WATER QUALITY CONDITIONS IN STEAMBOAT CREEK,WASHOE COUNTY, NEVADA, 1987-1991

WITH PARTICULAR EMPHASIS ON NONPOINT SOURCE LOADING OF NITROGEN, PHOSPHORUS AND SELECTED METALS

Prepared By:

John E. Reuter

Charles R. Goldman

Institute of Ecology
Division of Environmental Studies
University of California - Davis
Davis , California 95616
(916) 752-2913

Prepared For:

State of Nevada
Division of Environmental Protection
123 West Nye Lane
Carson City, Nevada 89710

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SUMMARY

While there is a currently established and comprehensive water quality monitoring program on the lower portion of the Truckee River downstream of Reno, and nutrient load entering the river from the Reno-Sparks Wastewater Treatment Facility (RSWTF) is well documented, very little is known about the magnitude and importance of nonpoint source (NPS) nutrients from the urban-agricultural watershed south of Reno. Indeed, in many systems, nonpoint source pollution to receiving bodies exceeds point source discharge. In response to this, the Nevada Division of Environmental Protection, in cooperation with the Washoe County Department of Comprehensive Planning has been conducting an extensive water quality monitoring program on Steamboat Creek and its major tributaries in order to (1) determine the relative magnitude of this creek with regard to nitrogen and phosphorus loading to the Truckee River and (2) determine its contribution of metals and its effect on downstream water quality. In this report we examine the data base which was collected between 1987 and 1991 when samples were taken bi-monthly from fifteen (15) locations. The purpose of this data evaluation is to: summarize physical, chemical and biological data taken during the 1987-1991 monitoring of Steamboat Creek and its major tributaries; describe changes in constituent concentration as water flows downstream towards the Truckee River; calculate changes in nitrogen and phosphorus load by reach of stream; describe changes in metals concentrations in the study system and identify sources; use correlational relationships to assist in the interpretation of water quality data; estimate nitrogen and phosphorus loading to the Truckee River via Steamboat Creek and compare this to other regional point and nonpoint sources; provide a preliminary evaluation of recommended N-removal techniques and; recommend future studies.

Throughout the entire period of record, and at all stations, flow ranged from a minimum of 0.0-0.1 cfs to a maximum of 84 cfs; with few exceptions, mean annual flow was uniform between each of the water years. The eight drainage tributaries to Steamboat Creek separated into three categories with respect to magnitude of discharge. Annual average flows were greatest at Steamboat Ditch and Boynton Slough - ±11-16 cfs; intermediate to low at Galena Creek, Whites Creek, and Alexander Ditch - ±3-5 cfs, and low at Thomas Creek, Rio Poco Drain and Yori Drain - ±1-4 cfs. The largest contributor of flow to Steamboat Creek was Boynton Slough with a mean annual discharge typically in the range of 12.0-16.2 cfs. Boynton Slough is a major route for regional agricultural return flows to the Truckee River; consequently, summer flows are very high. Flow at Kimlick Lane (just upstream from RSWTP and the most downstream station) was the largest in the system with a mean annual discharge which ranged from 23.5 to 34.2 cfs.

For nitrogen concentration the following generalizations were apparent; 1) N-concentrations were relatively consistent during each of the four years of monitoring, 2) TN, TKN and NO3 was typically lower at the upstream stations SB 3 (Pleasant Valley) - SB 10 (Thomas Creek) as compared to the remaining downstream stations; and concentrations rose significantly between SB 7 (Geiger Grade) and SB 11 (Short Lane), 3) TKN typically dominated TN with the clear exception of Yori Drain and to a lesser extent, Rio Poco and Boynton, and 4) NO3 concentrations in the Yori Drain were exceptionally high. TN-load to Steamboat Creek increased significantly between SB 7 and SB 11; this was related to surface and groundwater inputs of both TKN and NO3. TN-load was very high from downstream tributaries which drain either agricultural lands, receive groundwater flow with regionally high nitrate, or both. The project mean of the individual annual mean TN-load values in order of magnitude are Boynton Slough (73.7 lbs/day), Alexander Drain (31.1 lbs/day) Yori Drain (25.3 lbs/day), and

Rio Poco Drain (10.5 lbs/day). Nitrate load was relatively low in Alexander Drain and Rio Poco Drain, but much higher in Boynton Slough and Yori Drain. With the exception of 1991, the sum of NO3-load at these latter stations was very similar to that calculated at Kimlick Lane. TN-load from Steamboat Creek was 50-55% of the TN-load from the RSWTP.

The only tributary which showed a high P-concentration was Alexander Ditch. High flows of low P water in Boynton Slough acted to reduce the concentrations measured at Kimlick Lane. Water entering Steamboat Creek in the upper portion of the drainage (i.e. discharge from Little Washoe Lake and Galena Creek) did not carry significant P-loads relative to the more downstream locations. The increase in mean annual TP-load (3.31-8.48 lbs/day) and OP-load (2.27-6.41 lbs/day) between Geiger Grade and Short Lane was most likely the result of groundwater flow and irrigation return water with elevated P-concentration. This is supported by the seasonality of the P-spikes and by the fact that OP typically comprised 70-80% of the TP at Short Lane. Alexander Ditch and Boynton Slough typically contributed large P-loads to Steamboat Creek, on the order of 5-15 lbs/day. Conversely, Rio Poco Drain and Yori Drain discharged much less TP; 1-2 lbs/day. The region of the system which showed the greatest P-loading was that segment of the creek between the confluence of Yori Drain and Kimlick Lane. Mean annual TP-loading in this reach ranged from 6.86 to 30.36 lbs/day, with the majority in the particulate-P form. This was in contrast to all the upstream sites which was dominated by OP. TP-load from RSWTF ranged from 37-125 lbs/day over the period of record, with most values between 50-70 lbs/day; P-load from Steamboat Creek ranged from 7-150 lbs/day; however, values were commonly less in the 20-50 lbs/day range. Average daily load at Kimlick Lane from Oct-87 to Jun-91 was 43 lbs/day for TP and 18 lbs/day for OP.

The data indicated that the Steamboat Hot Springs were a significant source of arsenic, boron and chloride (plus TDS) to Steamboat Creek. The other measured constituents were not elevated by this nonpoint source. For all the constituents for which water quality standards have been established in the Steamboat Creek study area, only arsenic and boron routinely and significantly exceeded these standards. Given the rich geologic nature of the Steamboat Hot Springs and its thermal discharge to the creek it is not unexpected to find these high downstream concentrations.

1. INTRODUCTION

1.1. Background

As part of an overall effort to (1) monitor and evaluate current water quality conditions in Steamboat Creek, Washoe County, (2) document year-to-year changes in water quality conditions, (3) identify important nonpoint sources of nutrients to the Truckee River and (4) establish a data base from which meaningful water quality management plans can be formulated, the Nevada Division of Environmental Protection, in cooperation with Washoe County, began a routine water quality monitoring program on Steamboat Creek and selected tributaries. Steamboat Creek drains Big and Little Washoe Lakes and enters the Truckee River just east of downtown Reno.

While there is a currently established and comprehensive water quality monitoring program on the lower portion of the Truckee River downstream of Reno (Truckee River Consent Decree data base), and nutrient load entering the river from the Reno-Sparks Wastewater Treatment Facility (RSWTF) is well documented, very little is known about the magnitude and importance of nonpoint source nutrients from the urban-agricultural watershed south of Reno. The most detailed evaluation of nonpoint source nutrient loading to the Truckee River to date was made by Brock in 1991. Using flow and nutrient concentration data collected in September 1989, he calculated nitrogen and phosphorus loading from the North Truckee Drain and Steamboat Creek, and compared this to estimates of nutrient loading from irrigation return flows, groundwater inflow and direct discharge from the RSWTF.

In this report we:

- Summarize physical, chemical and biological data taken during the 1987-1991 monitoring of Steamboat Creek and its major tributaries,
- Describe changes in constituent concentration as water flows downstream towards the Truckee River,
- Calculate changes in nitrogen and phosphorus load by reach of stream,
- Describe changes in metals concentrations in the study system and identify sources,
- Use correlational relationships to assist in the interpretation of water quality data,

- Estimate nitrogen and phosphorus loading to the Truckee River via Steamboat Creek and compare this to other regional point and nonpoint sources,
- Provide a preliminary evaluation of recommended N-removal techniques and,
- Recommend future studies.

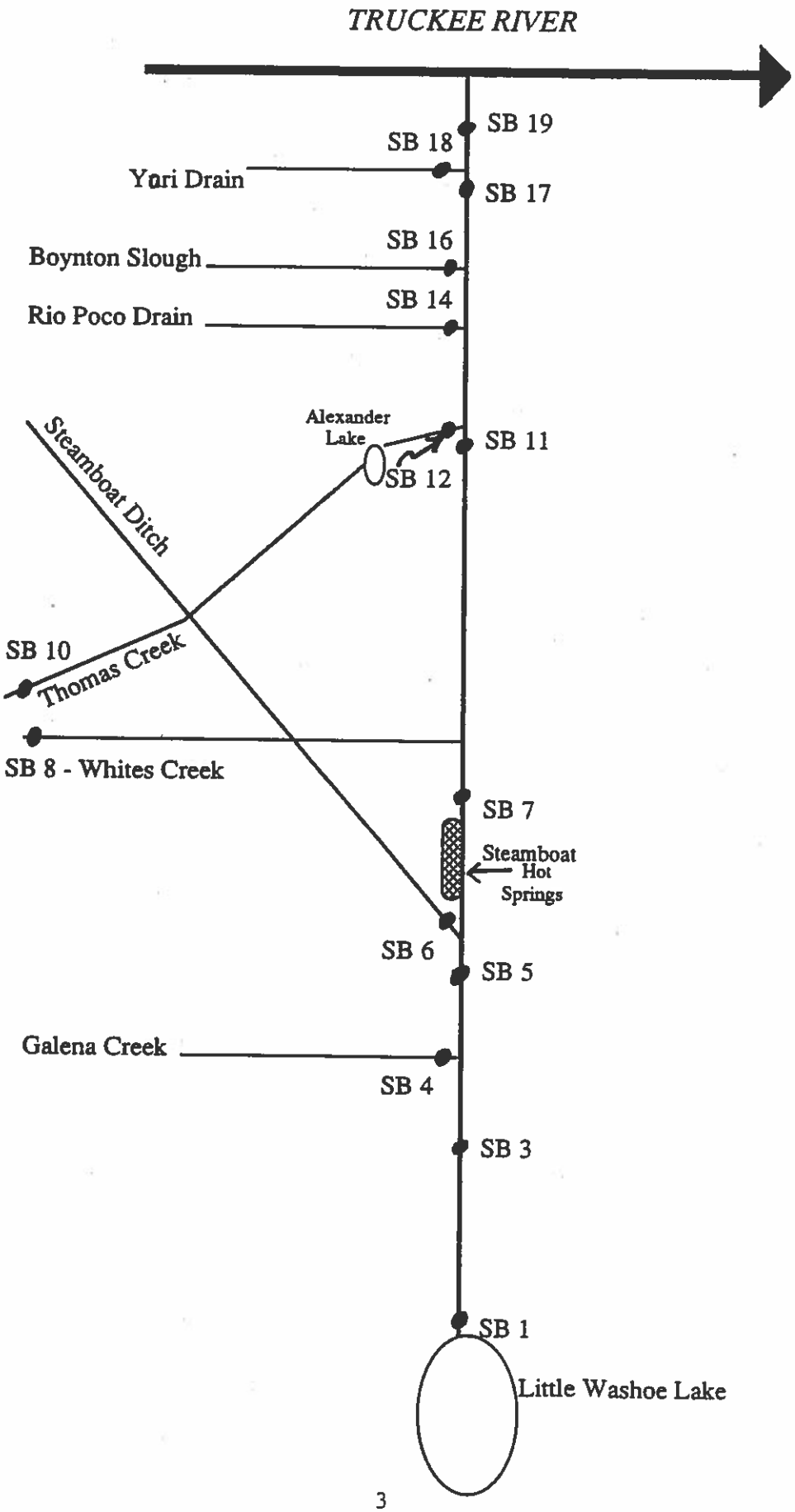
1.2. Study Site Location

A schematic map showing the project monitoring locations is given in Figure 1. A total of fifteen (15) stations were included in the sampling program. These include:

Sampling Point Name	Station ID
Little Washoe Outfall	SB 1
Pleasant Valley	SB 3
Galena Creek	SB 4
Rhodes Road	SB 5
Steamboat Ditch	SB 6
Geiger Grade	SB 7
Whites Creek	SB 8
Thomas Creek	SB 10
Short Lane	SB 11
Alexander Ditch	SB 12
Rio Poco Drain	SB 14
Boynton Slough	SB 16
Pembroke	SB 17
Yori Drain	SB 18
Kimlick (Clean Water Way)	SB 19

Of these stations, SB 1, SB 3, SB 5, SB 7, SB 11, SB 17 and SB 19 are in the main Steamboat Creek channel. The remainder of the stations were located on tributaries which

Figure 1. Schematic map of Steamboat Creek and sampling stations. Relative distance between stations along main trunk of Steamboat Creek is drawn to scale.



enter Steamboat Creek from the west. A more detailed description of the hydraulic flow in this system appears in section 2.1.

1.3. List of Constituents and Sampling Design

Water quality constituents included:

Routine Pollution - Total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC), turbidity, color, pH, alkalinity, bicarbonate, carbonate, total-N, Kjeldahl-N (TKN), nitrate-N, nitrite-N, ammonia-N, ortho-P, total-P, chloride and COD. The biological indicators, BOD_5, fecal coliform and fecal streptococci bacteria were also measured. Where applicable, concentrations are expressed as mg/l.

Metals - Arsenic, boron, cadmium, chromium, copper, iron, lead, mercury, selenium and zinc, expressed as µg/l.

Field Measurements - Water temperature, dissolved oxygen and flow (cfs).

Of these constituents, nitrite-N and ammonia-N were almost always below detection and were therefore not included in the evaluation. Color was also eliminated because of its difficulty of interpretation. Unionized ammonia was measured eight times during the study and all at SB 19.

Sampling commenced in October 1987 and followed a bimonthly schedule. Although this analysis only includes data through Jun-91, samples continue to be taken. At SB 1, samples were only taken on four dates between Apr-89 and Jun-91; consequently this station was not included in the data evaluation. Occasional gaps do exist in the data base because of samples were not taken or analytical difficulties were encountered. However, for such an extensive and comprehensive program the data is relatively complete.

Data for Steamboat Creek at Kimlick Lane (SB 19) comes from the Reno Sparks Wastewater Treatment Facility date base (21NEV4), with the exception of Feb-89, Apr-89, Jun-89 and Aug-89 which comes from the Desert Research Institute-NDEP data base (21NEV1).

1.4. Laboratory Methodology

All laboratory analyses were done by the Nevada State Health Laboratory following commonly accepted methodologies which are approved by the NDEP.

Like phosphate, arsenate forms a blue complex with molybdate during phosphorus analysis. When this occurs, phosphorus concentrations will be over estimated in proportion to the arsenic concentration. As a result, a correction must be applied to measurements of phosphorus when arsenic is present; typically this is done as part of the analytical procedure (Johnson 1971). While certain locations on Steamboat Creek contain elevated arsenic (i.e. most stations downstream of Steamboat Hot Springs - between SB 5 and SB 7), no correction was done during laboratory analysis. Consequently, we applied an empirical correction based on data obtained from P-analyses done at Pyramid Lake both with and without the laboratory arsenic correction (data courtesy of the Pyramid Lake Fisheries-Pyramid Lake Paiute Tribe). Pyramid Lake contains arsenic at a concentration of 100 µg/l.

The mean P-concentration of 23 individual Pyramid Lake water samples (0-75 m deep), chemically corrected for arsenic (after Johnson 1971) was 71 µg/l; the untreated mean concentration was 110 µg/l. This corresponds to {(0.110 mg P/l - 0.071 mg P/l)/0.100 mg As/l} or a phosphorus overestimate of 0.39 mg P per mg As. Assuming a linear relationship between As-concentration and P-overestimation, the following correction was applied to all phosphorus data:

$$P\ (mg/l)_{corr} = P\ (mg/l)_{measured} - [As\ (mg/l) \times 0.39\ (mgP/mgAs)]$$

1.5. Data Analysis

Nutrient loads were calculated for nitrogen and phosphorus by multiplying flow rates times concentration and converting to lbs/day. Data is frequently presented as a mean annual value for a particular Water Year. Each Water Year (WY) extends from 1 October to 31 September. With regard to nitrogen and phosphorus, the number of observations for each station within a specific WY is given in the concentration summary tables. The mean annual value represents the average of all values in a specific Water Year. The contour diagrams for concentrations presented for temperature, DO, TDS, EC, chloride and alkalinity represent concentrations measured at the main Steamboat Creek channel stations. Concentrations in the tributaries are

accounted for, to the extent that they have contributed to the measured concentrations in the creek proper.

2. RESULTS

2.1. Temperature, Flow and Dissolved Oxygen

Temperature exhibited the normal seasonal distribution of high summer and low winter values. In each of the four years where data is available, water temperature was clearly reduced in December and February (Table 1). Depending on station, winter values ranged from approximately 0-10°C. SB 8 and SB 10 were the coldest with temperatures between 0 and 2°C. This reflects the source of flow from the eastern slope of the Sierra Nevada mountains. Spring-time temperatures (measured in April) increased by as little as 2°C and as much as 18°C depending on location. Stations downstream of SB 7 showed the greatest increase during this period; this was especially true in April 1989 when temperature at stations SB 11 - SB 19 all exceeded 20°C. Similarly high temperatures occurred in June and August; the exception to this was 1990 when values increased by 5-10°C between these months. Typically, maximum summer temperatures did not exceed 25°C and had a range of 20-25°C. The seasonal change in water temperature in Steamboat Creek proper is graphically presented in Figure 2.

SB 8 and SB 10 exhibited the coldest overall temperatures at all times of the year. The annual range in values at these locations was approximately 0-15°C with most observations less than 10°C. Spring and summer temperatures at SB 3 and in Galena Creek (SB 4) were also relatively low and similar to those observed at SB 8 and SB 10. Winter temperature at SB 3 and SB 4 was, however, 2-3°C higher than at SB 8 and SB 10. Summer temperatures increased downstream at SB 5 and SB 7 but, with the exception of Jun-88 and Aug-90 at SB 5, measurements typically did not exceed 20°C. Again, with the exception of 1991, June and August temperatures increased by between 5 and 8°C between SB 7 and SB 11. This was very significant and indeed, the reach of creek between SB 7 and SB 11 marked the transition between summer temperatures which were less than 20°C upstream and greater than than 20°C downstream. Only during Jun-88, Aug-89 and Aug-90 did temperature at SB 11 or downstream exceed 25°C. Data from SB 4, SB 6, SB 12, SB 14, SB 16 and SB 18 show that

Table 1. Individual temperature (°C) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Temperature
(C)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	9.0	7.0	6.0	8.4	12.3	5.0	6.5	6.0	8.0	15.0	15.0	11.0	11.0	17.2
Dec-87	6.0	6.0	6.0		7.5	0.0	2.0	8.0	6.0	8.0	7.0	6.5	9.0	2.9
Feb-88	1.5	1.6	2.5		5.3	0	0.0	10.0	7.0	9.0	7.0	6.5	7.5	2.8
Apr-88	12.0	12.0	14.0		16.0	6	7.5	15.0	15.0	15.1	11.5	11.5	12.5	15.3
Jun-88	12.5	13.0	21.0	17.0	19.0	11	13.0	27.5	25.5	23.0	19.0	20.0	18.0	21.0
Aug-88	12.0	13.5	24.5	18.0	18.0	12.0	13.5	23.5	24.5	23.0	22.0	24.0	20.0	17.5
Oct-88											12.0	10.0	9.0	14.3
Dec-88	3.5	3.8	3.2		7.0	0.5	0.9	6.1	3.0	11.0	7.0	7.0	4.0	2.3
Feb-89	5.0	5.0	6.0		7.0	0.1	1.5	6.0	5.5	9.0	5.5	3.5	4.0	4.0
Apr-89	7.0	7.0	11.0		14.0	7.0	9.0	22.0	22.0	20.0	20.0	20.0	22.0	22.1
Jun-89	13.0	9.0	13.0	15.0	17.0	8.0	8.8	22.0	23.0	23.0	22.0	21.0	23.0	23.0
Aug-89	10.0	10.0	14.0	14.0	13.0	7.0	10.0	19.0	21.0	22.0	22.0	23.0	27.0	21.0
Oct-89	6.5	3.9	5.0	6.5	8.5	4.0	6.5	13.5	15.0	15.5	12.0	12.5	11.8	15.0
Dec-89	1.0	3.0	2.5		6.0	0.0	0.0	5.5	1.5	8.0	4.0	3.5	6.5	7.3
Feb-90	0.0	0.0	0.0		0.0	0.0	0.0	2.3	0.0	5.5	2.0	1.0	3.8	2.8
Apr-90	5.0	3.5	5.0		4.0	0.0	1.5	11.3	13.0	13.0	11.0	13.0	17.3	16.5
Jun-90	4.0	4.3	7.5	9.0	8.0	2.5	5.0	14.0	16.0		17.0	17.0	15.5	17.0
Aug-90	16.3	16.0	28.0	19.0		14.3	15.5	25.0	25.5	25.5	25.0	28.0	22.0	29.0
Oct-90	7.0	5.0	10.5		10.5	2.0	3.5	10.5	8.5	17.0	14.5	16.0	12.5	16.3
Dec-90	4.5	4.0	2.5		5.0	0.8	1.3	6.5	4.8	10.0	5.5	5.5	5.8	6.5
Feb-91	5.3	5.3	5.2		9.0	1.5	2.0	9.8	5.5	10.8	7.1	5.8	8.0	6.8
Apr-91	6.5	7.3	9.0		12.8	3.0	4.5	14.1	13.8	15.1	14.0	15.5	15.0	17.0
Jun-91	10.5	5.2	9.7	12.1	14.9	4.3	7.1	16.6	19.8	21.0	18.9	20.4	19.0	21.3

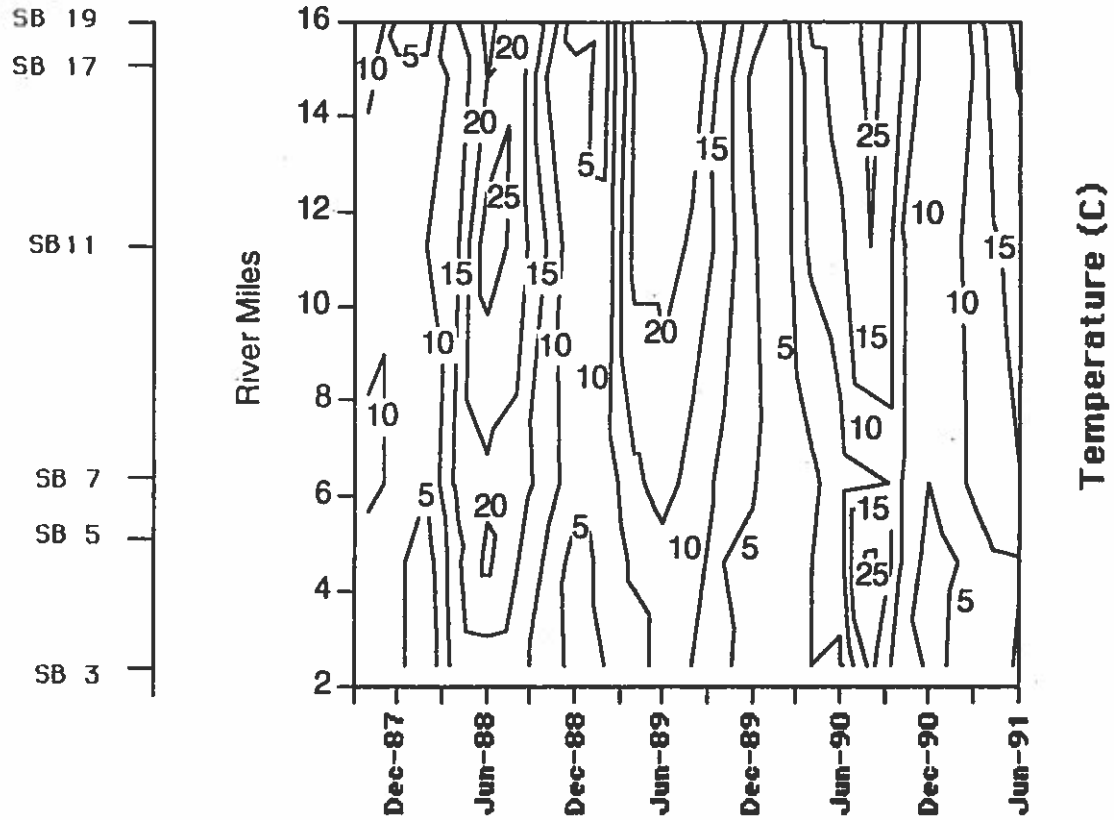


Figure 2. Contour plot of water temperature in the main Steamboat Creek channel; Oct-87 to Jun-91. Legend on left shows location of sampling station. River mile designation begins with 0 = outflow of Little Washoe Lake.

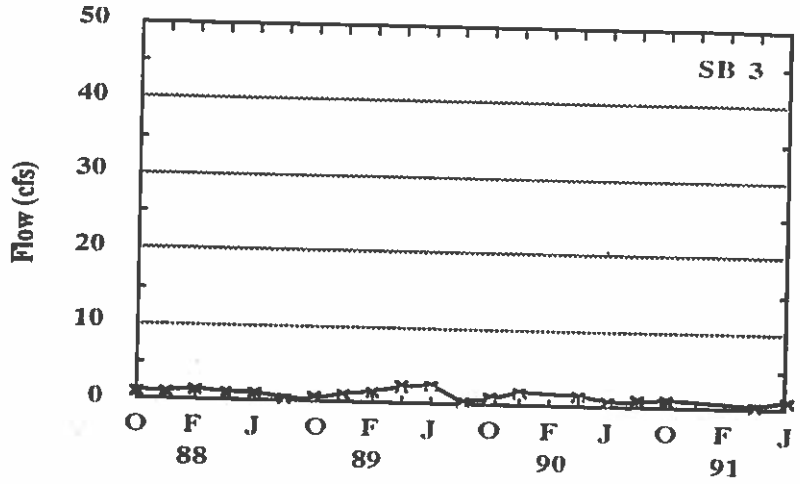
these tributary drainages did not have an important warming or cooling affect on Steamboat Creek. It is important to note that temperature was only measured once per day, typically between 09:00 and 13:00. Consequently, especially during the summer, the reported values probably do not represent maximum daily temperature. Additionally, since the sampling routine began at SB 3 in the morning and proceeded downstream to SB 19 by early afternoon, station-to-station differences may be the partial result of this timing.

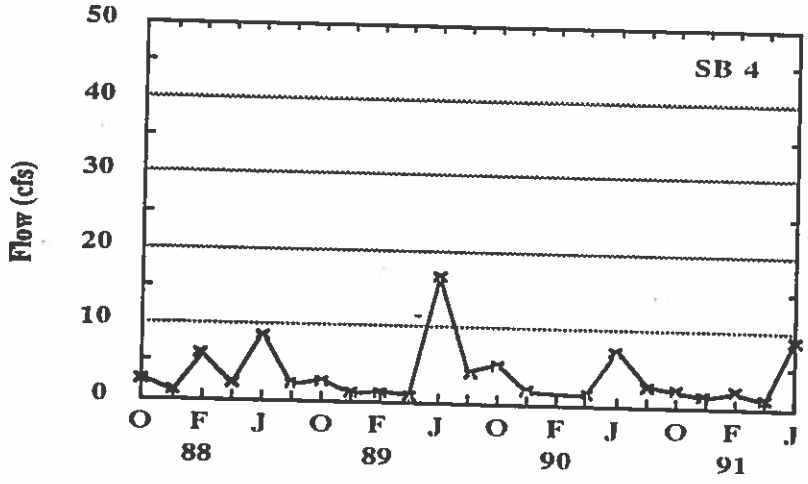
Throughout the entire period of record, and at all stations, flow ranged from a minimum of 0.0-0.1 cfs to a maximum of 84 cfs (Figure 3). With few exceptions, mean annual flow was uniform between each of the water years (i.e. WY 88, WY 89, WY 90 and WY 91)(Table 2). Consequently, intra-station relationships from year-to-year were also consistent.

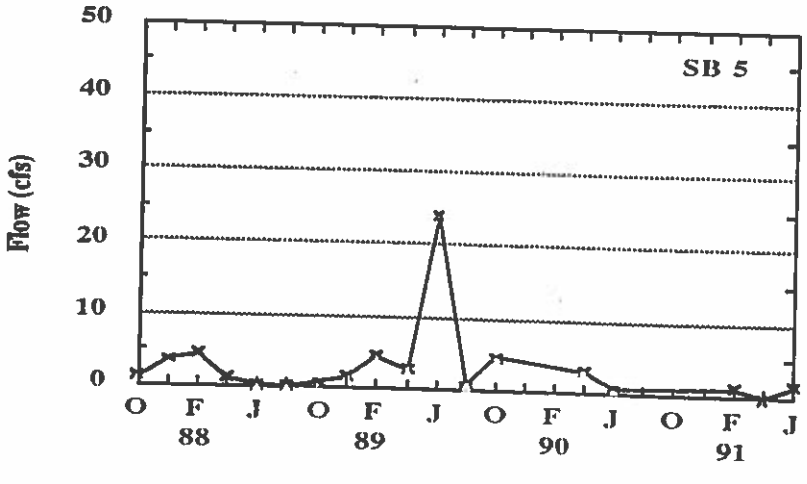
The eight drainage tributaries to Steamboat Creek separated into three categories with respect to magnitude of discharge. Annual average flows were greatest at SB 6 (Steamboat Ditch) and SB 16 (Boynton Slough) - ±11-16 cfs; intermediate to low at SB 4 (Galena Creek), SB 8 (Whites Creek), and SB 12 (Alexander Ditch) - ±3-5 cfs, and low at SB 10 (Thomas Creek), SB 14 (Rio Poco Drain) and SB 18 (Yori Drain) - ±1-4 cfs.

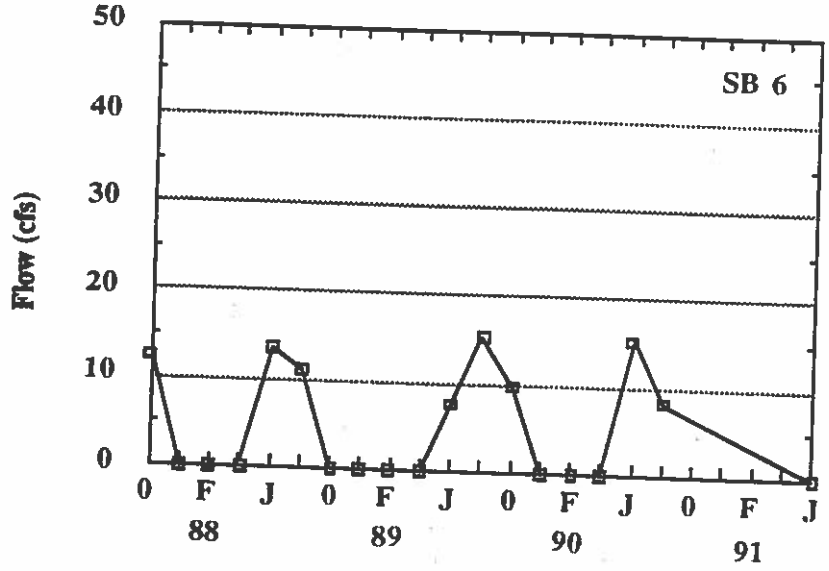
While it is not possible to calculate a quantitative hydrologic budget between SB 3 upstream and SB 19 downstream, we can use the mean annual flow calculations to discuss general trends in discharge as water travelled through the system. This discussion is particularly relevant to calculations and evaluation of nutrient loading. Discharge at SB 3 was relatively low with annual means ranging from 0.9 to 1.4 cfs. This was the lowest flow throughout the system and appeared not to have a major seasonal component (Figure 3). Galena Creek (SB 4), which originates in the Carson Range of the Sierra Nevada, entered Steamboat Creek with a flow of 3.0 to 4.3 cfs. At SB 5, 1.3 miles downstream of the confluence of Galena and Steamboat Creeks, mean annual flow ranged from 0.8 to 5.6 cfs. Given the bi-monthly level of sampling with measurements of instantaneous flow only, it appears as though there was no major net loss or gain in flow between SB 3 and SB 5, save the input from Galena Creek.

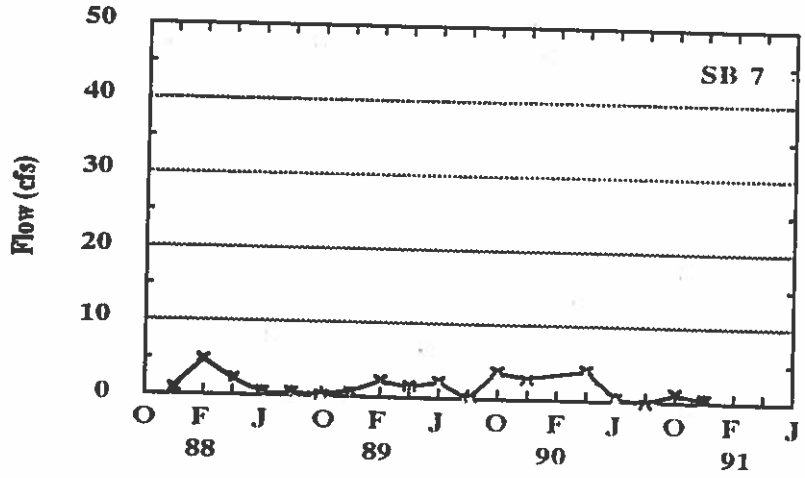
Figure 3. Distribution of individual flow measurements taken from the sampling network for the Steamboat Creek monitoring study; Oct-87 to Jun-91. Values reported as cubic feet per second (cfs).

