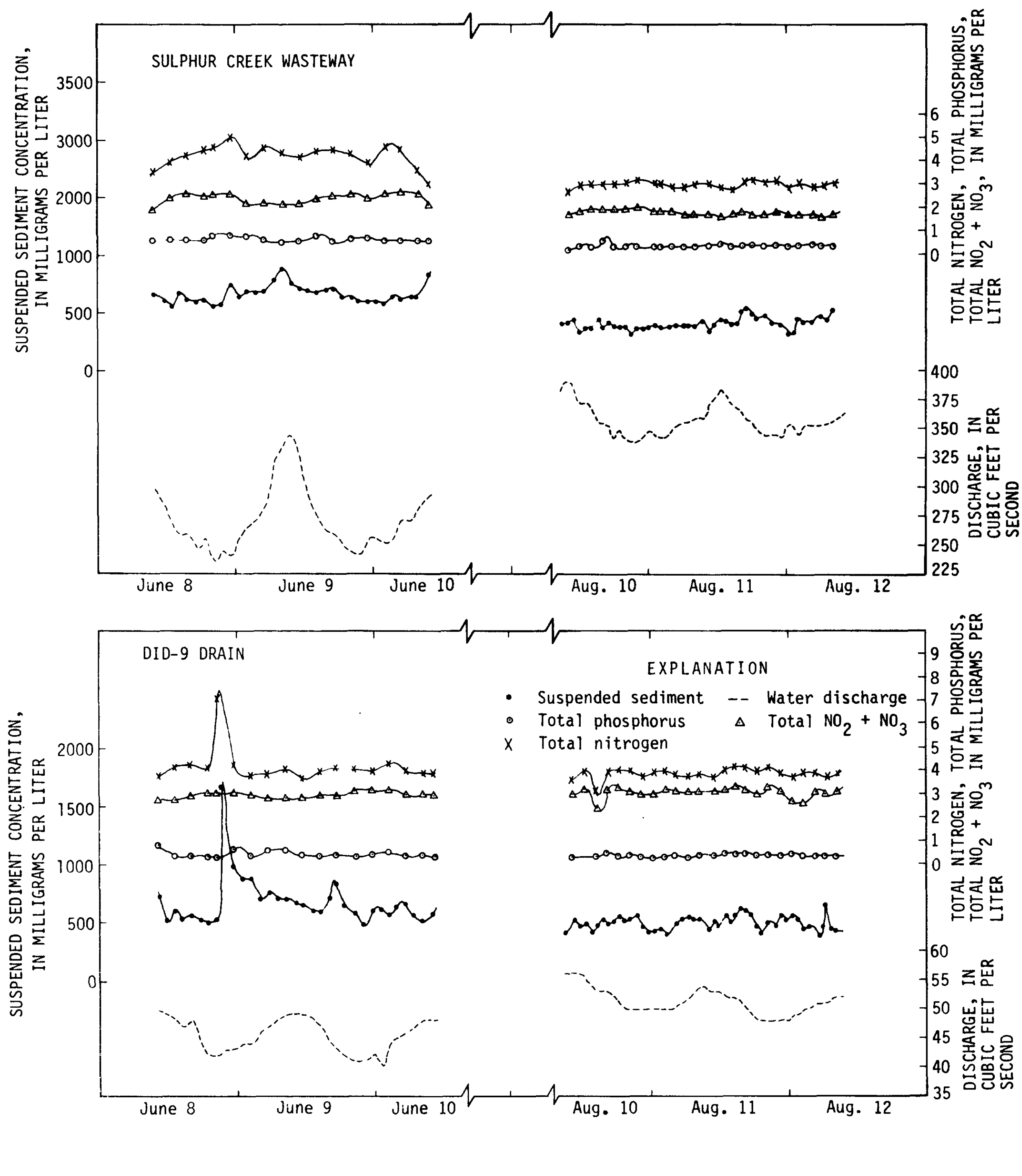


FIGURE 14.--Variations of water discharge and constituent concentrations during two 48-hour intensive studies at DID-9 Drain (site 6) and Sulphur Creek Wasteway (site 8).

TABLE 13.--Maximum variations of instantaneous concentrations and discharges about the daily mean concentration and discharge in the major drains in Sulphur Creek basin. (Variations are expressed at the 90-percent confidence level, and are based on two 48-hour studies, June 8-10, and August 10-12, 1976.)

| | | Maximum variations of instantaneous concentrations and discharges about the daily mean concentrations and discharges, in percent | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | Station name | Suspended-sediment concentration | Suspended-sediment discharge | Nitrate-plus-nitrite concentration | Nitrate-plus-nitrite discharge | Total nitrogen concentration | Total nitrogen discharge | Total phosphorus concentration | Total phosphorus discharge | Water discharge |
| 2 | DID-18 Drain | 41 | 41 | 17 | 16 | 31 | 30 | 65 | 63 | 16 |
| 3 | Washout Drain | 47 | 52 | 17 | 14 | 20 | 26 | 62 | 70 | 21 |
| 5 | Black Canyon Creek | 26 | 45 | 17 | 12 | 18 | 26 | 77 | 83 | 22 |
| 6 | DID-9 Drain | 48 | 46 | 16 | 16 | 26 | 23 | 49 | 50 | 12 |
| 7 | DID-3 Drain | 25 | 32 | 23 | 22 | 27 | 25 | 37 | 36 | 13 |
| 8 | Sulphur Creek Wasteway | 29 | 41 | 16 | 14 | 17 | 22 | 47 | 47 | 17 |
| | Range of variation | 25-48 | 32-52 | 16-23 | 12-22 | 17-31 | 22-30 | 37-77 | 36-83 | 12-22 |

## Unmeasured Sediment Discharge

Unmeasured sediment discharge in the Sunnyside and Roza Canals was large enough to require correction of the suspended-sediment discharges in order to obtain total-sediment discharges. Although no assessment of the unmeasured sediment discharge in the canals was attempted during the study period, four sand-fraction analyses were obtained later to aid in estimating it. The sand fraction of the suspended sediment averaged about 12 percent, which, by the nomographic procedure developed by Colby (1963), indicates that about 20 percent of the total-sediment discharge in the Roza and Sunnyside Canals is unmeasured sediment discharge.

Canals widths decreased in the downstream direction to help maintain nearly constant depths and velocities; therefore, it is expected that the unmeasured sediment discharge remains practically constant with respect to the suspended-sediment discharge. This proportionality is of importance to this study in that the unmeasured-sediment-discharge estimates tend to compensate each other in the mass balance equation; that is, the unmeasured sediment outflow from a subbasin tends to be nearly equal to the unmeasured sediment inflow.

The unmeasured sediment discharge of Roza and Sunnyside Canals, and also of Sulphur Creek Wasteway and DID-18, should have been more carefully assessed. Up to 5 percent of the uncertainty of the basin and subbasin yields and discharges could have been eliminated if the unmeasured sediment discharge were more closely defined.

## Storm Runoff

No major storm events occurred within the life of the study. The small amount of sediment data that was collected during minor-storm water runoff is tabulated in table 14. No nutrient sampling coincided with storm events.

Storm runoff in Sulphur Creek basin during the period of this study was not representative of a normal year's storm events. The winter of 1976-77 was extremely dry in eastern Washington and in many places was the driest winter on record, exceeding the 100-year drought-probability interval. In spite of the low level of storm activity, the 4 days exhibiting the effects of small storms produced 7 percent of the suspended-sediment discharge passing site 8 on Sulphur Creek Wasteway during the nonirrigation season. This sediment discharge was practically all from irrigated lands; the small storms produced no measureable runoff from the drylands.

When only irrigation water is applied to the land and no storm runoff is occurring, the sediment yield is nearly all from irrigated agricultural land. However, when a storm occurs with sufficient magnitude to produce runoff from the unirrigated upper reaches of the basin, the steep slopes there may produce sediment yields of equal or much greater magnitude than yields from the irrigated land.

TABLE 14.--Summary of data collected in the major drains during periods of stormwater runoff

| Site | Station name | Date | Time (24 hour) | Instantaneous water discharge ($ft^3/s$) | Temperature (°C) | Specific conductance (umhos/cm) | Turbidity (NTU) | Suspended sediment | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Concentration (mg/L) | Discharge (tons/day) |
| 7 | DID-3 Drain | 2/25/77 | 1045 | 17 | 8.6 | 649 | 55 | 1,000 | 46 |
| | | 2/28/77 | 1255 | 23 | 9.3 | 682 | 50 | 680 | 42 |
| | | 3/ 1/77 | 1230 | 17 | 11.8 | 799 | 15 | 273 | 12 |
| | | 3/ 3/77 | 1400 | 17 | 11.4 | 739 | 10 | 286 | 13 |
| 3 | Washout Drain | 2/25/77 | 1005 | 1.8 | 7.5 | 580 | 1 | 1 | .00 |
| | | 2/28/77 | 1215 | 3.0 | 9.4 | 402 | 20 | 45 | .36 |
| | | 3/ 1/77 | 1145 | 2.6 | 12.4 | 676 | 30 | 46 | .32 |
| | | 3/ 3/77 | 1120 | 2.1 | 10.2 | 539 | 3 | 9 | .05 |
| 2 | DID-18 Drain | 2/25/77 | 0915 | 4.2 | 8.4 | 606 | 15 | 118 | 1.3 |
| | | 2/28/77 | 1100 | 5.0 | 10.0 | 550 | 55 | 368 | 5.0 |
| | | 3/ 1/77 | 1130 | 4.0 | 11.8 | 720 | 10 | 128 | 1.4 |
| | | 3/ 3/77 | 1100 | 4.8 | 9.4 | 616 | 35 | 278 | 3.6 |
| 5 | Black Canyon Creek | 2/25/77 | 1020 | 6.5 | 7.6 | 536 | 4 | 51 | .90 |
| | | 2/28/77 | 1230 | 8.6 | 9.5 | 522 | 25 | 240 | 5.6 |
| | | 3/ 1/77 | 1200 | 7.4 | 10.3 | 660 | 4 | 86 | 1.7 |
| | | 3/ 3/77 | 1200 | 7.1 | 9.8 | 588 | 15 | 138 | 2.6 |
| 6 | DID-9 Drain | 2/25/77 | 1030 | 18 | 7.4 | 553 | 10 | 191 | 9.3 |
| | | 2/28/77 | 1235 | 23 | 9.2 | 475 | 25 | 402 | 25 |
| | | 3/ 1/77 | 1215 | 20 | 10.2 | 627 | 20 | 299 | 16 |
| | | 3/ 3/77 | 1250 | 20 | 10.0 | 508 | 6 | 244 | 13 |
| 8 | Sulphur Creek Wasteway | 2/25/77 | 1105 | 78 | 7.7 | 545 | 30 | 215 | 45 |
| | | 2/28/77 | 1320 | 81 | 9.3 | 522 | 40 | 383 | 84 |
| | | 3/ 1/77 | 1310 | 66 | 11.2 | 616 | 5 | 69 | 12 |
| | | 3/ 3/77 | 1530 | 67 | 11.5 | 594 | 6 | 91 | 16 |

It was hoped that a major storm would occur during the study, so that storm-produced yields from the upper unirrigated portion of the basin could be compared with those from the irrigated portion of the basin. Also, storm-produced yields in the irrigated portion could be compared with nonstorm yields from the same land. Because no major storms occurred during the study, these comparisons could not be made.

Failure to observe sediment discharges during a major storm doesn't reduce the main value of the results reported in this report. The objectives of the demonstration project and of the BMPs to be applied were to reduce sediment loss resulting from "less than desirable" irrigation practices, and not necessarily from storm runoff. Sediment loss in storm runoff may coincidentally be reduced by BMPs for irrigated agriculture, but reduction of sediment loss resulting from storm runoff has been demonstrated many time by the SCS, and was not a stated objective of the demonstration project.