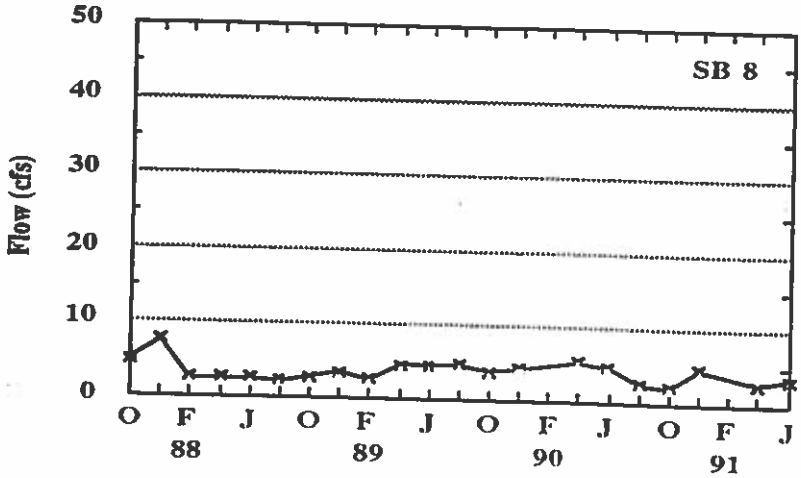

SB 3
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91

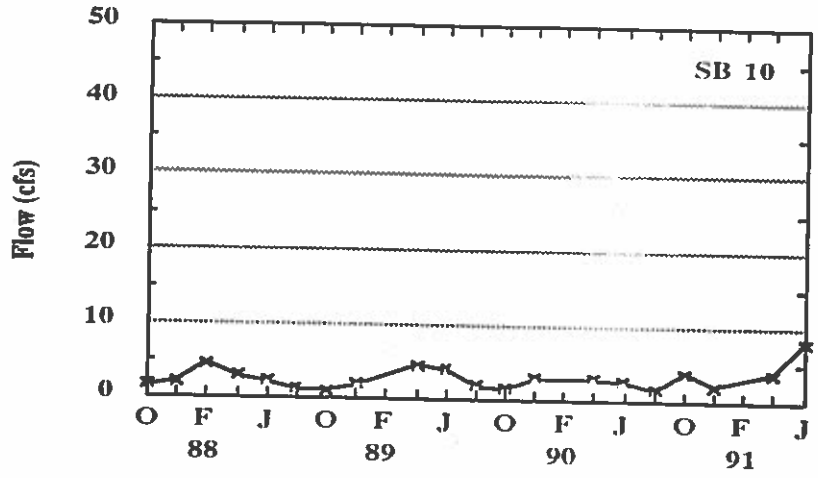

SB 4
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91

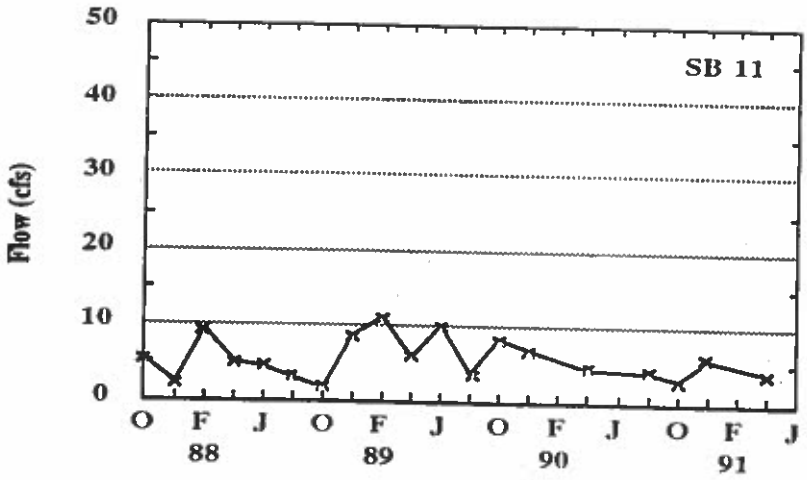

SB 5
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91

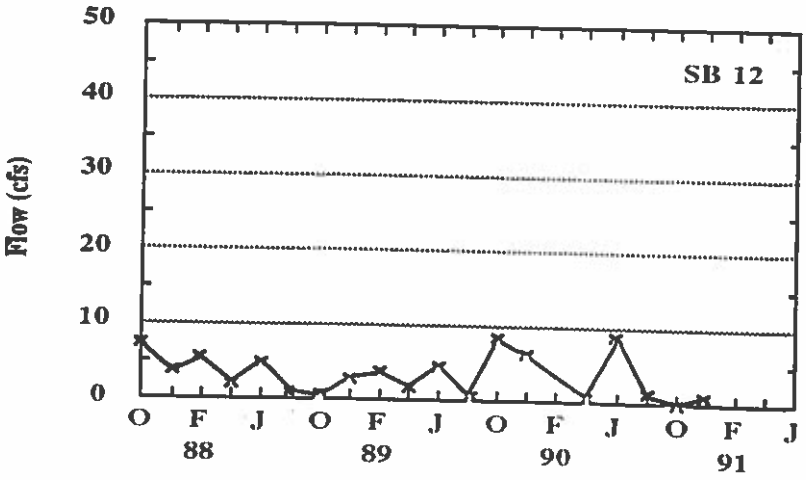

SB 6
Flow (cfs)
50
40
30
20
10
0
0 F J 0 F J 0 F J 0 F J
88
89
90
91

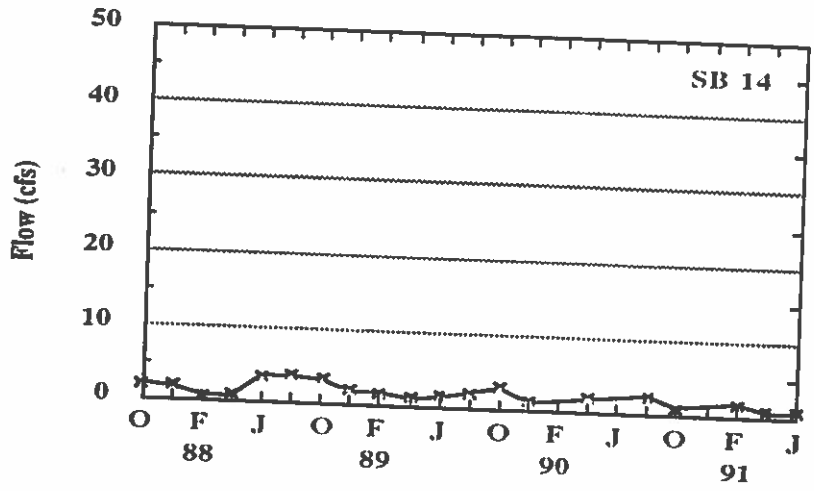

SB 7
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91

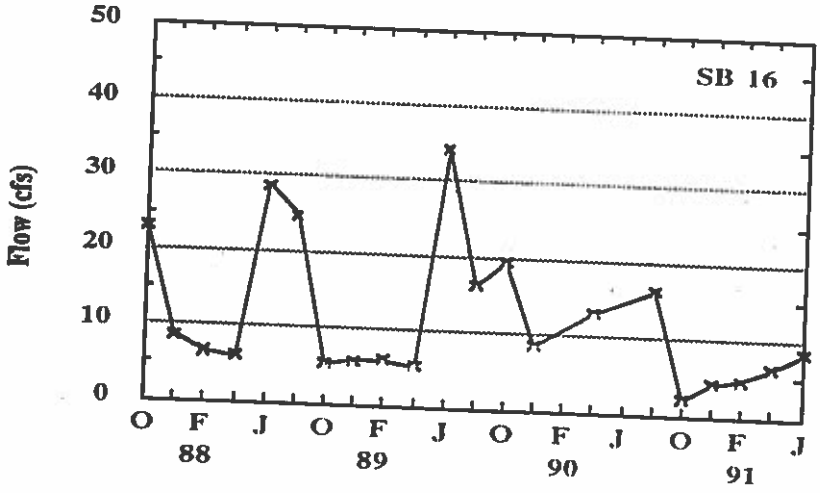

SB 8
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91

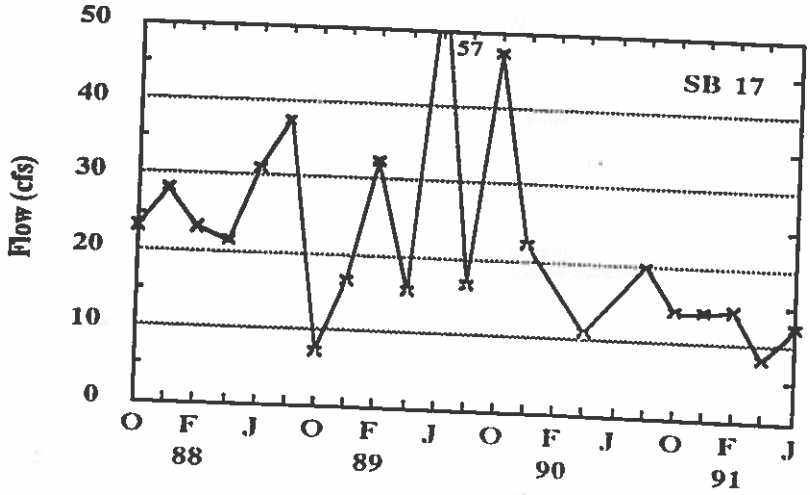

SB 10
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91

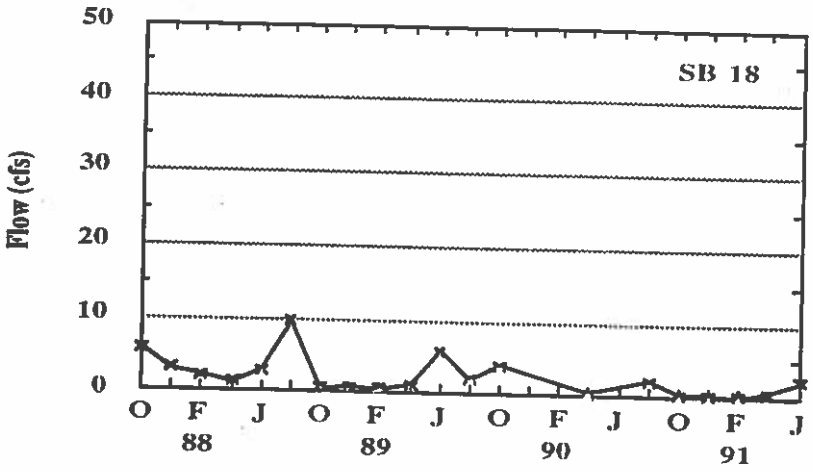

SB 11
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91


SB 12
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91


SB 14
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91


SB 16
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91


SB 17
57
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91


SB 18
Flow (cfs)
50
40
30
20
10
0
O F J O F J O F J O F J
88
89
90
91

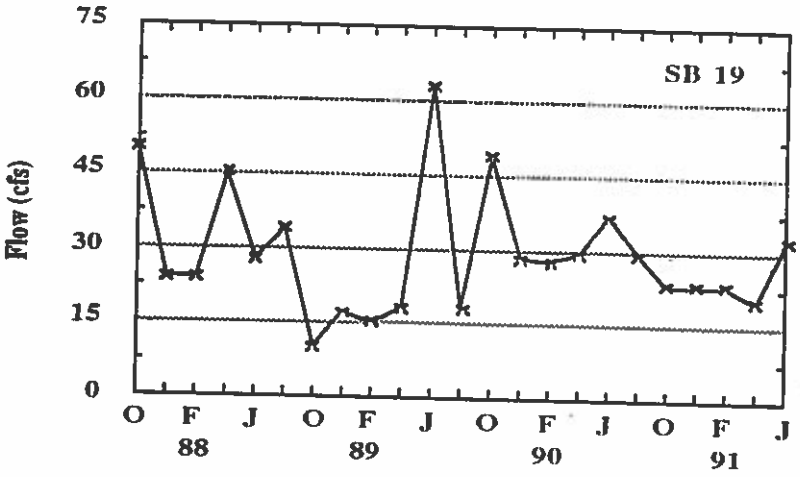

SB 19
Flow (cfs)
75
60
45
30
15
0
O F J O F J O F J O F J
88
89
90
91

Table 2. Mean annual flow for each water year during the period of record, WY88-WY91. Stations include all locations which were part of the Steamboat Creek sampling network. Values were obtained by taking the average of all observations made during the defined period. Flow is reported as cubic feet per second (1 cfs=28.52 liters/s). ID = insufficient data.

Station	WY 88	WY89	WY90	WY91
SB 3	1.1	1.4	1.2	0.9
SB 4	3.7	4.3	3.9	3.0
SB 5	1.8	5.6	2.9	0.8
SB 6	12.3	11.5	11.0	ID
SB7	1.7	1.3	2.1	0.8
SB 8	3.7	3.7	4.2	3.3
SB 10	2.4	2.6	2.1	4.4
SB 11	5.0	6.9	6.0	4.3
SB 12	4.0	2.3	5.0	ID
SB 14	2.0	1.6	2.0	1.0
SB 16	16.2	12.0	14.2	5.1
SB 17	27.4	24.3	25.0	12.5
SB 18	4.1	1.8	2.2	0.8
SB 19	34.2	23.5	33.5	24.2

This only takes into account the balance between agricultural diversions and return flow/groundwater discharge between these stations.

Mean annual flow in Steamboat Ditch (SB 6) was significant relative to flow in Steamboat Creek just upstream at SB 5; 11.0 to 12.3 cfs at SB 6 versus 0.8-5.6 cfs in the main channel. This section of Steamboat Ditch is the end of the much longer channel which diverts water from the Truckee River near the Nevada-California border for the purpose of agricultural-irrigation. This waterway also receives agricultural return flow from irrigated lands. In the 1.6 mile reach downstream of the Steamboat Ditch and Steamboat Creek confluence, almost all the additional flow from Steamboat Ditch was removed. Flow at SB 7 was 0.8 to 2.1 cfs and was similar to that measured upstream at SB 3. Actual water flow at SB 6 was limited to the summer months of June, August and October flow for agricultural-irrigation needs. During the winter, Steamboat Ditch at SB 6 was typically dry. Just downstream of Steamboat Ditch, the Crane-Chandler Ditch diverts water from Steamboat Creek for agricultural use to the north and east. One reason for construction of the Crane-Chandler Ditch was to have access to the relatively clean water in Steamboat Creek upstream of input from Steamboat Hot Springs which is located between the confluence of Steamboat Ditch and station SB 7 at Geiger Grade. As discussed below, the hot springs delivers very saline and agriculturally unacceptable water to Steamboat Creek. The data for flow on individual sampling dates also shows that discharge in Galena Creek was maximum June. Flow at SB 7 was lowest during the summer.

Between SB 7 and SB 11, Whites Creek (SB 8) and Thomas Creek (SB 10) were monitored, however, both sampling locations were a considerable distance upstream from their confluence with Steamboat Creek (refer to Figure 1). Mean annual flow at SB 8 ranged from 3.3 to 4.2 cfs; SB 10 showed a similar discharge ranging from 2.1-4.4 cfs. The combined flows at SB 8 and SB 7 were remarkably similar to those measured at SB 11 which is the next downstream station on Steamboat Creek at a distance of 5.0 miles from SB 7. Mean annual flows at SB 11 ranged from 4.3 to 6.9 cfs (Table 2). While not directly measured, agricultural return runoff from the Crane-Chandler Ditch and groundwater also enters Steamboat Creek

between SB 7 and SB 11. Groundwater from Mount Rose and the Carson Range also enters Steamboat Creek between SB 7 and SB 11 (L. Crowe pers. comm.)

The Alexander Ditch (SB 12), Rio Poco Drain (SB 14) and Boynton Slough (SB 16) all enter Steamboat Creek between SB 11 and SB 17. Alexander Ditch and Rio Poco Drain were relatively minor contributors to total flow in Steamboat Creek with mean annual flows of 2.3 to 5.0 cfs and 1.0-2.0 cfs, respectively. While there was no clear seasonal trend in discharge from these tributaries, it was not uncommon to have both high summer and winter flows (Figure 3).

The largest contributor of flow to Steamboat Creek was Boynton Slough. With the exception of WY 91 when flow was low at 5.1 cfs, mean annual discharge from Boynton Slough ranged from 12.0 to 16.2 cfs. The seasonality of flow at this station was quite dramatic (Figure 3). Boynton Slough is a major route for regional agricultural return flows to the Truckee River; consequently, summer flows are very high. The mean cumulative flow in the summer months of June, August and October was 20-25 cfs with winter flows typically in the range of 5 to 10 cfs. This pattern was consistent in WY 88, WY 89 and WY 90. It was not as apparent in WY 91 because of low summer flows. In each of the Water Years monitored (WY 88, WY 89, WY 90 and WY 91), the combined flows at SB 11, SB 12, SB 14 and SB 16 accounted for 99%, 94%, 109% and 88% of the discharge downstream at SB 17. Further downstream discharge from Yori Drain was relatively minor with a range of mean annual values of 0.8 to 4.1 cfs.

Flow at SB 19, the most downstream station was the largest in the system; mean annual discharge ranged from 23.5 to 34.2 cfs. The combined flow of SB 17 and SB 18 accounted for 92%, 111%, 79% and 51% of the discharge at SB 19 in Water Years, 88, 89, 90 and 91, respectively. Even though the seasonal pattern of flow at SB 17 and SB 19 was not well defined as at SB 16, many of the highest observations were made in the summer.

Dissolved oxygen was high at all stations and on all sampling dates. The majority of the measurements were in the range of 7-12 mg/l and only three times did concentrations drop

below 6 mg/l; i.e. SB 17 in Jun-89, SB 19 in Aug-89 and SB 5 in Aug-90. The lowest concentrations were most often found in June and August when there is lower oxygen solubility because of the higher water temperatures (Table 3, Figure 4). At a temperature of 20°C and accounting for elevation, water with a concentration of 8 mg/l oxygen is at 100% saturation. A saturation of 75% is attained at a concentration of 6 mg/l. No effort was made to sample just before sunrise when concentrations are expected to be minimum.

Chemical Oxygen Demand or COD is used to measure the organic content in waters. The COD test is extensively used because it requires minimal time; however, this test can not be used to differentiate between biologically utilizable and chemically inert organic matter. On the other hand BOD measures the amount of oxygen used in the metabolism of biodegradable organic matter. BOD ranged from <1-<6 mg/l (Table 4). Taken as background, SB 8 and SB 10 had an annual mean values of 1.25 and 1.19 mg/l, respectively. These were relatively low and not uncommon for this class of water. With the exception of Jun-89 at SB 4, inflows from Galena Creek and Steamboat Ditch were also low in BOD. Excluding the Jun-89 value of 9.00 mg/l, Galena Creek (SB 4) had a minimum BOD concentration of 0.30 mg/l a maximum of 1.50 mg/l and an annual mean of 0.94 mg/l. Steamboat Ditch (SB 6) had a minimum value of 1.24 mg/l a maximum of 1.55 mg/l and an annual mean of 1.41 mg/l (n=4). Between SB 5 (annual mean BOD 1.47 mg/l) and SB 7 (annual mean BOD 2.01 mg/l) BOD increased by 0.5 mg/l. Further downstream at SB 11, the maximum single BOD measurement was 5.06 mg/l with an annual mean of 2.27 mg/l. This represents a 0.78 mg/l increase relative to SB 5 but does not indicate a major source of BOD between these two stations. BOD at the downstream tributaries were 2.08-6.10 mg/l at SB 12 with an annual mean of 4.50 mg/l; 0.70-3.40 mg/l at SB 14 with an annual mean of 2.07 mg/l; and 1.67-4.30 mg/l at SB 16 with an annual mean of 2.55 mg/l. A comparison of SB 5 and SB 17 showed a 1.5 mg/l increase in BOD between these upstream and downstream stations. Relatively similar trends were found for COD, albeit the absolute values for this parameter in the main Steamboat Creek channel were 10-20 time

Table 3. Individual dissolved oxygen (mg/l) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Dissolved Oxygen
(mg/L)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	10.4	10.7	9.6	11.2	11.5	11.8	11.5	13.6	12.4	11.8	10.0	9.6	10.7	8.6
Dec-87	9.9	9.7	10.2		9.6	10.1	11.1	10.9	12.6	10.1	9.5	10.8	10.0	11.6
Feb-88	11.6	11.3	10.6		10.2	10.0	11.0	8.9	9.9	10.6	12.1	12.0	11.7	12.1
Apr-88	11.0	8.8	8.5		7.8	8.4	9.4	9.8	8.8	10.2	9.8	10.4	15.6	11.3
Jun-88	7.8	8.1	6.8	6.8	6.8	7.1	6.8	9.0	10.0	10.4	8.2	9.2	9.8	7.7
Aug-88	7.3	8.0	5.8	7.5	7.5	7.9	7.8	8.1	8.9	9.8	7.6	8.2	8.0	8.1
Oct-88											8.5	8.1	8.3	11.5
Dec-88	10.8	11.1	10.8		11.2	11.6	11.8	12.8	12.3	12.0	10.2	10.2	12.2	12.2
Feb-89	11.4	11.2	11.9		11.9	11.0	12.0	12.2	14.7	13.6	12.1	11.4	11.8	12.4
Apr-89	8.7	8.5	9.2		8.2	9.7	9.2	8.6	11.4	15.0	14.4	12.2	14.0	11.3
Jun-89	7.9	9.6	8.4	8.5	8.4	9.5	10.0	7.2	7.8	13.0	9.8	5.5	11.0	6.3
Aug-89	7.7	9.6	8.3	8.6	8.6	10.2	9.0	9.9	10.4	14.0	10.6	9.0	11.0	4.3
Oct-89	7.9	10.5	9.5	9.8	9.2	10.0	10.1	9.1	10.0	10.8	8.6	8.2	11.8	9.4
Dec-89	1.3	12.7	12.2		11.2	12.8	12.2	12.1	15.2	12.2	11.8	13.0	12.0	12.4
Feb-90	1.4	15.8	15.0		15.2	14.8	14.5	15.2	14.0	13.2	14.8	16.0	15.8	11.4
Apr-90	10.2	11.4	10.4		10.3	11.5	11.3	10.9	11.0	12.2	10.7	10.8	13.2	11.3
Jun-90	9.8	10.5	9.0	9.5	6.5	10.8	9.4	9.8	12.3		11.2	14.2	14.8	10.0
Aug-90	6.4	8.1	4.7	7.7		8.4	7.7	7.3	9.6	12.6	6.7	7.8	8.5	8.2
Oct-90	8.2	9.8	6.6		8.5	11.2	10.8	12.0	10.6	12.6	11.4	10.8	11.2	10.6
Dec-90	9.5													
Feb-91	9.4	10.1	9.6		10.4	10.9	10.7	10.5	12.2	12.0	8.2	10.6	9.0	10.6
Apr-91	10.6	11.1	9.5		10.8	11.8	11.3	10.8	10.9	15.3	15.6	11.7	11.1	11.6
Jun-91	8.6	10.5	9.1	9.0	10.2	10.3	9.6	9.0	10.2	14.3	10.5	8.7	12.9	11.4

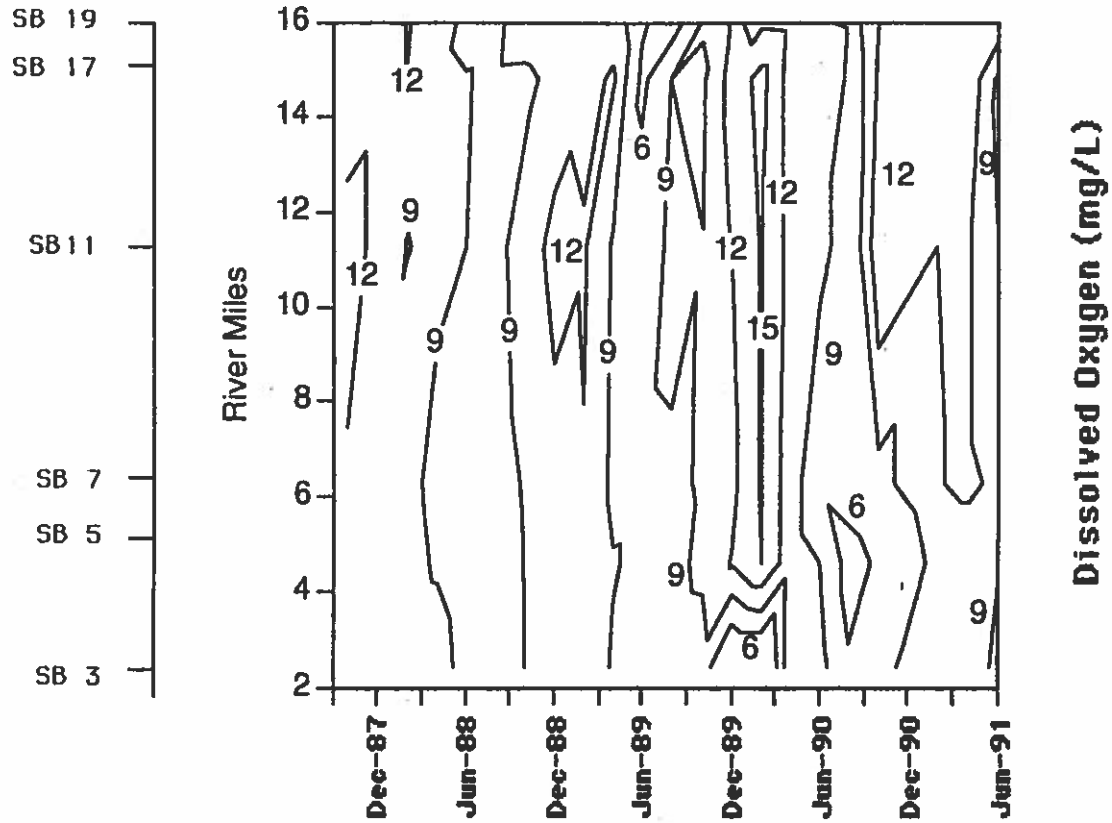


Figure 4. Contour plot of dissolved oxygen in the main Steamboat Creek channel; Oct-87 to Jun-91. Legend on left shows location of sampling station. River mile designation begins with 0 = outflow of Little Washoe Lake.

Table 4. Individual 5-day BOD (mg/l) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

BOD
(5 d, mg/L)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	2.00	0.78	1.36	1.24	1.90	1.06	1.16	0.81	2.89	1.54	1.67	1.94	1.21	1.70
Dec-87														2.80
Feb-88	1.61	0.85	2.00		1.91	1.71	1.42	1.89	2.08	1.57	2.29	1.51	1.60	
Apr-88														2.60
Jun-88	1.59	0.96	1.85	1.34	2.14	0.90	1.14	2.41	3.32	1.90		3.23	2.32	1.60
Aug-88														2.00
Oct-88	3.43	1.45	1.83		2.26	1.81	1.65	2.09	5.36	3.25	2.81	3.59	2.49	1.10
Dec-88														2.80
Feb-89	5.43	0.76	0.29		3.20	0.67	0.66	1.96	4.56	2.80	2.15	2.64	1.64	4.20
Apr-89														2.30
Jun-89	1.80	9.00	1.44	1.55	2.00	1.02	1.00	5.06	5.80	1.60	1.88	4.88	3.37	3.00
Aug-89														1.90
Oct-89														1.70
Dec-89														1.90
Feb-90														1.80
Apr-90	1.20	1.10	2.10		1.30	1.40	1.40	3.00	5.30	1.60	4.30	2.30	2.50	4.60
Jun-90														3.10
Aug-90	1.90	1.50	1.10	1.50		2.10	2.30	2.30	5.60	3.40	2.20	3.30	3.10	4.20
Oct-90														2.80
Dec-90	1.00	0.80	1.70		2.00	0.50	0.80	1.10	6.10	0.70	2.60	2.40	1.20	2.70
Feb-91														
Apr-91	0.60	0.30	1.00		1.40	1.40	0.40	2.10	4.00	2.30	3.10	3.50	2.50	5.20
Jun-91														3.50

Table 5. Individual COD (mg/l) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

COD
(mg/L)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87														
Dec-87	9.0	7.8	11.8		24.1	6.5	7.8	28.2	18.0	11.0	15.5	21.6	15.1	30.1
Feb-88														27.6
Apr-88	9.4	6.9	19.6		49.3	73	8.6	71.0	62.0	13.4	18.0	67.7	20.4	36.3
Jun-88														32.6
Aug-88	13.5	12.2	18.0	7.8	24.5	9.8	14.3	56.3	65.3	19.2	19.6	20.4	31.8	22.4
Oct-88														24.1
Dec-88	12.6	9.0	15.9		26.5	9.0	11.4	33.9	38.8	9.8	15.9	15.9	30.2	27.0
Feb-89														43.5
Apr-89	17.4	10.4	17.8		20.3	7.9	14.5	37.8	59.6	19.5	20.3	33.1	31.5	47.8
Jun-89														
Aug-89	12.1	8.7	16.6	6.2	31.6	5.4	9.2	33.2	119.0	10.8	19.6	24.9	14.1	20.4
Oct-89	15.5	13.8	23.0	13.0	22.2	9.2	14.2	37.7	40.6	17.2	15.9	32.7	16.8	36.5
Dec-89	13.4	9.1	16.6		32.4	8.3	10.7	36.7	20.5	11.5	17.8	29.6	16.6	26.1
Feb-90	10.2	4.8	13.8		19.6	3.7	7.8	32.6	36.7	6.5	14.3	26.9	11.8	16.7
Apr-90														27.9
Jun-90	10.0	10.8	19.1	12.5	53.2	9.6	10.4	65.4	57.7		17.5	30.8	19.1	27.0
Aug-90														30.0
Oct-90	19.1	9.4	20.4		65.2	6.5	8.5	53.4	73.2	19.1	17.1	39.8	4.8	23.3
Dec-90														14.2
Feb-91	13.3	8.6	17.2		17.6	3.9	8.6	22.3	20.3	6.6	54.3	32.1	36.8	32.1
Apr-91														34.9
Jun-91	21.6	12.2	21.6	15.1	28.2	9.8	8.6	30.2	48.6	12.2	22.8	44.9	18.0	35.5

higher than measured for BOD (Table 5). Despite higher BOD and COD values at SB 12 and SB 17 the water at these stations was able to maintain a high degree of oxygenation.

2.2 Ionic Constituents

The major ionic constituents included in this study were total dissolved solids (TDS), electrical conductivity (EC), alkalinity, and chloride. Data for these constituents and including pH are summarized in Tables 6-10 and Figures 5-8).

TDS at SB 3, just downstream from the outlet of Little Washoe Lake, ranged from 171 to 264 mg/l with most of the concentrations between 190 and 220 mg/l. Typically, higher concentrations were found in the summer months of June, August and October (Table 6). This was most likely the result of evaporative concentration since flow and TDS showed a significant negative correlation ($r=-0.61$, $p<0.01$). Inflow from Galena Creek (SB 4) contained a lesser TDS concentration that immediately upstream at SB 3, ranging from 63 to 135 mg/l. TDS demonstrated a seasonal pattern at this location with a highly significant negative correlation between flow and TDS ($r=-0.76$, $p<0.001$). However, unlike SB 3 which had lesser flows in the summer leading to evaporative concentration, flow at SB 4 was maximum in June (for irrigation purposes) and consequently, TDS was typically reduced in the summer.

Despite the fact that flow at SB 5 was generally higher than that at SB 3, the result of input of lower TDS discharge from Galena Creek, TDS concentration at SB 5 were slightly higher relative to SB 3. This may be the result of groundwater discharge in this reach of the creek. The statistical relationship between flow and TDS at SB 5 ($r=-0.52$, $p<0.05$) was not as strong as at SB 3 or SB 4. During the summer of 1988 (June-October) mean flow was reduced at SB 5 (0.23 cfs) relative to SB 3 (0.73 cfs) and TDS increased by ±20% between these stations. In contrast, during the summer of 1989, high flows from Galena Creek in June and October caused TDS at SB 5 to decline relative to SB 3.

Water in Steamboat Ditch at SB 6 had a low TDS concentration (50-100 mg/l) reflecting its pristine-like source, the Truckee River. This data also suggests that TDS loading to Steamboat

Table 6. Individual total dissolved solids (mg/l) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Total Dissolved Solids (mg/L)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	209	93	278	66	1758	65	89	712	513	344	148	283	179	275
Dec-87	208	117	228		1929	57	85	636	269	226	343	501	348	516
Feb-88	211	118	209		450	66	91	631	446	245	351	520	335	495
Apr-88	171	104	257		770	75	89	971	984	268	379	638	341	612
Jun-88	222	93	311	70	1322	69	93	737	432	266	213	302	198	352
Aug-88	240	105	315	70	1061	71	99	724	279	279	172	256	207	223
Oct-88	264	95	231		1751	67	86	1120	251	270	274	527	370	511
Dec-88	218	123	226		871	69	97	1048	383	296	385	385	599	591
Feb-89	207	114	199		395	66	96	735	365	270	365	569	332	556
Apr-89	213	135	222		556	84	99	861	400	248	392	654	330	634
Jun-89	205	70	163	67	267	54	67	662	502	308	214	406	159	384
Aug-89	236	89	218	73	712	60	87	853	372	349	209	285	182	272
Oct-89	236	95	199	102	295	64	101	426	252	281	200	329	228	333
Dec-89	215	122	216		491	64	10	935	253	273	369	475	349	474
Feb-90	197	127	264		502	67	96	900	601	264	380	559	315	516
Apr-90	189	116	222		484	69	92	1037	573	267	204	353	300	365
Jun-90	212	73	230	66	1295	56	93	422	307		198	307	195	302
Aug-90	228	107	369	72		68	102	492	360	328	194	294	230	272
Oct-90	264	105	325		1589	64	94	1064	440	301	374	575	304	392
Dec-90	230	124	228		1541	64	92	844	470	266	336	560	315	529
Feb-91	202	111	205		410	64	95	750	272	259	289	455	256	475
Apr-91	217	130	241		541	69	98	983	329	292	288	526	288	513
Jun-91	203	63	161	54	345	56	85	333	251	310	251	439	149	357

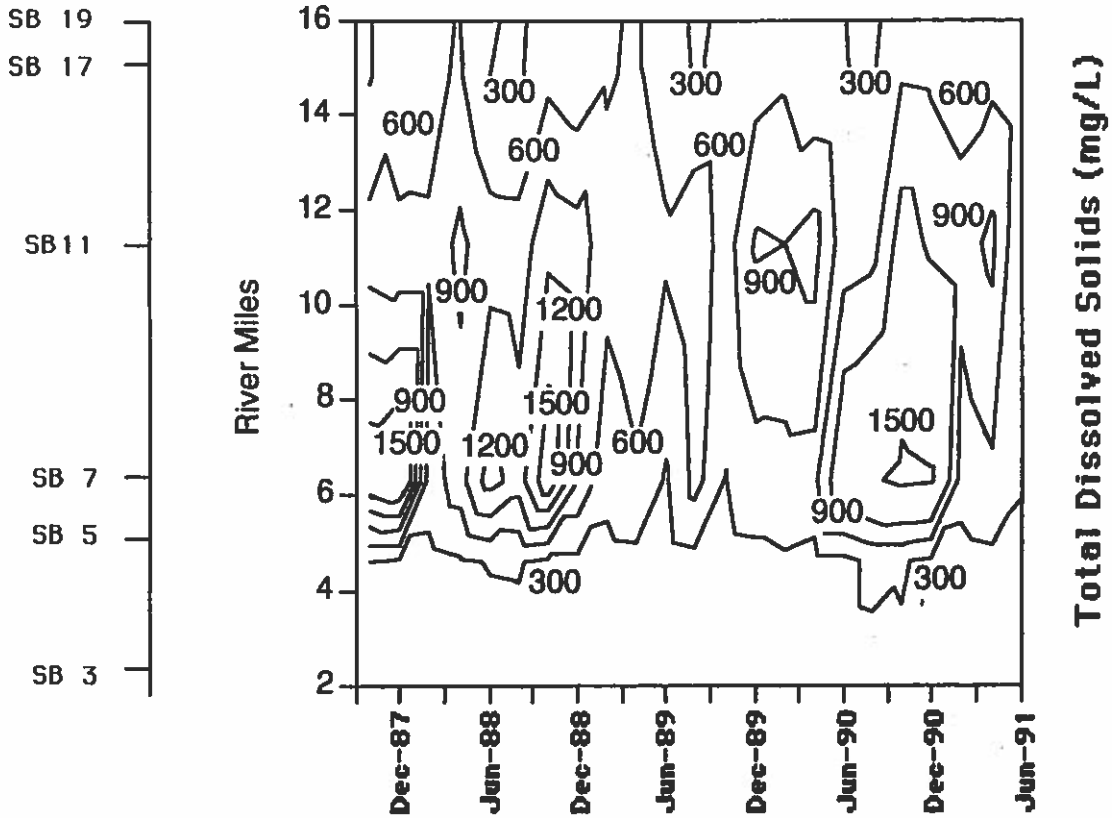


Figure 5. Contour plot of total dissolved solids (TDS) in the main Steamboat Creek channel; Oct-87 to Jun-91. Legend on left shows location of sampling station. River mile designation begins with 0 = outflow of Little Washoe Lake.

Creek from Steamboat Ditch was minimal. Similarly, Whites and Thomas Creek flows were low in TDS. At SB 8 concentrations ranged from 50-80 mg/l and at SB 10 they were slightly higher at 80-100 mg/l.

Measurements at SB 7 show a very large source of TDS-laden discharge between SB 5 and SB 7. The highest seasonal concentrations occurred in the months of June through December when values in the range of 1000-2000 mg/l were measured. At other times of the year, TDS ranged from 300-800 mg/l. The correlation between flow and TDS was highly significant ($p<0.01$) at SB 7 with an r-value of -0.64. In their comprehensive review of thermal hot springs in Nevada, Garside and Schilling (1979) report a TDS content of 2557 mg/l in discharge from the Steamboat Hot Springs which is located between SB 5 and SB 7. Maximum TDS was found when flow at SB 7 was less than 1 cfs. Since discharge from the springs is probably less seasonal in nature than surface flow, the seasonal increases in TDS represent those periods when discharge from the hot springs constituted a higher percentage of total creek flow. Garside and Schilling report discharges from the spring in the range of 0.7-1.8 cfs. Given that flow in Steamboat Creek at SB 7 range from 0.1 to 4.8 cfs, it is clear that this source can be a major contributor to flow (and therefore ionically rich discharge) in the creek. Between SB 5 and SB 7, TDS increased from a mean (Oct-87 to Jun-91) of 240 mg/l to 878 mg/l reflecting input from the hot springs. As discussed below, EC and chloride are also high in discharge from the Steamboat Hot Springs and are also elevated in Steamboat Creek at SB 7.

The influence of this high TDS source water from the Steamboat Hot Springs is also seen further downstream. Five miles downstream at SB 11, TDS was still high with a range of 350-1150 mg/l and a mean of 777 mg/l. While this represents a ±10% decrease in the overall mean concentration between SB 7 and SB 11, there were individual dates when TDS was higher at SB 11. This occurred primarily in December, February and April. The statistical relationship between TDS and flow at SB 11 was not significant ($p>0.05$, $r=0.31$).

Flow in the tributaries monitored at SB 12, SB 14 and especially SB 16 (Alexander Ditch, Rico Poco Drain and Boynton Slough, respectively) were major contributors to downstream flow; consequently, the TDS concentrations in these waters played a significant role in downstream concentration (note: during irrigation season, flow in Alexander Ditch is diverted). Mean TDS (Oct-87 to Jun-91) at SB 17 was 441 mg/l which represents a 40-45% decrease relative to SB 11. This was a direct consequence of low TDS in the tributary inflows. Rio Poco Drain and Boynton Slough contributed 82% of the total flow of the three main tributaries between SB 11 and SB 17 (mean flows at SB 12=3.0 cfs, SB 14=1.7 cfs and SB 16=11.9 cfs). TDS was identical at SB 14 and SB 16 and averaged 280-285 mg/l for the study period. This was low relative to SB 7 and SB 11 and only slightly higher than the overall mean at SB 5, above the Steamboat Hot Springs. The overall mean TDS at SB 12 was higher at 405 mg/l and reflective of the thermal spring geology in the area drained by the Alexander Ditch. TDS and flow were significantly ($p<0.001$) and negatively correlated ($r=-0.75$) at SB 16. This was not due to evaporative concentration since flow was high during the summer for agricultural purposes. Winter rains and runoff, which create a much lesser flow in Boynton Slough relative to the summer irrigation flows, most likely transport ionic constituents from the agricultural fields to the Slough. Flow and TDS at SB 17 were not significantly correlated ($p>0.05$, $r=0.30$).

Yori Drain (SB 18) had an overall TDS concentration of 283 mg/l which was relatively low and equal to that found at SB 14 and SB 16. Yori Drain discharge had very little affect on TDS at SB 19. TDS at this most downstream monitoring location was nearly identical in concentration and seasonal distribution to that at SB 17 with a project mean of 432 mg/l.

Data for electrical conductance (EC) is given in Table 7 and Figure 6. As expected, there was a very strong and positive statistical relationship between EC and TDS. For all stations combined, the r-value was 0.996 ($p<0.001$) with a 1.58 µS increase in EC for each 1 mg/l increase in TDS. When taken individually, the r-value for TDS vs. EC at each station was also >0.99 with the exceptions of SB 8 ($r=0.89$, $p<0.001$), SB 10 ($r=0.29$, $p>0.05$) and SB 19

Table 7. Individual electrical conductivity (µS) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Electrical Conductivity

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	305	124	437	107	2797	82	102	1076	828	505	244	448	285	442
Dec-87	291	139	333		2939	80	98	964	409	330	500	782	527	783
Feb-88	303	154	320		705	81	103	994	698	352	532	829	529	793
Apr-88	256	157	407		1248	85	100	1551	1571	404	562	990	519	482
Jun-88	342	128	465	107	2139	106	101	1170	664	396	312	457	317	464
Aug-88	373	133	468	111	1710	83	105	1113	339	412	265	394	310	361
Oct-88	373	116	346		2748	84	100	1703	361	398	426	812	565	813
Dec-88	318	163	341		1389	86	103	1675	582	433	582	582	944	866
Feb-89	285	141	291		585	80	102	113	516	380	524	848	497	868
Apr-89	359	181	363		877	97	99	1349	608	375	587	1004	511	992
Jun-89	302	80	213	81	396	64	80	922	668	451	312	576	235	505
Aug-89	314	104	306	113	1106	69	93	1253	480	504	315	432	277	616
Oct-89	365	118	289	112	474	78	111	653	375	415	315	507	350	472
Dec-89	328	150	325		754	79	103	1417	382	394	550	725	518	788
Feb-90	302	155	370		763	82	105	1339	909	363	539	848	468	833
Apr-90	275	148	328		747	83	100	1583	907	385	307	561	455	554
Jun-90	312	96	340	97	2045	69	105	577	432		291	461	280	453
Aug-90	338	138	493	113		80	114	776	538	480	297	461	343	433
Oct-90	401	142	498		2519	83	109	1660	708	451	589	814	480	738
Dec-90	342	156	334		2383	81	107	1244	715	378	497	852	470	820
Feb-91	317	140	314		638	81	105	1145	413	380	456	707	407	706
Apr-91	340	174	379		856	90	106	1491	517	444	413	835	450	758
Jun-91	286	81	216	78	544	69	84	485	346	447	372	680	224	464

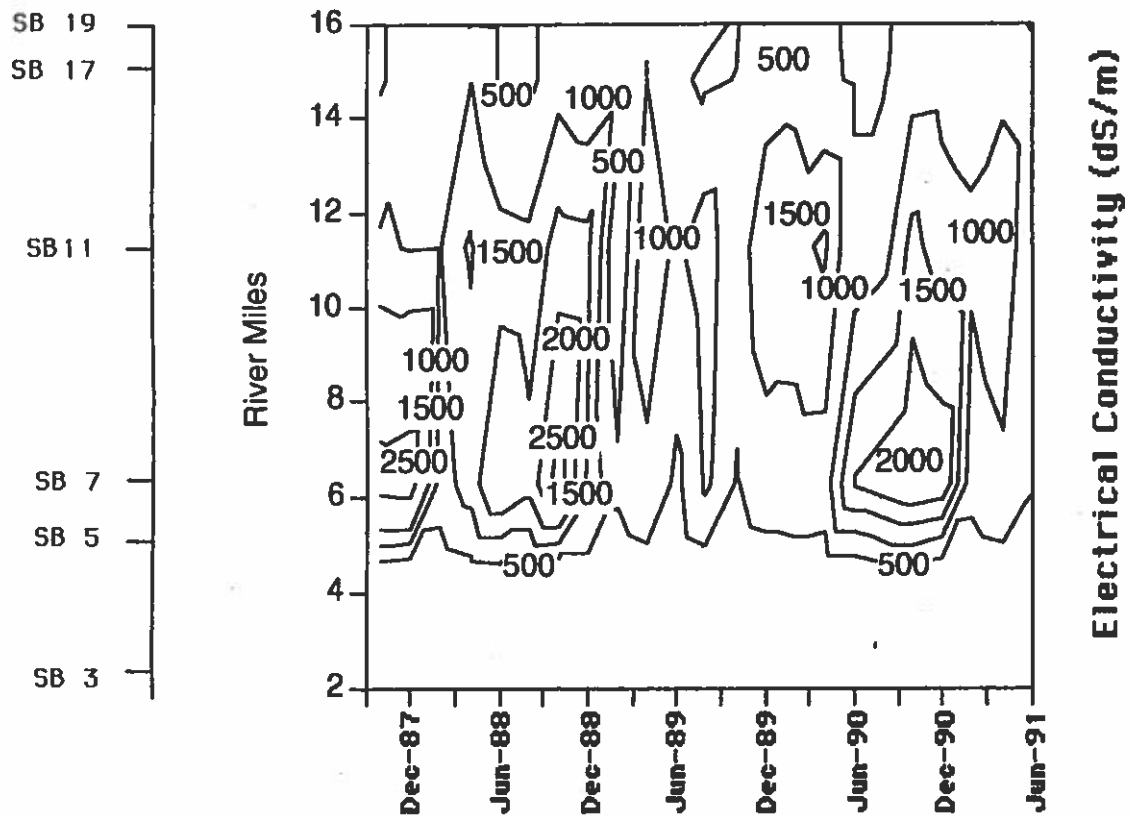


Figure 6. Contour plot of electrical conductivity in the main Steamboat Creek channel; Oct-87 to Jun-91. Legend on left shows location of sampling station. River mile designation begins with 0 = outflow of Little Washoe Lake.

($r=0.80$, $p<0.001$). The influence of high EC in the discharge from the Steamboat Hot Springs is also obvious in the data base.

Data for chloride concentration is given in Table 8 and Figure 7. The distribution and concentrations of chloride in this system were again unique, owing to the high levels of this constituent in discharge from the Steamboat Hot Springs. Background concentrations in SB 8 and SB 10 which drain the east slope of the Sierra Nevada was reported as zero (0) on all sampling dates. Downstream of the Little Washoe Lake outflow at SB 3 chloride ranged from 1-13 mg/l with a mean of 6 mg/l. The mean concentration at SB 5 increased to 11 mg/l (range 6-20 mg/l). Levels in Galena Creek and Steamboat Ditch were almost always less than 5 mg/l. Garside and Schilling (1979) reported chloride in Steamboat Hot Spring discharge to be in the range of 850-1000 mg/l. Concentrations measured at SB 7 reflected this high source ranging from 55 to 738 mg/l with a mean of 298 mg/l. Both the seasonal and station-to-station trends in chloride were nearly identical to those observed for TDS. Indeed, the relationship between TDS and chloride for all stations combined as positive and highly significant ($r=0.96$, $p<0.001$). Between SB 5 and SB 7, Cl increased by a factor of 25-30; from SB 7 to SB 11 it declined by 33% followed by an additional 41% decline between SB 11 and SB 17. As with TDS, Cl at SB 17 and SB 19 were virtually identical. It is noteworthy that at SB 7 chloride accounted for 40-45% of the TDS pool (as mg Cl:mg TDS). The downstream tributaries (SB 14, SB 16 and SB 18) showed low mean Cl concentrations (5-17 mg/l), and similar to that observed for TDS. SB 12 had a mean Cl content of 66 mg/l which was just slightly less than that found at SB 17 and SB 19.

Mean alkalinity over the period of record was 163 mg/l at SB 5, 184 mg/l at SB 7, 240 mg/l at SB 11, 186 mg/l at SB 17 and 192 mg/l at SB 19 (Table 9, Figure 8). The increase between SB 5 and SB 7 was much less than the elevation in TDS, EC and chloride concentration between these two sites. The higher values of these latter constituents at SB 7 were the direct result of inflow from the ionically enriched Steamboat Hot Springs. pH at all sites was relatively high but varied only between 7.9 and 8.9 (Table 10). According to

Table 8. Individual chloride (mg/l) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Chloride
(mg/L)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	2	2	10	2	690	0	0	164	124	10	7	37	7	34
Dec-87	3	1	6		738	0	0	158	28	3	10	88	12	93
Feb-88	5	5	9		106	0	0	164	94	4	15	97	14	88
Apr-88	1	0	8		220	0	0	243	213	4	12	122	15	121
Jun-88	4	0	14	1	480	0	0	184	90	3	5	33	6	50
Aug-88	7	2	17	2	385	0	0	170	15	6	6	25	9	17
Oct-88	4	1	9		670	0	0	290	16	5	11	96	17	91
Dec-88	8	3	8		283	0	0	283	69	7	14	14	118	111
Feb-89	8	3	10		88	0	0	180	37	4	19	109	15	107
Apr-89	10	7	14		144	0	0	228	56	4	18	136	18	137
Jun-89	11	3	7	2	55	0	0	114	64	6	8	58	6	55
Aug-89	7	3	11	3	243	0	0	233	36	7	9	28	8	31
Oct-89	5	4	8	2	78	0	0	82	26	7	8	52	9	52
Dec-89	5	5	9		122	0	0	248	27	4	15	69	15	48
Feb-90	7	3	12		130	0	0	235	124	3	15	114	16	102
Apr-90	4	2	10		118	0	0	297	124	3	10	64	14	64
Jun-90	6	3	13	3	500	0	0	81	36		8	41	9	39
Aug-90	4	2	12	2		0	0	110	65	6	8	35	10	31
Oct-90	7	2	20		590	0	0	305	80	4	18	92	15	61
Dec-90	6	2	9		600	0	0	218	85	3	17	110	15	102
Feb-91	7	4	9		93	0	0	210	38	4	50	94	23	99
Apr-91	7	3	15		138	0	0	290	55	6	14	108	13	100
Jun-91	5	2	7	2	99	0	0	61	24	6	14	83	7	58

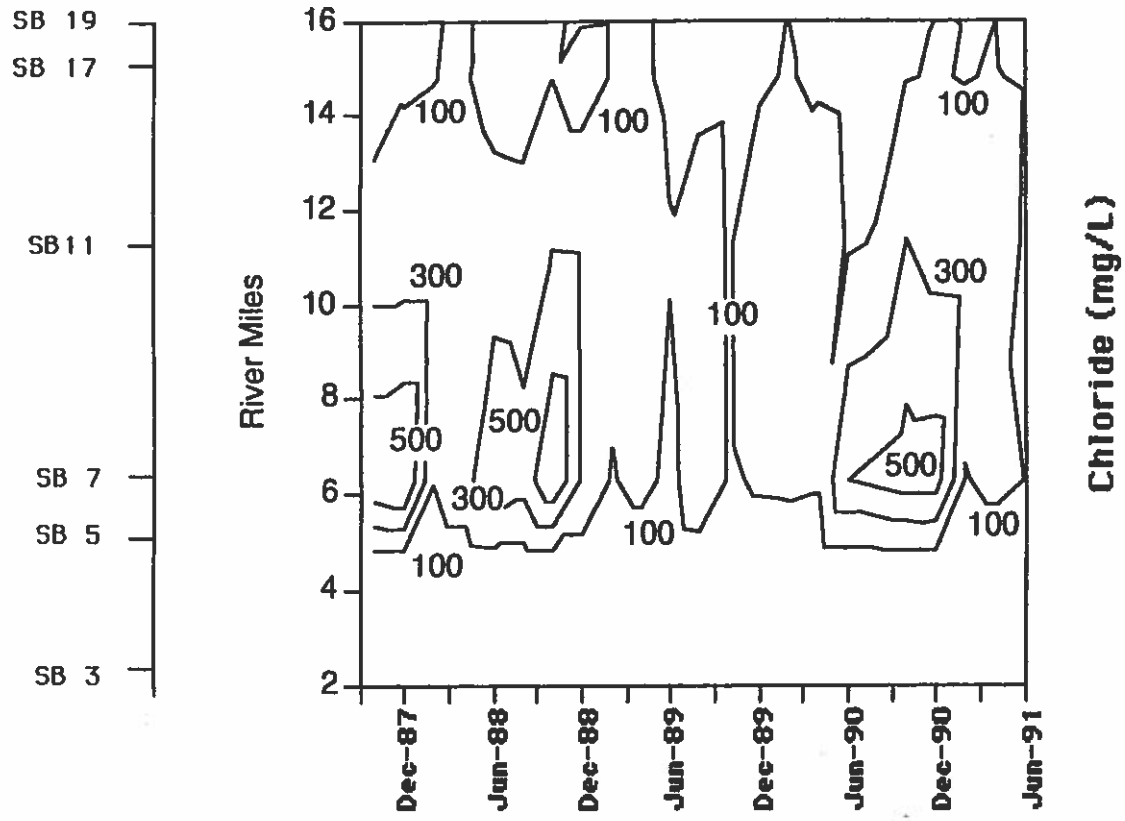


Figure 7. Contour plot of chloride in the main Steamboat Creek channel; Oct-87 to Jun-91. Legend on left shows location of sampling station. River mile designation begins with 0 = outflow of Little Washoe Lake.

Table 9. Individual total alkalinity (mg/l) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Alkalinity
(mg/L)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	150	56	202	44	246	30	48	236	202	192	92	134	94	135
Dec-87	146	64	162		246	26	48	204	158	154	178	208	176	208
Feb-88	150	78	156		170	34	52	216	190	166	192	216	180	206
Apr-88	126	76	190		234	26	50	316	288	190	200	246	168	237
Jun-88	164	56	224	42	198	28	50	244	178	176	122	150	110	160
Aug-88	182	64	212	52	180	32	52	246	154	182	110	138	114	128
Oct-88	186	56	158		254	32	52	334	152	192	162	216	184	215
Dec-88	152	76	154		196	28	48	304	170	200	204	204	232	227
Feb-89	130	66	132		148	32	50	236	192	188	178	220	168	216
Apr-89	168	82	162		190	36	52	266	208	186	222	252	148	238
Jun-89	132	30	90	30	96	22	38	220	230	214	122	164	80	163
Aug-89	156	48	142	50	138	24	50	242	202	248	128	146	98	125
Oct-89	186	52	130	60	96	30	60	164	142	186	122	146	116	141
Dec-89	162	68	148		168	24	52	288	138	188	202	208	182	251
Feb-90	148	68	168		172	30	50	270	264	176	190	218	162	235
Apr-90	138	70	154		178	32	52	286	252	188	106	142	164	170
Jun-90	152	42	158	36	218	26	50	124	164		114	148	104	175
Aug-90	168	64	226	50		32	38	168	156	226	112	150	124	161
Oct-90	190	64	228		252	32	56	280	216	212	216	212	160	183
Dec-90	156	72	156		232	30	48	254	222	180	170	210	166	240
Feb-91	142	62	144		156	32	54	222	134	180	102	168	122	204
Apr-91	154	82	168		192	32	54	268	160	212	144	200	158	230
Jun-91	140	32	94	28	98	24	40	128	132	216	146	188	78	185

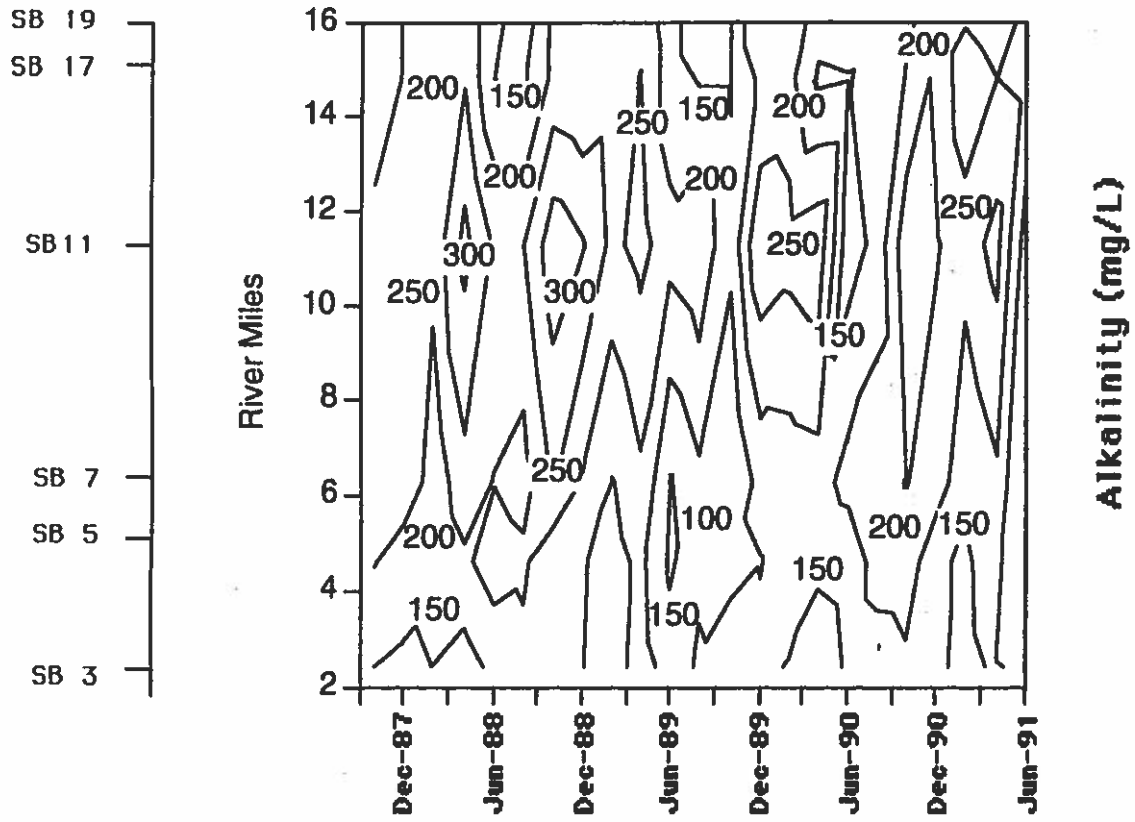


Figure 8. Contour plot of alkalinity in the main Steamboat Creek channel; Oct-87 to Jun-91. Legend on left shows location of sampling station. River mile designation begins with 0 = outflow of Little Washoe Lake.

Table 10. Individual pH observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

pH

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	8.27	8.19	8.19	8.16	8.16	8.01	8.02	8.43	8.48	8.40	8.39	8.41	8.36	7.90
Dec-87	7.99	7.97	8.04		8.00	8.06	7.95	8.40	8.74	8.27	8.09	8.32	8.15	8.20
Feb-88	8.11	8.03	8.07		8.09	7.75	7.80	8.30	8.31	8.23	8.29	8.24	8.18	8.40
Apr-88	7.94	8.01	7.92		8.28	6.81	8.24	8.50	8.56	8.61	8.34	8.41	8.47	8.40
Jun-88	8.50	8.23	8.42	8.11	8.34	7.98	8.14	8.63	8.82	8.56	8.24	8.24	8.41	8.15
Aug-88	8.24	8.16	7.98	8.13	8.16	7.86	8.06	8.41	8.74	8.21	8.36	8.46	8.05	8.10
Oct-88	8.36	8.18	8.44		8.21	7.93	8.06	8.41	8.44	8.42	8.31	8.47	8.35	8.60
Dec-88	8.04	8.07	7.95		8.06	7.79	7.89	8.37	8.43	8.22	8.15	8.15	8.26	8.20
Feb-89	8.21	8.23	8.30		8.21	7.76	7.85	8.39	8.76	8.52	8.31	8.36	8.23	8.10
Apr-89	8.13	8.20	8.20		8.24	7.88	7.95	8.65	8.62	8.94	8.68	8.55	8.73	8.50
Jun-89	8.04	7.95	8.05	7.89	8.11	7.90	7.98	8.26	8.31	8.40	8.28	8.13	8.35	7.50
Aug-89	8.22	8.02	8.17	8.08	8.22	7.74	7.99	8.47	9.17	8.42	8.52	8.61	8.76	7.90
Oct-89	8.50	8.20	8.41	8.28	8.37	8.09	8.22	8.53	8.66	8.50	8.50	8.52	8.55	8.40
Dec-89	8.33	8.20	8.29		8.28	7.93	8.06	8.43	8.50	8.37	8.39	8.43	8.40	7.60
Feb-90	8.44	8.28	8.52		8.51	8.07	8.18	8.61	8.63	8.58	8.57	8.65	8.38	8.60
Apr-90	8.19	8.21	8.22		8.28	7.68	8.09	8.57	8.69	8.52	8.25	8.65	8.83	8.50
Jun-90	8.05	8.00	8.18	8.14	8.45	7.98	8.17	8.27	8.82		8.84	8.60	9.17	8.90
Aug-90	8.36	8.20	8.29	8.10		8.00	8.15	8.41	8.96	8.60	8.43	8.69	8.34	8.30
Oct-90	8.22	8.21	8.29		8.18	8.06	8.09	8.50	8.88	8.51	8.57	8.73	8.54	8.20
Dec-90	8.19	8.21	8.19		8.06	8.06	8.03	8.44	8.78	8.45	8.34	8.46	8.32	8.20
Feb-91	8.17	8.11	8.13		8.23	7.95	7.98	8.38	8.72	8.45	8.01	8.42	8.16	8.60
Apr-91	8.37	8.31	8.39		8.39	7.98	8.16	8.57	8.68	8.69	8.78	8.74	8.51	8.70
Jun-91	8.38	8.48	8.24	8.31	8.18	8.20	8.14	8.27	8.80	8.75	8.48	8.35	8.96	7.80

equilibrium chemistry, at a pH of 9.0 and below, the CO_3^{+2}:HCO_3^- ratio is approximately 3%. However, because boron (as borate) contributes significantly to carbonate alkalinity at the measured pH levels, and since the hot springs were a significant source of high levels of boron, we would expect the CO_3^{+2}:HCO_3^- ratio in Steamboat Creek to be somewhat higher. The downstream tributaries SB 12, SB 14, SB 16 and SB 18 had mean alkanlinity values of 187, 193, 154 and 143 mg/l, respectively. For all purposes, alkalinity in the main Steamboat Creek channel was uniform. Galena Creek, Steamboat Ditch, Whites Creek and Thomas Creek had reduced alkalinity as they did for most of the measured ions.

2.3 Nitrogen

2.3.1 Concentration

Concentrations of total-N (TN), total Kjeldahl-N (TKN) and nitrate (NO3) on individual sampling dates and locations are presented in Figure 9. Mean annual concentrations of these parameters are summarized in Figures 10-12 and Table 11.

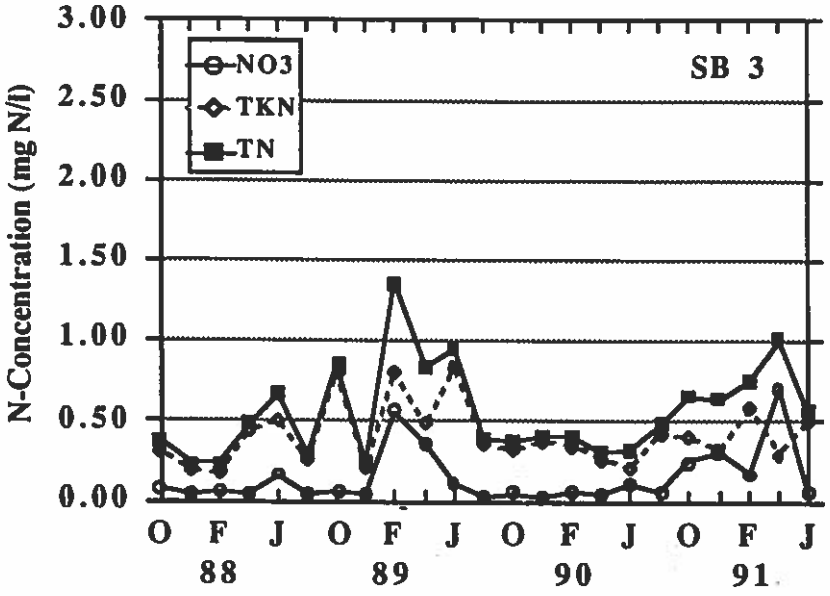
Most apparent were the station-to-station differences in nitrogen concentrations. Stations SB 8 and SB 10, on Whites Creek and Thomas Creek, respectively showed the lowest mean annual concentrations with values in the range of 0.16-0.28 mg total-N/l and 0.01-0.04 mg nitrate-N/l . These were very low for the Steamboat Creek watershed and typical of the more pristine mountainous headwaters of these creeks. TKN was the dominant N-species at both these stations accounting for 83-94% of the TN. There was a slight, albeit consistent seasonality in the distribution of TKN (and consequently TN) with high levels typically found in June and/or October. Flow was also reduced during this summer period as was particularly evident at SB 10 (refer to Figure 3). Maximum individual TN concentrations at SB 8 and SB 10 did not exceed 0.50 mg N/l with most values in the range of 0.15 to 0.30 mg N/l.

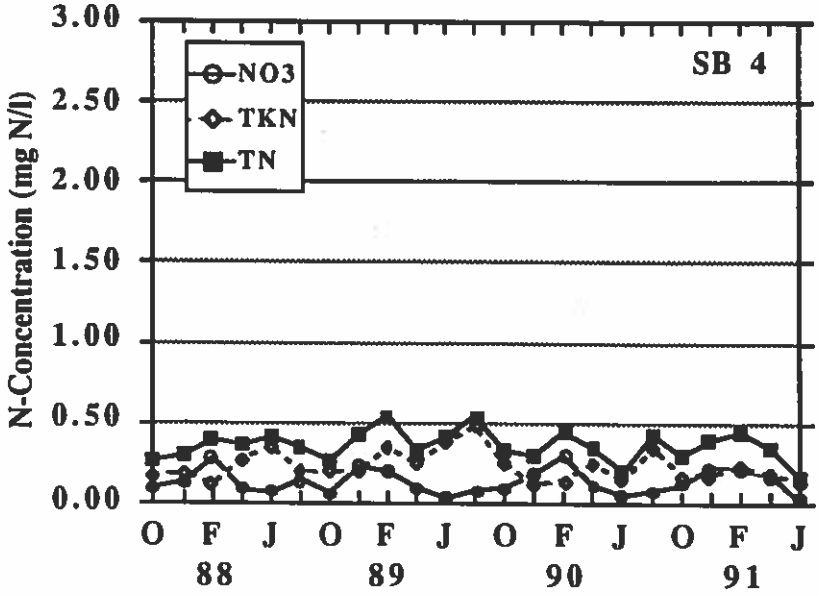
Galena Creek (SB 4) was also low in TN, albeit with elevated mean annual values of 0.33-0.42 mg N/l (Table 11). This higher TN was the result of overall higher NO3 concentrations

Table 11. Mean annual concentration of total-N, total Kjeldahl-N and nitrate at each of the Steamboat Creek sampling stations. Year refers to Water Year which covers the period October-September. Number of sampling dates per year was WY 88=6 (except SB 6=3), WY 89=6 (except SB 6=2), WY 90=6 (except SB 6=3, SB 7=5, SB 14=5), and WY 91=5 (except SB 6=1). Values expressed as mg/l.

Station	TN 88	TN 89	TN 90	TN 91	TKN 88	TKN 89	TKN 90	TKN 91	NO3 88	NO3 89	NO3 90	NO3 91
SB 3	0.39	0.77	0.39	0.73	0.32	0.58	0.33	0.43	0.07	0.19	0.06	0.30
SB 4	0.35	0.42	0.34	0.33	0.22	0.31	0.21	0.18	0.13	0.11	0.13	0.15
SB 5	0.65	0.61	0.75	0.41	0.47	0.53	0.45	0.28	0.18	0.08	0.30	0.13
SB 6	0.36	0.31	0.42	0.33	0.28	0.28	0.38	0.29	0.08	0.03	0.04	0.04
SB 7	0.56	0.58	0.47	0.44	0.47	0.51	0.35	0.40	0.09	0.07	0.12	0.04
SB 8	0.23	0.25	0.19	0.18	0.20	0.22	0.16	0.15	0.03	0.03	0.03	0.03
SB 10	0.26	0.28	0.25	0.16	0.23	0.24	0.22	0.15	0.03	0.04	0.03	0.01
SB 11	0.88	1.03	1.42	0.96	0.68	0.86	1.05	0.74	0.20	0.17	0.37	0.22
SB 12	1.47	2.32	1.54	1.71	1.13	2.12	1.41	1.63	0.34	0.20	0.13	0.08
SB 14	1.13	1.30	1.06	1.08	0.61	0.69	0.44	0.50	0.52	0.61	0.62	0.58
SB 16	1.25	1.18	1.18	1.51	0.75	0.68	0.65	0.91	0.50	0.50	0.53	0.60
SB 17	1.27	0.92	0.99	1.28	0.93	0.66	0.75	1.08	0.34	0.26	0.24	0.20
SB 18	2.61	2.97	2.32	2.20	0.93	0.85	0.67	1.03	1.68	2.12	1.65	1.17
SB 19	1.19	0.99	1.10	1.11	0.88	0.73	0.78	0.80	0.31	0.26	0.32	0.31

Figure 9. Distribution of nitrogen concentration taken from the sampling network for the Steamboat Creek monitoring study; Oct-87 to Jun-91. Concentrations are given for total-N (TN), total Kjeldahl-N (TKN) and nitrate (NO3), and are expressed as mg N/l.


SB 3
NO3
TKN
TN
N-Concentration (mg N/l)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
O F J O F J O F J O F J
88 89 90 91


SB 4
NO3
TKN
TN
N-Concentration (mg N/l)
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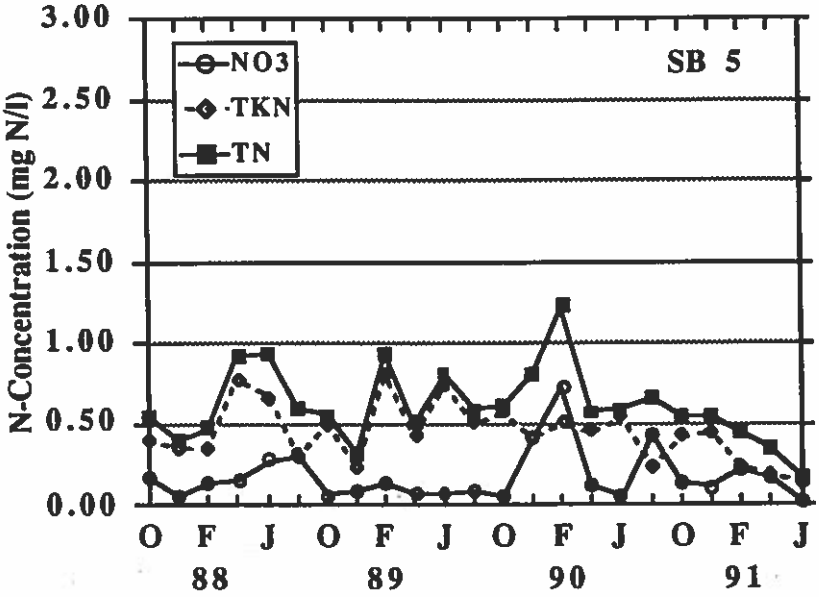
2.50
2.00
1.50
1.00
0.50
0.00
O F J O F J O F J O F J
88 89 90 91


SB 5
NO3
TKN
TN
N-Concentration (mg N/l)
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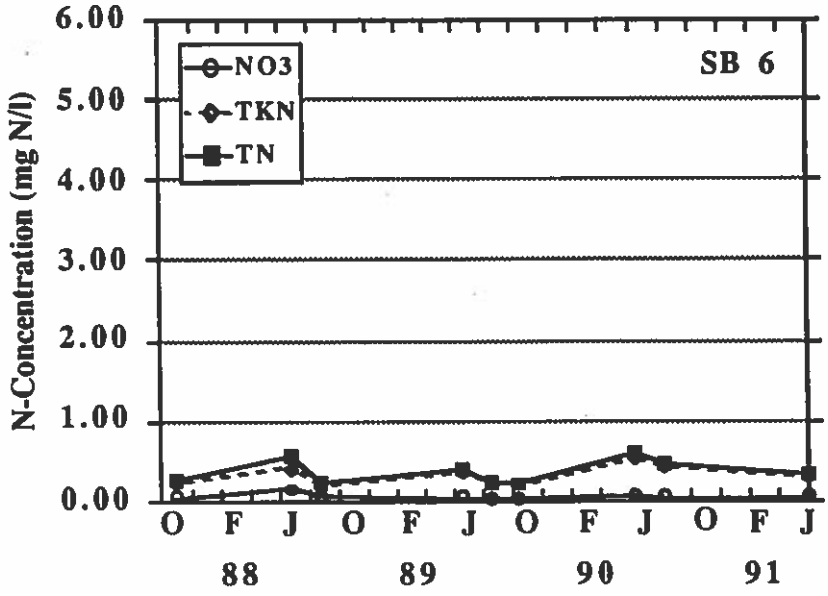
2.50
2.00
1.50
1.00
0.50
0.00
O F J O F J O F J O F J
88 89 90 91


SB 6
NO3
TKN
TN
N-Concentration (mg N/l)
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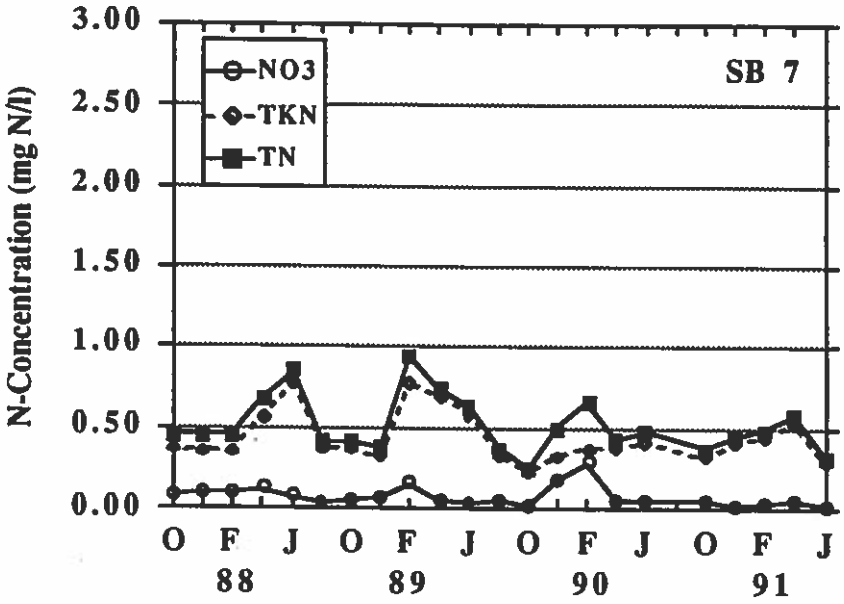
5.00
4.00
3.00
2.00
1.00
0.00
O F J O F J O F J O F J
88 89 90 91


SB 7
NO3
TKN
TN
N-Concentration (mg N/l)
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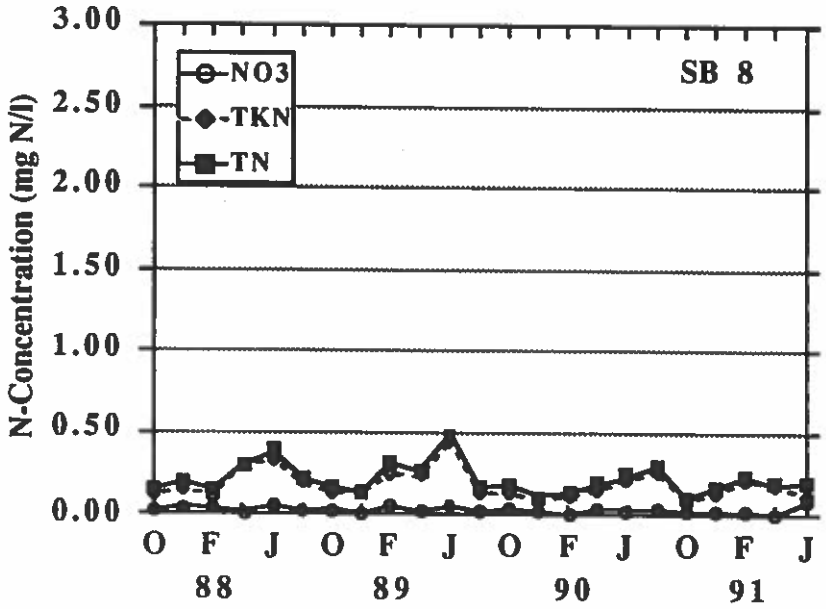
2.50
2.00
1.50
1.00
0.50
0.00
O F J O F J O F J O F J
88 89 90 91


SB 8
NO3
TKN
TN
N-Concentration (mg N/l)
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2.50
2.00
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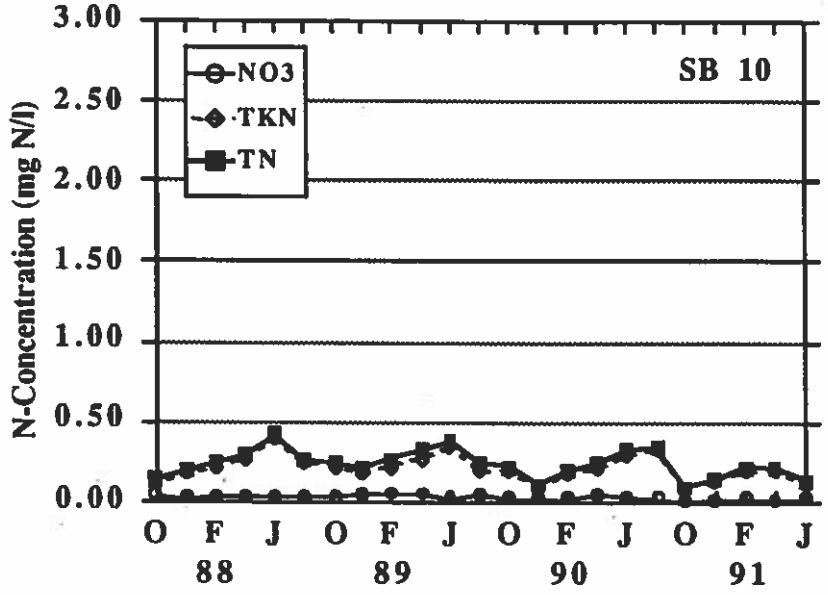
1.00
0.50
0.00
O F J O F J O F J O F J
88 89 90 91


SB 10
NO3
TKN
TN
N-Concentration (mg N/l)
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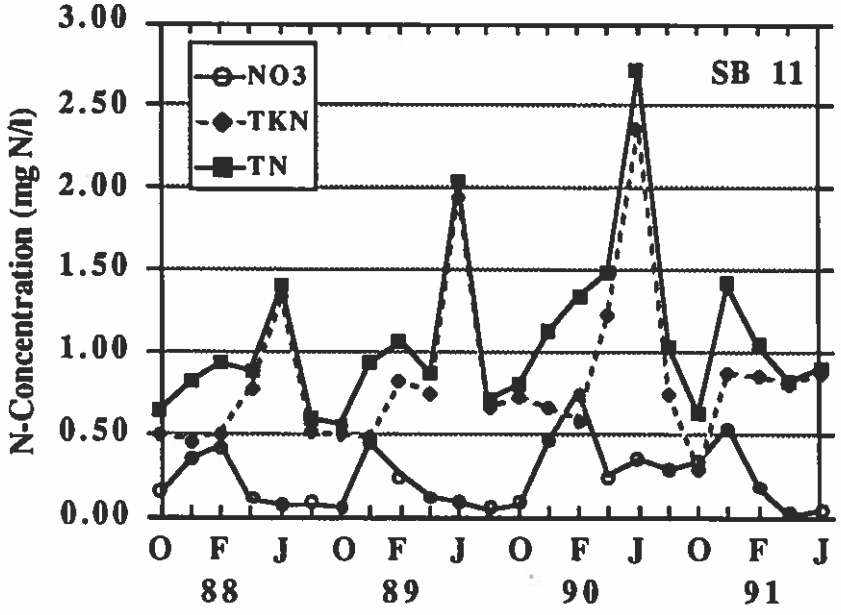
2.00
1.50
1.00
0.50
0.00
O F J O F J O F J O F J
88 89 90 91


SB 11
NO3
TKN
TN
N-Concentration (mg N/l)
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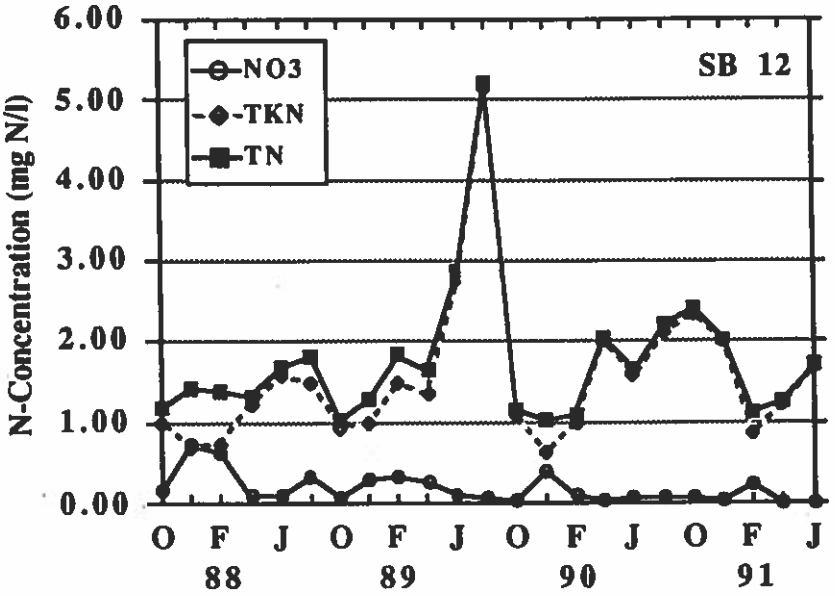
2.00
1.50
1.00
0.50
0.00
O F J O F J O F J O F J
88 89 90 91