## Two Mathematical Approximation Methods of Data Analysis

In the Sulphur Creek basin, constituent concentrations and discharges appear to follow some pattern of variation in time that is annually cyclic. Because of the cyclic variation, seasonal mean concentrations and seasonal constituent discharges were recomputed by two mathematical approximation methods of fitting theoretical time distributions to the data. Examples of the least-squares curves defined by the two mathematical approximations -- harmonic and fourth-degree polynomial analysis -- are illustrated in figures 15 and 16. The results compare favorably with those of the discharge-weighted averaging method, as can be seen by comparing tables 15, 16, and 17.

The mathematical approximations for the irrigation season are made using data covering the entire year of record, and the approximations for the nonirrigation season are made using data covering the nonirrigation season only. The reason for this separation is as follows. The effects of irrigation are superimposed on the ground-water effects during the irrigation season. Hence, the irrigation-season data reflect both overland flow and ground-water inflow, and are best described by fitting to both seasons. During the nonirrigation season, ground-water inflow is dominant, and the overland flow virtually absent. This situation can best be described by fitting to only nonirrigation season data.

Harmonic and polynomial analyses offer potential alternative methods of analyzing water-quality data from an irrigation system such as that found in the Sulphur Creek basin; that is, one that has relatively stable stream-flow and seasonably cyclic constituent discharges. These methods will not work during periods affected by storms, but do provide a means for separating the effect of storms from the gradual seasonal trend.

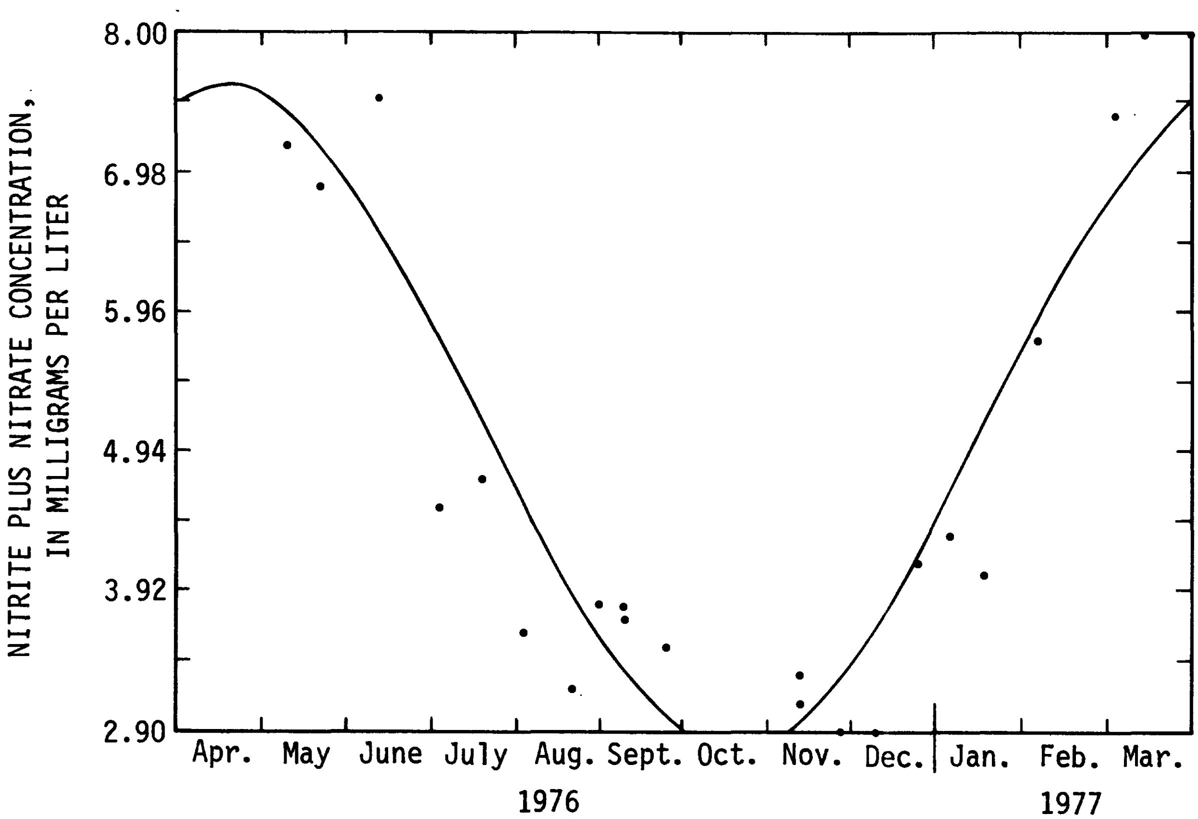


FIGURE 15.--Harmonic analysis of nitrate-plus-nitrite concentrations in DID-18 Drain (site 2), for the period April 1976 through March 1977.

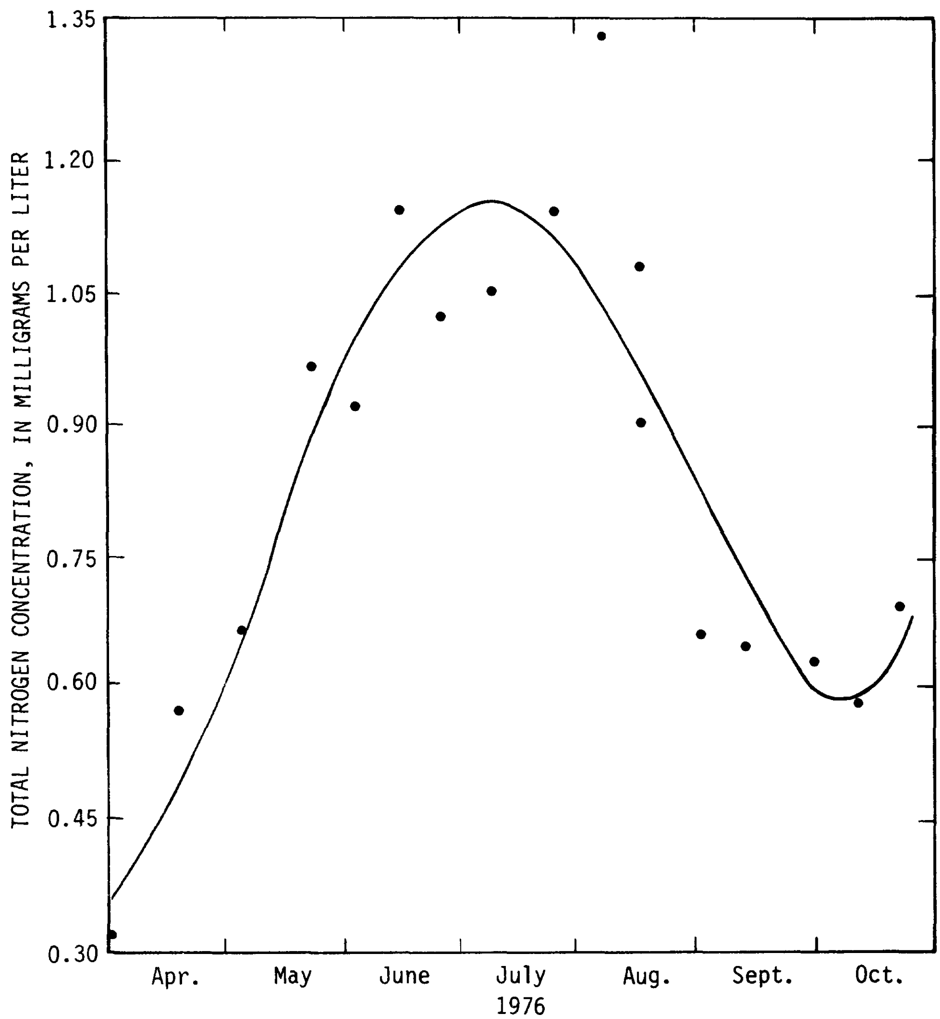


FIGURE 16.--Fourth-degree-polynomial analysis of total-nitrogen concentrations in Sunnyside Canal at Edison Road (site 16), for the 1976 irrigation season.

TABLE 15.--Constituent discharges and concentrations in Roza and Sunnyside Canals and in the major drains in the Sulphur Creek basin during the 1976 irrigation and 1976-77 nonirrigation seasons, calculated by discharge-weighted-averaging[1]

| Site | Station name | Nitrate-plus-nitrite (as N) | | Total nitrogen (as N) | | Total phosphorus (as P) | | Suspended sediment | |
|---|---|---|---|---|---|---|---|---|---|
| | | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) |
| | Roza Canal (irrigation season) | | | | | | | | |
| 9 | At Scoon Road | 0.10 ± 0.02 | 31 ± 6 | 0.34 ± 0.06 | 100 ± 20 | 0.07 ± 0.02 | 21 ± 4 | 37 ± 4 | 11,000 ± 2,000 |
| 10 | Below Sulphur Creek Wastway | .09 ± .02 | 22 ± 4 | .33 ± .06 | 82 ± 15 | .07 ± .02 | 18 ± 3 | 55 ± 6 | 14,000 ± 2,000 |
| 11 | At Black Canyon Road | .09 ± .02 | 19 ± 4 | .35 ± .07 | 77 ± 17 | .08 ± .02 | 18 ± 3 | 63 ± 7 | 14,000 ± 2,000 |
| 12 | At Factory Road | .08 ± .02 | 16 ± 3 | .37 ± .07 | 71 ± 15 | .09 ± .02 | 17 ± 3 | 88 ± 10 | 17,000 ± 2,000 |
| 13 | At Wilgus Road | .08 ± .02 | 12 ± 2 | .39 ± .08 | 58 ± 13 | .09 ± .02 | 14 ± 3 | 86 ± 10 | 13,000 ± 2,000 |
| | Sunnyside Canal (irrigation season) | | | | | | | | |
| 14 | At Maple Grove Road | .11 ± .02 | 46 ± 10 | .41 ± .07 | 170 ± 30 | .13 ± .02 | 52 ± 9 | 120 ± 20 | 48,000 ± 8,000 |
| 15 | Below Sulphur Creek Wasteway | .17 ± .03 | 58 ± 11 | .48 ± .08 | 170 ± 30 | .14 ± .02 | 50 ± 9 | 140 ± 20 | 48,000 ± 7,000 |
| 16 | At Edison Road | .15 ± .03 | 51 ± 11 | .51 ± .09 | 170 ± 30 | .16 ± .03 | 53 ± 9 | 180 ± 20 | 61,000 ± 10,000 |
| 17 | At Bethany Road | .16 ± .03 | 51 ± 11 | .54 ± .09 | 170 ± 30 | .16 ± .03 | 50 ± 9 | 180 ± 20 | 57,000 ± 9,000 |
| 18 | At Grandview | .19 ± .03 | 55 ± 11 | .57 ± .10 | 160 ± 30 | .18 ± .03 | 51 ± 9 | 210 ± 30 | 62,000 ± 10,000 |
| | Drains (irrigation season) | | | | | | | | |
| 7 | DID-3 | 2.7 ± .2 | 49 ± 4 | 4.8 ± .3 | 89 ± 7 | 1.1 ± .1 | 20 ± 2 | 580 ± 20 | 11,000 ± 700 |
| 3 | Washout | 2.4 ± .1 | 15 ± 1 | 4.2 ± .2 | 26 ± 2 | .59 ± .09 | 3.7 ± .6 | 680 ± 40 | 4,300 ± 400 |
| 2 | DID-18 | 3.5 ± .1 | 34 ± 2 | 5.2 ± .4 | 51 ± 4 | 1.0 ± .2 | 9.9 ± 1.6 | 1,200 ± 100 | 11,000 ± 900 |
| 5 | Black Canyon Creek | 3.6 ± .2 | 46 ± 3 | 6.0 ± .3 | 76 ± 6 | .94 ± .17 | 12 ± 2 | 1,300 ± 100 | 17,000 ± 1,300 |
| 6 | DID-9 | 3.2 ± .1 | 79 ± 7 | 4.0 ± .2 | 99 ± 8 | .34 ± .04 | 8.5 ± 1.2 | 450 ± 30 | 11,000 ± 900 |
| 8 | Sulphur Creek Wasteway | 1.8 ± .1 | 300 ± 19 | 2.8 ± .1 | 470 ± 40 | .41 ± .05 | 68 ± 8.4 | 380 ± 20 | 64,000 ± 4,800 |
| | Drains (nonirrigation season)[2] | | | | | | | | |
| 7 | DID-3 | 4.8 ± .2 | 33 ± 3 | 8.0 ± .8 | 56 ± 7 | 1.2 ± .1 | 8.1 ± 1.1 | 180 ± 7 | 1,200 ± 90 |
| 3 | Washout | 7.9 ± .5 | 8.1 ± .6 | 8.3 ± .6 | 8.5 ± .9 | .14 ± .04 | .14 ± .04 | 15 ± 1 | 15 ± 2 |
| 2 | DID-18 | 7.2 ± .4 | 20 ± 2 | 7.9 ± .9 | 22 ± 2 | .26 ± .06 | .75 ± .17 | 210 ± 20 | 610 ± 52 |
| 5 | Black Canyon | 8.2 ± .5 | 34 ± 2 | 8.7 ± .6 | 36 ± 4 | .16 ± .05 | .64 ± .19 | 100 ± 3 | 410 ± 37 |
| 6 | DID-9 | 5.5 ± .3 | 51 ± 4 | 6.3 ± .6 | 59 ± 6 | .24 ± .05 | 2.2 ± .4 | 260 ± 20 | 2,400 ± 220 |
| 8 | Sulphur Creek Wasteway | 5.1 ± .3 | 160 ± 12 | 5.9 ± .4 | 190 ± 18 | .32 ± .06 | 10 ± 1.8 | 66 ± 4 | 2,100 ± 180 |