SB 12
NO3
TKN
TN
N-Concentration (mg N/l)
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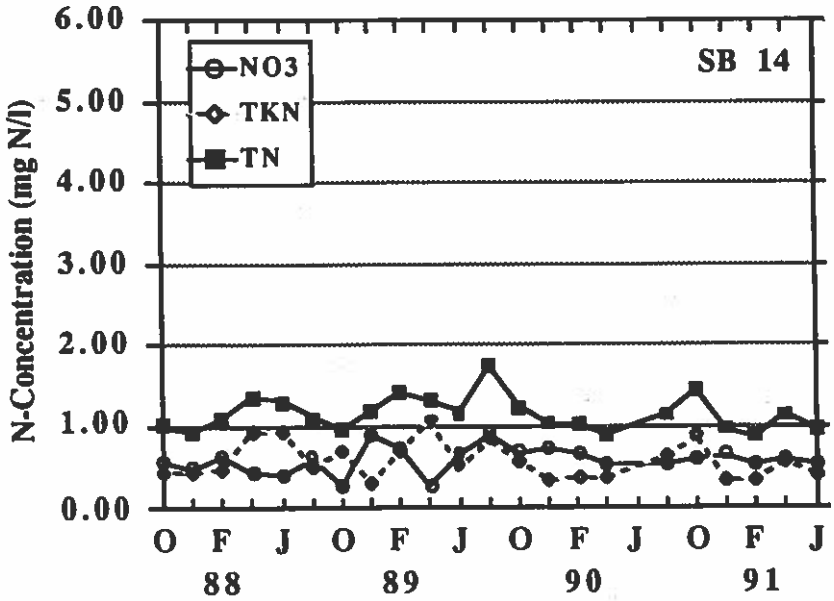
5.00
4.00
3.00
2.00
1.00
0.00
O F J O F J O F J O F J
88 89 90 91


SB 14
NO3
TKN
TN
N-Concentration (mg N/l)
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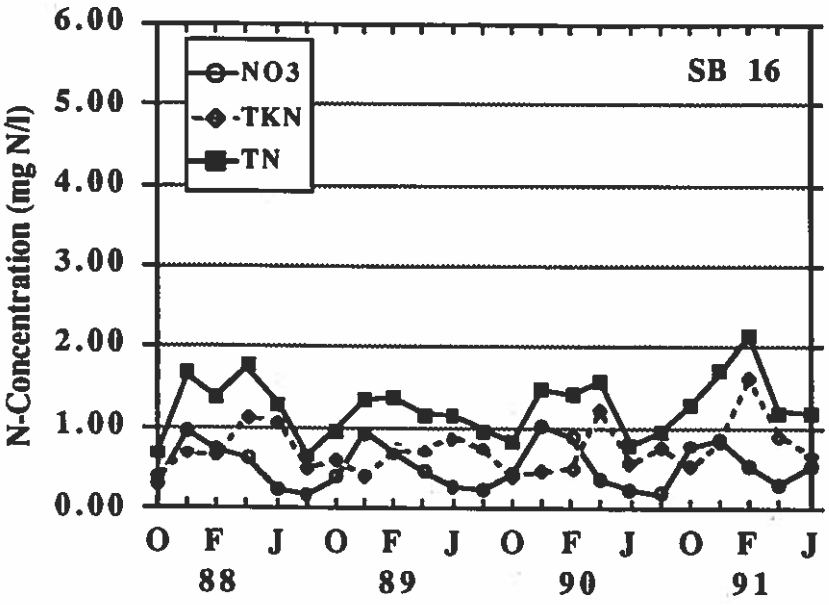
5.00
4.00
3.00
2.00
1.00
0.00
O F J O F J O F J O F J
88 89 90 91


SB 16
NO3
TKN
TN
N-Concentration (mg N/l)
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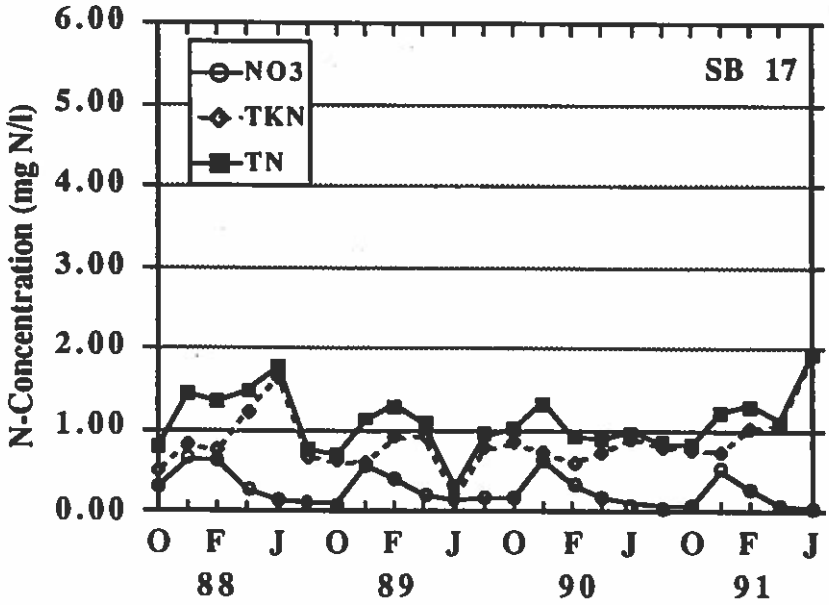
5.00
4.00
3.00
2.00
1.00
0.00
O F J O F J O F J O F J
88 89 90 91


SB 17
NO3
TKN
TN
N-Concentration (mg N/l)
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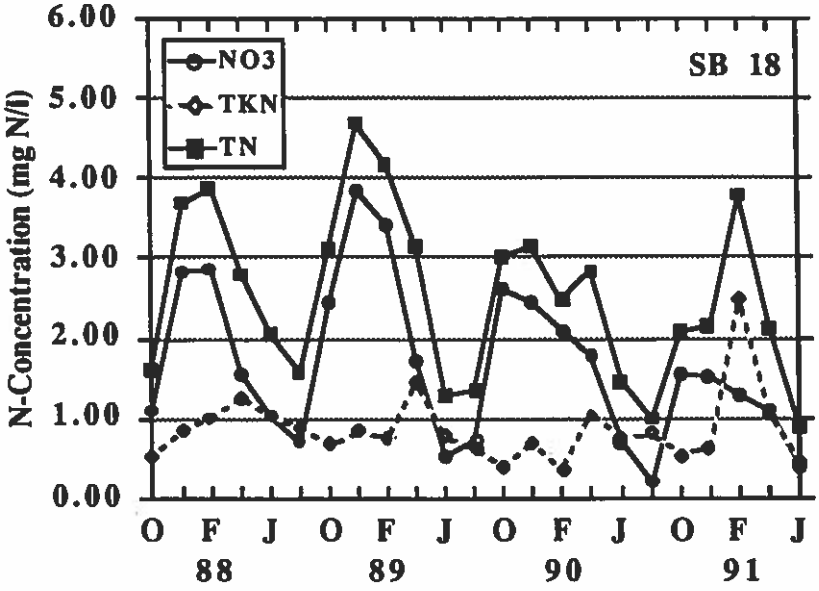
5.00
4.00
3.00
2.00
1.00
0.00
O F J O F J O F J O F J
88 89 90 91


SB 18
NO3
TKN
TN
N-Concentration (mg N/l)
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5.00
4.00
3.00
2.00
1.00
0.00
O F J O F J O F J O F J
88 89 90 91

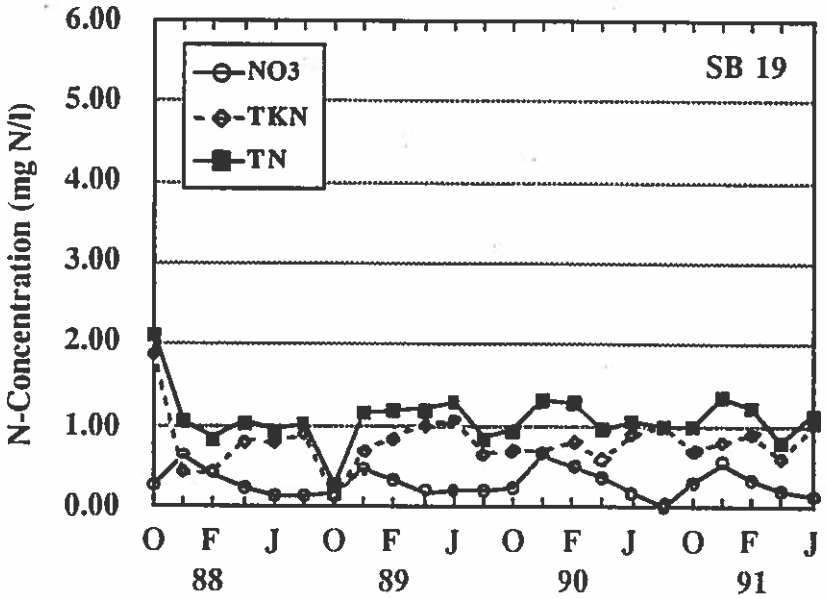

SB 19
NO3
TKN
TN
N-Concentration (mg N/l)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
O F J O F J O F J O F J
88 89 90 91

Figure 10 Mean annual concentration of total nitrogen (TN). Years represent Water Year (1 Oct-31 Sept).

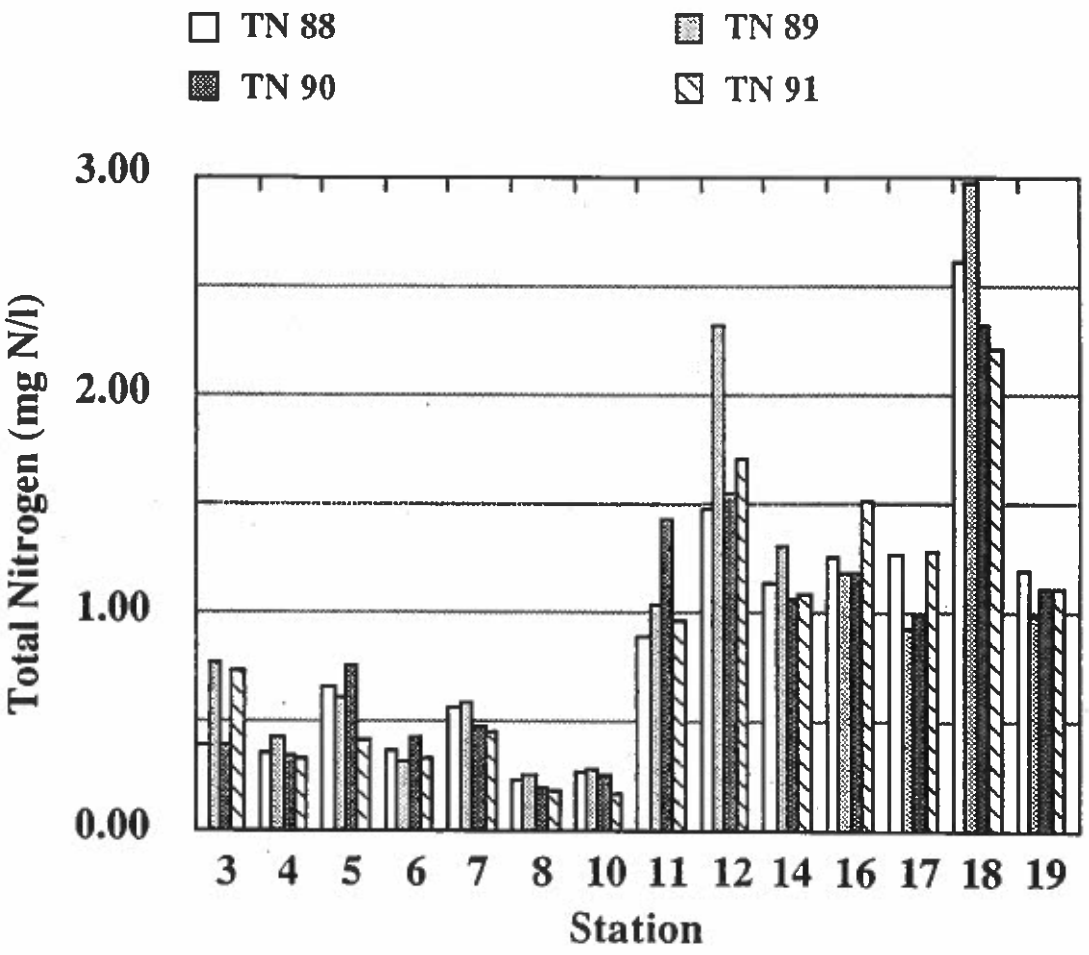


Figure 11 Mean annual concentration of total Kjeldahl nitrogen (TKN). Years represent Water Year (1 Oct-31 Sept).

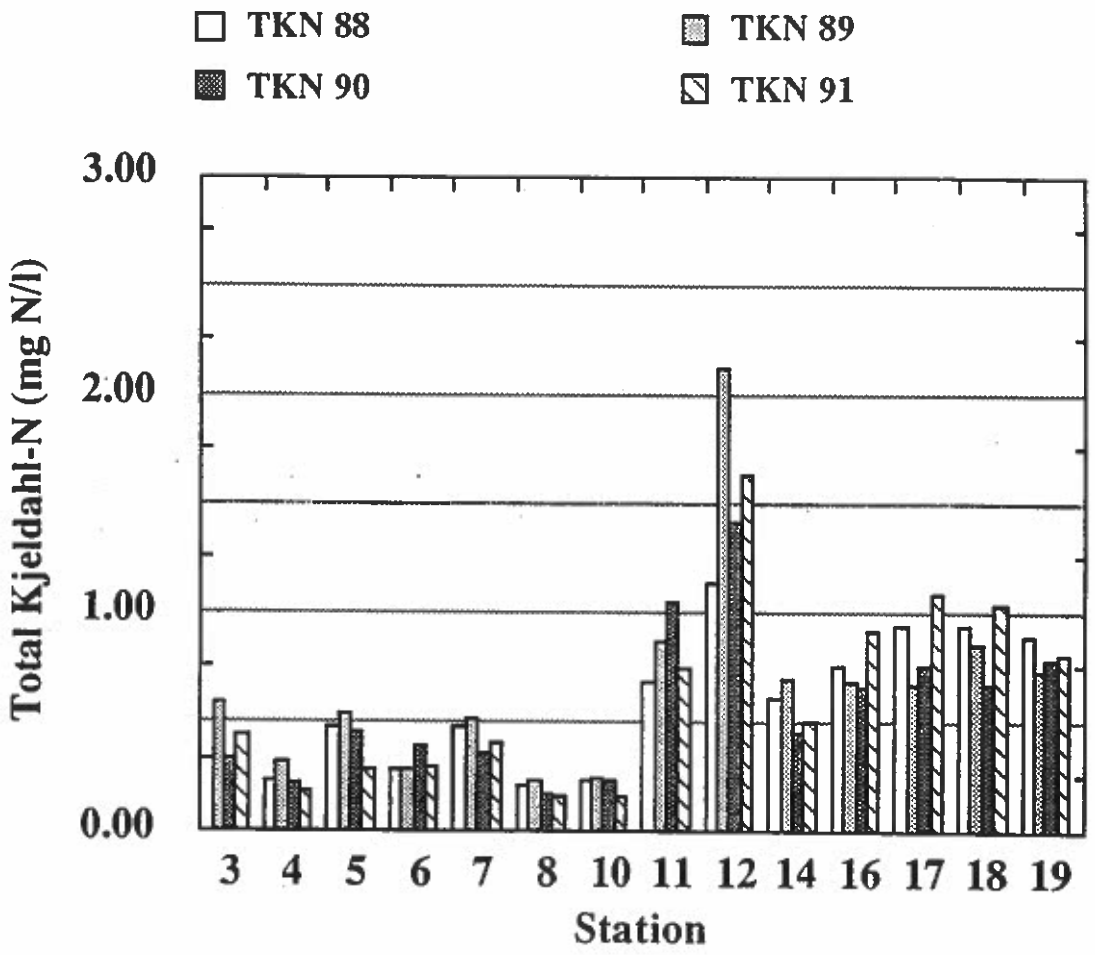
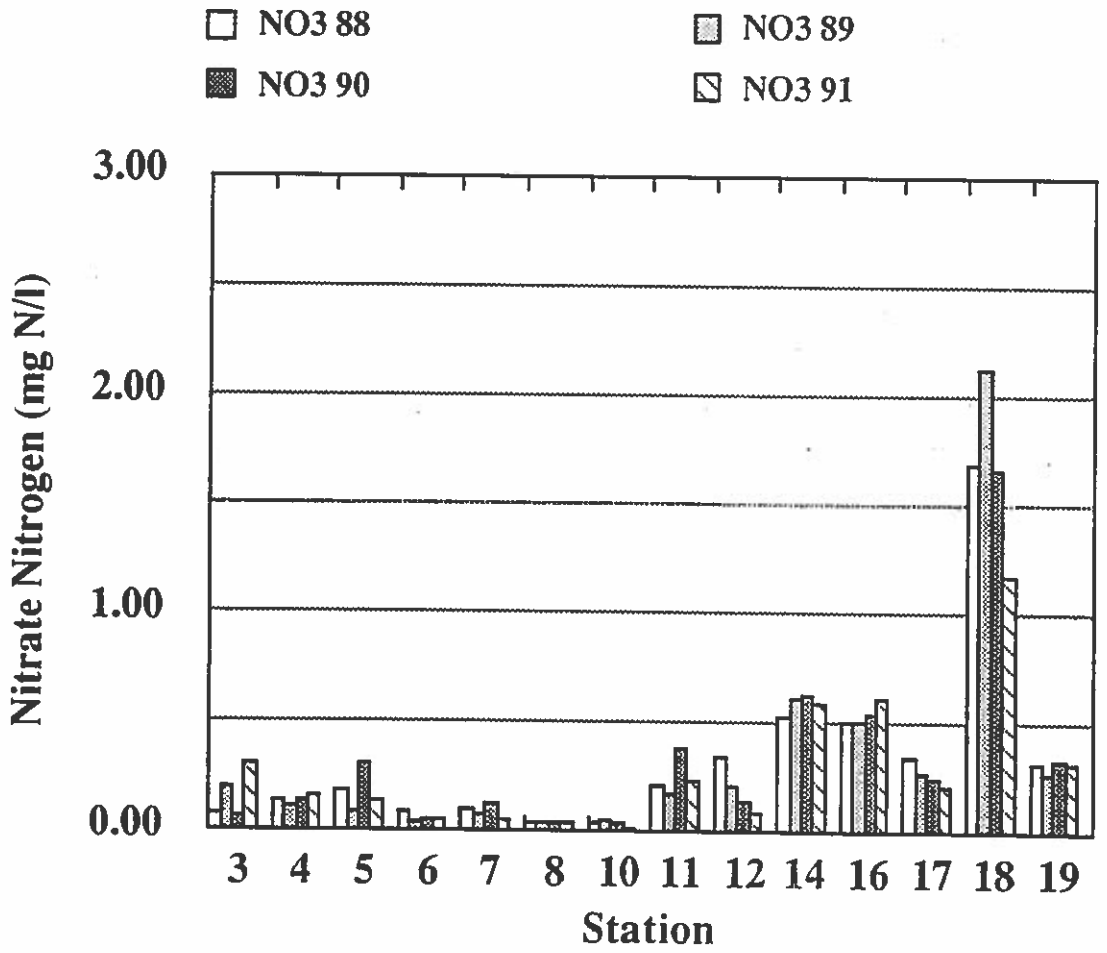


Figure 12 Mean annual concentration of nitrate nitrogen (NO3). Years represent Water Year (1 Oct-31 Sept).



during the entire period of record. Mean TKN at SB 4, SB 8, and SB10 for the period Oct 87-Jun 91 was nearly identical at 0.23 mg N/l and 0.20 mg N/l, respectively. NO3 concentration over this same period, however, was 0.13 mg N/l at SB 4 and only 0.03 mg N/l at SB 8/10. Only nine individual samples were taken during the entire period of record at SB 6 (Steamboat Ditch). A summary of this data showed that while the mean annual concentrations of TN at SB 6 and SB 4 were similar, NO3 was much less important at SB 6. NO3 accounted for 10-22% of the TN pool at SB 6, but 26-45% at SB 4 (Table 12).

Stations SB 3, SB 5 and SB 7, all on the main trunk of Steamboat Creek, were elevated in TN relative to the tributaries in this vicinity (i.e. SB 6, SB 8 and SB 10); however, they were much lower than concentrations observed in Steamboat Creek further downstream. Mean annual TN ranged from 0.39 to 0.77 mg N/l at SB 3, 0.41 to 0.75 mg N/l at SB 5, and 0.44 to 0.58 mg N/l at SB 7. Station SB 3 was the most upstream location that was routinely sampled. This site is approximately 2.4 miles downstream of the outlet of Little Washoe Lake and receives flow from Browns Creek (not sampled) just upstream. Since Browns Creek originates in the Sierra Nevada and does not travel through urbanized areas, and since discharge from Little Washoe Lake was minimal during the period of record, it is most likely that the relatively elevated N-concentrations at SB 3 reflect conditions in groundwater seepage from surrounding land. Maximum individual TN concentrations at SB 3 ranged from 1.0-1.3 mg N/l with TKN accounting for 59-82% of TN (Table 12). Both TKN and NO3 contributed to peak TN concentrations at SB 3 in Feb-Apr of WY 89 and WY 91; however, the distribution of TN and NO3 did not show any consistent seasonality (Figure 9). There was no clear relationship between flow and either of the three N-species. With the exception of Jun-Aug 1988 and Feb-90 when NO3 was elevated (0.30-0.72 mg N/l), TN concentrations at SB 5 followed those of TKN. As found for SB 3, TKN accounted for 60-87% of TN.

Between SB 7 and SB 11, TN concentration rose sharply by +0.32 mg N/l in WY 88, +0.45 mg N/l in WY 89, +0.95 mg N/l in WY 90 and +0.52 mg N/l in WY 91. Mean annual TN concentrations at SB 11 were 0.88, 1.03, 1.42 and 0.96 mg N/l (Table 11). Drainage

Table 12. Ratio of nitrate to total-N concentration and ortho-P to total-P concentration in water samples collected from the Steamboat Creek drainage sampling stations. Dervived from mean annual concentration data.

Station	NO3/TN 88	NO3/TN 89	NO3/TN 90	NO3/TN 91	OP/TP 88	OP/TP 89	OP/TP 90	OP/TP 91
SB 3	0.18	0.25	0.15	0.41	0.85	0.80	0.73	0.67
SB 4	0.37	0.26	0.38	0.45	0.75	0.67	0.50	0.50
SB 5	0.28	0.13	0.40	0.32	0.81	0.79	0.71	0.73
SB 6	0.22	0.10	0.10	0.12	0.75	0.33	0.20	0.11
SB 7	0.16	0.12	0.26	0.09	0.88	0.77	0.77	0.75
SB 8	0.13	0.12	0.16	0.17	0.67	0.67	0.67	0.50
SB 10	0.12	0.14	0.12	0.06	1.00	0.67	0.67	0.67
SB 11	0.23	0.17	0.26	0.23	0.86	0.77	0.75	0.67
SB 12	0.23	0.09	0.08	0.05	0.77	0.59	0.52	0.24
SB 14	0.46	0.47	0.58	0.54	0.70	0.75	0.58	0.50
SB 16	0.40	0.42	0.45	0.40	0.78	0.78	0.71	0.59
SB 17	0.27	0.28	0.24	0.16	0.73	0.68	0.67	0.57
SB 18	0.64	0.71	0.71	0.53	0.81	0.75	0.67	0.50
SB 19	0.26	0.26	0.29	0.28	0.46	0.32	0.55	0.50

from Steamboat Hot Springs was not the apparent cause of this increase since concentrations at SB 7 were relatively low and similar to SB 5. A more detailed look at the seasonal distribution of TN, TKN and NO3 on each individual sampling at stations SB 7 and SB 11 highlights the downstream increase in TN (Figure 9). The distribution of nitrogen at SB 7 exhibited a clearer seasonal pattern with higher concentrations of TN during Feb-Jun for each of the four monitoring years (Figure 9). These periods correspond to the time when surface runoff and groundwater flow from the surrounding land would be greatest. In WY 88, WY 89 and WY 91 this increase was primarily due to higher TKN levels. In WY 90, both TKN and NO3 contributed equally to TN, however, only NO3 showed an increase at that time.

The seasonal distribution of TN, TKN and NO3 at SB 11, with its higher overall concentrations relative to SB 7, showed marked seasonal fluctuations which appeared consistent between years (Figure 9). In WY 88, WY 89 and WY 90, the distribution of TN, TKN and NO3 was nearly identical. Nitrate concentration clearly peaked in either December or February (as it also did in WY 91) at a value ranging from 0.43-0.75 mg N/l. With the exception of WY 90, NO3 levels returned to a baseline of ±0.05 mg N/l during the summer. TKN showed a similar pattern; however, peak concentrations were typically delayed until June. Each year, TKN declined to a baseline of 0.6-0.8 mg N/l in Aug-Oct. This was followed by a sharp spike in concentration in June when values of 1.33, 1.95 and 2.36 mg N/l were measured in WY 88, WY 89 and WY 90, respectively. This pattern was not observed in WY 91. The occurrence of large summertime spikes of TKN-dominated TN were the result of agricultural-irrigation surface return and first-flush flows which drain over fields containing plant material and more importantly cattle excrement from a herd of 3,000-10,000 (L. Crowe pers. comm.) which use the area just south of SB 11 on a seasonal basis. This is supported by the fact that numbers of fecal coliform bacteria were typically higher during the early summer. The high NO3 concentrations in the winter resulted from seasonal groundwater flow which has drained fertilized agricultural land and is high in soluble nitrogen. Finally, uptake of NO3 by

attached algae is most likely for the decline in concentration during the summer decline (L. Crowe pers. comm.).

Stations SB 12, SB 14 and SB 16 carry agricultural return flows to Steamboat Creek. All contained similarly high concentrations of TN. Mean annual TN ranged from 1.06 to 2.32 mg N/l with most values in the range 1.1-1.7 mg N/l (Table 11). With the exception of a very large TN spike in Aug-89 of 5.22 mg N/l at SB 12, which was nearly 100% TKN, the distribution of TN, TKN and NO3 in these three tributary drainages was also very similar. At SB 14 and SB 16, TKN and NO3 concentrations were very similar (±0.50-0.60 mg N/l) and contributed equally to TN (Figure 9; Table 12). In contrast, TKN at SB 12 dominated TN as was more commonly seen at the upstream stations. The seasonal patterns of TKN and NO3 distribution at SB 16 was identical to that observed at SB 11; i.e. high winter NO3 concentrations followed by high TKN in spring-early summer. Land use in the Boynton Slough drainage (SB 16) is similar to that described for SB 11 with groundwater high in NO3 and livestock grazing. The explanation given above for the seasonal changes in nitrogen at SB 11 also applies to SB 16. (note: Flows at SB 16 were maximum in Jun-Aug [Figure 3] further supporting the idea of seasonal irrigation water draining TKN-enriched runoff into the Slough during this time of year).

SB 17 and SB 16 exhibited similar concentrations and seasonal patterns of nitrogen. This is not surprising given that flow from SB 16 contributed about half the total volume in Steamboat Creek at SB 17.

TN concentration in the Yori Drain (SB 18) was the highest for any station with mean annual values ranging from 2.20-2.97 mg N/l (Table 11). Maximum concentrations on individual sampling dates were as high as 4-5 mg N/l (Figure 9). Nitrate was clearly the most dominant form of N, accounting for 53-71% of TN. This was the highest percent contribution for nitrate at any station with mean annual NO3 levels of 1.17-2.12 mg N/l and maximum individual concentrations in the 2.5-3.5 mg N/l range. NO3 in Yori Drain followed the same seasonal pattern observed at SB 7, SB 11, SB 16 and SB 17; i.e. winter maximum and

summer minimum (Figure 9). A major purpose of the drain is the relieve seasonally high groundwater conditions at McCarran Airport. Given this, and the fact that the regional groundwater is high in nitrate as a result of agricultural activities, the observed pattern at SB 18 is not unexpected.

SB 19 was the most downstream station but above the discharge for the Reno-Sparks WTF. Despite the very high concentrations of NO3 in Yori Drain (tributary to Steamboat Creek between SB 17 and SB 19), nitrate declined at SB 19 as a result of dilution by the main Steamboat Creek flow. Indeed, mean annual NO3 was 0.26-0.32 mg N/l and accounted for 25-30% of TN. Mean annual TN ranged from 0.99 to 1.19 mg N/l and was very similar to that found immediately upstream at SB 17.

Figures 10-12 provide a summary of mean annual nitrogen concentration by location and highlight the following observations presented above; 1) N-concentrations were relatively consistent during each of the four years of monitoring, 2) TN, TKN and NO3 was typically lower at the upstream stations SB 3 - SB 10 as compared to the remaining downstream stations; and concentrations rose significantly between SB 7 and SB 11, 3) TKN typically dominated TN with the clear exception of SB 18 and to a lesser extent, SB 14 and SB 16, and 4) NO3 concentrations in the Yori Drain were exceptionally high.

2.3.2 Load

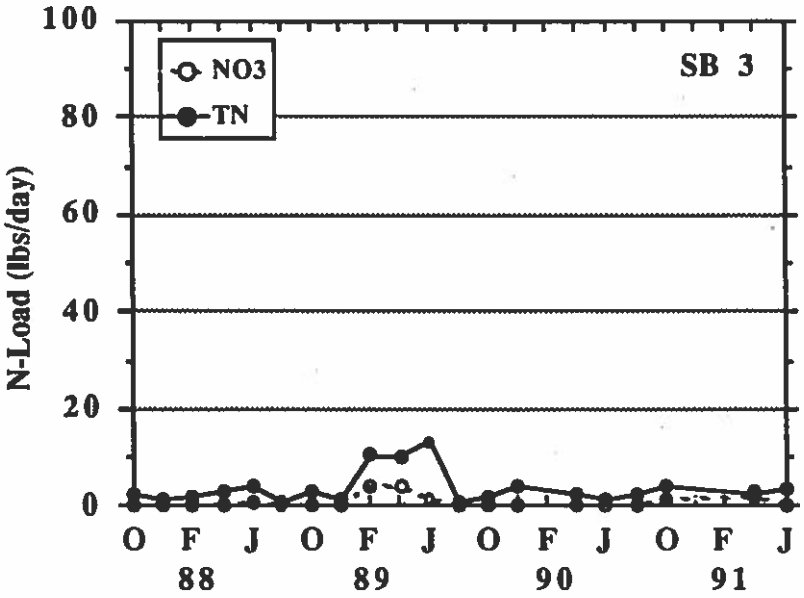
2.3.2.1 TN and NO_3 Load by Tributary and Reach

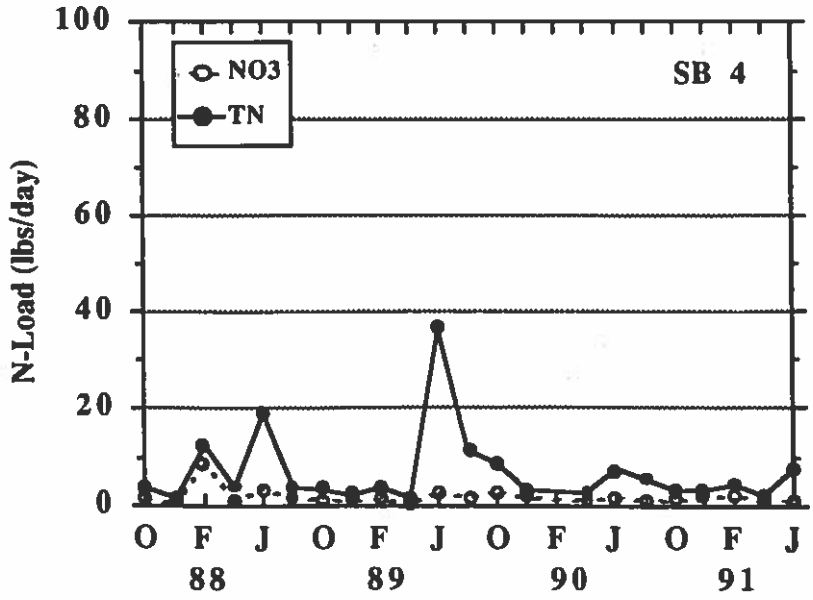
From the perspective of algal physiology and the growth response of these organisms to nitrogen, concentration is critical. However, since Steamboat Creek drains into the Truckee River and ultimately to Pyramid Lake, mass loading of nitrogen to these downstream waterbodies is also very important. Indeed, it is the total mass loading from all tributaries and diffuse nonpoint sources that affects downstream concentrations in the Truckee. In addition, identification of regions with high load is important from a regulatory and mitigation perspective. N-load in Steamboat Creek was calculated for TN and NO3; it was assumed TKN-load would represent the residual. Since load is the product of flow times concentration,

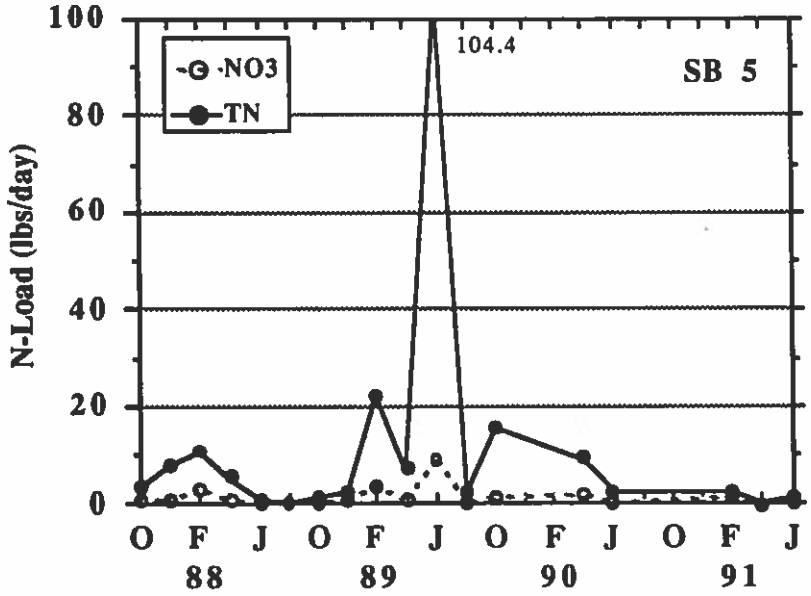
Table 13. Mean annual load of total-N and nitrate at each of the Steamboat Creek sampling stations. Year refers to Water Year which covers the period October-September. Number of sampling dates per year is identical to that for N-concentration except where flow data is missing. ID=insufficient data (n≤1). Values expressed as lbs/day.

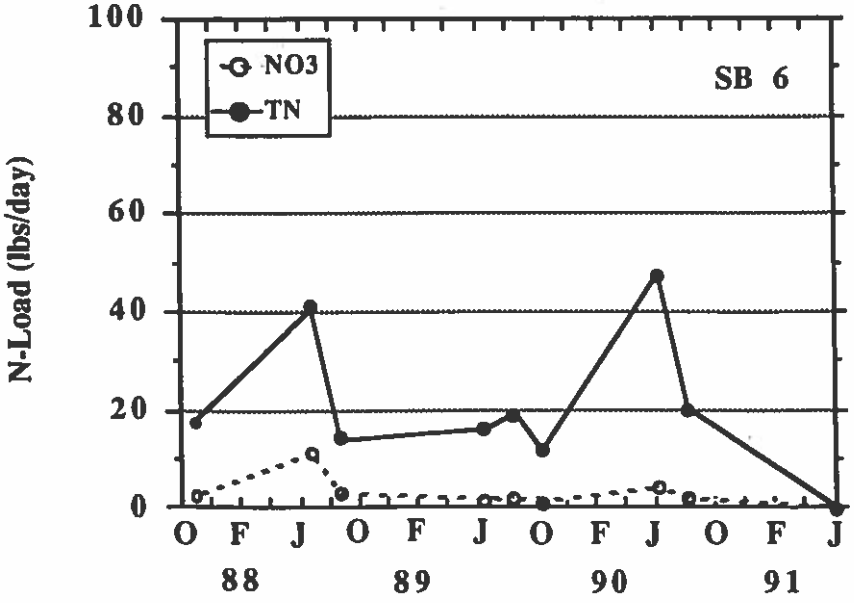
Station	TN 88	TN 89	TN 90	TN 91	NO3 88	NO3 89	NO3 90	NO3 91
SB 3	2.3	6.4	2.5	3.4	0.4	1.8	0.3	1.2
SB 4	7.3	9.8	5.5	4.0	2.6	1.3	1.5	1.4
SB 5	4.8	23.3	9.2	1.3	1.0	2.4	1.2	0.5
SB 6	24.1	17.4	26.4	ID	5.4	1.6	2.3	ID
SB 7	4.3	5.1	5.0	ID	0.8	0.6	1.0	ID
SB 8	4.3	5.2	4.4	2.9	0.7	0.6	0.8	0.6
SB 10	3.4	4.2	2.8	3.4	0.4	0.5	0.3	0.3
SB 11	24.2	44.0	34.1	24.4	6.1	7.6	8.4	7.7
SB 12	30.5	26.5	36.8	ID	7.4	2.8	4.2	ID
SB 14	12.0	12.5	12.0	5.6	5.5	5.8	6.5	2.9
SB 16	93.1	74.3	87.1	40.3	30.7	24.5	33.5	15.1
SB 17	185.0	104.2	139.4	86.0	47.3	33.0	34.5	14.2
SB 18	47.9	18.6	27.9	6.6	29.3	11.1	21.2	3.6
SB 19	235.2	141.7	195.9	146.0	52.2	31.6	55.1	39.2

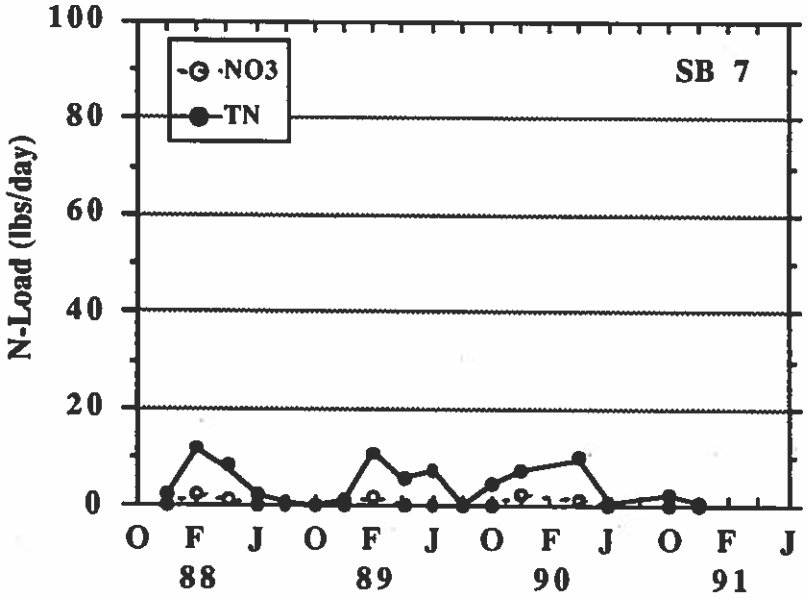
Figure 13 Distribution of nitrogen load taken from the sampling network for the Steamboat Creek monitoring study; Oct-87 to Jun-91. Calculations represent the product of flow and concentration and are given for total-N (TN) and nitrate (NO3); total Kjeldahl-N represents the residual. Values expressed as pounds per day (lbs/d).


100
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
SB 3
O F J O F J O F J O F J
88 89 90 91


100
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
SB 4
O F J O F J O F J O F J
88 89 90 91


100
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
104.4
SB 5
O F J O F J O F J O F J
88 89 90 91


100
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
SB 6
O F J O F J O F J O F J
88 89 90 91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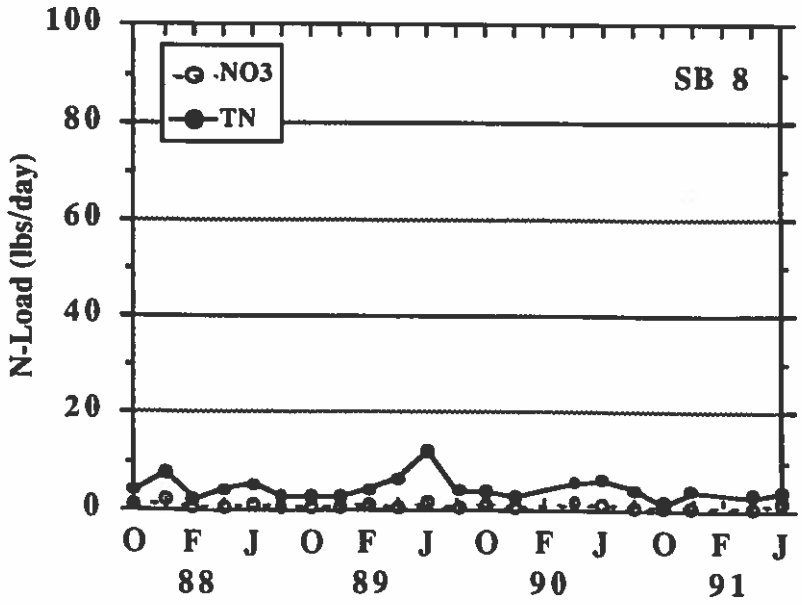
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
SB 7
O F J O F J O F J O F J
88 89 90 91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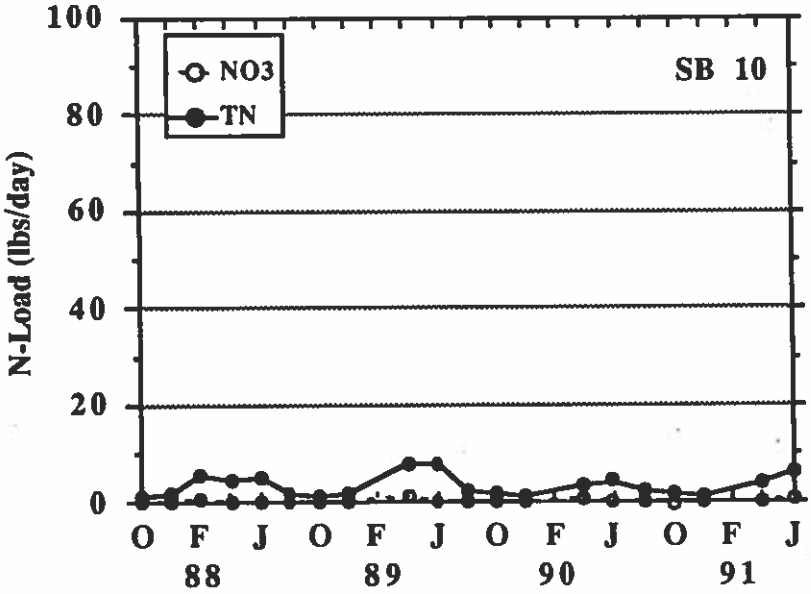
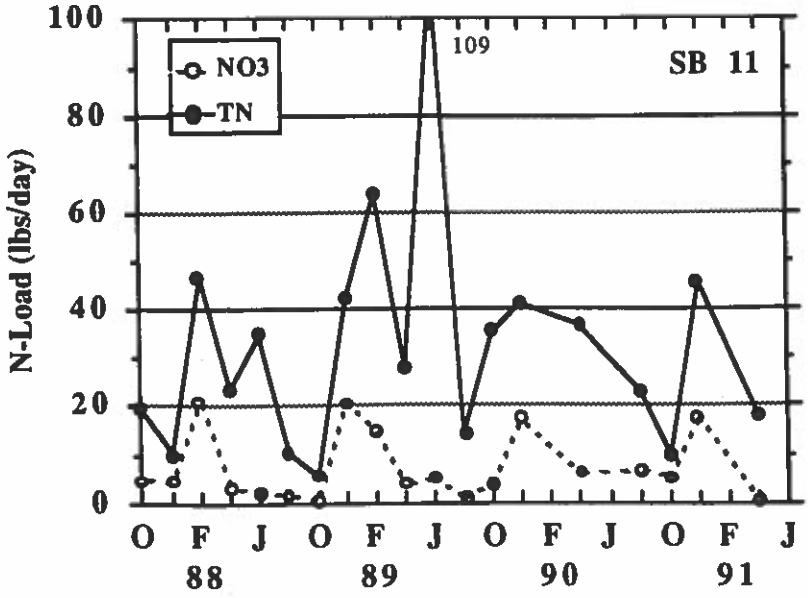
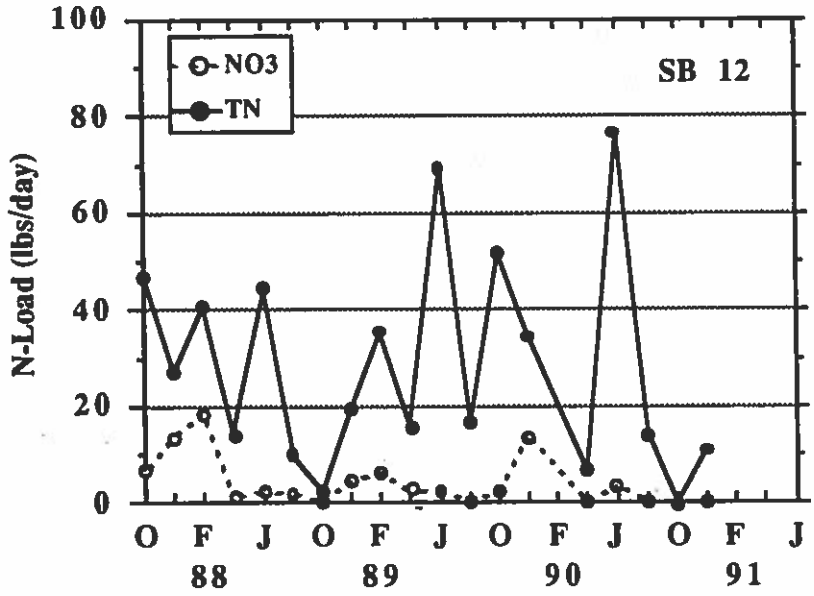
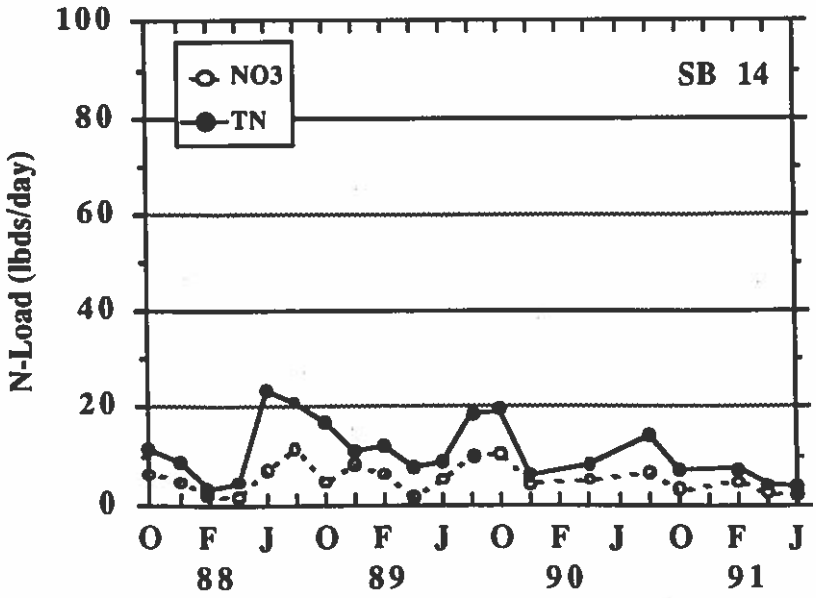
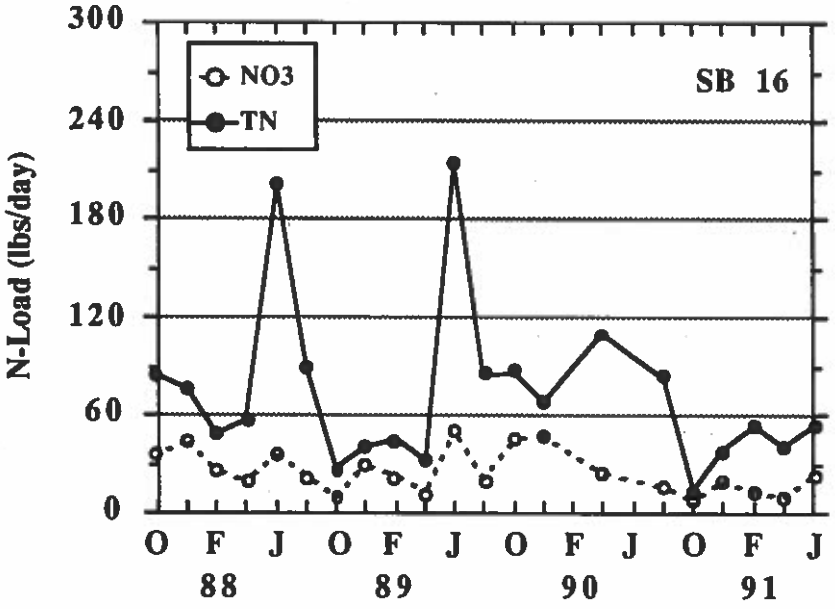
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
SB 8
O F J O F J O F J O F J
88 89 90 91

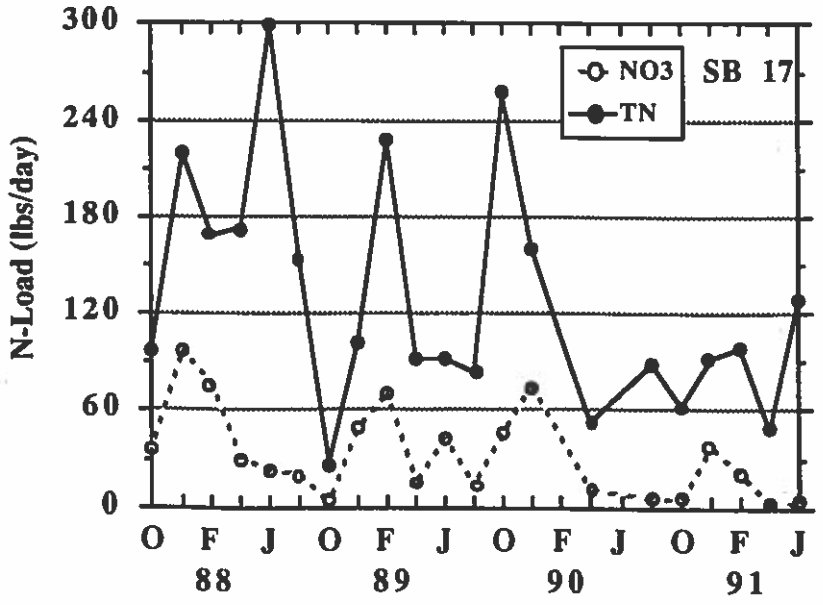

100
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
SB 10
O F J O F J O F J O F J
88 89 90 91

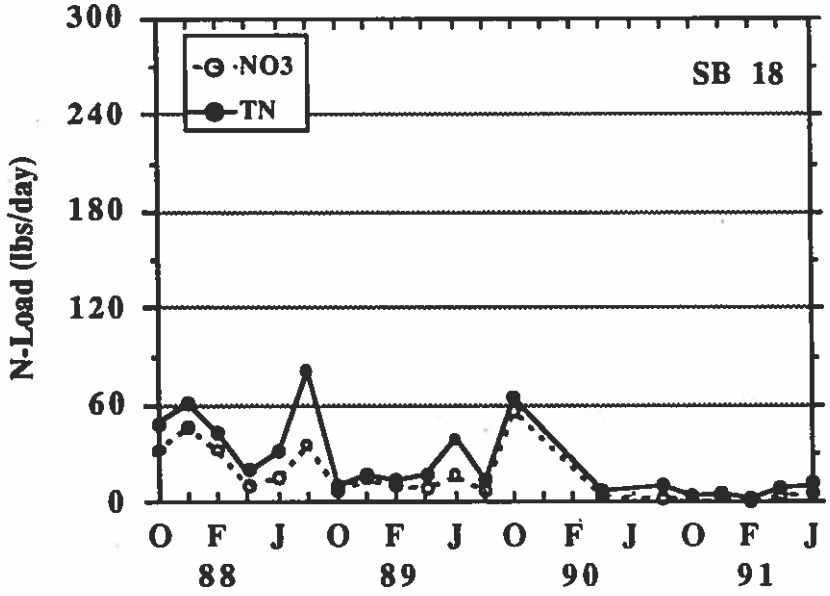

100
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
109
SB 11
O F J O F J O F J O F J
88 89 90 91


100
80
60
40
20
0
N-Load (lbs/day)
NO3
TN
SB 12
O F J O F J O F J O F J
88 89 90 91


100
80
60
40
20
0
N-Load (lbds/day)
NO3
TN
SB 14
O F J O F J O F J O F J
88 89 90 91


300
240
180
120
60
0
N-Load (lbs/day)
NO3
TN
SB 16
O F J O F J O F J O F J
88 89 90 91


300
240
180
120
60
0
N-Load (lbs/day)
NO3
TN
SB 17
O F J O F J O F J O F J
88 89 90 91


300
240
180
120
60
0
N-Load (lbs/day)
-O-NO3
TN
SB 18
O F J O F J O F J O F J
88 89 90 91

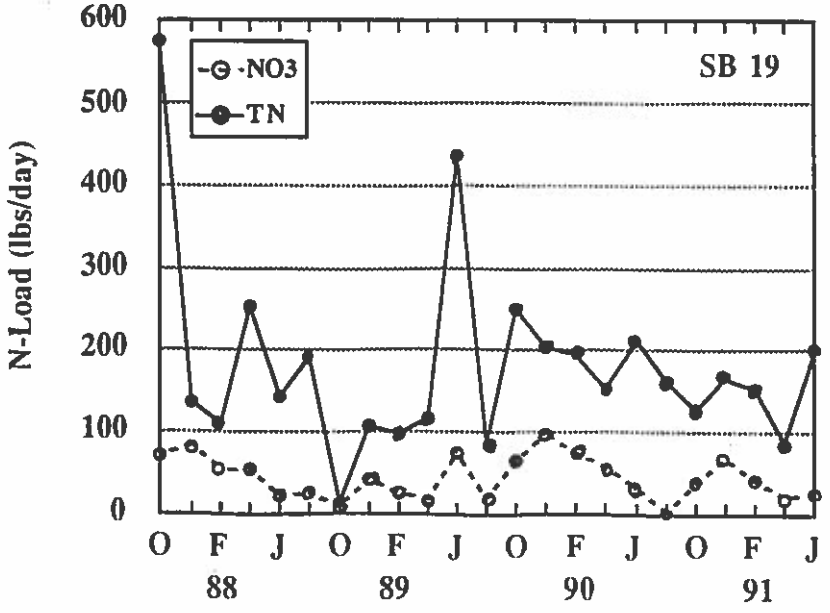

600
500
400
300
200
100
0
N-Load (lbs/day)
-O-NO3
TN
SB 19
O F J O F J O F J O F J
88 89 90 91

Figure 14 Mean annual load of total nitrogen (TN) in lbs/day. Years represent Water Year (1 Oct-31 Sept).

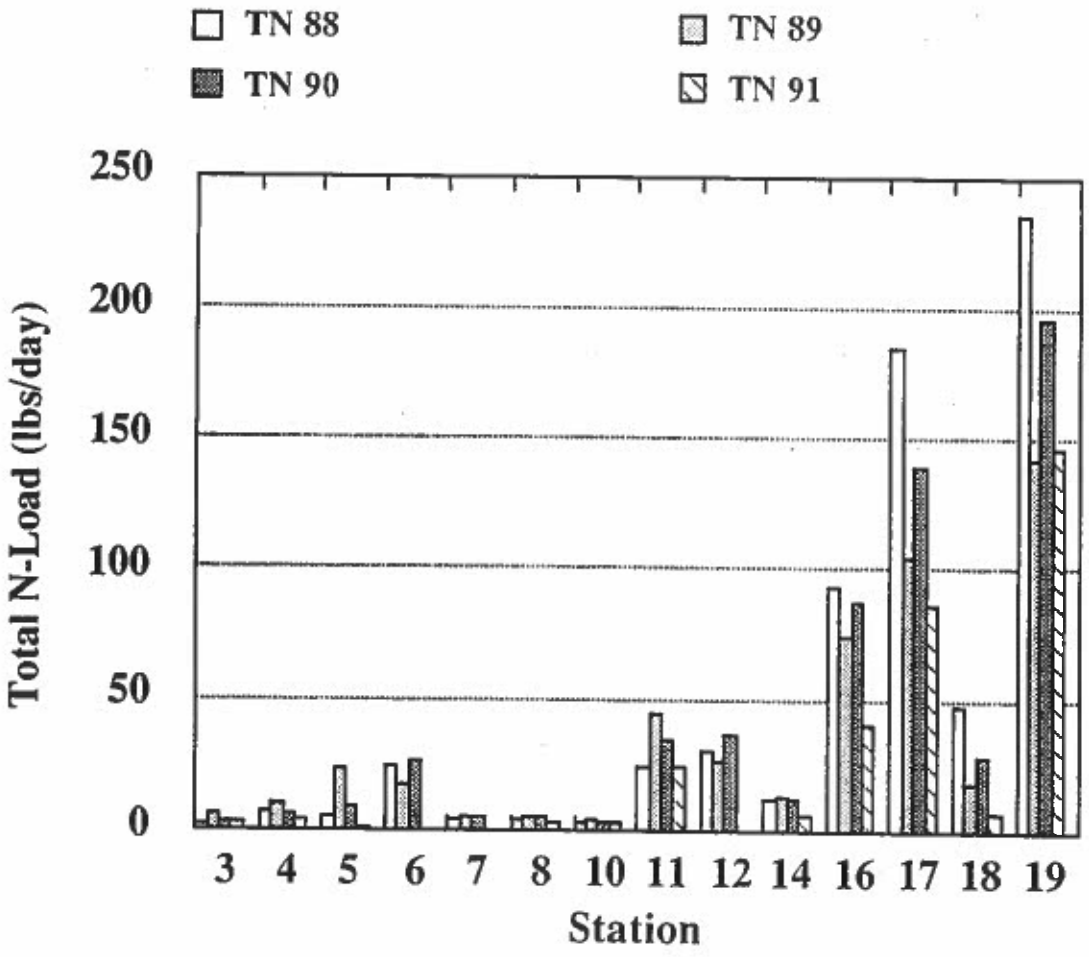
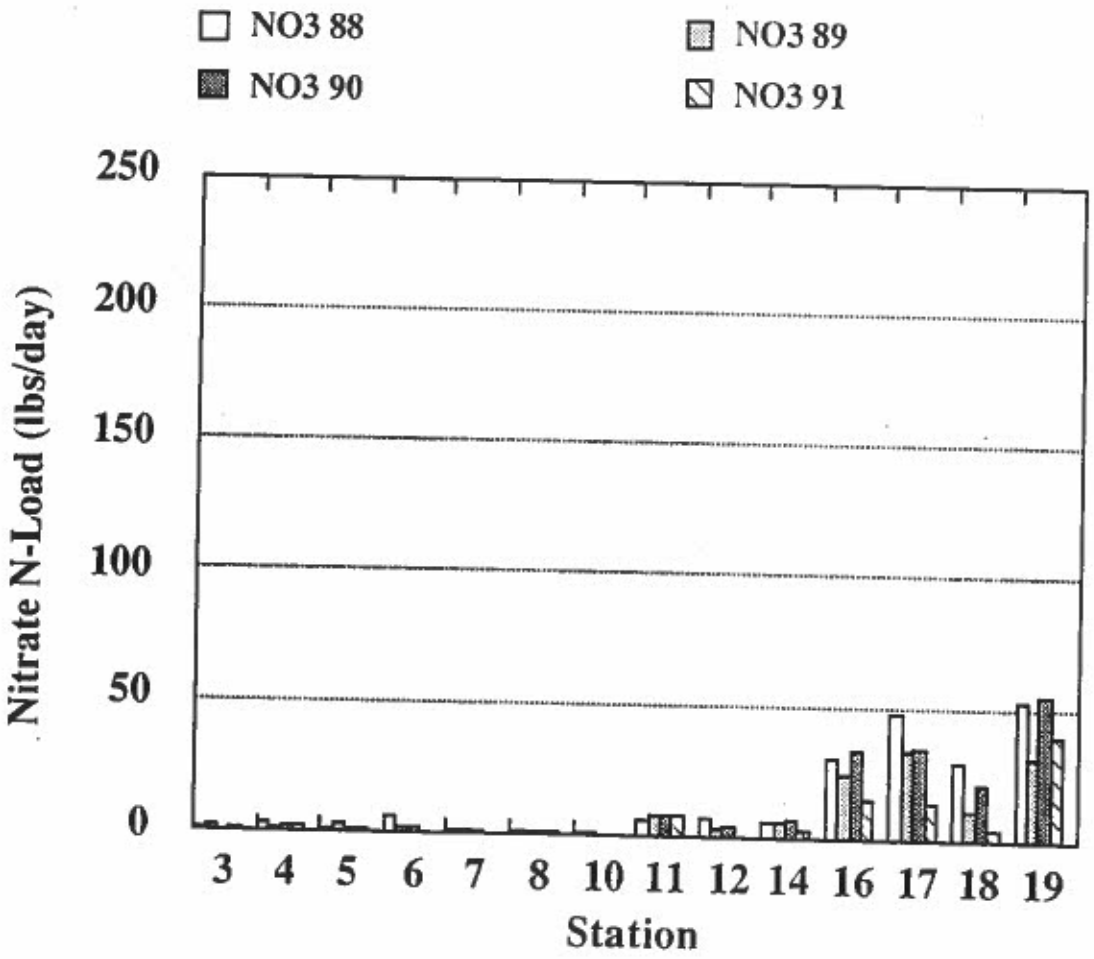


Figure 15 Mean annual load of nitrate nitrogen (NO3) in lbs/day. Years represent Water Year (1 Oct-31 Sept).



both parameters are important. However, unless accompanied by high flows, regions or tributaries with only high concentrations are less important, vis-a-vis, downstream water quality. The relationships for the percent contribution of NO3 and TKN to TN-load will be identical to those presented for N-concentration since the same flow factor is applied to both TKN and NO3 at a given sampling time and location (refer to Table 12).

Figure 13 shows the seasonal pattern of N-loading at each station by presenting the individual calculated values for each sampling date. Table 13 and Figures 14-15 provide summary data on mean annual loading on TN and NO3 during WY 88, WY 89, WY 90 and WY 91 at all stations. Table 14 summarizes N-loading in Steamboat Creek by reach.

Mean annual TN-load at SB 8 and SB 10 was very low ranging from 2.8-5.2 pounds/day (lbs/day). Nitrate loading at these stations was also low, 0.3-0.8 lbs/day. SB 3, the "head waters" of the study system had a similar low TN-load -2.5-6.4 lbs/day, and a NO3-load of 0.3-1.8 lbs/day (Table 13). Inflow from Galena Creek (SB 4) contained elevated loads for TN and NO3 relative to SB 3. Mean annual TN-load ranged from 4.0 to 9.8 lbs/day with NO3-load at 1.3-2.6 lbs/day. The TN-load and NO3-load at SB 4 were ±30% and ±80% higher than those upstream at SB 3, primarily because of higher flows and not higher concentrations. By mathematically combining the loads at SB 3 and SB 4 we can compare this value to the load at SB 5 to see if a downstream changed occurred between the confluence of Galena and Steamboat Creeks and station SB 5 located 1.3 miles downstream. TN-load decreased in this reach during WY 88 and WY 91 by 4.8 and 6.1 lbs/day and increased in WY 89 and WY 90 by 7.1 and 1.2 lbs/day respectively (Table 14). Nitrate declined in this reach in each of the water years by 0.5 to 2.1 lbs/day. Mean annual nitrate load at SB 5 ranged from 0.5-2.4 lbs/day; however, the range for TN-load was much higher at 1.3-23.3 lbs/day (Table 13). This was largely the result of an elevated TN-load of 104.4 lbs/day found in Jun-89 when flow was uncharacteristically high (refer to Figure 3).

The next downstream tributary to Steamboat Creek is Steamboat Ditch (SB 6). Mean annual loads of TN measured at SB 6 were typically higher than those at SB 5 (just upstream in

Table 14. Summary of nitrogen loading in Steamboat Creek by reach. Values are expressed as lbs-N/day and represent the mean of all the instantaneous loads calculated during each year. Stations SB 3+4, SB 5+6, SB 11+12 and SB 17+18 represent calculated or unsampled locations along Steamboat Creek immediately downstream of the confluence of a tributary (i.e. SB 4, SB 6, SB 12, and SB 18). Loads for these stations were calculated as the sum of the tributary N-load and the Steamboat Creek station just upstream. With the exception of SB 3 and SB 4, the combined stations are directly adjacent to the corresponding Steamboat Creek station. Part A indicates the contribution of the major tributaries relative to load in Steamboat Creek at the closest upstream station and Part B gives estimates for loading which occurred between stations on Steamboat Creek but which were not related to the major tributaries. (Refer to Figure 1 for station location). Values in parentheses () in Part A denote load in Steamboat Creek at closest upstream actual or calculated station. ID=insufficient data.

TOTAL NITROGEN

A. Tributary Load

Station	WY 88	WY 89	WY 90	WY 91
SB 4	+7.3 (2.3)	+9.8 (6.4)	+5.5 (2.3)	+4.0 (3.4)
SB 6	+24.1 (4.8)	+17.4 (23.3)	+26.4 (9.2)	ID
SB 12	+30.5 (24.2)	+26.5 (44.0)	+36.8 (34.1)	ID
SB 14	+12.0 (54.7)	+12.5 (70.5)	+12.0 (70.9)	+5.6 (ID)
SB 16	+93.1 (54.7)	+74.3 (70.5)	+87.1 (12.0)	+40.3 (ID)
SB 18	+47.9 (185.0)	+18.6 (104.2)	+27.9 (139.4)	+6.6 (86.0)

B. Load in Steamboat Creek Between Major Tributaries

SB 3+4 to SB 5	-4.8	+7.1	+1.2	-6.1
SB 5+6 to SB 7	-24.6	-35.6	-30.6	ID
SB 7 to SB 11	+19.9	+38.9	+29.1	ID
SB 17+18 to SB 19	+2.3	+18.9	+28.6	+53.4

Table 14. (cont.)

NITRATE - N

A. Tributary Load

Station	WY 88	WY 89	WY 90	WY 91
SB 4	+2.6 (0.4)	+1.3 (1.8)	+1.5 (0.3)	+1.4 (1.2)
SB 6	+5.4 (1.0)	+1.6 (2.4)	+2.3 (1.2)	ID
SB 12	+7.4 (6.1)	+2.8 (7.6)	+4.2 (8.4)	ID
SB 14	+5.5 (13.5)	+5.8 (10.4)	+6.5 (12.6)	+2.9 (ID)
SB 16	+30.7 (13.5)	+24.5 (10.4)	+33.5 (12.6)	+15.1 (ID)
SB 18	+29.3 (47.3)	+11.1 (33.0)	+21.2 (34.5)	+3.6 (14.2)

B. Load in Creek Between Major Tributaries

SB 3+4 to SB 5	-2.0	-0.7	-0.6	-2.1
SB 5+6 to SB 7	-5.6	-3.4	-1.5	ID
SB 7 to SB 11	+5.3	+7.0	+7.4	ID
SB 17+18 to SB 19	-24.4	-12.5	-0.6	+21.4

Steamboat Creek). TN-load at SB 6 ranged from 17.4-26.4 lbs/day and was the result of higher flow and not higher concentrations at SB 6. Nitrate loading from Steamboat Ditch ranged from 1.6-5.4 lbs/day (Table 14).

Between the Steamboat Creek - Steamboat Ditch confluence (SB 5+6) and SB 7 (the next downstream station), TN and NO3 load dropped sharply (Table 14). This pattern, which was observed during each of the years of record was due to the fact that the Crane-Chandler Ditch diverted the majority of Steamboat Creek flow, and consequently N-load, for agricultural purposes. While this N-load may have been lost at this specific point in the hydraulic system, agricultural runoff return from the areas serviced by the Crane-Chandler Ditch re-enter Steamboat Creek between SB 7 and SB 11. During each of the Water Years of record, TN-load increased significantly between SB 7 and SB 11; 19.9 lbs/day in WY 88, 38.9 lbs/day in WY 89, and 29.1 lbs/day in WY 90 (Table 14). Indeed, the project mean for TN-load loss between SB 5+6 and SB 7 and the gain between SB 7 and SB 11 were nearly identical (-30.3 lbs/day and +29.3 lbs/day, respectively; Table 14). Similarly, NO3-loading increased between SB 7 and SB 11 by 5.3-7.4 lbs/day which was somewhat greater than the loss of 1.5-5.6 lbs/day between SB 5+6 and SB 7 (Table 14). The mean annual TN and NO3 loads at SB 11 were consistently and significantly higher than at any of the upstream stations. TN ranged from 24.2-44.0 lbs/day and NO3, 6.1-8.4 lbs/day (Table 13). As discussed above for N-concentration this reach of the creek is immediately downstream from agricultural, and especially livestock, uses. Drainage of irrigation water in this area delivers both higher flows and higher N-concentration to Steamboat Creek at SB 11. As with concentration, the seasonality of N-load is evident with NO3-peaks in winter and TKN-peaks in spring-early summer (Figure 13).

While the concentrations of TN and NO3 were much higher in the Alexander Ditch tributary (SB 12) than in Steamboat Ditch, flows were less at SB 12 and consequently N-loads were comparable. Mean annual TN-loads at SB 12 were 30.5, 26.5 and 36.8 lbs/day in WY 88, WY 89 and WY 90, respectively. NO3-loads for these years were 7.4, 2.8 and 4.2

lbs/day at SB 12. Similarly, because of low flows in the Rio Poco Drain (SB 14), TN-loads were lower than at SB 6 or SB 12 ranging from 12.0 to 12.5 lbs/day. In contrast, nitrate accounted for 46-54% of the mean annual N-load at SB 14; higher than at the upstream stations.

Boynton Slough (SB 16) was the major tributary contributor of N-load to Steamboat Creek. Both high flows and high N-concentrations contributed to the load of both TN and NO3 at SB 16. Mean annual TN concentrations at SB 16 ranged from 1.18 to 1.51 mg N/l and flows ranged from 6.4-16.2 cfs. The TN-load at SB 16 in WY 88 and WY 90 were very large at ±85-95 lbs/day (Table 14). TN-load at this station was slightly reduced in WY 89 to 74.3 lbs/day with 40.3 lbs/day in WY 91. Nitrate was a major contributor accounting for 40-45% of the TN-load. Peaks in TN-load at SB 16 were largely associated with the summer agricultural return flow. The Yori Ditch (SB 18) also carries agricultural return flow and enters Steamboat Creek downstream of the Boynton Slough. While flows at SB 18 were relatively low, and similar to those measured at SB 4, NO3 concentrations were extremely high (mean annual values of 1.17-2.12 mg N/l). As a result, TN and NO3 load at this station were also high and particularly in WY 88 and WY 90 when mean annual TN-load was 47.9 and 27.9 lbs/day, respectively with NO3 accounting for 60-70%. when NO3 (127.1 lbs/day) comprised 87% of the TN-load (145.6 lbs/day). The contribution of TN-load from the Yori Drain was similar to that from Alexander Ditch but greater than the Rio Poco Drain (Table 14). At the same time, nitrate load from Yori Drain was 2-4 time greater than at Alexander Ditch or Rio Poco Drain.

By combining the N-loads at SB 17 and SB 18 (confluence of Yori Drain and Steamboat Creek), and comparing this to N-loads at SB 19, it can be seen that NO3-loads typically decreased in WY 88, WY 89 and WY 91 (Table 14). In the 1.1 miles between these two locations NO3-load declined by 24.4 lbs/day in WY 88, 12.5 lbs/day in WY 89, and 0.6 lbs/day in WY 90; in WY 91, NO3-load increased by 21.4 lbs/day (Table 14). TN-load between SB 17+18 and SB 19 increased in this reach for each of the monitoring years.

In summary, TN-load to Steamboat Creek increased significantly between SB 7 and SB 11; this was related to surface and groundwater inputs of both TKN and NO3. TN-load was very high from downstream tributaries which drain either agricultural lands, receive groundwater flow with regionally high nitrate, or both. The project mean of the individual annual mean TN-load values in order of magnitude are Boynton Slough (SB 16; 73.7 lbs/day), Alexander Drain (SB 12; 31.1 lbs/day) Yori Drain (SB 18; 25.3 lbs/day), and Rio Poco Drain (SB 14; 10.5 lbs/day). Nitrate load was relatively low in Alexander Drain and Rio Poco Drain, but much higher in Boynton Slough and Yori Drain. With the exception of WY 91, the sum of NO3-load at SB 16 and SB 18 was very similar to that calculated at SB 19.

2.3.2.2 Regional Point and Nonpoint Source N-Loading to the Truckee River

Current water quality studies on the Truckee River (Brock et al. 1992) and Pyramid Lake (e.g. Lebo et al. 1992, Reuter et al. 1993) all demonstrate the over riding importance of nitrogen in the stimulation periphyton (river) and phytoplankton (lake) growth and the consequence of this increased algal growth on dissolved oxygen concentrations. This recent understanding prompted regulators to require AWT for nitrogen at the Reno Sparks WTF (now named Truckee Meadows Water Reclamation Facility) which was on-line and operational in early 1989, and fully functional in mid-summer 1989. As the efficiency of the RSWTF has been improved to achieve near maximum N-removal (in terms of effluent concentration), attention has focused on (1) maximum total daily loads from the WTF and (2) the contribution of nonpoint sources (NPS) of nitrogen to the Truckee River. NPS pollution is much more difficult to identify, quantify, regulate and mitigate than the more conventional point sources. Consequently, most municipalities around the nation are only now beginning to quantify the NPS contribution to total loads in receiving waters.

Table 15a provides a comparison between calculated TN loads from Steamboat Creek and the RSWTP during the same period of record. The Steamboat Creek load was assumed to be that calculated at station SB 19. The influence of AWT N-removal controls on TN discharge from the WTF is obvious. During WY 88 (Oct, Dec, Feb, Apr, Jun and Aug) the mean load

Table 15a. Comparison of total nitrogen loading from Steamboat Creek (SBC) and the Truckee Meadows Water Reclamation Facility (TMWRF) (formerly the Reno-Sparks Wastewater Treatment Facility). Values are given as pounds per day. Estimates for Steamboat Creek are taken from station SB 19 which is located near the confluence of Steamboat Creek and the Truckee River but, upstream of the TMWRF. TMWRF N-loading values were obtained from Tom Swan at that facility. Unless indicated loading is in terms of total-N (TN=TKN+NO_3).

DATE	TMWRF	SBC
Water Year 88		
Oct 1987	3666[a]	576
Dec	3591[b]	137
Feb 1988	3529[b]	111
Apr	4277	254
Jun	4052	143
Aug	3271[c]	190
Water Year 89		
Oct 1988	2907	14
Dec	952	106
Feb 1989	902	96
Apr	686	117
Jun	760	434
Aug	517	83
Water Year 90		
Oct 1989	667	250
Dec	981	129
Feb 1990	493	196
Apr	562	153
Jun	321	212
Water Year 91		
Dec 1990	460	167[d]
Feb 1991	339	153[d]
Apr	318	86
Jun	262	199

[a] N as ammonia
[b] N as TKN
[c] N as ammonia + nitrate
[d] Assumes flow of 23 cfs

Table 15b. Estimates TN-loading to the Truckee River from Steamboat Creek (SBC) in relation to other regional nonpoint and point sources located from McCarran to Derby Dam. IRRET=irrigation return flows, GRNDIF=groundwater inflow. All data except for the SBC-current study and RSWTF values are taken from Brock (1991) and represent the period September 1989. Loads are expressed as lbs/day. TDIN=NH4+NO3. TN=TKN+NO3.

LOCATION	TN	TDIN
NTD (Sep 89)	223	126
SBC - Brock (Sep 89)	194	21
SBC - Current study (Sep 89)[a]	167	42
SBC - Current study (Oct 87 - Jun 91)	185	45
IRRET (Sep 89)	97	23
GRNDINF (Sep 89)	0	0
RSWTF (Sep 89)	592	251[b]
RSWTF (Oct 90 - Sep 91)	345	146[b]

[a] mean of Aug 89 and Oct 89

[b] assumes same TDIN:TN as in Sep 89

expressed as lbs N/day from the facility was approximately 3700 lbs/day. In contrast, the TN-load during WY 91 (Dec, Feb, Apr and Jun), two years after the AWT became operational, was reduced to 345 lbs/day. Assuming that NPS N-loading from Steamboat Creek in WY 88 - WY 91 is representative of other years, and that these loading values will be relatively uniform (mean = 185 lbs/day) until which time some of nonpoint sources tributary to Steamboat Creek can be controlled, and that TN discharge from the WTF remains similar to that recorded in Oct-90 to Sep-91, the ratio of TN loading from Steamboat Creek versus the RSWTP is close to 1:2 (1:1.86) (SBC:RSWTP), or stated a different way, TN-load from Steamboat Creek was 50-55% of the TN-load from the RSWTP.

Brock (1991) intensively measured N-concentration and flow in the Lower Truckee River and its tributaries from McCarran to Marble Bluff during the period 6-15 September, 1989. These data were used to calculate N-load from the two main tributaries, North Truckee Drain (NTD) and Steamboat Creek (SBC); groundwater inflows and diffuse irrigation return flows were estimated; and loading from Helms Pit, also included in the NTD loading values, was estimated. Brock also reported on P-loading from these same sources. Not only does this data give loading values for a variety of regional nonpoint sources, it also provides us with an independent estimate of loading from Steamboat Creek. The September 1989 sampling was not part of the NDEP database currently being evaluated.