[1]Confidence limits are based on some computations and some estimations, but are reliable to at least 90-percent confidence level.
[2]For the nonirrigations season, the discharge from each drain is also the total surficial outflow of the respective subbasin because the canals are all dry.

TABLE 16.--Constituent discharges and concentrations in Roza and Sunnyside Canals and in the major drains in the Sulphur Creek basin during the 1976 irrigation and 1976-77 nonirrigation seasons, calculated by harmonic analaysis[1]

| Site | Station name | Nitrate-plus-nitrite (as N) | | Total nitrogen (as N) | | Total phosphorus (as P) | | Suspended sediment | |
|---|---|---|---|---|---|---|---|---|---|
| | | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) |
| | Roza Canal (irrigation season) | | | | | | | | |
| 9 | At Scoon Road | 0.11 ± 0.05 | 34 ± 12 | 0.34 ± 0.05 | 100 ± 20 | 0.06 ± 0.01 | 21 ± 3 | 35 ± 4 | 11,000 ± 1,000 |
| 10 | Below Sulphur Creek Wastway | .08 ± .02 | 21 ± 4 | .32 ± .03 | 79 ± 7 | .07 ± .01 | 18 ± 1 | 51 ± 4 | 13,000 ± 1,000 |
| 11 | At Black Canyon Road | .08 ± .02 | 20 ± 4 | .34 ± .04 | 76 ± 8 | .08 ± .01 | 18 ± 2 | 58 ± 5 | 14,000 ± 2,000 |
| 12 | At Factory Road | .07 ± .02 | 16 ± 5 | .34 ± .05 | 70 ± 11 | .09 ± .01 | 17 ± 1 | 84 ± 8 | 17,000 ± 2,000 |
| 13 | At Wilgus Road | .08 ± .03 | 12 ± 4 | .37 ± .06 | 57 ± 11 | .08 ± .01 | 14 ± 1 | 81 ± 6 | 13,000 ± 1,000 |
| | Sunnyside Canal (irrigation season) | | | | | | | | |
| 14 | At Maple Grove Road | .11 ± .02 | 45 ± 7 | .41 ± .04 | 160 ± 20 | .12 ± .02 | 52 ± 7 | 110 ± 10 | 49,000 ± 6,000 |
| 15 | Below Sulphur Creek Wasteway | .17 ± .07 | 59 ± 24 | .47 ± .07 | 170 ± 30 | .13 ± .02 | 49 ± 5 | 130 ± 10 | 49,000 ± 5,000 |
| 16 | At Edison Road | .14 ± .02 | 50 ± 7 | .49 ± .04 | 170 ± 10 | .15 ± .02 | 52 ± 5 | 170 ± 10 | 62,000 ± 4,000 |
| 17 | At Bethany Road | .15 ± .02 | 50 ± 5 | .52 ± .05 | 170 ± 20 | .15 ± .02 | 50 ± 6 | 170 ± 10 | 58,000 ± 4,000 |
| 18 | At Grandview | .18 ± .02 | 55 ± 7 | .54 ± .06 | 160 ± 20 | .16 ± .02 | 51 ± 4 | 200 ± 20 | 62,000 ± 7,000 |
| | Drains (irrigation season) | | | | | | | | |
| 7 | DID 3 | 2.9 ± .3 | 51 ± 4 | 5.2 ± .4 | 91 ± 6 | 1.1 ± .1 | 21 ± 2 | 580 ± 40 | 11,000 ± 700 |
| 3 | Washout | 2.9 ± .5 | 16 ± 1 | 4.5 ± .6 | 28 ± 4 | .56 ± .08 | 4.2 ± .5 | 630 ± 70 | 4,400 ± 500 |
| 2 | DID 18 | 3.8 ± .3 | 33 ± 1 | 5.5 ± .3 | 48 ± 3 | 1.0 ± .3 | 9.3 ± 1.8 | 1,200 ± 100 | 11,000 ± 1,000 |
| 5 | Black Canyon Creek | 4.1 ± .6 | 49 ± 4 | 6.5 ± .8 | 79 ± 11 | .91 ± .15 | 11 ± 3 | 1,300 ± 100 | 18,000 ± 2,000 |
| 6 | DID 9 | 3.4 ± .2 | 80 ± 6 | 4.2 ± .3 | 100 ± 10 | .33 ± .04 | 8.5 ± .8 | 440 ± 20 | 11,000 ± 1,000 |
| 8 | Sulphur Creek Wasteway | 2.1 ± .5 | 300 ± 20 | 3.3 ± .6 | 480 ± 30 | .44 ± .05 | 70 ± 6 | 400 ± 20 | 66,000 ± 4,000 |
| | Drains (nonirrigation season)[2] | | | | | | | | |
| 7 | DID 3 | 5.0 ± .8 | 34 ± 5 | 8.1 ± .8 | 58 ± 6 | 1.2 ± .2 | 8.4 ± 1.2 | 180 ± 20 | 1,300 ± 100 |
| 3 | Washout | 7.9 ± .3 | 8.3 ± .4 | 8.3 ± .3 | 8.4 ± .4 | .13 ± .01 | .14 ± .01 | 14 ± 3 | 16 ± 4 |
| 2 | DID 18 | 7.2 ± .4 | 20 ± 1 | 7.9 ± .4 | 23 ± 1 | .31 ± .07 | .78 ± .16 | 210 ± 20 | 630 ± 60 |
| 5 | Black Canyon | 8.2 ± .4 | 32 ± 3 | 8.7 ± .5 | 34 ± 3 | .15 ± .04 | .64 ± .13 | 88 ± 8 | 430 ± 40 |
| 6 | DID 9 | 5.5 ± .3 | 53 ± 3 | 6.3 ± .6 | 60 ± 6 | .23 ± .08 | 2.2 ± .8 | 240 ± 10 | 2,300 ± 200 |
| 8 | Sulphur Creek Wasteway | 5.2 ± .7 | 160 ± 20 | 6.1 ± .7 | 180 ± 20 | .31 ± .04 | 10 ± 1 | 62 ± 16 | 2,300 ± 900 |

[1]Confidence limits are based on a computed 90-percent confidence level.

[2]For the nonirrigations season, the discharge from each drain is also the total surficial outflow of the respective subbasin because the canals are all dry.

TABLE 17.--Constituent discharges and concentrations in Roza and Sunnyside Canals and in the major drains in the Sulphur Creek basin during the 1976 irrigation and 1976-77 nonirrigation seasons, calculated by fourth-degree-polynomial analysis[1]

| Site | Station name | Nitrate-plus-nitrite (as N) | | Total nitrogen (as N) | | Total phosphorus (as P) | | Suspended sediment | |
|---|---|---|---|---|---|---|---|---|---|
| | | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) | Discharge-weighted mean concentration (mg/L) | Seasonal discharge (tons) |
| | Roza Canal (irrigation season) | | | | | | | | |
| 9 | At Scoon Road | 0.10 ± 0.03 | 30 ± 9 | 0.33 ± 0.05 | 99 ± 14 | 0.07 ± 0.01 | 20 ± 2 | 36 ± 1 | 11,000 ± 3,000 |
| 10 | Below Sulphur Creek Wastway | .08 ± .02 | 21 ± 5 | .32 ± .03 | 79 ± 8 | .07 ± .01 | 17 ± 1 | 51 ± 4 | 13,000 ± 1,000 |
| 11 | At Black Canyon Road | .08 ± .02 | 18 ± 4 | .33 ± .04 | 74 ± 9 | .07 ± .01 | 17 ± 2 | 58 ± 4 | 14,000 ± 1,000 |
| 12 | At Factory Road | .07 ± .03 | 16 ± 5 | .34 ± .05 | 68 ± 11 | .08 ± .01 | 16 ± 1 | 83 ± 7 | 17,000 ± 1,000 |
| 13 | At Wilgus Road | .07 ± .03 | 11 ± 4 | .36 ± .06 | 56 ± 10 | .09 ± .01 | 14 ± 1 | 81 ± 5 | 13,000 ± 1,000 |
| | Sunnyside Canal (irrigation season) | | | | | | | | |
| 14 | At Maple Grove Road | .11 ± .02 | 44 ± 7 | .40 ± .03 | 160 ± 10 | .12 ± .02 | 50 ± 6 | 110 ± 10 | 48,000 ± 6,000 |
| 15 | Below Sulphur Creek Wasteway | .17 ± .07 | 60 ± 20 | .42 ± .07 | 150 ± 30 | .13 ± .01 | 48 ± 3 | 130 ± 10 | 48,000 ± 4,000 |
| 16 | At Edison Road | .14 ± .02 | 49 ± 6 | .49 ± .03 | 170 ± 10 | .15 ± .02 | 52 ± 5 | 170 ± 10 | 61,000 ± 3,000 |
| 17 | At Bethany Road | .16 ± .02 | 49 ± 5 | .52 ± .05 | 170 ± 20 | .15 ± .02 | 49 ± 4 | 170 ± 10 | 56,000 ± 3,000 |
| 18 | At Grandview | .18 ± .02 | 53 ± 6 | .53 ± .05 | 160 ± 20 | .16 ± .01 | 49 ± 3 | 200 ± 20 | 61,000 ± 7,000 |
| | Drains (irrigation season) | | | | | | | | |
| 7 | DIO-3 | 2.9 ± .3 | 49 ± 4 | 5.0 ± .4 | 89 ± 6 | 1.1 ± .1 | 20 ± 1 | 580 ± 30 | 11,000 ± 500 |
| 3 | Washout | 2.7 ± .4 | 16 ± 1 | 4.2 ± .5 | 27 ± 4 | .56 ± .07 | 3.9 ± .5 | 640 ± 60 | 4,400 ± 400 |
| 2 | DID-18 | 3.7 ± .2 | 33 ± 1 | 5.6 ± .3 | 49 ± 3 | 1.1 ± .2 | 9.6 ± 1.7 | 1,200 ± 100 | 11,000 ± 1,000 |
| 5 | Black Canyon Creek | 3.8 ± .4 | 47 ± 3 | 6.1 ± .6 | 77 ± 9 | .90 ± .12 | 12 ± 2 | 1,300 ± 100 | 17,000 ± 1,400 |
| 6 | OID-9 | 3.3 ± .2 | 80 ± 5 | 4.1 ± .3 | 100 ± 10 | .33 ± .04 | 8.5 ± .7 | 440 ± 20 | 11,000 ± 400 |
| 8 | Sulphur Creek Wasteway | 1.8 ± .3 | 300 ± 20 | 2.9 ± .3 | 470 ± 40 | .43 ± .03 | 69 ± 4 | 400 ± 20 | 66,000 ± 3,000 |
| | Drains (nonirrigation season)[2] | | | | | | | | |
| 7 | DID-3 | 4.8 ± .7 | 34 ± 7 | 8.0 ± 1.5 | 58 ± 18 | 1.2 ± .2 | 8.2 ± 1.9 | 180 ± 40 | 1,200 ± 300 |
| 3 | Washout | 7.8 ± 1.1 | 7.9 ± 1.0 | 8.3 ± 1.2 | 8.3 ± 1.4 | .13 ± .01 | .16 ± .68 | 15 ± 7 | 17 ± 7 |
| 2 | DID-18 | 7.2 ± .2 | 20 ± 1 | 7.9 ± .8 | 22 ± 3 | .30 ± .12 | .81 ± .68 | 210 ± 40 | 600 ± 130 |
| 5 | Black Canyon | 8.2 ± 1.2 | 33 ± 6 | 8.7 ± 1.1 | 35 ± 6 | .15 ± .11 | .64 ± .68 | 90 ± 15 | 410 ± 80 |
| 6 | DID-9 | 5.5 ± .5 | 52 ± 3 | 6.3 ± 2.0 | 60 ± 17 | .24 ± .23 | 2.3 ± .2 | 240 ± 20 | 2,500 ± 300 |
| 8 | Sulphur Creek Wasteway | 5.1 ± .6 | 150 ± 20 | 6.0 ± .6 | 180 ± 20 | .32 ± .11 | 10 ± 4 | 62 ± 38 | 2,300 ± 2,100 |