Brock's TN-loading calculations for Steamboat Creek were similar, albeit slightly greater than those presented in this report. For August and October 1989 we found a mean TN loading rate of 167 lbs/day while Brock found a value of 194 lbs/day in September of the same year (Table 15b). Both these estimates were of a similar magnitude to the loading rate for the period of record for the current study, i.e. October 1987 - June 1991 with a TN-load of 185 lbs/day. For Brock's TN-load estimate he used a flow of 30 cfs and a TN-concentration of 1.18 mg N/l. For our estimate of Sep-89 TN-load we used a mean flow of 34 cfs and a TN-concentration of 0.91 mg N/l. Brock's estimated TDIN-load (as NO3+NO2+NH4) was lower than that reported in the current study; i.e. 50% of our estimate for the period August and

October 1989 and 47% of our estimate for the period October 1987 - June 1991. Nitrate concentration in Brock's September 1989 data base was reported as 0.09 mg N/l as compared to 0.20 mg N/l and 0.25 mg N/l in August 1989 and October 1989 in the present study. Throughout the October 1987 to June 1991 period of record, nitrate at SB 19 typically ranged from 0.15 to 0.60 mg N/l with a mean±SD of 0.30±0.17 mg N/l. The 0.09 mg N/l concentration measured by Brock was less than the second lowest concentration at SB 19 throughout the entire study and we believe, underestimates the contribution made by nitrate to N-loading by Steamboat Creek to the Truckee River.

The contribution of the various identified point (RSWTF) and nonpoint (NTD, SBC, IRRET and GRNDINF) sources of N-loading to the Truckee River from McCarran to Derby Dam in September 1989 is presented in Table 15b. These values include Brock's data for NTD, IRRET and GRNDIFL; RSWTF N-loading, estimate for Sep-89; and SBC data from the current study, estimate of Sep-89. The sum of NPS and point (RSWTF) N-load for Sep-89 was 1,079 lbs/day-TN and 442 lbs/day-TDIN. NPS N-load accounted for ±45% to the total-N load for both TN and TDIN. These percent contributions by NPS-N will be higher to the extent that minor discharges were not accounted for and to the extent that regional groundwater discharges NO3 to the Truckee River during the late winter-early summer period. This was not estimated by Brock who looked only at September when groundwater flow would be expected to be minimal. NTD, SBC and IRRET contributed 21%, 15% and 9%, respectively to point+NPS TN-load and 29%, 10% and 5% to the combined TDIN-load. While it appears that TDIN is a more important contributor to TN-load in NTD relative to SCB this is based on a minimal sampling effort in the NTD. In the NTD, TDIN accounted for 57% of the TN-load, 25% in Steamboat Creek and 24% in irrigation return flows. These compare to a 42% contribution of DIN to TN-load at the RSWTF. In NTD, greater than 95% of the DIN was as nitrate.

2.4. Phosphorus

2.4.1. P-Concentration

Details of P-concentration by station and sampling date are presented in Figure 16. Summaries of P-concentration by Water Year are given in Figures 17 and 18, and Table 16.

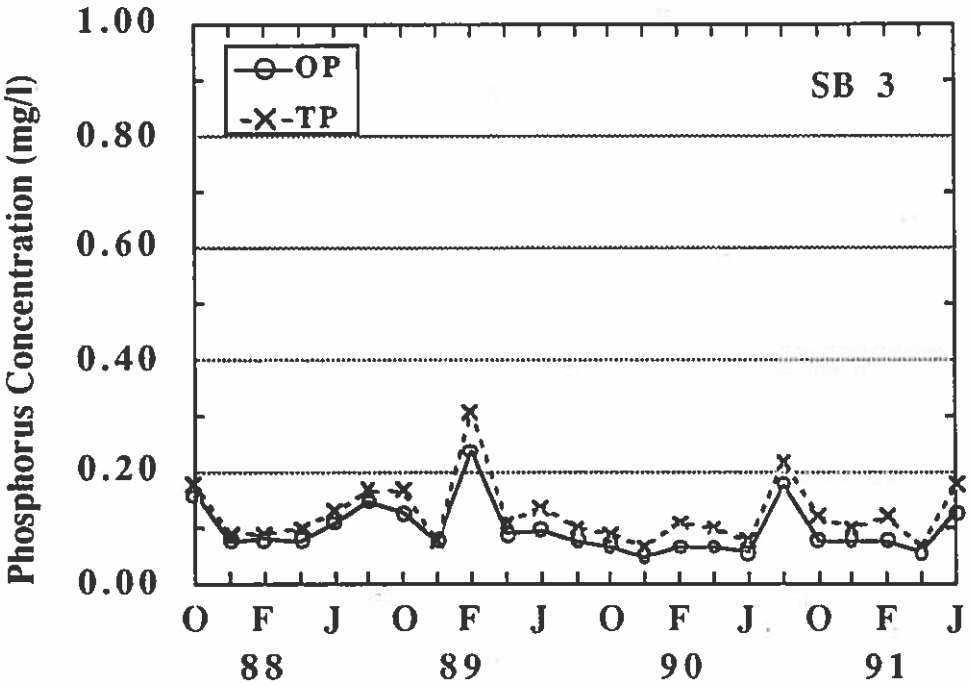
Water quality sampling at SB 1, the outlet of Little Washoe Lake, was very limited; as a result it is not possible to directly determine the P-content of discharge from the lake. A complete set of data from Oct-87 to Jun-91 is available at SB 3, a distance of 2.4 miles downstream. Only Browns Creek, a tributary originating in the Carson Range, enters Steamboat Creek upstream of SB 3. Phosphorus concentration at SB 3 was relatively uniform with the exception of small spikes of 0.20-0.30 mg/l which occurred in Feb-89, Aug-90 and Jun-91. For the remainder of the sampling dates, TP ranged from 0.08 to 0.18 mg/l (Figure 16). When expressed on the basis of mean annual concentration, TP ranged from 0.11 to 0.15 mg/l with OP (ortho-P range of mean annual concentration 0.08 to 0.12 mg/l) accounting for 67%-85% of this total (Tables 12 and 16). The higher concentrations found in Feb-89, Aug-90 and Jun-91 resulted from increases in OP but did not appear to be associated with increased flow. Similarly, these spikes did not consistently correspond to high TSS concentrations or turbidity. Assuming that the P-content of Browns Creek was similar to that measured in Galena Creek (SB 4) (i.e. very low and in the range of 0.02-0.04 mg/l), it can be concluded that, at least during this study when regional precipitation and baseline flow was relatively low, Little Washoe Lake was not a major source of phosphorus to Steamboat Creek.

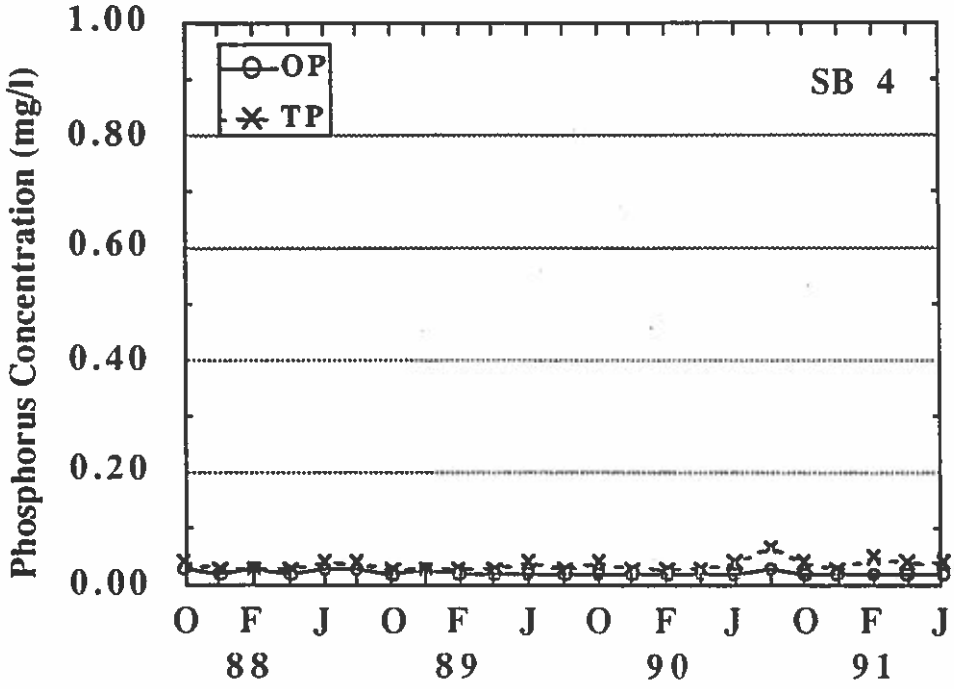
Downstream from Galena Creek at SB 5, TP and OP concentrations were very similar to those measured at SB 3. Mean annual concentration of TP ranged from 0.14 to 0.16 mg/l while OP ranged from 0.10 to 0.13 mg/l (Table 16). In WY 88 through WY 91, OP again was the dominant form of phosphorus accounting for 70-80% of the TP pool (Table 12). The small spikes that were seen at SB 3 were not as pronounced at SB 5. While a clear seasonal pattern of P-concentration at SB 5 was not evident, it did appear that levels declined during the

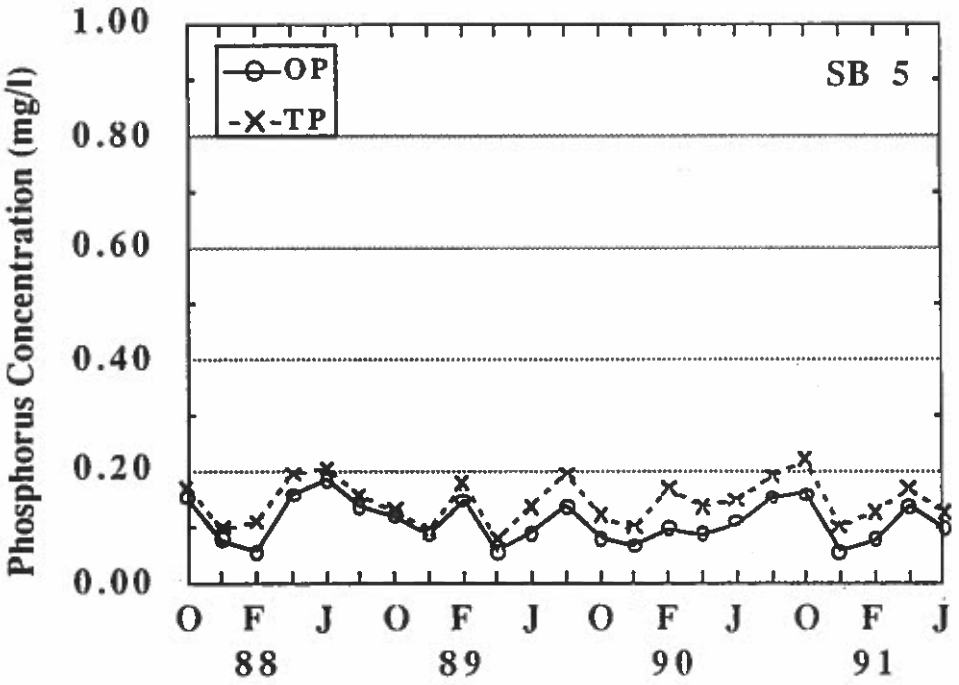
Table 16. Mean annual concentration of ortho-phosphorus and total phosphorus at each of the Steamboat Creek sampling stations. Each year represents a Water Year (1 Oct - 31Sep). Number of sampling dates per year was six (n=6) with the exception of 1988 where SB 6 n=3, 1989 SB 6 n=2, 1990 SB 6 n=3, and 1991 SB6 n=1; all stations n=5. Values expressed as mg/l and corrected for arsenic interference.

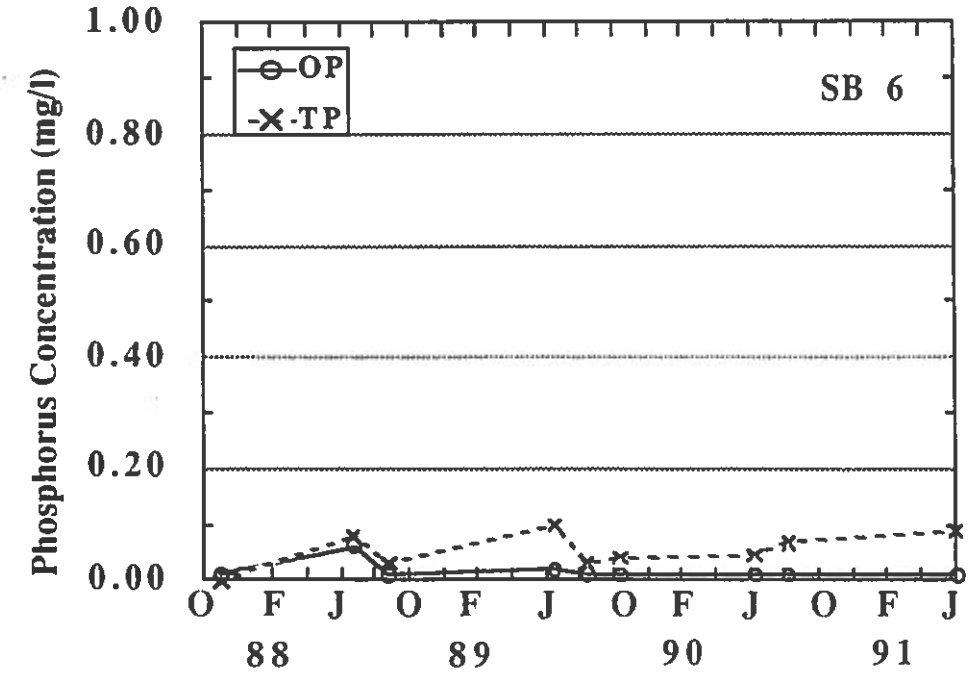
Station	OP 88	OP 89	OP 90	OP 91	TP 88	TP89	TP 90	TP 91
SB 3	0.11	0.12	0.08	0.08	0.13	0.15	0.11	0.12
SB4	0.03	0.02	0.02	0.02	0.04	0.03	0.04	0.04
SB 5	0.13	0.11	0.10	0.11	0.16	0.14	0.14	0.15
SB 6	0.03	0.02	0.01	0.01	0.04	0.06	0.05	0.09
SB 7	0.23	0.10	0.10	0.12	0.26	0.13	0.13	0.16
SB 8	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04
SB 10	0.05	0.04	0.04	0.04	0.05	0.06	0.06	0.06
SB 11	0.19	0.17	0.27	0.14	0.22	0.22	0.36	0.21
SB 12	0.24	0.22	0.14	0.06	0.31	0.37	0.27	0.25
SB 14	0.07	0.06	0.07	0.06	0.10	0.08	0.12	0.12
SB 16	0.07	0.07	0.12	0.10	0.09	0.09	0.17	0.17
SB 17	0.11	0.13	0.12	0.13	0.15	0.19	0.18	0.23
SB 18	0.13	0.09	0.08	0.06	0.16	0.12	0.12	0.12
SB 19	0.11	0.09	0.11	0.12	0.24	0.28	0.20	0.24

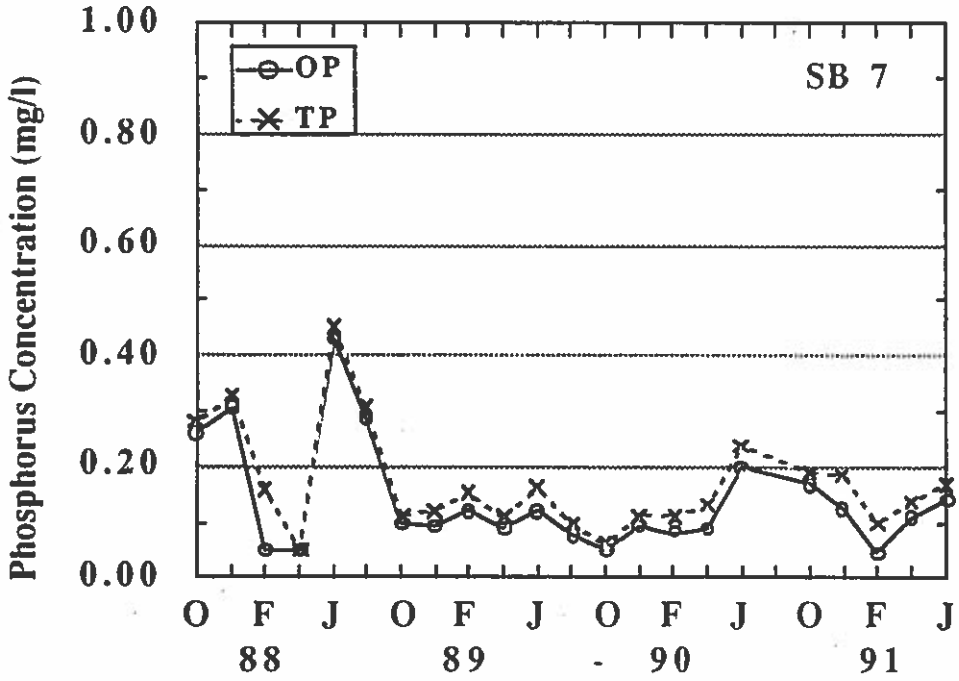
Figure 16. Distribution of phosphorus concentration taken from the sampling network for the Steamboat Creek monitoring study; Oct-87 to Jun-91. Concentrations are given for ortho-P and total-P, and are expressed as mg/l.


1.00
0.80
0.60
0.40
0.20
0.00
Phosphorus Concentration (mg/l)
OP
TP
SB 3
O F J O F J O F J O F J
88 89 90 91


1.00
0.80
0.60
0.40
0.20
0.00
Phosphorus Concentration (mg/l)
OP
TP
SB 4
O F J O F J O F J O F J
88 89 90 91


1.00
0.80
0.60
0.40
0.20
0.00
Phosphorus Concentration (mg/l)
OP
TP
SB 5
O F J O F J O F J O F J
88 89 90 91


1.00
0.80
0.60
0.40
0.20
0.00
Phosphorus Concentration (mg/l)
OP
TP
SB 6
O F J O F J O F J O F J
88 89 90 91


Phosphorus Concentration (mg/l)
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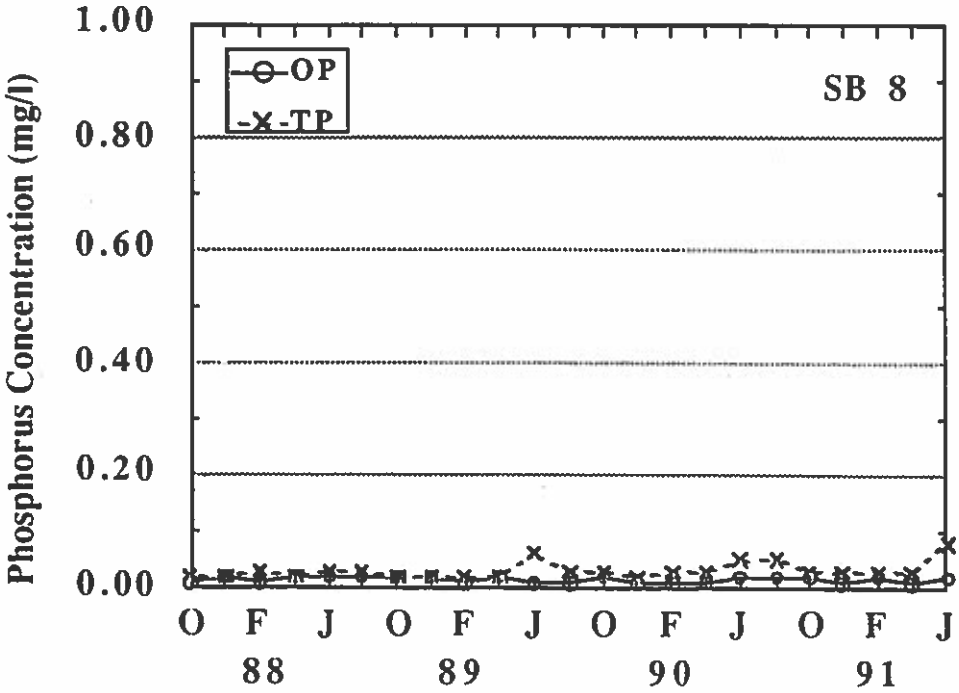
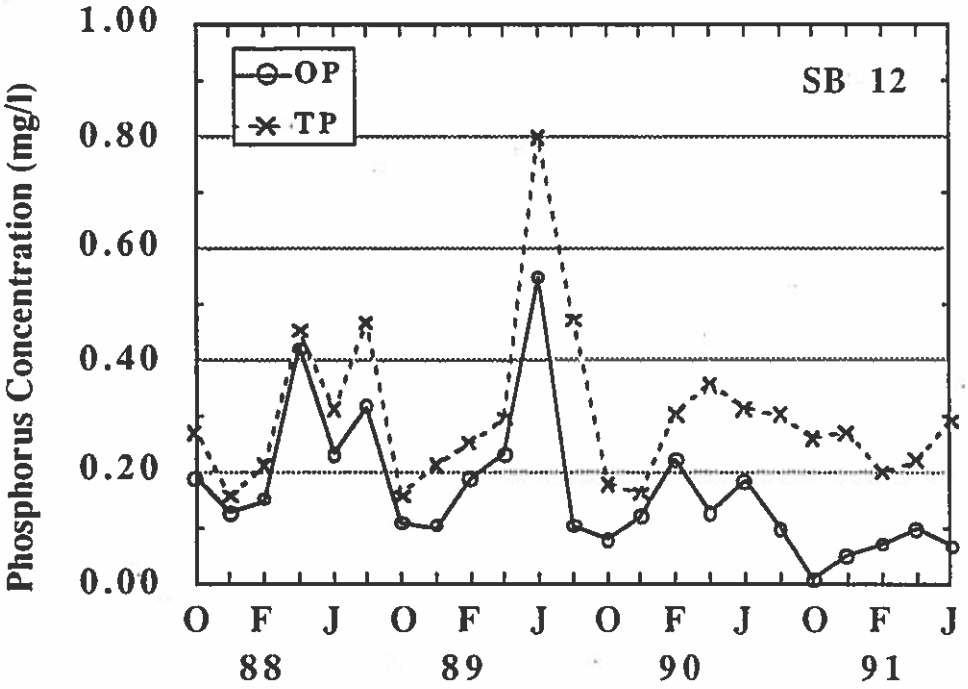
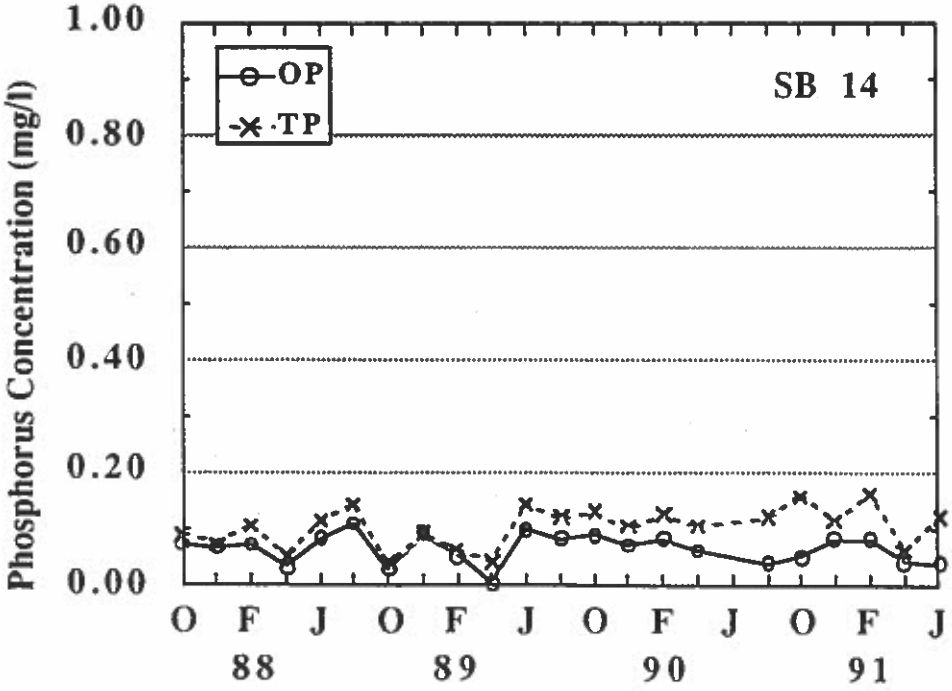
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 7
O F J O F J O F J O F J
88 89 90 91


Phosphorus Concentration (mg/l)
1.00
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 8
O F J O F J O F J O F J
88 89 90 91


SB 12
OP
TP
Phosphorus Concentration (mg/l)
1.00
0.80
0.60
0.40
0.20
0.00
O F J O F J O F J O F J
88 89 90 91


SB 14
OP
TP
Phosphorus Concentration (mg/l)
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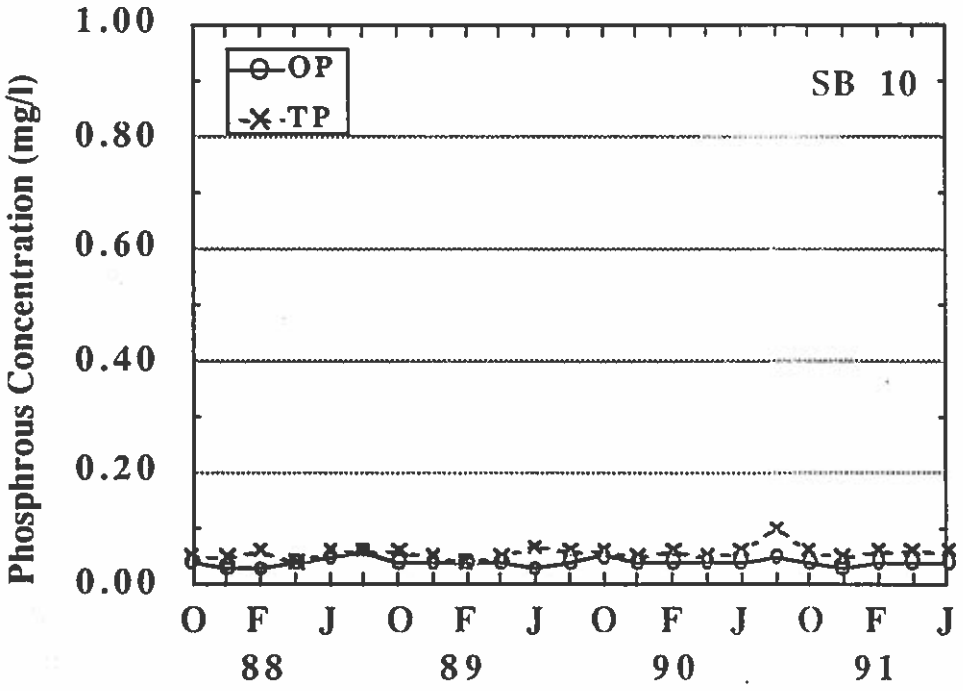
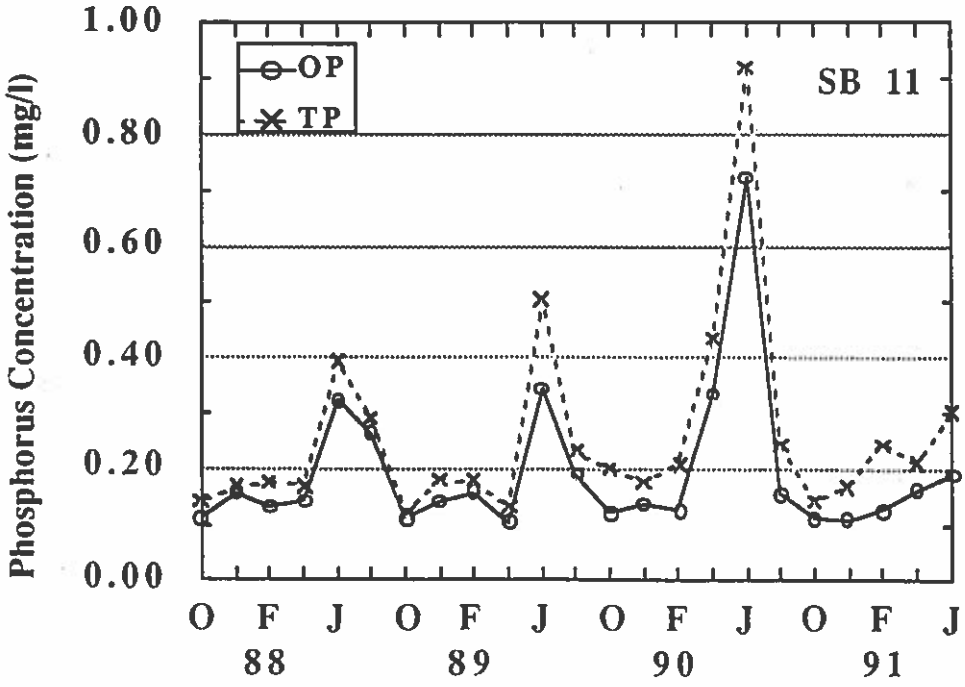
0.80
0.60
0.40
0.20
0.00
O F J O F J O F J O F J
88 89 90 91


Phosphrous Concentration (mg/l)
1.00
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 10
O F J O F J O F J O F J
88 89 90 91


Phosphorus Concentration (mg/l)
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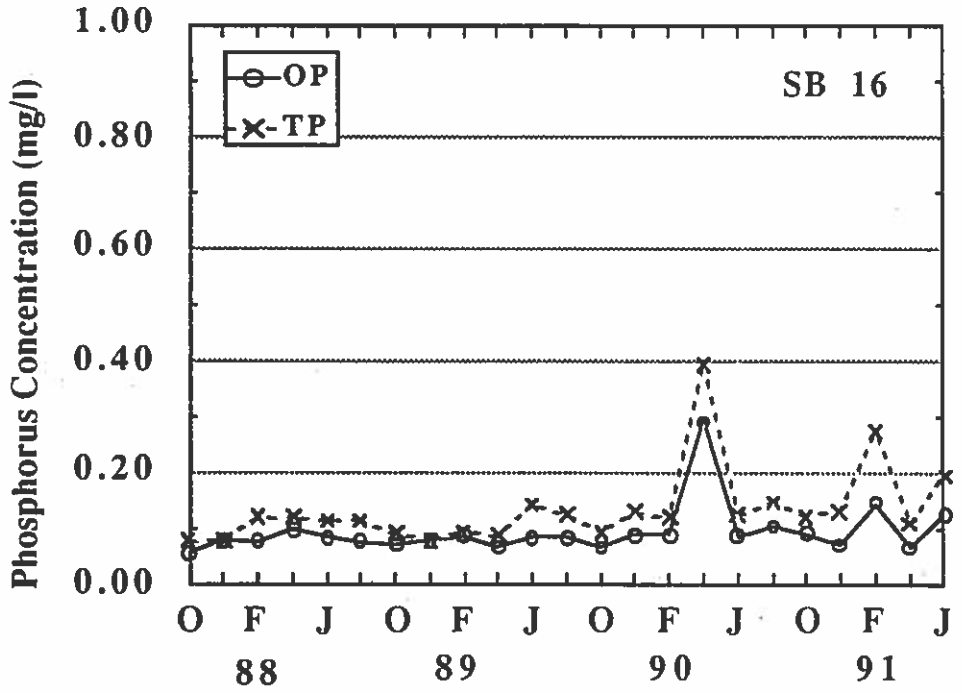
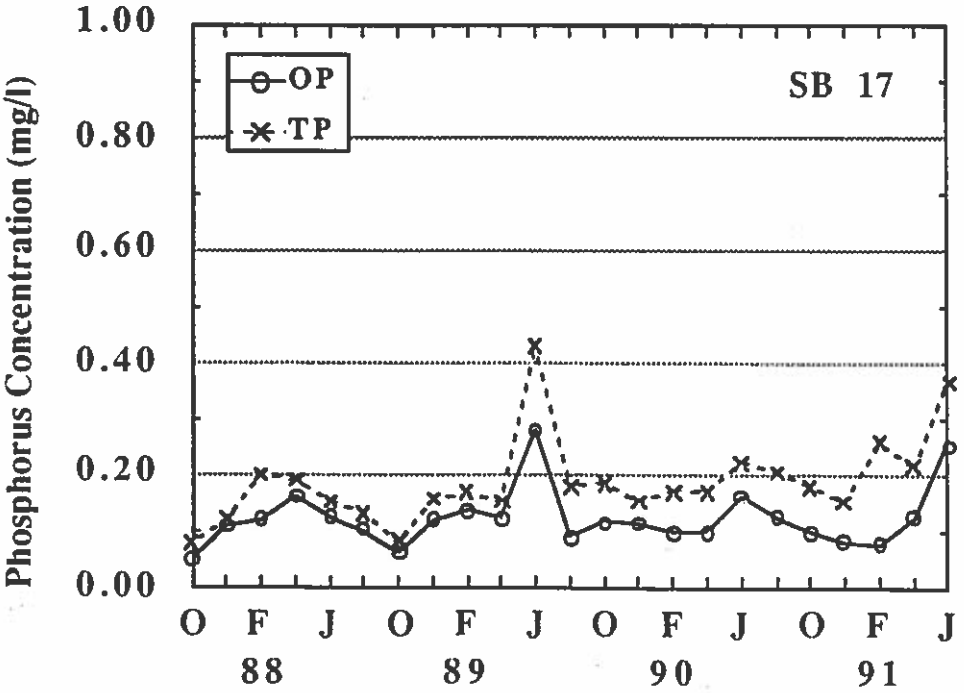
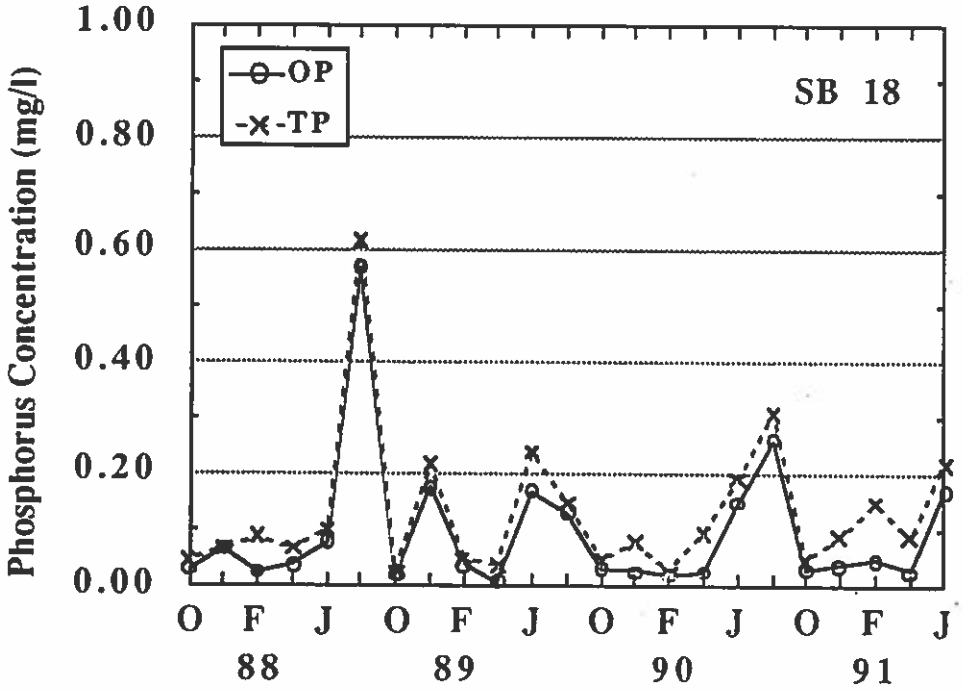
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 11
O F J O F J O F J O F J
88 89 90 91


Phosphorus Concentration (mg/l)
1.00
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 16
O F J O F J O F J O F J
88 89 90 91


Phosphorus Concentration (mg/l)
1.00
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 17
O F J O F J O F J O F J
88 89 90 91


Phosphorus Concentration (mg/l)
1.00
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 18
O F J O F J O F J O F J
88 89 90 91

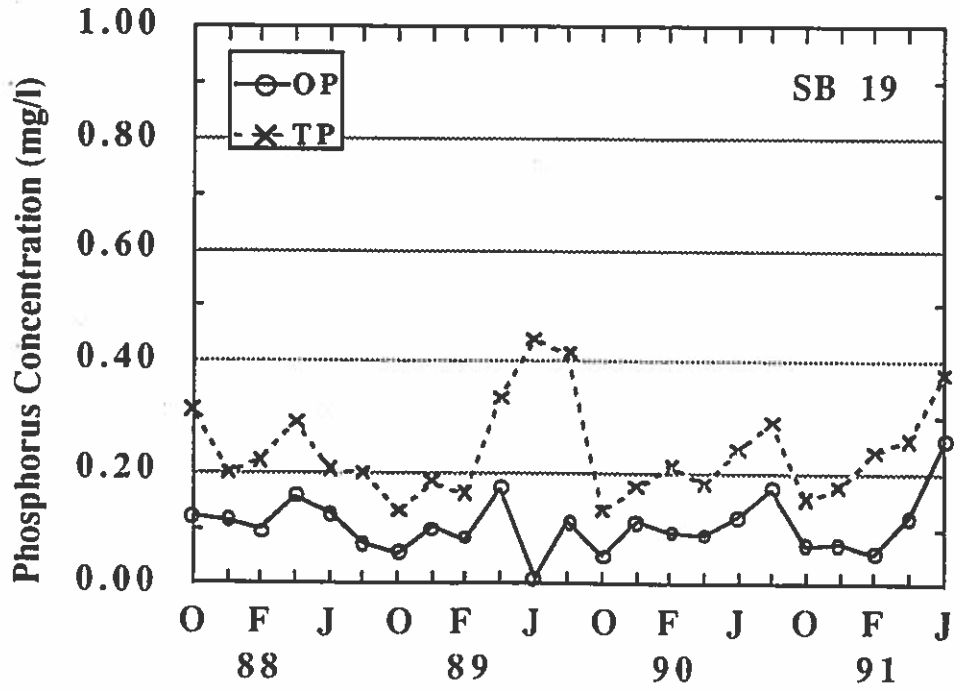

Phosphorus Concentration (mg/l)
1.00
0.80
0.60
0.40
0.20
0.00
OP
TP
SB 19
O F J O F J O F J O F J
88 89 90 91

Figure 17 Mean annual concentration of ortho-P (OP). Years represent Water Year (1 Oct-31 Sep).