[1]Confidence limits are based on a computed 90-percent confidence level.

[2]For the nonirrigations season, the discharge from each drain is also the total surficial outflow of the respective subbasin because the canals are all dry.

## SUMMARY

The following is a summary of the results, based on data collected April 1976 to March 1977:

1. The net (inflow minus outflow) contributions of Roza Canal to the Sulphur Creek basin were: water inflow--97,000 acre-feet; total sediment outflow, 3,000 tons; nitrate-plus-nitrite (as N) inflow, 19 tons; total nitrogen inflow, 42 tons; and total phosphorus inflow, 7 tons.

2. The net contributions of Sunnyside Canal to the Sulphur Creek basin were: water inflow, 82,000 acre-feet; total sediment outflow, 18,000 tons; nitrate-plus-nitrite outflow, 9 tons; total nitrogen inflow, 10 tons; and total phosphorus inflow, 1 ton.

3. Roza Canal contributed more of all nutrients to the basin than it removed, and Sunnyside Canal contributed more total nitrogen and total phosphorus than it removed.

4. About 41,000 acre-feet of the water in Sulphur Creek Wasteway was excess water spilled from Roza and Sunnyside Canals. This spilled water tended to reduce constituent concentrations and water temperatures in Sulphur Creek Wasteway.

5. For the 12 months spanning the 1976 irrigation season and the 1976-77 nonirrigation season, Sulphur Creek Wasteway discharged 66,000 tons of sediment, 460 tons of nitrate-plus-nitrite, 660 tons of total nitrogen, and 78 tons of total phosphorus to the Yakima River. The five major drains discharged a total of 59,000 tons of sediment, 370 tons of nitrate-plus-nitrite, 520 tons of total nitrogen, and 66 tons of total phosphorus to Sulphur Creek Wasteway.

6. Constituent concentrations in the drains were generally 5 to 20 times greater than in the delivery waters. Mean suspended-sediment concentrations in the drains ranged from 380 mg/L for Sulphur Creek Wasteway to 1300 mg/L for Black Canyon Creek. Mean sediment concentrations in the canals at the point of entry into Sulphur Creek basin were 37 mg/L for Roza Canal and 120 mg/L for Sunnyside Canal.

7. Net constituent outflows for the nonirrigation season, expressed as percentages of the total year's outflow, are as follows: sediment, 3 percent; nitrate-plus-nitrite, 36 percent; total nitrogen--32 percent; and total phosphorus, 17 percent. Little error in the calculation of annual net-sediment outflows would be caused by using only the irrigation season data. A much larger error would result, however, if a similar assumption is made for nutrients.

8. Nitrate-plus-nitrite constituted 70 percent of the total nitrogen outflow in the irrigation season and 84 percent in the nonirrigation season. Nitrate-plus-nitrite discharges were a considerably greater fraction of the total nitrogen discharge in the drains than in the canals, by about 35 percent.

9. Temperatures in the drains were about 2°C warmer than in the canals.

10. Sediment yields during the irrigation season in the Sulphur Creek basin ranged from 0.5 ton per acre for DID-9 subbasin to 7.0 tons per acre for DID-18 subbasin, and 1.9 tons per acre for the entire basin. During the nonirrigation season, yields were less than 0.2 ton per acre for all subbasins, and only 0.05 ton per acre for the entire basin. Sediment yields coincided with the order of increasing percentage of land slopes greater than 2 percent. DID-9 subbasin produced the lowest yield and also had the lowest average land slope of all the subbasins studied.

11. Nutrient yields for the basin during the irrigation season were about 14 pounds per acre for nitrite-plus-nitrate, 19 pounds per acre for total nitrogen, and 2.4 pounds per acre for total phosphorus. Nutrient yields during the nonirrigation season were 8 pounds per acre for nitrite-plus-nitrate, 9 pounds per acre for total nitrogen, and 0.5 pound per acre for total phosphorus.

12. Storm runoff was not a major factor during the study, but the little evidence available suggests it could, at times, be equal to or more important than irrigation as a cause of sediment discharge.

13. A net change in sediment discharge from the DID 18 and Black Canyon Creek subbasins of about 27 percent and 23 percent, respectively, would be necessary to be detectable. For the entire Sulphur Creek basin, the magnitude of change that could be detected would be about 10 percent. Nutrient discharges and yields were much less precise than those for suspended sediment, because nutrients were sampled less frequently. To achieve the same level of confidence as that attained for suspended sediment, nutrients would need to be collected at about four times the frequency of the 1976 sampling.

14. In the Sulphur Creek basin, constituent concentrations and discharges appear to be annually cyclic; therefore, seasonal mean concentrations and discharges were computed by harmonic and polynomial analysis -- both methods of fitting theoretical time distributions to the data. The results compared favorably with those of the discharge-weighted averaging method. Harmonic and polynomial analyses are potential alternative methods of analyzing water-qualtiy data for an irrigation system that has as stable streamflow, as is found in the Sulphur Creek basin.

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APPENDIX 1. Results of linear-regression analysis[1] of 21 variables, for sites in the Sulphur Creek basin where correlation coefficients were better than 0.8

| Site no. | Station name | Constituents correlated X | Constituents correlated Y | Correlation coefficient | Regression coefficients A | Regression coefficients B | Standard error of estimate Y |
|---|---|---|---|---|---|---|---|
| | Roza Canal | | | | | | |
| 12 | At Factory Road | Sediment | Total phosphorus | 0.88 | 0.05154 | 0.0004583 | 0.01274 |
| | | Nitrite-plus-nitrate | Total nitrogen | .82 | .1888 | 2.154 | .09674 |
| | | Log discharge | Log nitrite-plus-nitrate | .84 | -10.64 | 3.712 | .1871 |
| | | --do-- | Log total nitrogen | .81 | -5.253 | 1.878 | .1139 |
| | | Log sediment | --do-- | .82 | -1.230 | .4221 | .1136 |
| | | --do-- | Log total phosphorus | .91 | -1.716 | .3587 | .06261 |
| | | Log nitrite-plus-nitrate | Log total nitrogen | .84 | .03479 | .4190 | .09444 |
| | | Log total nitrogen | Log total phosphorus | .88 | -.7572 | .6741 | .07007 |
| 13 | At Wilgus Road | Sediment | Total phosphorus | .92 | .04338 | .0006206 | .01168 |
| | | Log sediment | Log total phosphorus | .90 | -1.893 | .4607 | .07102 |
| | | Log nitrite-plus-nitrate | Log total nitrogen | .87 | .2217 | .5728 | .08673 |
| | Sunnyside Canal | | | | | | |
| 15 | Below Sulphur Creek Wasteway | Suspended sediment | Total phosphorus | .83 | .0803 | .00050 | .0240 |
| 16 | At Edison Road | Nitrate-plus-nitrite | Total nitrogen | .90 | .3179 | .9424 | .0699 |
| | | Suspended sediment | Total phosphorus | .84 | .0992 | .00035 | .0221 |
| 17 | At Bethany Road | Sediment | Phosphorus | .88 | .0780 | .00051 | .0267 |
| 18 | At Grandview | --do-- | --do-- | .94 | .0828 | .00049 | .0216 |
| | Drain Sites | | | | | | |
| 7 | DID-3 | Streamflow | Nitrate-plus-nitrite | -.90 | 7.065 | -.1219 | .4524 |
| | | Nitrate-plus-nitrite | Total nitrogen | .88 | 1.811 | 1.115 | .6321 |
| 3 | Washout | Log suspended sediment | Log total phosphorus | .95 | -1.830 | .5776 | .0791 |
| 2 | DID-18 | Streamflow | Nitrate-plus-nitrite | -.86 | 5.913 | -.1340 | .2804 |
| | | Log streamflow | Log total nitrogen | -.82 | 1.771 | -.8543 | .0583 |
| | | Log suspended sediment | Log total phosphorus | .89 | -2.646 | .8679 | .1198 |
| | | Total nitrogen | Total phosphorus | .84 | 1.582 | .4942 | .4463 |
| 5 | Black Canyon Creek | Suspended sediment | Total nitrogen | .87 | 3.517 | .0021 | 1.124 |
| | | Log total nitrogen | Log total phosphorus | .90 | -1.435 | 1.730 | .1380 |
| 6 | DID-9 | Nitrate-plus-nitrite | Total nitrogen | .95 | .9534 | .9534 | .2547 |
| 8 | Sulphur Creek Wasteway | Log specific conductance | Log nitrate-plus-nitrite | .80 | -2.337 | 1.045 | .0617 |
| | | Log suspended sediment | Log total phosphorus | .84 | -2.044 | .6460 | .1011 |
| | | Log nitrate-plus-nitrite | --do-- | .92 | .1733 | 1.075 | .0471 |
| | | Total nitrogen | Total phosphorus | .80 | -.0963 | .1800 | .1030 |

[1] Regression equation is of form Y = A X + B, and log Y = A log X + B.