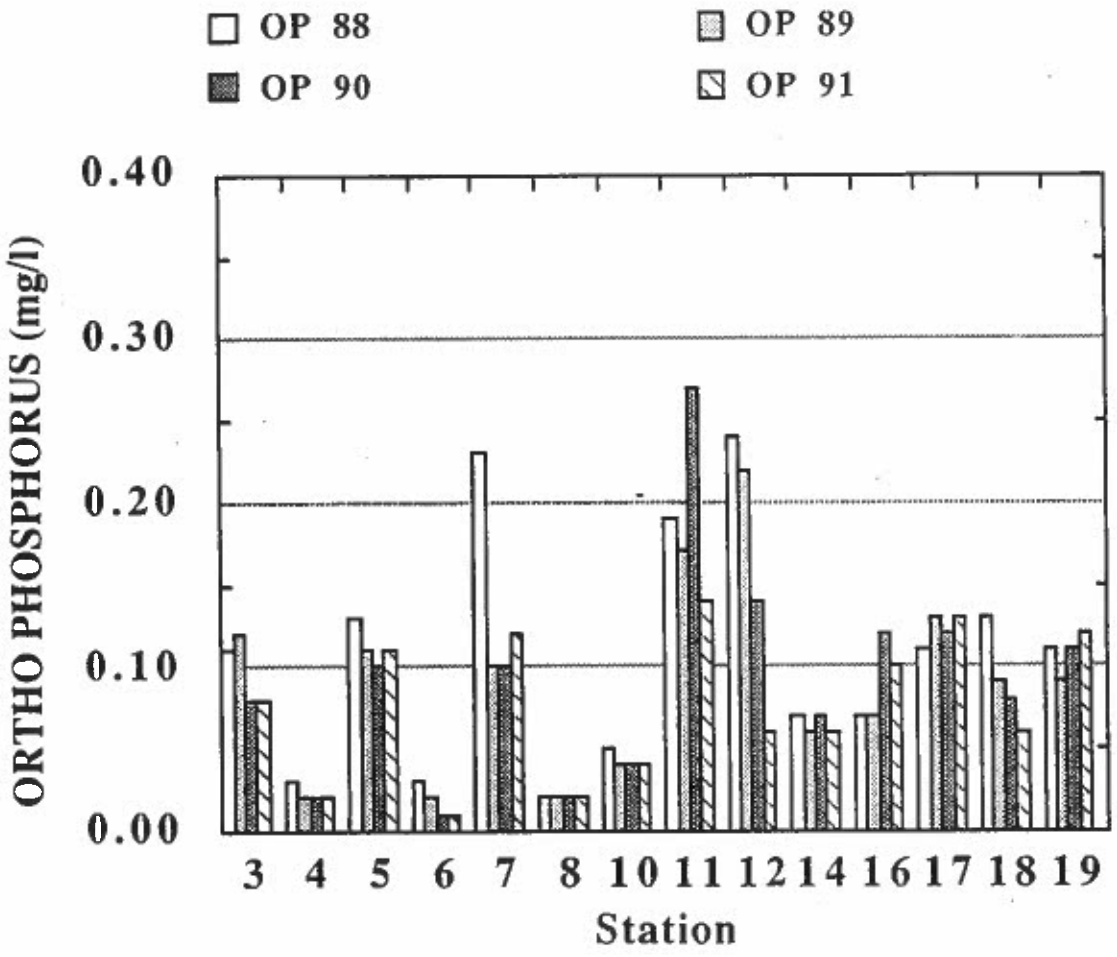
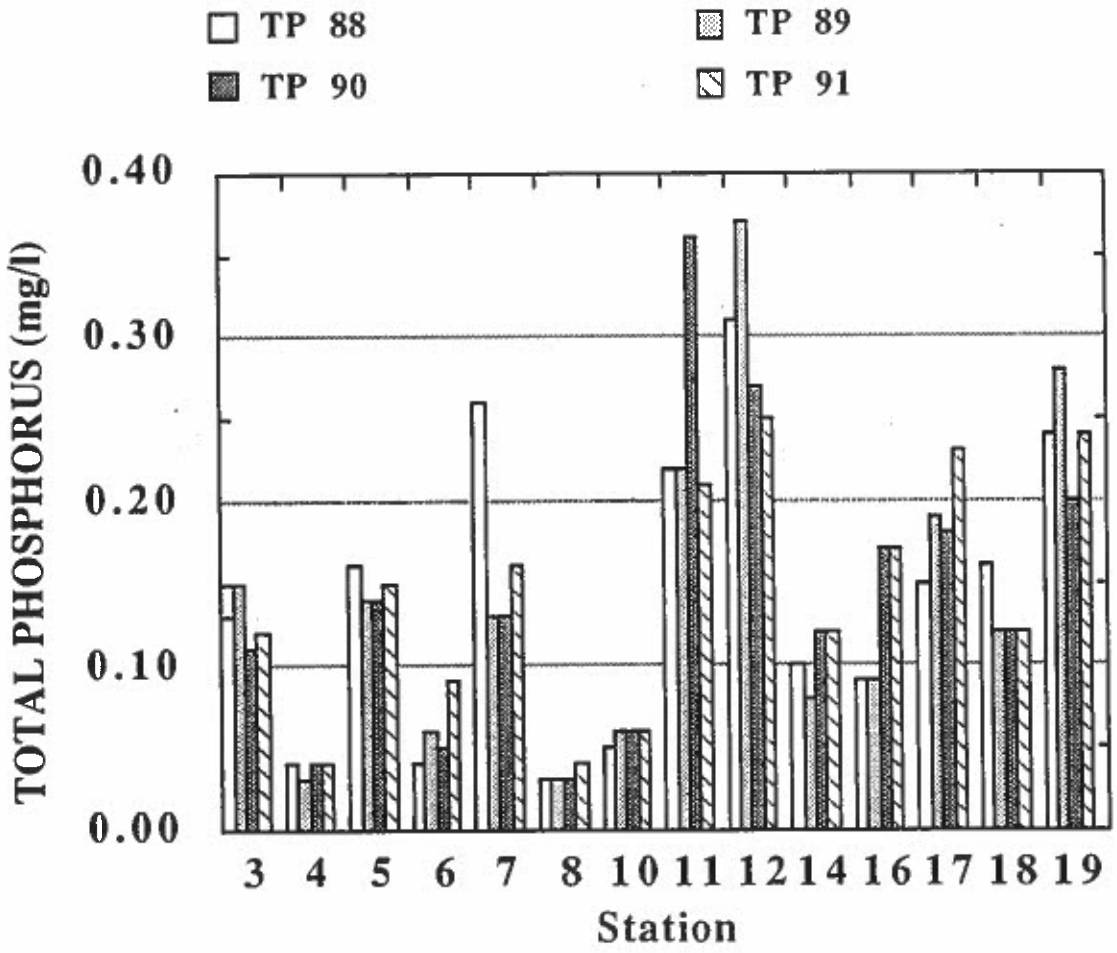


Figure 18 Mean annual concentration of Total-P (TP). Years represent Water Year (1 Oct-31 Sep).



winter-early spring period (e.g. minimum concentrations were found in Feb-88, Apr-89, Dec-90 and Dec-91; Figure 16). As discussed for nitrogen, SB 6 (Steamboat Ditch) was only sampled for water quality during the summer months of June, August and October. The single highest TP concentration was 0.09 mg/l and the mean annual concentration was low at 0.04-0.09 mg/l for TP and 0.01-0.03 mg/l for OP. It is clear that Steamboat Ditch was not a major source of P to Steamboat Creek during the summer. Similarly, as they drain the eastern slope of the Sierra Nevada, Whites Creek (SB 8) and Thomas Creek (SB 10) were very low in phosphorus. The maximum, single observed TP concentration at SB 8 was 0.08 mg/l and 0.10 mg/l at SB 10. Mean annual TP at both stations ranged from 0.03 to 0.06 (Table 16).

Despite the fact that water is diverted into the Crane-Chandler Ditch immediately downstream of the confluence of Steamboat Ditch and Steamboat Creek, and that the Steamboat Hot Springs discharges to the creek in this vicinity, P-concentrations were similar at SB 5 and SB 7. Indeed, with the exception of WY 88, these two stations were nearly identical in terms of both seasonality and absolute concentration (Figure 16, Table 16). In WY 88, the mean annual OP and TP concentrations were 0.23 mg/l and 0.26 mg/l, respectively; these values were nearly double those calculated for WY 89, WY 90 and WY 91. It is interesting to note that with the exception of a single date, the OP:TP ratio in WY 88 exceeded 0.90, and that the seasonal distribution of P at SB 7 in WY 88 was similar to that at SB 5, albeit more exaggerated. The much lower concentrations in Feb-88 and Apr-88 corresponded to periods of seasonal high flow.

Station SB 11 is 5.0 miles downstream from SB 7. While there are no major tributaries to Steamboat Creek in this reach, there is agricultural return flow from the lands irrigated by the Crane-Chandler Ditch and groundwater flow from the east slope of the Sierra Nevada (see discussion in section 2.1.). Once again, OP accounted for 65-85% of the TP concentration and showed clear and discrete annual peaks in June of WY 88, WY 89 and WY 90, and a lesser peak in June of WY 91 (Figure 16). In each of these four years the OP peak concentrations were 0.32 mg/l, 0.34 mg/l, 0.72 mg/l and 0.19 mg/l; TP peak concentrations were 0.39 mg/l,

0.50 mg/l, 0.92 mg/l and 0.30 mg/l. Except for the annual summer peaks, OP and TP concentration at SB 11 consistently was in the 0.15-0.20 mg/l range; this was similar, although higher than at SB 7. The June peaks in phosphorus at SB 11 were most probably the result of seasonal groundwater draining adjacent agricultural lands and perhaps, to a lesser extent, stream bank erosion.

Mean annual TP concentration in the Alexander Ditch (SB 12) ranged from 0.25 to 0.37 mg/l and 0.06 to 0.24 for OP (Table 16). The ratio of OP:TP was 0.77, 0.59, 52 and 0.24, and lower than that observed at SB 7 and SB 11 (Table 12). Seasonal peaks in P-concentration were found at SB 12 and occurred in Apr-88 (TP=0.45 mg/l) and Aug-88 (TP=0.47 mg/l), Jun-89 (TP=0.80 mg/l), Apr-90 (TP=0.36 mg/l) and Jun-91 (TP=0.29 mg/l). Baseline concentration was approximately 0.20 mg/l for TP and 0.15 mg/l for OP. As at SB 7, both TP and OP were significantly correlated to TDS, albeit less strongly (r=0.60-OP and r=0.67-TP, $p<0.01$). Neither form of phosphorus was significantly correlated with flow at SB 12; however, TP was positively correlated with total suspended solids (r=0.42, p=0.04). OP and TSS were not significantly correlated ($p>0.05$). Both OP and TP were also positively correlated with TDS (OP--r=0.51, p=0.01 and TP--r=0.41, p=0.05). From the data available we suspect that the distribution of phosphorus at SB 12 is related to both the flow of groundwater through P-enriched soils and also surface or streambank erosion.

Stations SB 14 (Rio Pico Drain) and SB 16 (Boynton Slough) were very similar with respect to P-concentration. Both had a OP:TP ratio of 0.50-0.78 (Table 12), both had reduced concentrations relative to SB 7, SB 11 and SB 12 (mean annual OP and TP concentrations at SB 14 were 0.06-0.07 mg/l and 0.08-0.12 mg/l respectively, and at SB 16, 0.07-0.12 mg/l for OP and 0.09-0.17 mg/l for TP), and with the exception of Apr-90 and Feb-91 (at SB 16) both demonstrated uniform levels throughout the period of record (Figure 16).

At SB 17, downstream of the confluence of SB 12, SB 14 and SB 16, phosphorus was much more seasonally uniform than at either SB 7 or SB 11 (Figure 16). Concentrations on individual sampling dates typically ranged from 0.05 to 0.15 mg/l for OP and 0.15 to 0.20

mg/l for TP. Only two seasonal spikes were observed; Jun-89 and Jun-91. The reduction of the seasonal spikes and general lowering of overall concentration at this station (mean annual concentration of OP at SB 17 was 0.11-0.13 mg/l and 0.15-0.23 for TP; Table 16) was most likely the result of dilution by flow from Boynton Slough (SB 16). Since the OP:TP ratio was so high in the downstream flow, the efficiency of the Rosewood Lakes Golf Course pond, which lies in Steamboat Creek, is not expected to be high.

With the exception of Aug-88 when there was a large OP spike at ±0.60 mg/l, P-concentration in the Yori Drain was not high (Figure 16). The mean annual concentration for either OP or TP ranged from 0.06 to 0.16 mg/l (Table 16). At SB 19, just upstream from the RSWTF, OP was typically low and in the range of 0.05-0.15 mg/l. TP was much higher and typically in the range 0.15-0.30 mg/l (Figure 16). The OP:TP ratio was the lowest at any station with a mean annual range of 0.32-0.55 (Table 12). This suggests the importance of sediment-based phosphorus from streambank and surface soil erosion. In Jun-89 TP at SB 19 was 0.44 mg/ as compared to a OP concentration of only 0.01 mg/l. At that time flow was 63 cfs, the highest discharge measured during the entire study.

In summary, ortho-P constituted a significant fraction of the total-P pool. At least during the period of record which occurred during a regional drought, P-concentration in waters from Little Washoe Lake was minimal. The only tributary which showed a high P-concentration was Alexander Ditch. High flows of low P water in Boynton Slough acted to reduce the concentrations measured at SB 19.

2.4.2. P-Load

2.4.2.1. OP and TP Loading by Tributary and Reach

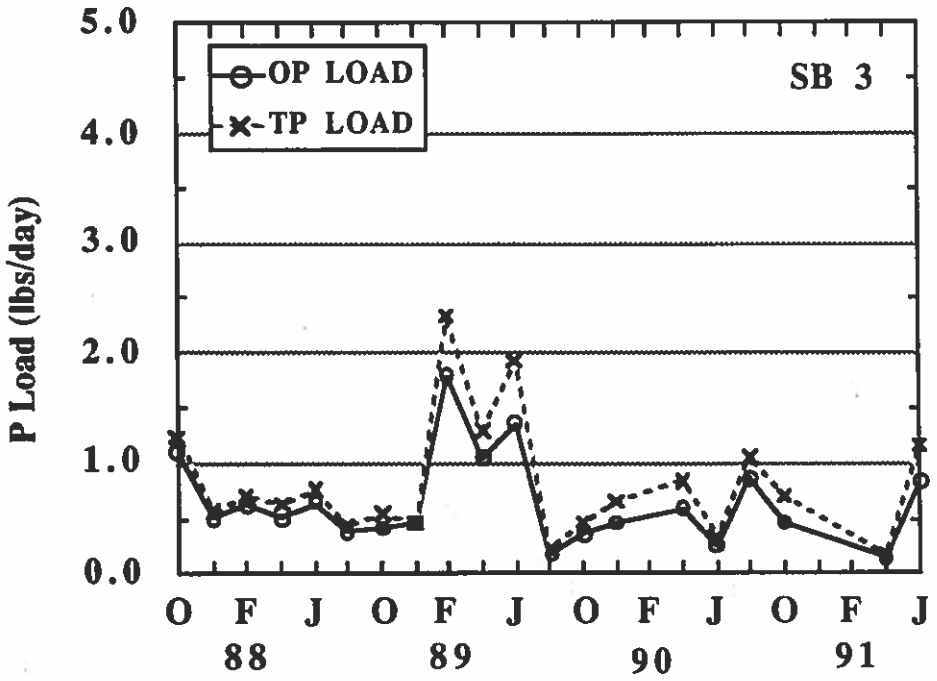
Details of P-loading by station and individual sampling date are presented in Figure 19. Summaries of P-loading by Water Year are given in Figures 20 and 21, and Table 17.

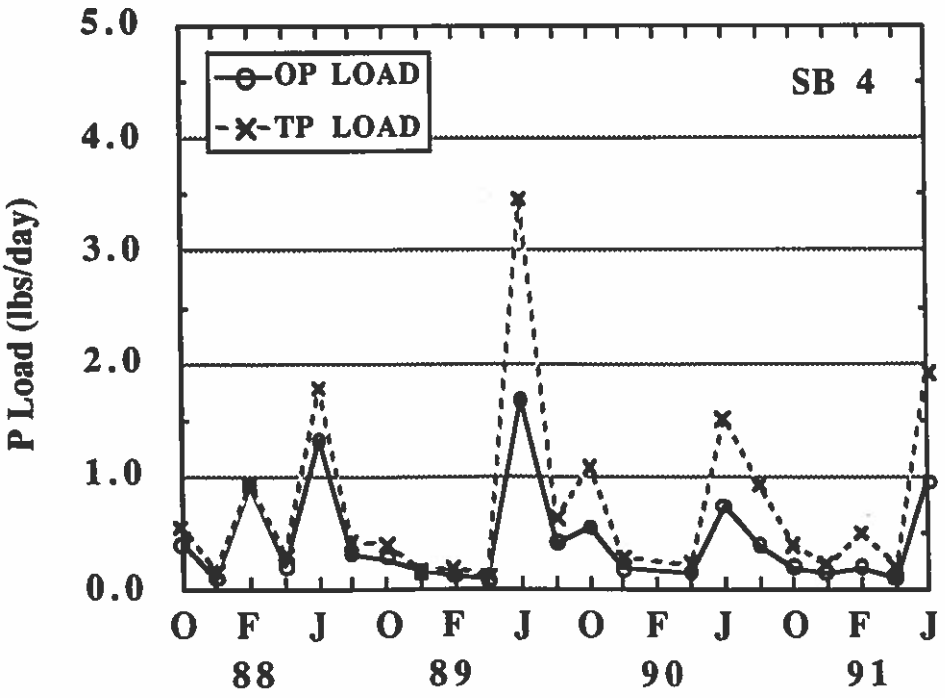
As was the case for nitrogen, P-load is highly influenced by flow. Stations SB 3, SB 4, SB 8, SB 10 and SB 14 carried the lowest TP-loads with mean annual values ranging from 0.65-1.27 lbs/day. The TP-load from Galena Creek (SB 4) was similar to that already present

Table 17. Mean annual LOAD of ortho-phosphorus and total phosphorus at each of the Steamboat Creek sampling stations. Number of sampling dates per year was six (n=6) with the exceptions of 1988 SB 6=3, SB 7=5, SB 8=3; 1989 SB 6=2, SB 10=5; 1990 SB 3,4,8,10,12,19=5, SB 7,11,14,16,17=4, SB 5,6,18=3; 1991 SB 4,17, 18=5, SB 8,10,14,16=4, SB 3,5,11=3, SB 7,12,19=2, SB 6=1. Values expressed as pounds per day (kg/h x 52.91=lbs/day) and arsenic corrected.

Station	OP 88	OP 89	OP 90	OP 91	TP 88	TP 89	TP 90	TP 91
SB 3	0.63	0.88	0.52	0.50	0.72	1.12	0.68	0.68
SB4	0.54	0.45	0.40	0.32	0.69	0.82	0.81	0.65
SB 5	0.84	2.89	1.32	0.40	1.17	4.12	1.99	0.58
SB 6	1.87	0.82	0.59	0.00	2.70	3.17	3.01	0.00
SB 7	1.00	0.68	1.14	0.64	1.61	0.86	1.50	0.76
SB 8	0.43	0.28	0.33	0.24	0.55	0.59	0.76	0.74
SB 10	0.49	0.50	0.48	0.89	0.67	0.80	0.68	1.36
SB 11	4.69	7.09	5.51	2.91	5.71	9.34	7.89	4.07
SB 12	4.45	3.58	3.45	0.14	5.91	5.37	6.22	0.73
SB 14	0.89	0.58	0.73	0.31	1.16	0.78	1.27	0.72
SB 16	6.64	5.33	10.17	2.84	9.06	7.99	14.02	4.73
SB 17	16.30	23.52	15.61	8.41	21.25	34.59	24.41	15.67
SB 18	5.47	1.22	1.20	0.50	6.20	1.68	1.59	0.72
SB 19	21.80	8.28	19.27	28.81	46.21	43.13	36.79	46.75

Figure 19 Distribution of phosphorus **load** taken from the sampling network for the Steamboat Creek monitoring study; Oct-87 to Jun-91. Calculations represent the product of flow and concentration and are given for ortho-P and total-P. values are expressed as pounds per day.


SB 3
OP LOAD
TP LOAD
P Load (lbs/day)
5.0
4.0
3.0
2.0
1.0
0.0
O F J O F J O F J O F J
88 89 90 91


SB 4
OP LOAD
TP LOAD
P Load (lbs/day)
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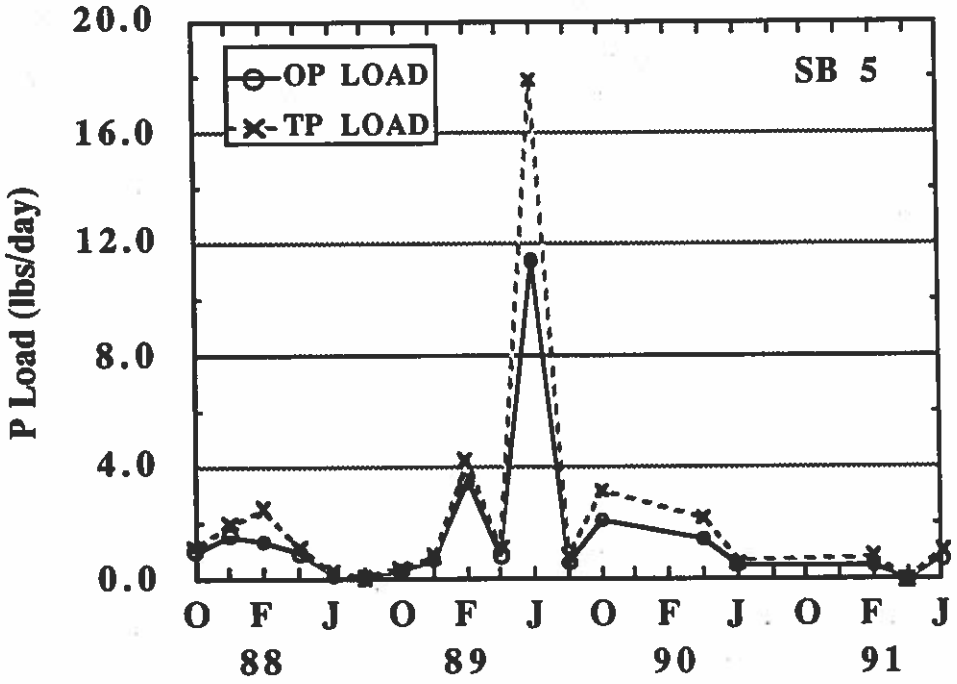
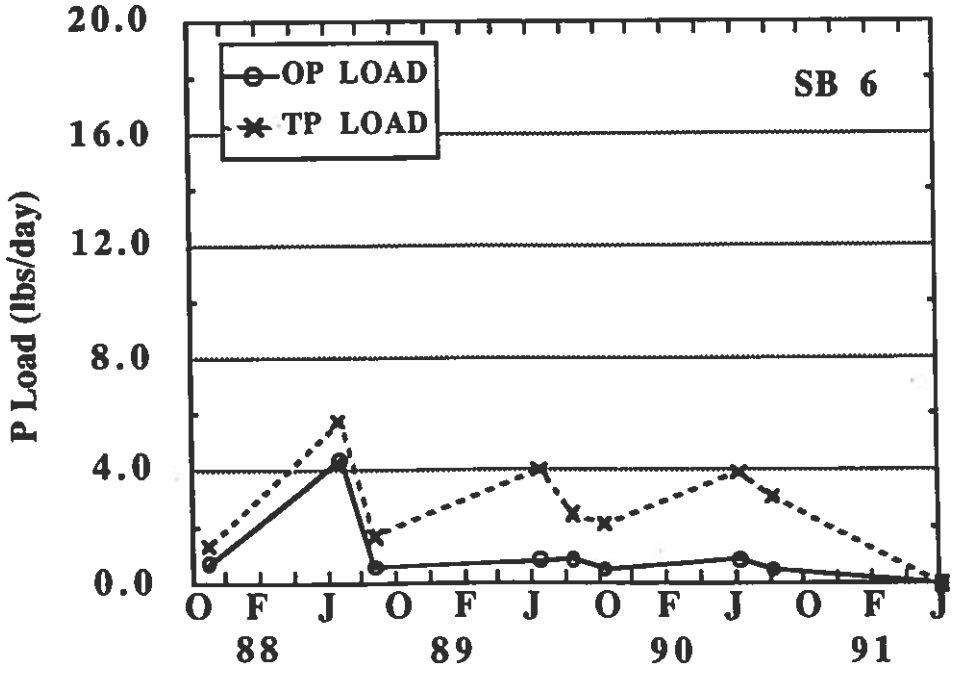
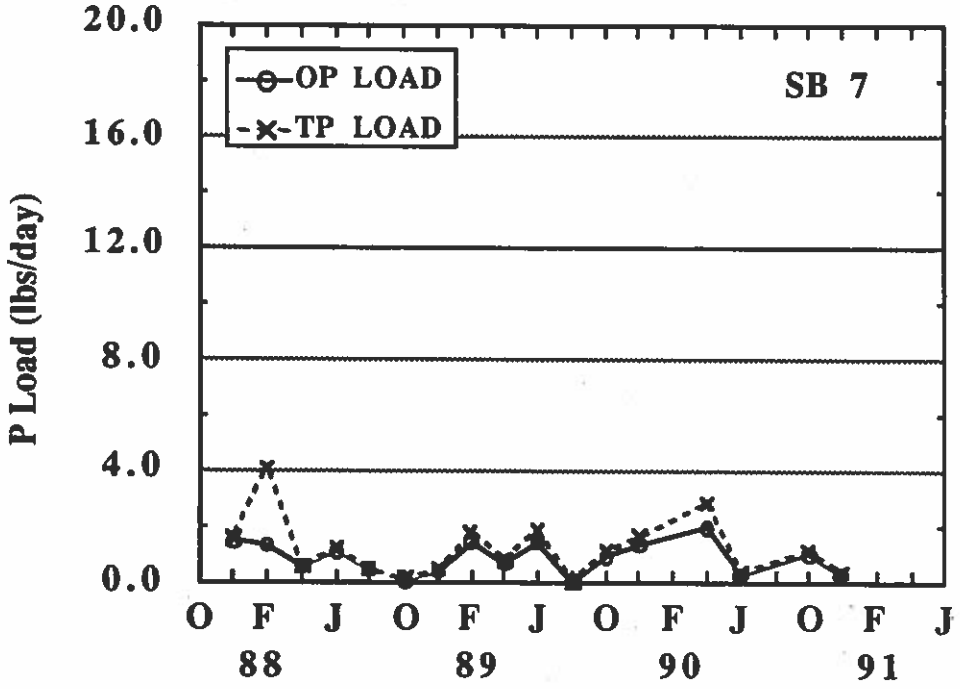
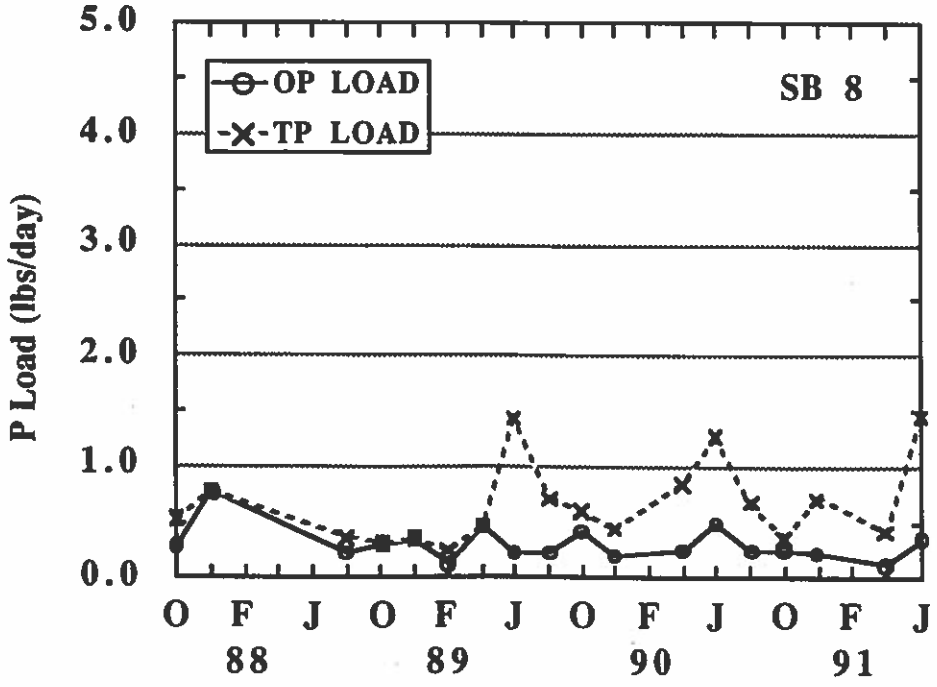
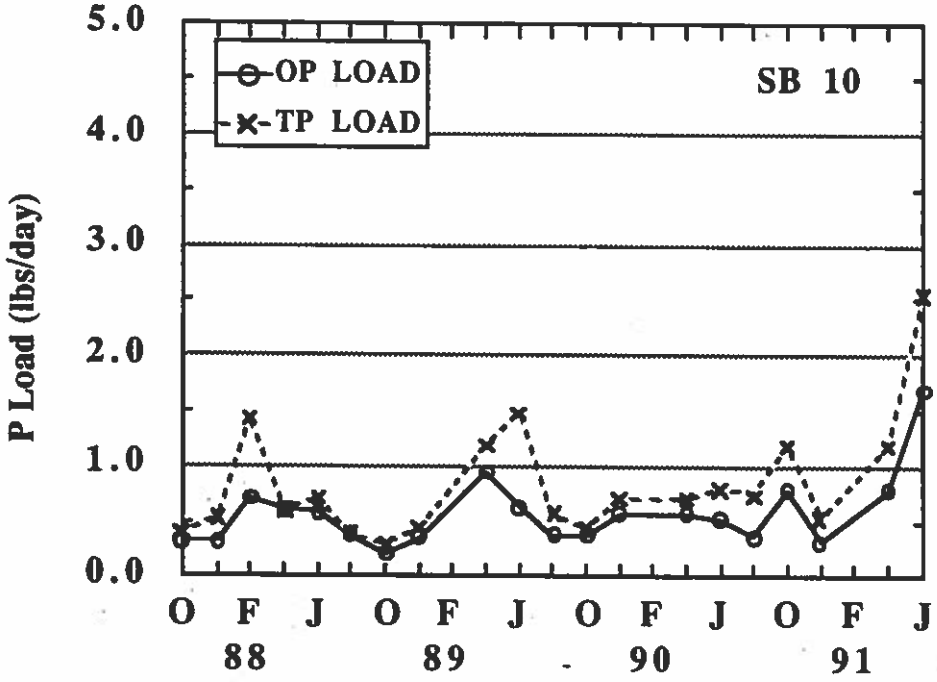
4.0
3.0
2.0
1.0
0.0
O F J O F J O F J O F J
88 89 90 91


20.0
16.0
12.0
8.0
4.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 5
O F J O F J O F J O F J
88 89 90 91


20.0
16.0
12.0
8.0
4.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 6
O F J O F J O F J O F J
88 89 90 91


20.0
16.0
12.0
8.0
4.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 7
O F J O F J O F J O F J
88 89 90 91


5.0
4.0
3.0
2.0
1.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 8
O F J O F J O F J O F J
88 89 90 91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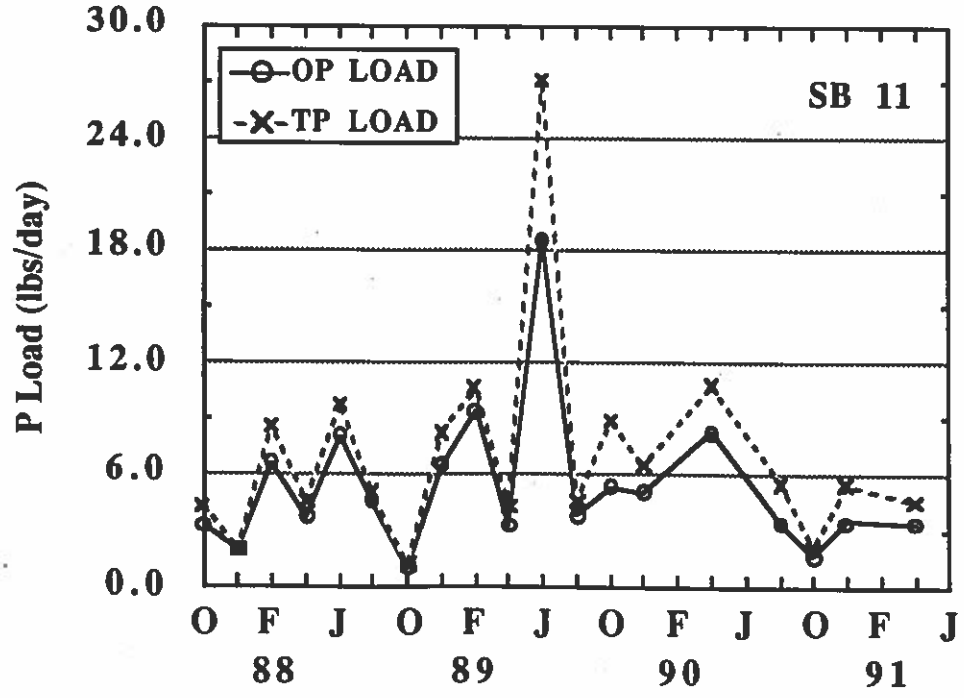
4.0
3.0
2.0
1.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 10
O F J O F J O F J O F J
88 89 90 91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24.0
18.0
12.0
6.0
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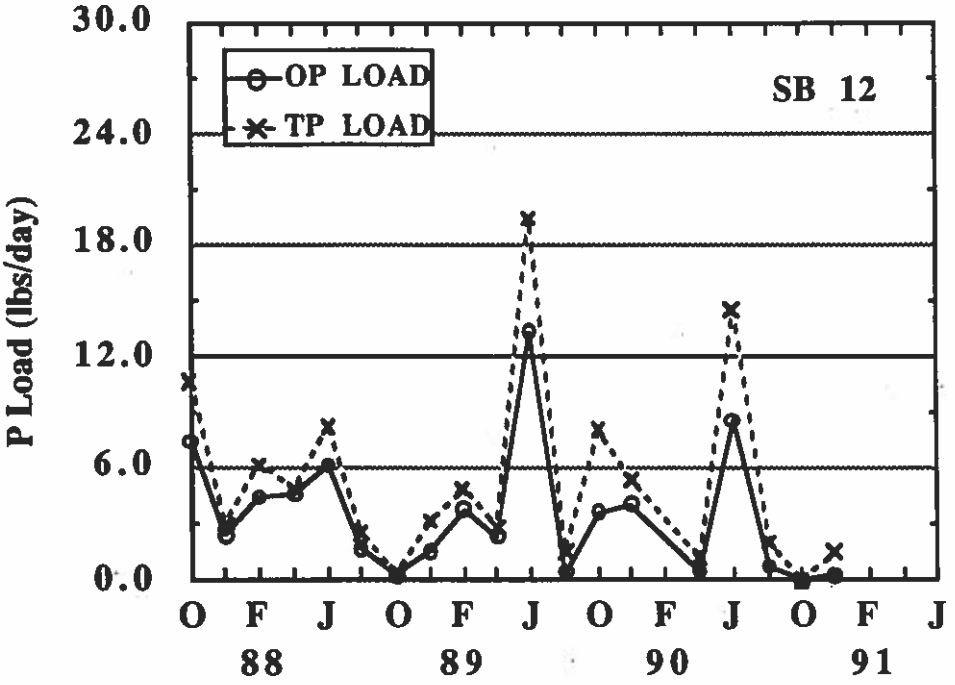
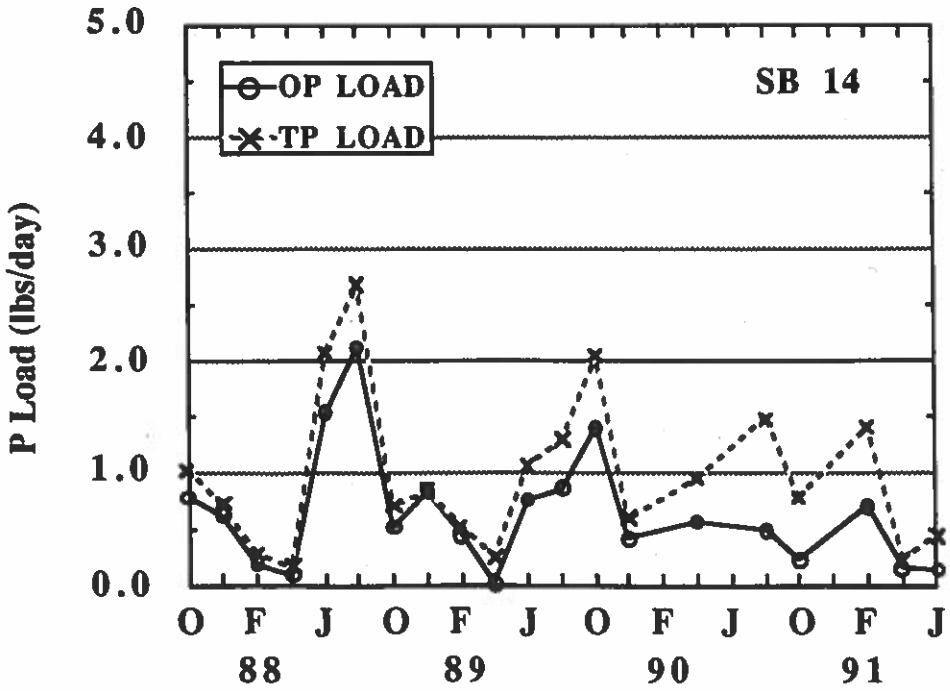
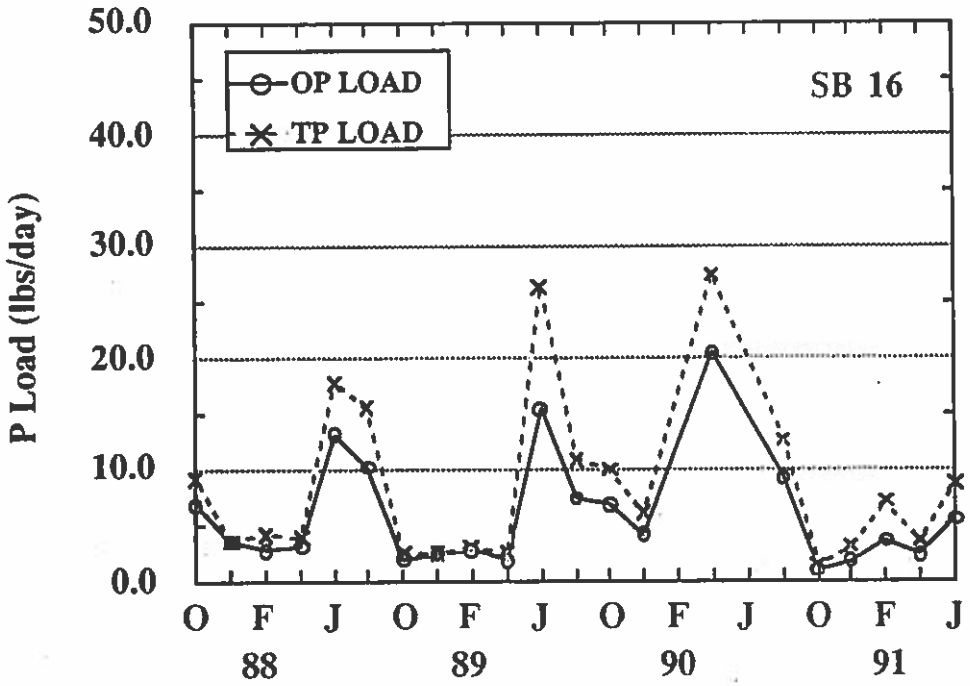
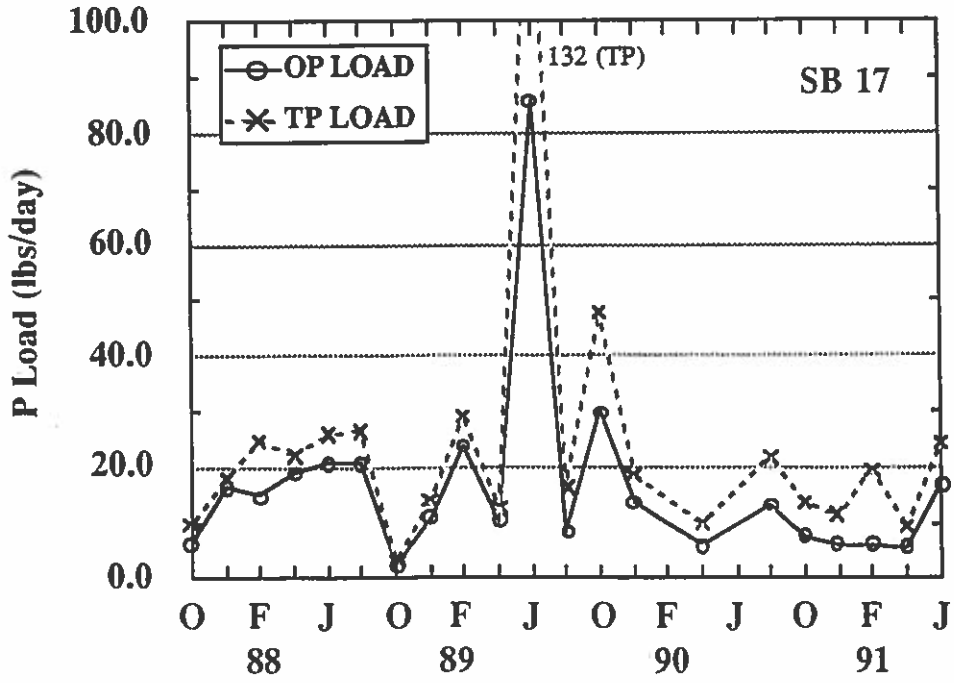
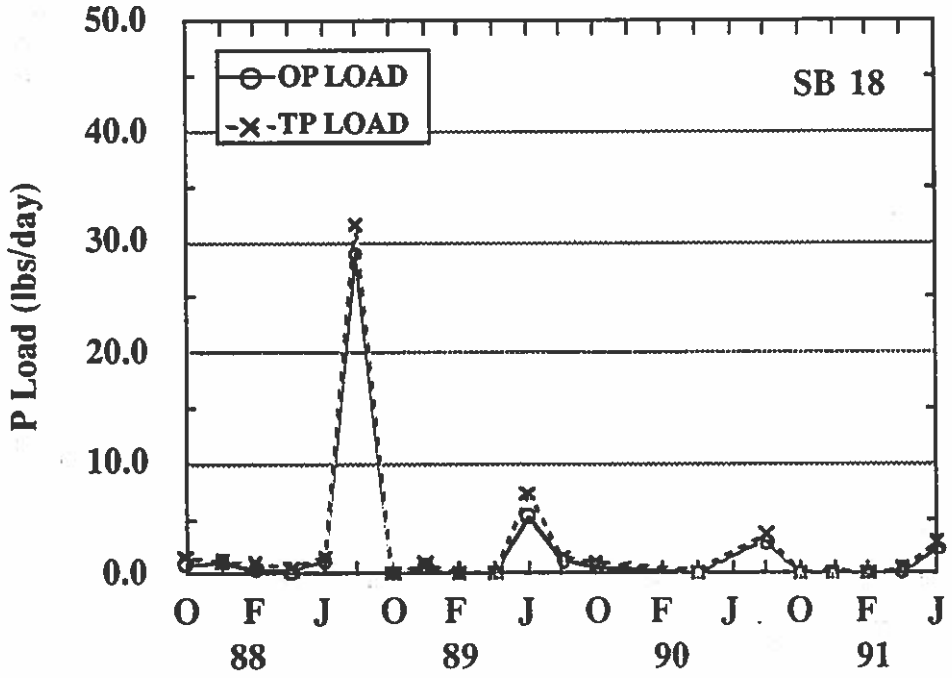
P Load (lbs/day)
OP LOAD
TP LOAD
SB 11
O F J O F J O F J O F J
88 89 90 91