APPENDIX 2.--Maximum and minimum observed values of selected constituents in Roza and Sunnyside Canals in Sulphur Creek basin, during the 1976 irrigation season

| Site | Station name | Constituent | Number of samples | Extremes | |
|---|---|---|---|---|---|
| | | | | Maximum | Minimum |
| | Roza Canal | | | | |
| 9 | At Scoon Road | Water discharge ($ft^3/s$) | -- | 680 | 373 |
| | | Water temperature ($^oC$) | 57 | 19.6 | 4.4 |
| | | Specific conductance (umhos/cm) | 58 | 123 | 69 |
| | | Suspended-sediment concentration (mg/L) | 58 | 108 | 1 |
| | | Turbidity (NTU) | 58 | 13 | 1 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .48 | .0 |
| | | Total nitrogen as N (mg/L) | 18 | .64 | .13 |
| | | Total phosphorus as P (mg/L) | 18 | .12 | .04 |
| 10 | Below Sulphur Creek Wasteway | Water discharge ($ft^3/s$) | Continuous | 570 | 30 |
| | | Water temperature ($^oC$) | 58 | 19.8 | 7.0 |
| | | Specific conductance (umhos/cm) | 59 | 123 | 67 |
| | | Suspended-sediment concentration (mg/L) | 59 | 124 | 8 |
| | | Turbidity (NTU) | 59 | 11 | 2 |
| | | Nitrite-plus-nitrate as N (mg/L) | 19 | .21 | .01 |
| | | Total nitrogen as N (mg/L) | 19 | .53 | .19 |
| | | Total phosphorus as P (mg/L) | 19 | .10 | .02 |
| 11 | At Black Canyon Creek crossing | Water discharge ($ft^3/s$) | -- | 515 | 252 |
| | | Water temperature ($^oC$) | 57 | 20 | 7.2 |
| | | Specific conductance (umhos/cm) | 58 | 123 | 72 |
| | | Suspended-sediment concentration (mg/L) | 58 | 149 | 8 |
| | | Turbidity (NTU) | 58 | 14 | 2 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .22 | .0 |
| | | Total nitrogen as N (mg/L) | 18 | .54 | .21 |
| | | Total phosphorus as P (mg/L) | 18 | .12 | .03 |
| 12 | At Factory Road | Water discharge ($ft^3/s$) | -- | 438 | 225 |
| | | Water temperature ($^oC$) | 58 | 21.3 | 6.8 |
| | | Specific conductance (umhos/cm) | 58 | 123 | 58 |
| | | Suspended-sediment concentration (mg/L) | 58 | 216 | 10 |
| | | Turbidity (NTU) | 58 | 15 | 2 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .28 | .0 |
| | | Total nitrogen as N (mg/L) | 18 | .78 | .13 |
| | | Total phosphorus as P (mg/L) | 18 | .12 | .04 |
| 13 | At Wilgus Road | Water discharge ($ft^3/s$) | -- | 329 | 187 |
| | | Water temperature ($^oC$) | 56 | 22.1 | 7.4 |
| | | Specific conductance (umhos/cm) | 58 | 128 | 54 |
| | | Suspended-sediment concentration (mg/L) | 58 | 175 | 15 |
| | | Turbidity (NTU) | 58 | 16 | 2 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .26 | .0 |
| | | Total nitrogen as N (mg/L) | 18 | .84 | .20 |
| | | Total phosphorus as P (mg/L) | 18 | .12 | .04 |
| | Sunnyside Canal | | | | |
| 14 | At Maple Grove Road | Water discharge ($ft^3/s$) | -- | 870 | 450 |
| | | Water temperature ($^oC$) | 57 | 20.8 | 8.0 |
| | | Specific conductance (umhos/cm) | 58 | 160 | 66 |
| | | Suspended-sediment concentration (mg/L) | 58 | 477 | 17 |
| | | Turbidity (NTU) | 58 | 18 | 3 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .22 | .03 |
| | | Total nitrogen as N (mg/L) | 18 | .61 | .28 |
| | | Total phosphorus as P (mg/L) | 18 | .20 | .05 |
| 15 | Below Sulphur Creek Wasteway | Water discharge ($ft^3/s$) | Continuous | 768 | 100 |
| | | Water temperature ($^oC$) | 58 | 20.6 | 8.4 |
| | | Specific conductance (umhos/cm) | 58 | 165 | 55 |
| | | Suspended-sediment concentration (mg/L) | 58 | 448 | 13 |
| | | Turbidity (NTU) | 58 | 21 | 3 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .73 | .05 |
| | | Total nitrogen as N (mg/L) | 18 | 1.00 | .27 |
| | | Total phosphorus as P (mg/L) | 18 | .20 | .08 |
| 16 | At Edison Road | Water discharge ($ft^3/s$) | -- | 740 | 150 |
| | | Water temperature ($^oC$) | 58 | 20.2 | 8.2 |
| | | Specific conductance (umhos/cm) | 58 | 160 | 60 |
| | | Suspended-sediment concentration (mg/L) | 58 | 394 | 24 |
| | | Turbidity (NTU) | 58 | 25 | 3 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .28 | .06 |
| | | Total nitrogen as N (mg/L) | 18 | .69 | .39 |
| | | Total phosphorus as P (mg/L) | 18 | .21 | .10 |
| 17 | At Bethany Road | Water discharge ($ft^3/s$) | -- | 690 | 120 |
| | | Water temperature ($^oC$) | 58 | 20.6 | 8.6 |
| | | Specific conductance (umhos/cm) | 58 | 160 | 72 |
| | | Suspended-sediment concentration (mg/L) | 58 | 3.93 | 21 |
| | | Turbidity (NTU) | 58 | 31 | 2 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .27 | .06 |
| | | Total nitrogen as N (mg/L) | 18 | .84 | .38 |
| | | Total phosphorus as P (mg/L) | 18 | .27 | .09 |
| 18 | At Grandview | Water discharge ($ft^3/s$) | -- | 650 | 155 |
| | | Water temperature ($^oC$) | 56 | 21.5 | 8.2 |
| | | Specific conductance (umhos/cm) | 58 | 165 | 76 |
| | | Suspended-sediment concentration (mg/L) | 58 | 776 | 19 |
| | | Turbidity (NTU) | 58 | 38 | 3 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | .32 | .09 |
| | | Total nitrogen as N (mg/L) | 18 | 1.00 | .38 |
| | | Total phosphorus as P (mg/L) | 18 | .27 | .08 |

APPENDIX 3.--Maximum and minimum observed values of selected characteristics in the major drains in Sulphur Creek basin, during the 1976 irrigation season and the 1976-77 nonirrigation season

| Site | Station name | Constituent or characteristic | Number of samples | Extremes Maximum | Extremes Minimum |
|---|---|---|---|---|---|
| | | **Irrigation Season** | | | |
| 2 | DID-18 Drain | Water discharge ($ft^3/s$) | Continuous | 23 | 9.3 |
| | | Water temperature ($^oC$) | 58 | 23.2 | 10.1 |
| | | Specific conductance (umhos/cm) | 59 | 800 | 365 |
| | | Suspended-sediment concentration (mg/L) | 59 | 4,030 | 258 |
| | | Turbidity (NTU) | 59 | 200 | 5 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | 4.7 | 2.9 |
| | | Total nitrogen as N (mg/L) | 18 | 9.2 | 3.6 |
| | | Total phosphorus as P (mg/L) | 18 | 3.8 | .34 |
| | | **Nonirrigation Season** | | | |
| | | Water discharge ($ft^3/s$) | Continuous | 11 | 2.0 |
| | | Water temperature ($^oC$) | 33 | 14.4 | 5.9 |
| | | Specific-conductance (umhos/cm) | 33 | 808 | 594 |
| | | Suspended sediment concentration (mg/L) | 33 | 351 | 104 |
| | | Turbidity (NTU) | 33 | 15 | 5 |
| | | Nitrite-plus-nitrate as N (mg/L) | 8 | 8.0 | 5.8 |
| | | Total nitrogen as N (mg/L) | 8 | 9.1 | 6.5 |
| | | Total phosphorus as P (mg/L) | 8 | .64 | .15 |
| | | **Irrigation Season** | | | |
| 3 | Washout Drain | Water discharge ($ft^3/s$) | -- | 19 | 3.7 |
| | | Water temperature ($^oC$) | 57 | 24.8 | 11.0 |
| | | Specific-conductance (umhos/cm) | 58 | 670 | 232 |
| | | Suspended-sediment concentration (mg/L) | 58 | 1,780 | 10 |
| | | Turbidity (NTU) | 58 | 117 | 3 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | 3.5 | 1.6 |
| | | Total nitrogen as N (mg/L) | 18 | 7.6 | 2.4 |
| | | Total phosphorus as P (mg/L) | 18 | 1.2 | .17 |
| | | **Nonirrigation Season** | | | |
| | | Water discharge ($ft^3/s$) | -- | 4.0 | 1.7 |
| | | Water temperature ($^oC$) | 32 | 14.4 | 3.6 |
| | | Specific conductance (umhos/cm) | 32 | 800 | 519 |
| | | Suspended-sediment concentration (mg/L) | 32 | 46 | 2 |
| | | Turbidity (NTU) | 32 | 4 | 1 |
| | | Nitrite-plus-nitrate as N (mg/L) | 8 | 8.5 | 7.3 |
| | | Total nitrogen as N (mg/L) | 8 | 9.0 | 7.6 |
| | | Total phosphorus as P (mg/L) | 8 | .16 | .11 |
| | | **Irrigation Season** | | | |
| 5 | Black Canyon Creek | Water discharge ($ft^3/s$) | Continuous | 33 | 7.9 |
| | | Water temperature ($^oC$) | 58 | 24.0 | 10.5 |
| | | Specific conductance (umhos/cm) | 59 | 650 | 285 |
| | | Suspended-sediment concentration (mg/L) | 58 | 2,960 | 84 |
| | | Turbidity (NTU) | 59 | 184 | 8 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | 4.8 | 1.9 |
| | | Total nitrogen as N (mg/L) | 18 | 11.0 | 2.3 |
| | | Total phosphorus as P (mg/L) | 18 | 2.0 | .18 |
| | | **Nonirrigation Season** | | | |
| | | Water discharge ($ft^3/s$) | Continuous | 16 | 1.9 |
| | | Water temperature ($^oC$) | 33 | 13.7 | 4.6 |
| | | Specific conductance (umhos/cm) | 33 | 720 | 478 |
| | | Suspended-sediment concentration (mg/L) | 33 | 171 | 9 |
| | | Turbidity (NTU) | 33 | 7 | 1 |
| | | Nitrite-plus-nitrate as N (mg/L) | 8 | 9.4 | 6.9 |
| | | Total nitrogen as N (mg/L) | 8 | 9.8 | 7.3 |
| | | Total phosphorus as P (mg/L) | 8 | .23 | .11 |

APPENDIX 3.--Maximum and minimum observed values of selected characteristics in the major drains in Sulphur Creek basin, during the 1976 irrigation season and the 1976-77 nonirrigation season--Continued

| Site | Station name | Constituent or characteristic | Number of samples | Extremes Maximum | Extremes Minimum |
|---|---|---|---|---|---|
| | | Irrigation Season | | | |
| 6 | DID-9 Drain | Water discharge ($ft^3/s$) | Continuous | 59 | 16 |
| | | Water temperature (°C) | 58 | 23.0 | 10.1 |
| | | Specific conductance (umhos/cm) | 59 | 670 | 345 |
| | | Suspended-sediment concentration (mg/L) | 59 | 769 | 66 |
| | | Turbidity (NTU) | 59 | 62 | 2 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | 5.3 | 2.6 |
| | | Total nitrogen as N (mg/L) | 18 | 6.2 | 3.3 |
| | | Total phosphorus as P (mg/L) | 18 | .53 | .17 |
| | | Nonirrigation Season | | | |
| | | Water discharge ($ft^3/s$) | Continuous | 33 | 12 |
| | | Water temperature (°C) | 33 | 13.4 | 4.3 |
| | | Specific conductance (umhos/cm) | 33 | 700 | 502 |
| | | Suspended-sediment concentration (mg/L) | 33 | 364 | 97 |
| | | Turbidity (NTU) | 33 | 15 | 3 |
| | | Nitrite-plus-nitrate as N (mg/L) | 8 | 6.3 | 3.8 |
| | | Total nitrogen as N (mg/L) | 8 | 8.7 | 4.4 |
| | | Total phosphorus as P (mg/L) | 8 | .46 | .16 |
| | | Irrigation Season | | | |
| 7 | DID-3 Drain | Water discharge ($ft^3/s$) | Continuous | 44 | 15 |
| | | Water temperature (°C) | 58 | 25.0 | 11.1 |
| | | Specific conductance (umhos/cm) | 59 | 800 | 337 |
| | | Suspended-sediment concentration (mg/L) | 59 | 1,570 | 115 |
| | | Turbidity (NTU) | 59 | 88 | 5 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | 5.8 | 1.9 |
| | | Total nitrogen as N (mg/L) | 18 | 8.4 | 3.3 |
| | | Total phosphorus as P (mg/L) | 18 | 1.6 | .64 |
| | | Nonirrigation Season | | | |
| | | Water discharge ($ft^3/s$) | Continuous | 24 | 11 |
| | | Water temperature (°C) | 33 | 14.9 | 5.8 |
| | | Specific conductance (umhos/cm) | 33 | 828 | 539 |
| | | Suspended-sediment concentration (mg/L) | 33 | 520 | 65 |
| | | Turbidity (NTU) | 33 | 30 | 6 |
| | | Nitrite-plus-nitrate as N (mg/L) | 8 | 7.0 | 1.2 |
| | | Total nitrogen as N (mg/L) | 8 | 10.0 | 4.3 |
| | | Total phosphorus as P (mg/L) | 8 | 1.7 | .31 |
| | | Irrigation Season | | | |
| 8 | Sulphur Creek Wasteway | Water discharge ($ft^3/s$) | Continuous | 456 | 132 |
| | | Water temperature (°C) | 58 | 23.7 | 9.6 |
| | | Specific conductance (umhos/cm) | 59 | 580 | 195 |
| | | Suspended-sediment concentration (mg/L) | 58 | 743 | 94 |
| | | Turbidity (NTU) | 59 | 36 | 6 |
| | | Nitrite-plus-nitrate as N (mg/L) | 18 | 2.5 | .92 |
| | | Total nitrogen as N (mg/L) | 18 | 4.4 | 1.4 |
| | | Total phosphorus as P (mg/L) | 18 | .70 | .18 |
| | | Nonirrigation Season | | | |
| | | Water discharge ($ft^3/s$) | Continuous | 128 | 50 |
| | | Water temperature (°C) | 33 | 13.6 | 4.6 |
| | | Specific conductance (umhos/cm) | 33 | 704 | 396 |
| | | Suspended-sediment concentration (mg/L) | 33 | 328 | 9 |
| | | Turbidity (NTU) | 33 | 12.0 | 2.0 |
| | | Nitrite-plus-nitrate as N (mg/L) | 8 | 6.4 | 1.2 |
| | | Total nitrogen as N (mg/L) | 8 | 7.3 | 1.9 |
| | | Total phosphorus as P (mg/L) | 8 | .41 | .24 |

APPENDIXES 4a-4h.--Coefficients for mathematical approximations of constituent concentrations and discharges by harmonic analysis and fourth-degree-polynomial analysis. Coefficients based on data collected April 1, 1976 to March 31, 1977

[Note: Coefficients for irrigation season constituent concentrations and discharges are obtained from a least-squares fit of the entire year's data. Coefficients for the nonirrigation seasons are obtained from a least-squares fit of the nonirrigation season's data only.]

| Station name | Site | Harmonic analysis | | | | | | Fourth-degree-polynomial analysis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nonirrigation | | | Irrigation | | | Nonirrigation | | | | | Irrigation | | | | |
| | | A | Ø | M | A | Ø | M | c | e | f | g | h | c | e | f | g | h |
| **Appendix 4a.--Coefficients for calculation of nitrate-plus-nitrite concentrations, in mg/L** | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 0.09 | 1.80 | 0.16 | -- | -- | -- | -- | -- | 7.73501 | -68.26049 | 217.02617 | -293.05196 | 142.68790 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | .08 | 4.37 | .04 | -- | -- | -- | -- | -- | .82825 | -8.30455 | 29.18253 | -40.51628 | 19.38903 |
| At Black Canyon Road | 11 | -- | -- | -- | .08 | 4.48 | .03 | -- | -- | -- | -- | -- | 2.55803 | -22.91667 | 73.49532 | -97.73270 | 45.99942 |
| At Factory Road | 12 | -- | -- | -- | .11 | 4.47 | .01 | -- | -- | -- | -- | -- | 2.38620 | -21.49594 | 69.06239 | -91.58497 | 42.81739 |
| At Wilgus Road | 13 | -- | -- | -- | .07 | 4.55 | .04 | -- | -- | -- | -- | -- | 2.32677 | -21.10068 | 68.33095 | -91.62750 | 43.46684 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | .05 | 3.06 | .11 | -- | -- | -- | -- | -- | 1.52237 | -13.83665 | 45.67598 | -62.48778 | 30.57592 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | .07 | 1.17 | .21 | -- | -- | -- | -- | -- | -5.47476 | -48.71094 | -147.84417 | 188.54547 | -86.02224 |
| At Edison Road | 16 | -- | -- | -- | .06 | 3.40 | .13 | -- | -- | -- | -- | -- | 2.88355 | -25.78977 | 83.28423 | -111.95568 | 53.79021 |
| At Bethany Road | 17 | -- | -- | -- | .06 | 3.10 | .15 | -- | -- | -- | -- | -- | 2.43274 | -21.10004 | 67.09979 | -89.09865 | 42.46311 |
| At Grandview | 18 | -- | -- | -- | .06 | 3.65 | .16 | -- | -- | -- | -- | -- | 4.24780 | -37.26604 | 118.77516 | -158.41661 | 75.57688 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 2.99 | 0.63 | 3.42 | 2.00 | .75 | 3.81 | -3365.10090 | 12714.72488 | -17905.69661 | 11152.10065 | -2590.82773 | 12.36305 | -33.86632 | 23.54796 | 13.60688 | -10.82685 |
| Washout | 3 | 1.06 | 1.14 | 7.17 | 3.29 | 1.33 | 4.76 | -374.53209 | 1484.03628 | -2167.55370 | 1411.57075 | -345.43851 | -7.78267 | 92.52346 | -275.96833 | 323.17209 | -123.75960 |
| DID-18 | 2 | 1.91 | 1.24 | 5.88 | 2.40 | 1.27 | 5.18 | 274.95302 | -1467.45503 | 2728.54464 | -2119.97424 | 591.49826 | 2.30282 | 32.65228 | -132.95167 | 178.89855 | -73.3390 |
| Black Canyon (DID-5) | 5 | 2.32 | 1.08 | 6.66 | 2.67 | 1.21 | 5.59 | 948.19153 | -3573.34526 | 5004.04759 | -3058.56197 | 688.33995 | -15.13448 | 147.43676 | -390.90409 | 418.14650 | -151.04406 |
| DID-9 | 6 | 2.21 | 1.04 | 4.06 | 1.71 | 1.01 | 4.29 | -997.14907 | 3713.24989 | -5148.95820 | 3169.94694 | -731.10709 | 4.04869 | 19.86693 | -97.47957 | 133.74892 | -54.40291 |
| Sulphur Creek | 8 | 4.86 | 1.03 | 2.04 | 2.19 | 1.16 | 3.35 | -3232.22777 | 12207.56670 | -17219.61856 | 10770.86916 | -2520.45036 | -21.32645 | 167.27764 | -415.85835 | 422.53685 | -146.91098 |
| **Appendix 4b.--Coefficients for calculation of nitrate-plus-nitrite discharges, in tons** | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 0.06 | 2.28 | 0.19 | -- | -- | -- | -- | -- | 11.21778 | -98.83258 | 313.06713 | -420.06697 | 202.86223 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | .13 | 4.39 | .03 | -- | -- | -- | -- | -- | 1.66200 | -15.97693 | 53.68220 | -72.29600 | 33.76122 |
| At Black Canyon Road | 11 | -- | -- | -- | .14 | 4.48 | .02 | -- | -- | -- | -- | -- | 3.19016 | -28.95752 | 93.22806 | -123.75802 | 57.91069 |
| At Factory Road | 12 | -- | -- | -- | .14 | 4.45 | -.00 | -- | -- | -- | -- | -- | 3.16525 | -27.99777 | 88.21135 | -115.21728 | 53.20802 |
| At Wilgus Road | 13 | -- | -- | -- | .07 | 4.53 | .02 | -- | -- | -- | -- | -- | 2.13641 | -19.49236 | 63.01774 | -84.18509 | 39.73035 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | .13 | 3.76 | .17 | -- | -- | -- | -- | -- | 3.33466 | -30.72740 | 101.34268 | -137.07827 | 65.70649 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | .04 | .34 | .30 | -- | -- | -- | -- | -- | -10.87619 | -94.60050 | -283.91566 | 360.80265 | -165.12488 |
| At Edison Road | 16 | -- | -- | -- | .18 | 4.01 | .16 | -- | -- | -- | -- | -- | 4.20801 | -39.18577 | 129.63559 | -175.32460 | 83.67844 |
| At Bethany Road | 17 | -- | -- | -- | .15 | 3.90 | .18 | -- | -- | -- | -- | -- | 2.93755 | -27.49980 | 92.15425 | -125.33042 | 60.03481 |
| At Grandview | 18 | -- | -- | -- | .19 | 4.15 | .17 | -- | -- | -- | -- | -- | 4.92800 | -45.59027 | 150.59531 | -204.05696 | 97.59515 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 0.11 | 0.70 | 0.15 | .03 | 5.40 | .24 | -128.34406 | 483.96176 | -679.89890 | 422.37565 | -97.86914 | .05320 | 1.14404 | -1.97634 | 1.07035 | -.03198 |
| Washout | 3 | .03 | 4.07 | .07 | .02 | 4.42 | .07 | 4.59021 | -16.43927 | 22.68307 | -14.15057 | 3.36012 | -.14938 | 1.28443 | -2.33135 | 1.65744 | -.41419 |
| DID-18 | 2 | .05 | 2.50 | .11 | .04 | 3.64 | .15 | 10.27390 | -48.59575 | 84.45863 | -63.27832 | 17.28581 | .16221 | -.46455 | 1.76816 | -1.98666 | .65656 |
| Black Canyon (DID-5) | 5 | .09 | 2.35 | .16 | .05 | 3.73 | .22 | 125.36964 | -489.85698 | 714.67822 | -460.32717 | 110.37441 | .86655 | 6.42874 | -13.21650 | 11.63724 | -3.76414 |
| DID-9 | 6 | .13 | 1.73 | .24 | .05 | 3.98 | .37 | -33.74570 | 138.37881 | -213.65824 | 146.56008 | -37.68427 | -.54921 | 5.83114 | -12.53351 | 11.40760 | -3.79179 |
| Sulphur Creek | 8 | .83 | 1.22 | .40 | .36 | 4.15 | 1.31 | -911.02473 | 3477.01343 | -4949.49173 | 3118.84476 | -734.20505 | -2.21444 | 18.39096 | -29.09075 | 11.22717 | -3.23818 |

APPENDIXES 4a-4h.--Coefficients for mathematical approximations of constituent concentrations and discharges by harmonic analysis and fourth-degree-polynomial analysis. Coefficients based on data collected April 1, 1976 to March 31, 1977--Continued

| Station name | Site | Harmonic analysis | | | | | | Fourth-degree-polynomial analysis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nonirrigation | | | Irrigation | | | Nonirrigation | | | | | Irrigation | | | | |
| | | A | Ø | M | A | Ø | M | c | e | f | g | h | c | e | f | g | h |
| Appendix 4c.--Coefficients for calculation of total-nitrogen concentrations, in mg/L | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 0.06 | 3.87 | 0.31 | -- | -- | -- | -- | -- | 3.07591 | -29.52801 | 106.23670 | -155.93311 | 80.39222 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | .14 | 4.63 | .24 | -- | -- | -- | -- | -- | -.18466 | 1.94192 | -.78533 | -2.39163 | 1.35456 |
| At Black Canyon Road | 11 | -- | -- | -- | .17 | 4.58 | .24 | -- | -- | -- | -- | -- | 1.53250 | -14.76592 | 55.99085 | -82.43075 | 41.31582 |
| At Factory Road | 12 | -- | -- | -- | .32 | 4.52 | .16 | -- | -- | -- | -- | -- | 4.23583 | -40.16802 | 137.41288 | -189.02757 | 90.18146 |
| At Wilgus Road | 13 | -- | -- | -- | .21 | 4.52 | .25 | -- | -- | -- | -- | -- | 5.87169 | -54.87448 | 186.98338 | -261.59809 | 128.69262 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | .04 | 3.76 | .39 | -- | -- | -- | -- | -- | 4.53870 | -40.05057 | 134.77878 | -189.13005 | 94.40933 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | .06 | 4.78 | .44 | -- | -- | -- | -- | -- | 4.55487 | -41.58861 | 141.60816 | -197.84245 | 97.53010 |
| At Edison Road | 16 | -- | -- | -- | .13 | 4.52 | .42 | -- | -- | -- | -- | -- | 6.32525 | -54.49425 | 177.72395 | -241.44823 | 116.44529 |
| At Bethany Road | 17 | -- | -- | -- | .16 | 4.14 | .44 | -- | -- | -- | -- | -- | 2.57619 | -21.74937 | 74.23603 | -101.46412 | 48.35415 |
| At Grandview | 18 | -- | -- | -- | .25 | 4.52 | .40 | -- | -- | -- | -- | -- | 9.10465 | -80.77229 | 264.40746 | -359.01874 | 172.54291 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 3.73 | 0.76 | 6.01 | 2.66 | .79 | 6.40 | -1142.03219 | 3957.41409 | -5047.94846 | 2823.65576 | -582.25689 | 5.36410 | 36.44324 | -156.29198 | 198.45837 | -75.80861 |
| Washout | 3 | 1.40 | 1.10 | 7.64 | 2.55 | 1.03 | 5.84 | 224.68460 | -864.60642 | 1265.50020 | -805.20995 | 188.21117 | -29.94752 | 255.13553 | -643.57470 | 657.03787 | -229.94308 |
| DID-18 | 2 | 2.20 | 1.19 | 6.41 | 2.16 | .88 | 6.59 | 1338.67046 | -5597.88119 | 8700.76995 | -5929.56465 | 1496.80350 | 16.40591 | -29.81168 | -16.86719 | 81.55152 | -43.06310 |
| Black Canyon (DID-5) | 5 | 2.50 | 1.10 | 7.01 | 1.73 | .47 | 7.07 | 1446.55501 | -5504.05320 | 7789.56901 | -4830.91167 | 1108.06682 | 51.70725 | 405.29197 | -959.17302 | 923.80476 | -309.20702 |
| DID-9 | 6 | 3.42 | 1.19 | 3.94 | 1.72 | .99 | 5.11 | 1153.29490 | -4843.49260 | 7523.02893 | -5105.01333 | 1279.57069 | -1.45327 | 63.57603 | -201.17223 | 235.01149 | -89.17811 |
| Sulphur Creek | 8 | 4.82 | .98 | 2.98 | 1.93 | 1.07 | 4.30 | -2470.83953 | 9155.27020 | -12655.93690 | 7757.10545 | -1778.53654 | -29.44260 | 223.81427 | -532.52850 | 520.11727 | -175.49451 |
| Appendix 4d.--Coefficients for calculation of total-nitrogen discharges, in tons | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 0.28 | 4.26 | 0.35 | -- | -- | -- | -- | -- | 7.10131 | -67.92429 | 234.26893 | -329.63105 | 162.94026 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | .32 | 4.53 | .21 | -- | -- | -- | -- | -- | 1.41571 | -14.17233 | 53.82228 | -75.41759 | 34.80198 |
| At Black Canyon Road | 11 | -- | -- | -- | .36 | 4.55 | .17 | -- | -- | -- | -- | -- | 3.33520 | -33.03435 | 117.86680 | -165.88302 | 80.04090 |
| At Factory Road | 12 | -- | -- | -- | .43 | 4.50 | .10 | -- | -- | -- | -- | -- | 6.37019 | -60.01887 | 200.33232 | -270.85969 | 127.57908 |
| At Wilgus Road | 13 | -- | -- | -- | .25 | 4.51 | .14 | -- | -- | -- | -- | -- | 6.09851 | -57.44227 | 193.59103 | -267.64815 | 130.05797 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | .34 | 4.41 | .62 | -- | -- | -- | -- | -- | 7.91701 | -74.24406 | 259.52749 | -368.77653 | 183.41880 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | .42 | 4.63 | .59 | -- | -- | -- | -- | -- | -5.21276 | -55.43233 | 208.49562 | -305.16198 | 153.02393 |
| At Edison Road | 16 | -- | -- | -- | .60 | 4.51 | .50 | -- | -- | -- | -- | -- | 4.84286 | -51.36595 | 197.14489 | -291.68310 | 146.73489 |
| At Bethany Road | 17 | -- | -- | -- | .57 | 4.35 | .51 | -- | -- | -- | -- | -- | 1.46090 | -20.47003 | 94.23955 | -146.79930 | 74.31465 |
| At Grandview | 18 | -- | -- | -- | .69 | 4.50 | .41 | -- | -- | -- | -- | -- | 10.12290 | -98.26777 | 342.39167 | -480.34698 | 234.22042 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 0.10 | 0.77 | 0.30 | .07 | 4.70 | .41 | 12.32019 | -63.83581 | 116.23540 | -88.85553 | 24.51788 | .96596 | 8.37817 | -16.61046 | 13.24775 | -3.69255 |
| Washout | 3 | .03 | 4.05 | .07 | .07 | 4.84 | .10 | 9.29260 | -34.85678 | 49.63360 | -31.59951 | 7.57641 | -1.14789 | 8.30419 | -17.84885 | 15.50166 | -4.75719 |
| DID-18 | 2 | .06 | 2.49 | .12 | .07 | 4.32 | .20 | 35.10797 | -145.30829 | 224.86287 | -153.29454 | 38.79108 | .38643 | -1.28277 | 3.75700 | -4.25556 | 1.53824 |
| Black Canyon (DID-5) | 5 | .10 | 2.36 | .17 | .16 | 4.57 | .30 | 142.97155 | -558.13646 | 813.44489 | -523.40904 | 125.38187 | -3.44873 | 23.93430 | -50.67405 | 44.12235 | -13.70629 |
| DID-9 | 6 | .19 | 1.68 | .24 | .09 | 4.13 | .45 | 99.44072 | -386.27541 | 558.84609 | -355.21217 | 83.63208 | -1.18079 | 10.17918 | -21.32671 | 18.77048 | -6.02052 |
| Sulphur Creek | 8 | .75 | 1.23 | .61 | .89 | 4.35 | 1.88 | -761.89013 | 2887.08448 | -4077.40156 | 2548.50436 | -594.99051 | -6.29897 | 44.93364 | -73.91712 | 45.04199 | -8.57714 |

APPENDIXES 4a-4h.--Coefficients for mathematical approximations of constituent concentrations and discharges by harmonic analysis and fourth-degree-polynomial analysis. Coefficients based on data collected April 1, 1976 to March 31, 1977--Continued

| Station name | Site | Harmonic analysis | | | | | | Fourth-degree-polynomial analysis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nonirrigation | | | Irrigation | | | Nonirrigation | | | | | Irrigation | | | | |
| | | A | Ø | M | A | Ø | M | c | e | f | g | h | c | e | f | g | h |
| Appendix 4e.--Coefficients for calculation of total phosphorus concentrations, in mg/L | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 0.03 | 4.95 | 0.05 | -- | -- | -- | -- | -- | -1.06644 | 8.67539 | 23.27647 | 26.86990 | -11.29975 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | .04 | 4.70 | .05 | -- | -- | -- | -- | -- | .90064 | 7.15551 | -18.76420 | 21.16887 | -8.80142 |
| At Black Canyon Road | 11 | -- | -- | -- | .05 | 4.61 | .05 | -- | -- | -- | -- | -- | .52058 | 3.63422 | -7.42719 | 6.13461 | -1.76617 |
| At Factory Road | 12 | -- | -- | -- | .05 | 4.68 | .06 | -- | -- | -- | -- | -- | .53641 | 3.85568 | -7.98121 | 6.67107 | -1.95690 |
| At Wilgus Road | 13 | -- | -- | -- | .06 | 4.69 | .05 | -- | -- | -- | -- | -- | .38085 | 2.29103 | -2.50199 | -1.11687 | 1.89144 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | .06 | 4.75 | .09 | -- | -- | -- | -- | -- | 1.20598 | -11.50726 | 41.33402 | -60.26874 | 30.60329 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | .08 | 4.64 | .09 | -- | -- | -- | -- | -- | 1.38217 | -13.69326 | 49.84297 | -72.97405 | 37.05843 |
| At Edison Road | 16 | -- | -- | -- | .06 | 4.86 | .12 | -- | -- | -- | -- | -- | .88978 | -8.05961 | 29.54724 | -43.43828 | 22.00781 |
| At Bethany Road | 17 | -- | -- | -- | .10 | 4.87 | .10 | -- | -- | -- | -- | -- | -.26639 | .49949 | 7.36827 | -19.11633 | 12.33086 |
| At Grandview | 18 | -- | -- | -- | .13 | 4.73 | .09 | -- | -- | -- | -- | -- | .64022 | -7.69086 | 33.06815 | -52.31966 | 27.45040 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 0.7527 | 0.66 | 0.8089 | .40 | 6.25 | 1.16 | -538.65110 | 1991.49775 | -2741.21035 | 1667.89494 | -378.22917 | -2.69584 | 30.99180 | -77.79957 | 75.05084 | -24.37189 |
| Washout | 3 | .0622 | 1.34 | .0908 | .36 | 5.01 | .38 | 10.83048 | -40.59429 | 56.18209 | -33.48178 | 7.21334 | -4.47885 | 34.06628 | -75.11973 | 66.03382 | -20.36020 |
| DID-18 | 2 | .3700 | 4.92 | .5444 | .64 | 5.43 | .80 | 481.01396 | -1913.15695 | 2841.19501 | -1866.86895 | 458.08035 | 13.39621 | -70.49321 | 147.19406 | -134.47181 | 44.47193 |
| Black Canyon (DID-5) | 5 | .0508 | 1.67 | .1169 | .69 | 5.06 | .58 | -2.79873 | 19.57813 | -41.15622 | 35.25751 | -10.72088 | -11.22865 | 81.81775 | -181.71148 | 161.97325 | -50.67909 |
| DID-9 | 6 | .2039 | 1.43 | .0855 | .08 | 4.72 | .29 | 346.77981 | -1371.03538 | 2018.05444 | -1309.81724 | 316.34219 | -1.97675 | 14.99493 | -32.89413 | 29.60843 | -9.46664 |
| Sulphur Creek | 8 | .2062 | 1.33 | .1691 | .14 | 5.29 | .38 | 104.11854 | -404.94924 | 584.84060 | -370.54972 | 86.91783 | -4.24139 | 31.82155 | -72.54649 | 67.14019 | -21.81301 |
| Appendix 4f.--Coefficients for calculation of total phosphorus discharges, in tons | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 0.08 | 4.71 | 0.06 | -- | -- | -- | -- | -- | -.93646 | 6.60640 | -14.15407 | 12.42144 | -3.90056 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | .07 | 4.60 | .05 | -- | -- | -- | -- | -- | -.61848 | 4.19794 | -8.35766 | 6.84390 | -2.08159 |
| At Black Canyon Road | 11 | -- | -- | -- | .09 | 4.57 | .04 | -- | -- | -- | -- | -- | -.10360 | -.51783 | 6.55676 | -12.70312 | 6.98491 |
| At Factory Road | 12 | -- | -- | -- | .08 | 4.60 | .04 | -- | -- | -- | -- | -- | -.09785 | -.33869 | 5.50447 | -11.00531 | 6.14901 |
| At Wilgus Road | 13 | -- | -- | -- | .07 | 4.62 | .03 | -- | -- | -- | -- | -- | .08284 | -1.81511 | 9.68221 | -16.30393 | 8.67985 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | .19 | 4.67 | .15 | -- | -- | -- | -- | -- | 2.14240 | -22.22931 | 83.69384 | -124.37698 | 63.40376 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | .23 | 4.61 | .11 | -- | -- | -- | -- | -- | -1.67697 | -19.67331 | 78.94381 | -120.93088 | 62.61748 |
| At Edison Road | 16 | -- | -- | -- | .21 | 4.68 | .14 | -- | -- | -- | -- | -- | -.15589 | -2.24065 | 21.83792 | -42.75924 | 24.46629 |
| At Bethany Road | 17 | -- | -- | -- | .23 | 4.74 | .12 | -- | -- | -- | -- | -- | -1.26056 | 5.65843 | 2.38920 | -23.27531 | 17.74035 |
| At Grandview | 18 | -- | -- | -- | .27 | 4.66 | .10 | -- | -- | -- | -- | -- | .66175 | -10.82176 | 51.50492 | -84.27735 | 44.69521 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 0.0285 | 0.72 | 0.036 | .04 | 4.84 | .08 | -19.02518 | 69.64417 | -94.76177 | 56.93362 | -12.73428 | .57336 | 4.17623 | -8.57888 | 7.05775 | -2.03185 |
| Washout | 3 | .0003 | 3.65 | .0010 | .02 | 4.87 | .01 | .00100 | .00000 | -.00000 | .00000 | -.00000 | -.21358 | 1.50103 | -3.18875 | 2.71575 | -.81394 |
| DID-18 | 2 | .0049 | 4.52 | .0082 | .03 | 4.91 | .03 | 8.84911 | -34.85568 | 51.28004 | -33.38202 | 8.11319 | .22636 | -1.09427 | 2.58965 | -2.71783 | .99533 |
| Black Canyon (DID-5) | 5 | .0021 | 2.74 | .0036 | .05 | 4.89 | .03 | -.71458 | 3.09881 | -4.93074 | 3.44725 | -.89646 | -.86139 | 5.94478 | -12.77425 | 11.09020 | -3.39557 |
| DID-9 | 6 | .0096 | 1.81 | .0077 | .02 | 4.38 | .03 | 23.95348 | -93.58850 | 136.24869 | -87.53283 | 20.93784 | -.25186 | 1.68760 | -3.22945 | 2.50469 | -.69547 |
| Sulphur Creek | 8 | .0202 | 2.21 | .0525 | .21 | 4.71 | .23 | 22.67352 | -86.43979 | 122.99081 | -77.12784 | 17.97187 | -2.15634 | 15.54969 | -31.75727 | 25.87757 | -7.44801 |

**APPENDIXES 4a-4h.--Coefficients for mathematical approximations of constituent concentrations and discharges by harmonic analysis and fourth-degree polynomial analysis. Coefficients based on data collected April 1, 1976 to March 31, 1977--Continued**

| Station name | Site | Harmonic analysis | | | | | | Fourth-degree-polynomial analysis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nonirrigation | | | Irrigation | | | Nonirrigation | | | | | Irrigation | | | | |
| | | A | Ø | M | A | Ø | M | c | e | f | g | h | c | e | f | g | h |
| Appendix 4g.--Coefficients for calculation of suspended-sediment concentrations, in mg/L | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 31 | 5.55 | 26 | -- | -- | -- | -- | -- | -343.98397 | 2860.11716 | -6856.69451 | 6428.51262 | -2056.72948 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | 58 | 4.95 | 21 | -- | -- | -- | -- | -- | -465.66008 | 2921.54768 | -4364.85211 | 697.53844 | 1410.51693 |
| At Black Canyon Road | 11 | -- | -- | -- | 65 | 4.99 | 25 | -- | -- | -- | -- | -- | -165.14550 | 176.22021 | 4752.13026 | -11978.62711 | 7666.07145 |
| At Factory Road | 12 | -- | -- | -- | 106 | 4.90 | 27 | -- | -- | -- | -- | -- | -79.41763 | -1485.18783 | 12948.73983 | -25762.71260 | 15136.38079 |
| At Wilgus Road | 13 | -- | -- | -- | 93 | 4.87 | 32 | -- | -- | -- | -- | -- | 473.26531 | -5523.67283 | 23095.30346 | -36358.68729 | 19069.53392 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | 153 | 4.80 | 28 | -- | -- | -- | -- | -- | 200.02935 | -4425.98231 | 23612.36952 | -40678.47965 | 22172.59436 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | 169 | 4.84 | 36 | -- | -- | -- | -- | -- | -923.80735 | 4816.33601 | -2977.11175 | -8063.03398 | 7618.03792 |
| At Edison Road | 16 | -- | -- | -- | 218 | 4.83 | 49 | -- | -- | -- | -- | -- | -364.43447 | -701.77133 | 16815.02953 | -36602.46089 | 21820.99053 |
| At Bethany Road | 17 | -- | -- | -- | 225 | 4.83 | 45 | -- | -- | -- | -- | -- | -693.03870 | 1497.14672 | 11976.58962 | -32587.39054 | 20882.29225 |
| At Grandview | 18 | -- | -- | -- | 252 | 4.83 | 64 | -- | -- | -- | -- | -- | 244.92947 | -24362.46537 | 87272.23600 | -125165.831 | 61691.37443 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 130 | 1.53 | 90 | 326 | 4.89 | 413 | -71731.59878 | 260495.63809 | -349958.3974 | 206816.14986 | -45405.24650 | -6449.20473 | 46157.98540 | -100869.7588 | 89236.44072 | -27852.70315 |
| Washout | 3 | 8.83 | 3.25 | 16.12 | 528 | 5.05 | 378 | 14957.82703 | -57852.42542 | 83542.76300 | -53305.61582 | 12674.24535 | -9144.53977 | 66521.85872 | -148779.9787 | 133492.00109 | -42021.25832 |
| DID-18 | 2 | 43 | 1.63 | 181 | 7.64 | 5.13 | 6.18 | -101258.4027 | 406521.54473 | -607566.345 | 401509.65525 | -98997.55473 | -2187.31087 | 28761.88768 | -69037.67333 | 61268.60799 | -18607.85207 |
| Black Canyon (DID-5) | 5 | 47 | 2.27 | 67 | 1011 | 4.82 | 743 | -24077.59955 | 106874.55160 | -174517.6121 | 125027.20460 | -33211.12670 | -19255.11622 | 31676.02733 | -281294.5403 | 243144.81982 | -74174.40061 |
| DID-9 | 6 | 164 | 1.73 | 130 | 157 | 4.64 | 357 | 59807.65310 | -224688.9992 | 312717.47586 | -189792.6136 | 42245.94610 | -31209.38462 | 22935.88882 | -49847.10811 | 44320.52738 | -14017.82121 |
| Sulphur Creek | 8 | 23 | .83 | 48 | 277 | 4.78 | 251 | 1184.43233 | -2686.47978 | 768.85380 | 1893.28928 | -1095.83137 | -4166.53193 | 28853.09090 | -60331.73692 | 50713.49600 | -15017.53556 |
| Appendix 4h.--Coefficients for calculation of suspended-sediment discharges, in tons | | | | | | | | | | | | | | | | | |
| Roza Canal | | | | | | | | | | | | | | | | | |
| At Scoon Road | 9 | -- | -- | -- | 55 | 5.24 | 30 | -- | -- | -- | -- | -- | -516.55324 | 3677.38358 | -7001.97401 | 4130.35866 | -125.52986 |
| Below Sulphur Creek Wasteway | 10 | -- | -- | -- | 90 | 4.85 | 17 | -- | -- | -- | -- | -- | -368.92073 | 1340.00766 | 2712.06185 | -10612.96684 | 7347.44957 |
| At Black Canyon Road | 11 | -- | -- | -- | 95 | 4.85 | 18 | -- | -- | -- | -- | -- | -40.99370 | -1613.47935 | 12192.74721 | -23411.17625 | 13517.11953 |
| At Factory Road | 12 | -- | -- | -- | 125 | 4.80 | 14 | -- | -- | -- | -- | -- | 241.13503 | -4751.21425 | 23936.93303 | -40715.33469 | 22250.52506 |
| At Wilgus Road | 13 | -- | -- | -- | 86 | 4.77 | 16 | -- | -- | -- | -- | -- | 591.06593 | -6610.77539 | 25845.00330 | -39073.94624 | 19981.95680 |
| Sunnyside Canal | | | | | | | | | | | | | | | | | |
| At Maple Grove Road | 14 | -- | -- | -- | 354 | 4.77 | 44 | -- | -- | -- | -- | -- | 265.37292 | -8979.44699 | 51054.70535 | -89479.47090 | 49068.00150 |
| Below Sulphur Creek Wasteway | 15 | -- | -- | -- | 352 | 4.80 | 43 | -- | -- | -- | -- | -- | -2245.63079 | 12005.59179 | -11132.36887 | -11405.17291 | 13733.59659 |
| At Edison Road | 16 | -- | -- | -- | 448 | 4.79 | 55 | -- | -- | -- | -- | -- | -1151.40634 | 1048.51055 | 27985.09288 | -67535.89314 | 41569.47009 |
| At Bethany Road | 17 | -- | -- | -- | 424 | 4.79 | 47 | -- | -- | -- | -- | -- | -1483.93891 | 3588.04697 | 20917.38915 | -59702.04295 | 38694.44919 |
| At Grandview | 18 | -- | -- | -- | 467 | 4.74 | 45 | -- | -- | -- | -- | -- | 31.99866 | -15805.98807 | 79000.69494 | -128505.8961 | 67562.35260 |
| Drains | | | | | | | | | | | | | | | | | |
| DID-3 | 7 | 3 | 1.92 | 6 | 36 | 4.66 | 34 | -3094.60141 | 11587.05697 | -16074.87986 | 9828.89329 | -2237.79068 | 615.43439 | 4113.95852 | -8449.65761 | 7033.24226 | -2074.31753 |
| Washout | 3 | .17 | 3.97 | .2 | 19 | 4.98 | 12 | 97.68747 | -366.27418 | 513.93954 | -319.43798 | 74.16810 | 367.64899 | 2592.51965 | -5718.89725 | 5085.78978 | -1590.10542 |
| DID-18 | 2 | 2 | 3.04 | 4 | 39 | 4.82 | 33 | -2228.95853 | 8963.64921 | -13380.95397 | 8813.34098 | -2163.38335 | 282.32405 | 2201.65268 | -4570.68871 | 3689.68698 | -1037.01403 |
| Black Canyon (DID-5) | 5 | 2 | 3.20 | 3 | 73 | 4.71 | 46 | -182.00622 | 1067.57033 | -2044.19030 | 1627.26032 | -466.12683 | 1370.87232 | 9072.80544 | -18898.97386 | 15965.38035 | -4768.70851 |
| DID-9 | 6 | 8 | 2.35 | 11 | 32 | 4.41 | 38 | 3968.20085 | -14251.33614 | 18934.14982 | -10931.25554 | 2297.44741 | 402.69493 | 2689.70729 | -5250.53546 | 4147.02697 | -1168.26887 |
| Sulphur Creek | 8 | 9 | 4.90 | 20 | 246 | 4.67 | 190 | -5018.83200 | 20909.85458 | -32227.33430 | 21827.33207 | -5480.35510 | -882.76016 | 19466.99686 | -38746.68217 | 30663.32754 | -8507.81564 |