30.0
24.0
18.0
12.0
6.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 12
O F J O F J O F J O F J
88 89 90 91


5.0
4.0
3.0
2.0
1.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 14
O F J O F J O F J O F J
88 89 90 91


50.0
40.0
30.0
20.0
10.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 16
O F J O F J O F J O F J
88 89 90 91


100.0
80.0
60.0
40.0
20.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
132 (TP)
SB 17
O F J O F J O F J O F J
88 89 90 91


50.0
40.0
30.0
20.0
10.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
SB 18
O F J O F J O F J O F J
88 89 90 91

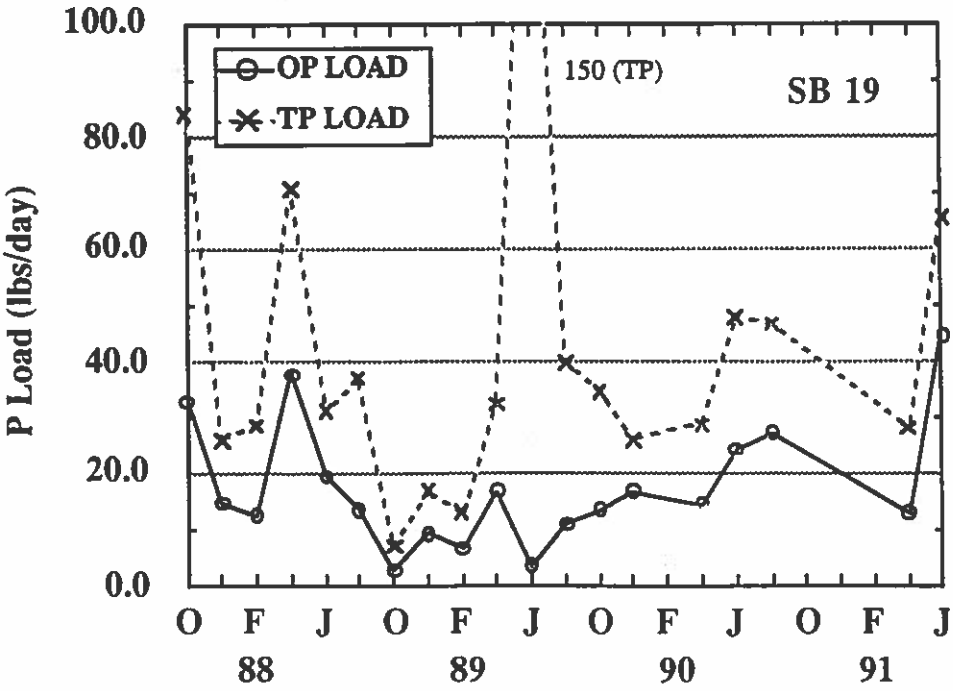

100.0
80.0
60.0
40.0
20.0
0.0
P Load (lbs/day)
OP LOAD
TP LOAD
150 (TP)
SB 19
O F J O F J O F J O F J
88 89 90 91

Figure 20 Mean annual load of ortho-P (OP). Years represent water year (1 Oct - 31 Sept).

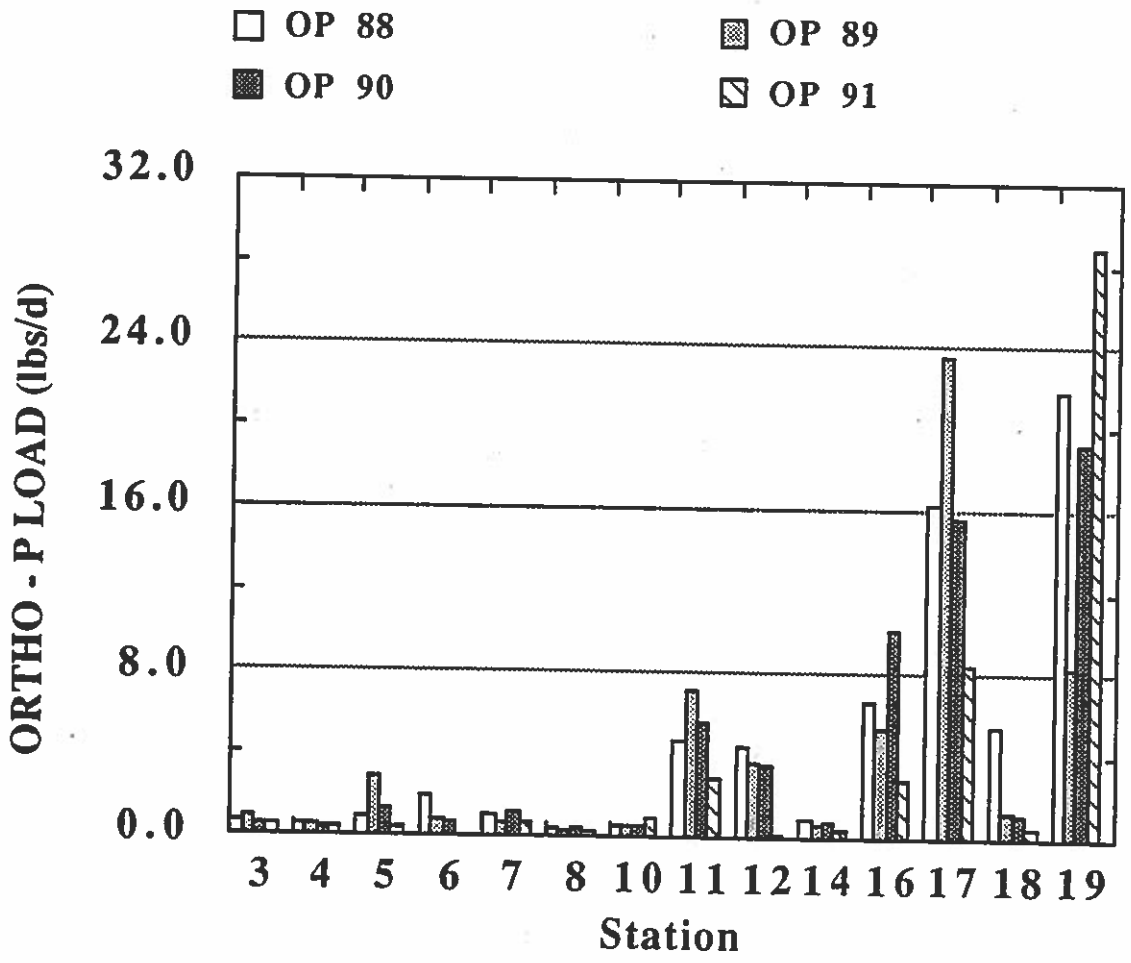
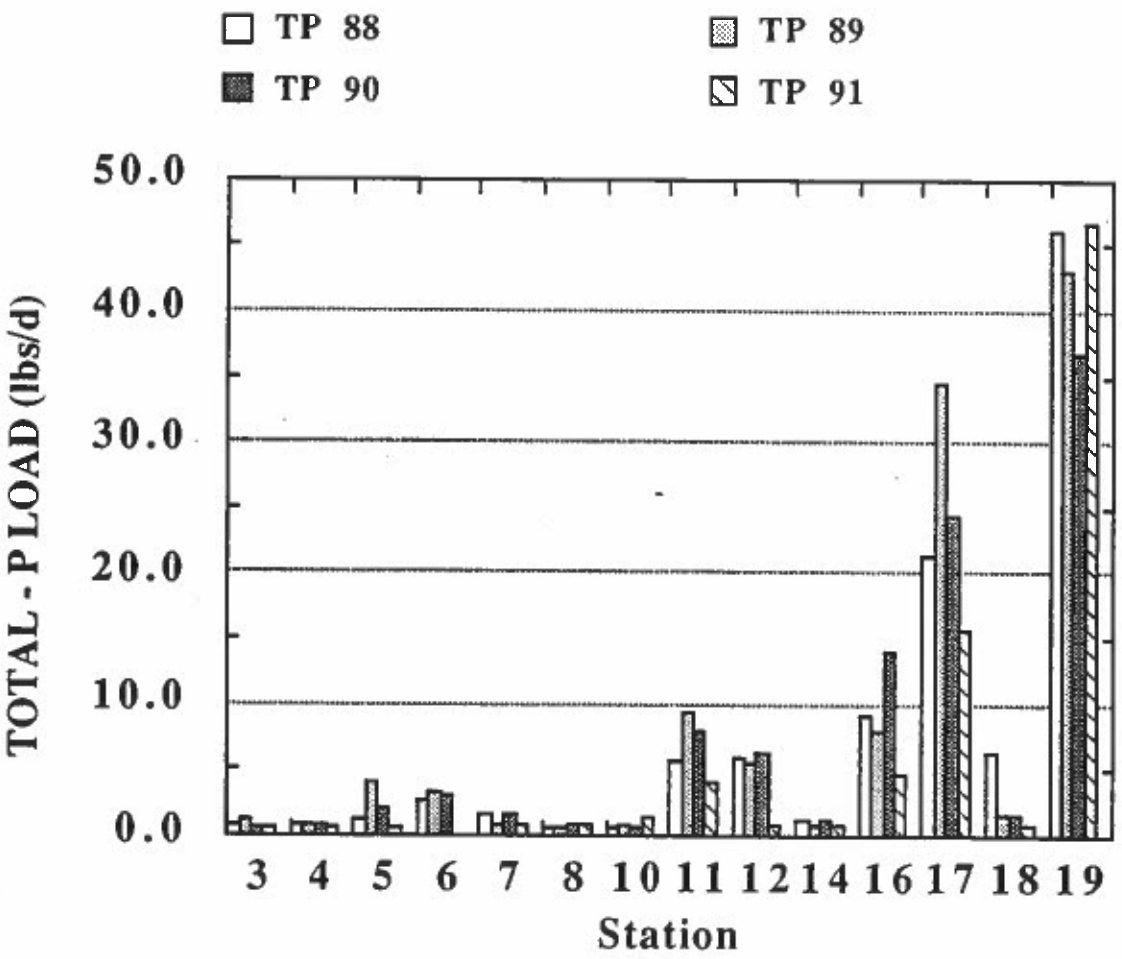


Figure 21 Mean annual load of total-P (TP). Years represent water year (1 Oct - 31 Sept).



in Steamboat Creek upstream at SB 3, i.e. 0.65 to 0.82 lbs/day. While the TP-concentrations at SB 5 were similar to those at SB 3, load at SB 5 was higher because of the increased flow at this station; this was especially true in WY 89 when a high mean annual flow (5.6 cfs) coupled with a moderate mean annual concentration (0.14 mg/l) yielded a relatively high mean annual load of 4.19 lbs/day. For WY 88, WY 90 and WY 91, the sum of P-load at SB 3 and SB 4 was comparable to that downstream at SB 5 (Table 18); this suggests that Galena Creek was the only significant source of P to Steamboat Creek between Pleasant Valley and Rhodes Road. Despite the low concentrations at SB 6 (0.01-0.10 mg/l), high flows in Steamboat Ditch resulted in a mean annual load which ranged from 2.70-3.17 lbs/day. The TP 91 load value in Table 17 is presented as 0.00 lbs/day. This resulted from the fact that sampling was on one date only, when flow was negligible.

Between the confluence of Steamboat Ditch and Steamboat Creek (SB 5+6) downstream to SB 7 at Geiger Grade, TP declined 2.26 lbs/day in WY 88, 6.43 lbs/day in WY 89, 3.50 lbs/day in WY 90 and remained relatively constant in WY 90 (Table 18). Given that there was no major change in concentration between these two locations, the observed reduction of P-load can be attributed almost entirely to the reduced flow at SB 7, due to irrigation diversion in the Crane-Chandler Ditch. Despite there being no direct tributary inflow between SB 7 and SB 11, P-load increased dramatically between these two stations; i.e. WY 88 - 4.10 lbs/day, WY 89 - 8.48 lbs/day, WY 90 - 6.39 lbs/day and WY 91 - 3.31 lbs/day for TP. As discussed above, groundwater flow and irrigation return water with elevated P-concentration must be entering Steamboat Creek between these two stations.

P-loading from Alexander Ditch was significant relative to the load just upstream at SB 11 with mean annual TP-loads ranging from 5.37 to 6.22 lbs/day in WY 88-90 (Tables 17 and 18). TP-load in WY 91 was anomalously low at 0.73 lbs/day. In WY 88 and WY 90, TP-load at SB 12 was approximately equal to that at SB 11, and in WY 89 the SB 12 load was 55-60% of that already in the creek. SB 14 and SB 18 had either low flows, low P-concentration or both and consequently did not significantly contribute to the overall P-load to Steamboat Creek (the mean

Table 18. Summary of phosphorus loading in Steamboat Creek by reach. Values are expressed as lbs-P/day. Stations SB 3+4, SB 5+6, SB 11+12 and SB 17+18 represent unsampled locations along Steamboat Creek immediately downstream of the confluence of a tributary (i.e. SB 4, SB 6, SB 12, and SB 18). Loads for these stations were calculated as the sum of the tributary P-load and the main creek station just upstream. With the exception of SB 3 and SB 4, the combined stations are directly adjacent. Part A indicates the contribution of the major tributaries relative to load in the main creek at the closest upstream station and Part B gives estimates for loading not related to the major tributaries. (Refer to Figure 1 for station location). Values in parentheses () in Part A denote load in main creek at closest upstream actual or calculated station.

TOTAL PHOSPHORUS

A. Tributary Load

Station	WY 88	WY 89	WY 90	WY 91
SB 4	+0.69 (0.72)	+0.82 (1.12)	+0.81 (0.68)	+0.65 (0.68)
SB 6	+2.70 (1.17)	+3.17 (4.12)	+3.01 (1.99)	0.00 (0.58)
SB 12	+5.91 (5.71)	+5.37 (9.34)	+6.22 (7.89)	+0.73 (4.07)
SB 14	+1.16 (11.62)	+0.78 (9.34)	+1.27 (14.11)	+0.72 (4.83)
SB 16	+9.06 (11.62)	+7.99 (9.34)	+14.02 (14.11)	+4.73 (4.83)
SB 18	+6.20 (21.25)	+1.68 (34.59)	+1.59 (24.41)	+0.72 (15.67)

B. Load in Creek Between Major Tributaries

SB 3+4 to SB 5	-0.24	+2.18	+0.50	-0.75
SB 5+6 to SB 7	-2.26	-6.43	-3.50	+0.18
SB 7 to SB 11	+4.10	+8.48	+6.39	+3.31
SB 17+18 to SB 19	+18.76	+6.86	+10.79	+30.36

Table 18. (cont.)

ORTHO-P

A. Tributary Load

Station	WY 88	WY 89	WY 90	WY 91
SB 4	+0.54 (0.63)	+0.45 (0.88)	+0.40 (0.52)	+0.32 (0.50)
SB 6	+1.87 (0.84)	+0.82 (2.89)	+0.59 (1.32)	+0.00 (0.40)
SB 12	+4.45 (4.69)	+3.58 (7.09)	+3.45 (5.51)	+0.14 (2.91)
SB 14	+0.89 (9.14)	+0.58 (10.67)	+0.73 (8.96)	+0.31 (3.05)
SB 16	+6.64 (9.14)	+5.33 (10.67)	+10.17 (8.96)	+2.84 (3.05)
SB 18	+5.47 (16.30)	+1.22 (23.52)	+1.20 (15.61)	+0.50 (8.41)

B. Load in Creek Between Major Tributaries

SB 3+4 to SB 5	-0.33	+1.56	+0.40	-0.42
SB 5+6 to SB 7	-1.71	-3.03	-0.77	+0.24
SB 7 to SB 11	+3.69	+6.41	+4.37	+2.27
SB 17+18 to SB 19	+0.03	-16.46	+2.46	+19.90

annual TP-loads from SB 14 and SB 18 typically were 0.72-1.68 lbs/day). The only exception to this was on the single sampling in Aug-88 when high flows and high concentration combined to produce a TP-load on that date of 31.61 lbs/day. The highest P-loading from any of the monitored tributaries came from Boynton Slough (SB 16) and was the direct consequence of higher flows and not higher concentrations. Annual TP-load at this location were WY 88 - 9.06 lbs/day, WY 89 - 7.99 lbs/day, WY 90 - 14.02 lbs/day and WY 91 4.73 lbs/day (Table 18). The combination of TP-loads from SB 12, SB 14 and SB 16 with the instream load at SB 11 yielded a high load at SB 17 (Table 17).

For two of the four Water Years (WY 88 and WY 90) OP-load between the confluence of Steamboat Creek and Yori Drain (SB 17+18), and SB 19 at Kimlick Lane was minimal; +0.03 and +2.46 lbs/day, respectively. In WY 89 OP-load declined by 16.46 lbs/day, and in WY 91 it increased by 19.90 lbs/day (Table 18). In contrast TP-load between these two locations increased in each year by 18.76 lbs/day in WY 88, 6.86 lbs/day in WY 89, 10.79 lbs/day in WY 90 and 30.36 lbs/day in WY 91. This represents the largest increase in TP-load between any two stations on the Steamboat Creek system, regardless of whether or not there was a tributary input. Since this increase appeared to come primarily from particulate-P (much larger increase in TP-load relative to OP-load) this most likely resulted from surface soil or creek bank erosion. This is certainly an area where erosion control and soil stabilization should be focused.

In summary, water entering Steamboat Creek in the upper portion of the drainage (i.e. discharge from Little Washoe Lake and Galena Creek) did not carry significant P-loads relative to the more downstream locations. The load in Steamboat Ditch was typically 3-4 times greater than in Galena Creek and resulted from increased flow and not increased P-concentration. The calculated loss of P between SB 5+6 and SB 7 (Gieger Grade) was due to the diversion of flow in the Crane-Chandler Ditch for irrigation. The increase in mean annual TP-load (3.31-8.48 lbs/day) and OP-load (2.27-6.41 lbs/day) between SB 7 and SB 11 was most likely the result of groundwater flow and irrigation return water with elevated P-

concentration. This is supported by the seasonality of the P-spikes and by the fact that OP typically comprised 70-80% of the TP at SB 11. Alexander Ditch (SB 12) and Boynton Slough (SB 16) normally contributed large P-loads to Steamboat Creek, on the order of 5-15 lbs/day. Conversely, Rio Poco Drain (SB 14) and Yori Drain (SB 18) discharged much less TP; 1-2 lbs/day. The region of the system which showed the greatest P-loading was that segment of the creek between the confluence of Yori Drain (SB17+18) and SB 19. Mean annual TP-loading in this reach ranged from 6.86 to 30.36 lbs/day, with the majority in the particulate-P form. This was in contrast to all the upstream sites which was dominated by OP. It is recommended that this area be targeted for erosion control, soil stabilization and riparian/wetland vegetation restoration. To reduce P-loading from Alexander Ditch, Boynton Slough and the adjacent lands between SB 7 and SB 11, a more detailed study of agricultural practices should be undertaken.

2.4.2.2. Regional Point and Nonpoint Source P-Loading to the Truckee River

As done for nitrogen, phosphorus load from the RSWTF during the period Oct-87 to Jun-91, and the September 1989 loading estimates of Brock are compared to data obtained during this study.

In Table 19a, daily loads calculated from the Steamboat Creek data in this report are compared to daily loads from the RSWTF. While the load from RSWTF ranged from 37-125 lbs/day over the period of record, most values were between 50-70 lbs/day. Similarly, P-load from Steamboat Creek ranged from 7-150 lbs/day; however, values were commonly less and in the 20-50 lbs/day range. Average daily load at SB 19 from Oct-87 to Jun-91 was 43 lbs/day for TP and 18 lbs/day for OP (Table 19b). This compares favorably with Brock's September 1989 estimate of 38 lbs TP/day for Steamboat Creek, and indeed, it was identical to our Sep-89 estimate of 37 lbs/day. For both point and nonpoint sources, OP typically accounted for approximately one-half of the TP load. Of the calculated nonpoint loads in Sep-89, Steamboat Creek (37 lbs/day) exceeded the North Truckee Drain (20 lbs/day) and irrigation return flow from McCarran to Derby Dam (32 lbs/day).

Table 19. Comparison of total phosphorus loading from Steamboat Creek (SBC) and the Truckee Meadows Water Reclamation Facility (TMWRF) (formerly the Reno-Sparks Wastewater Treatment Facility). Values are given as pounds per day. Estimates for Steamboat Creek are taken from station SB 19 which is located near the confluence of Steamboat Creek and the Truckee River but, upstream of the TMWRF. TMWRF P-loading values were obtained from Tom Swan at that facility.

DATE	TMWRF	SBC
Water Year 88		
Oct 1987	97	84
Dec	125	26
Feb 1988	118	29
Apr	113	71
Jun	47	31
Aug	79	37
Water Year 89		
Oct 1988	71	7
Dec	37	17
Feb 1989	66	13
Apr	70	32
Jun	70	150
Aug	52	40
Water Year 90		
Oct 1989	28	35
Dec	50	26
Feb 1990	49	26[a]
Apr	56	29
Jun	80	48
Water Year 91		
Dec 1990	67	21[a]
Feb 1991	77	29[a]
Apr	52	28
Jun	53	65

[a] Assumes flow of 23 cfs

Table 19b . Best estimates P-loading to the Truckee River from Steamboat Creek (SBC) in relation to other monitored regional nonpoint and point sources located from McCarran to Derby Dam. Helms Pit discharges into the North Truckee Drain (NTD) and is also included in values for NTD N-loading. IRRET=irrigation return flows, GRNDIF=groundwater inflow. All data except for the SBC and RSWTF (Sep 89) values taken from the current study come from Brock (1991) and represent the period September 1989. Loads are expressed as lbs/day.

LOCATION	OP	TP
NTD (Sep 89)	11	20
SBC - Brock (Sep 89)	15	38
SBC - Current study (Sep 89)[a]	12	37
SBC - Current study (Oct 87 - Jun 91)	18	43
IRRET (Sep 89)	27	32
GRNDINF (Sep 89)	0	0
RSWTF (Sep 89)[a]	16	40
RSWTF (Oct 90 - Sep 91)	33	69

[a] mean of Aug 89 and Oct 89

Comparison of nonpoint sources of P in Sep-89 (NTD, SBC, IRRET) to discharge from the RSWTF indicates that of a total combined load of 129 lbs TP/day, 89 lbs/day or 69% came from nonpoint. For OP this percentage was even higher at 76% from nonpoint. Since the RSWTF P-load estimate for Sep-89 was low relative to the period Oct 90-Sep 91, the importance of nonpoint P may be somewhat overestimated; however, the Sep-89 data does not include groundwater inflow which could be important at other times of the year. Consequently, we conclude that nonpoint source P-loading to the Truckee River from McCarran to Derby Dam is very important and that on an annual basis nonpoint loading exceeds point source loading for TP and OP.

2.5. Metals

2.5.1. Data Summary

Concentrations of the priority pollutant metals arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), selenium (Se) and zinc (Zn), as well as boron (B) and iron (Fe) are given by station and sampling date in Table 20. The distribution of Cd, Cr, Cu, Hg, Pb and Se were similar in that concentrations were typically below the analytical limit of detection (Cd - 1 µg/l, Cr - 5 µg/l, Cu - 10 µg/l, Hg - 0.5 µg/l, Pb - 5 µg/l, Se - 1 µg/l). Cadmium was not found above detection limits at SB 3, SB 4, SB 5, SB 6, SB 10, SB 14, SB 16 and SB 18. Stations SB 7 and SB 11 showed Cd above detection on four and three occasions, respectively. Further downstream at SB 11 this metals was >1 µg/l twice. At the remaining stations, this metal was measured above detection on only a single occasion (Table 21). The maximum concentration on any sampling date was 7 µg/l at station SB 7. Chromium showed a similar distribution in that this metal was infrequently measured at above detection concentrations throughout the period of record. Measurements were below detection at SB 3, SB 4, SB 6, SB 8, SB 10 and SB 14. For chromium, the maximum concentration measured was 11 µg/l at SB 18 and SB 19. Eight stations had a maximum single concentration of greater than 5 µg/l. With the exception of SB 19, when Cr was above detection on 2 individual sampling dates, this metal was never observed on more than one date at any station.

Table 20. Concentration of heavy metals, TDS, TSS and flow for the Steamboat Creek monitoring stations. Values for metals are expressed as µg/l. TSS and TDS are mg/l; flow cfs. The \-symbol denotes data was below detection.

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 3	Oct-87	1.3	209	11	\	\	10	\	\	\	\	5	300	\
SB 3	Dec-87	1.2	208	1										
SB 3	Feb-88	1.5	211	3	\	\	10	\	\	\	10	3	300	100
SB 3	Apr-88	1.2	171	17	\	\	10	\	\	\	20	4	360	100
SB 3	Jun-88	1.1	222	6	\	\	10	\	\	\	10	3	310	\
SB 3	Aug-88	0.5	240	5										
SB 3	Oct-88	0.6	264	9										
SB 3	Dec-88	1.1	218	4	\	\	\	\	\	\	\	\	220	300
SB 3	Feb-89	1.4	207	11	\	\	\	\	\	\	10	4	280	100
SB 3	Apr-89	2.2	213	2										
SB 3	Jun-89	2.6	205	7	\	\	\	\	\	\	10	7	290	\
SB 3	Aug-89	0.4	236	4	\	\	20	\	\	\	10	\	220	\
SB 3	Oct-89	1.0	236	3										
SB 3	Dec-89	1.8	215	1										
SB 3	Feb-90		197	22										
SB 3	Apr-90	1.6	189	9										
SB 3	Jun-90	0.8	212	5										
SB 3	Aug-90	0.9	228	17										
SB 3	Oct-90	1.1	264	7										
SB 3	Dec-90		230	6										
SB 3	Feb-91		202	10										
SB 3	Apr-91	0.5	217	9										
SB 3	Jun-91	1.2	203	8			-							

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 4	Oct-87	2.5	93	4	\	\	\	\	\	\	10	\	450	\
SB 4	Dec-87	1.0	117	1										
SB 4	Feb-88	5.9	118	2										
SB 4	Apr-88	2.0	104	4										
SB 4	Jun-88	8.5	93	13	\	\	10	\	\	\	10	3	580	\
SB 4	Aug-88	2.0	105	7										
SB 4	Oct-88	2.5	95	7										
SB 4	Dec-88	1.0	123	4	\	\	\	\	\	\	10	\	290	100
SB 4	Feb-89	1.2	114	3	\	\	10	\	\	\	20	\	210	\
SB 4	Apr-89	0.8	135	4										
SB 4	Jun-89	16.5	70	6	\	\	\	\	\	\	10	\	320	\
SB 4	Aug-89	4.0	89	6	\	\	10	\	\	\	10	\	350	\
SB 4	Oct-89	5.0	95	3										
SB 4	Dec-89	1.8	122	1										
SB 4	Feb-90		127	5										
SB 4	Apr-90	1.4	116	5										
SB 4	Jun-90	7.2	73	6										
SB 4	Aug-90	2.5	107	14										
SB 4	Oct-90	1.9	105	2										
SB 4	Dec-90	1.4	124	3										
SB 4	Feb-91	1.9	111	6										
SB 4	Apr-91	1.0	130	6										
SB 4	Jun-91	8.9	63	12										

Table 20. (cont.)

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 5	Oct-87	1.2	278	8	\	\	\	\	\	\	\	8	450	\
SB 5	Dec-87	3.7	228	5										
SB 5	Feb-88	4.3	209	13	\	\	10	\	\	\	10	6	470	\
SB 5	Apr-88	1.1	257	7										
SB 5	Jun-88	0.2	311	6	\	\	\	\	\	\	10	11	740	100
SB 5	Aug-88	0.1	315	4	\	\	\	\	\	\	20	8	160	100
SB 5	Oct-88	0.5	231	9										
SB 5	Dec-88	1.5	226	2	\	\	\	\	\	\		10	420	100
SB 5	Feb-89	4.4	199	18	\	\	10	\	\	\	20	6	380	\
SB 5	Apr-89	2.6	222	9	\	\	10	\	\	\		4	610	\
SB 5	Jun-89	23.9	163	17	\	\	30	\	\	\	20	4	430	\
SB 5	Aug-89	0.8	218	11	\	\	20	\	\	\	10	7	670	100
SB 5	Oct-89	4.8	199	13	\	\	\	\	\	1	\	6	540	\
SB 5	Dec-89		216	10	\	\	\	\	\	\	20	6	470	\
SB 5	Feb-90		264	21	\	\	\	\	\	\	10	\	690	\
SB 5	Apr-90	3.0	222	12	\	7	\	\	\	\	\	6	590	\
SB 5	Jun-90	0.8	230	11	\	\	\	\	\	\	\	7	630	\
SB 5	Aug-90		369	6	\	\	\	\	\	\	\	24	470	\
SB 5	Oct-90		325	14	\	\	\	\	\	\	\	11	940	\
SB 5	Dec-90		228	10	\	\	\	\	\	\	\	4	510	100
SB 5	Feb-91	1.1	205	8	\		\	\	\	1	30	5	450	\
SB 5	Apr-91	0.0	241	5	\		\	\	\	2	\	9	720	100
SB 5	Jun-91	1.4	161	6	\		\	\	\	\	\	5	420	100

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 6	Oct-87	12.3	66	8										
SB 6	Jun-88	13.5	70	99	\	\	10	\	0.8	\	10	3	430	\
SB 6	Aug-88	11.0	70	39	\	\	\	\	\	\	10	3	190	\
SB 6	Jun-89	7.5	67	101	\	\	\	\	\	\	10	\	230	\
SB 6	Aug-89	15.4	73	41	\	\	20	\	\	\	10	\	260	\
SB 6	Oct-89	9.7	102	27	\	\	\	\	\	\		4	360	\
SB 6	Jun-90	15.2	66	106	\	\	\	\	\	\	10	\	870	\
SB 6	Aug-90	8.2	72	84	\	\	\	\	\	\	\	6	670	\
SB 6	Jun-91	0.0	54	108	\	\	\	\	\	\	10	\	950	100

Table 20. (cont.)

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 7	Oct-87		1758	9	5	\	\	\	\	\	10	1630	790	36500
SB 7	Dec-87	0.9	1929	2	7	\	\	14	\	\	10	1420	1180	39800
SB 7	Feb-88	4.8	450	37	1	\	10	\	0.5	\	10	256	700	5500
SB 7	Apr-88	2.2	770	7	3	\	\	\	\	\	20	1110	1220	24000
SB 7	Jun-88	0.5	1322	11	\	\	10	\	0.8	\	10	1410	460	26100
SB 7	Aug-88	0.3	1061	9	\	\	\	\	\	\	10	1060	380	20900
SB 7	Oct-88	0.2	1751	8										
SB 7	Dec-88	0.7	871	17	\	\	\	\	\	\	10	500	690	14600
SB 7	Feb-89	2.2	395	33	\	\	\	\	\	\	20	202	620	4300
SB 7	Apr-89	1.4	556	5	\	\	20	\	\	\	\	362	590	7300
SB 7	Jun-89	2.2	267	16	\	\	\	\	\	\	10	200	400	2800
SB 7	Aug-89	0.1	712	11	\	\	\	\	\	\	\	670	240	13600
SB 7	Oct-89	3.5	295	6	\	\	\	\	\	\	\	182	320	3900
SB 7	Dec-89	2.7	491	4	\	\	\	\	\	\	10	305	410	5900
SB 7	Feb-90		502	13	\	\	\	\	\	\	\	280	560	6300
SB 7	Apr-90	4.1	484	5	\	6	\	\	\	\	\	335	520	5500
SB 7	Jun-90	0.3	1295	4	\	\	\	\	\	\	\	1180	400	25800
SB 7	Aug-90	0.0												
SB 7	Oct-90	1.1	1589	4	\	\	\	\	\	\	\	960	690	30600
SB 7	Dec-90	0.4	1541	11	\	\	\	\	\	\	\	760	790	30000
SB 7	Feb-91		410	10	\	\		\	\	\	10	212	560	4300
SB 7	Apr-91		541	7	1	\		\	\	2	20	285	700	6800
SB 7	Jun-91		345	10	\	\		\	\	\	10	330	530	5400

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 8	Oct-87	5.0	65	3										
SB 8	Dec-87	7.5	57	8										
SB 8	Feb-88		66	6										
SB 8	Apr-88		75	3										
SB 8	Jun-88		69	10										
SB 8	Aug-88	2.3	71	10	\	\	10	\	\	\	\	\	250	100
SB 8	Oct-88	2.9	67	6										
SB 8	Dec-88	3.4	69	4	\	\	\	\	\	\	10	\	180	100
SB 8	Feb-89	2.5	66	5										
SB 8	Apr-89	4.5	84	6										
SB 8	Jun-89	4.5	54	37										
SB 8	Aug-89	4.6	60	6	\	\	20	\	\	\	\	\	220	\
SB 8	Oct-89	3.8	64	4										
SB 8	Dec-89	4.3	64	3										
SB 8	Feb-90		67	8										
SB 8	Apr-90	5.4	69	8										
SB 8	Jun-90	4.8	56	27										
SB 8	Aug-90	2.5	68	68										
SB 8	Oct-90	2.3	64	8										
SB 8	Dec-90	4.6	64	23										
SB 8	Feb-91		64	10										
SB 8	Apr-91	2.7	69	12										
SB 8	Jun-91	3.4	56	72										

Table 20. (cont.)

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 10	Oct-87	1.5	89	4										
SB 10	Dec-87	2.0	85	2										
SB 10	Feb-88	4.5	91	11										
SB 10	Apr-88	2.9	89	7										
SB 10	Jun-88	2.2	93	13	\	\	10	\	\	\	10	\	260	\
SB 10	Aug-88	1.2	99	15										
SB 10	Oct-88	0.9	86	9										
SB 10	Dec-88	1.7	97	3	\	\	\	\	\	\	10	\	210	\
SB 10	Feb-89		96	9										
SB 10	Apr-89	4.5	99	9										
SB 10	Jun-89	4.0	67	16										
SB 10	Aug-89	1.8	87	13	\	\	40	\	\	\	30	\	320	\
SB 10	Oct-89	1.4	101	5										
SB 10	Dec-89	2.7	95	4										
SB 10	Feb-90		96	10										
SB 10	Apr-90	2.7	92	6										
SB 10	Jun-90	2.5	93	15										
SB 10	Aug-90	1.4	102	32										
SB 10	Oct-90	3.7	94	6										
SB 10	Dec-90	2.0	92	6										
SB 10	Feb-91		95	7										
SB 10	Apr-91	3.7	98	8										
SB 10	Jun-91	8.0	85	13										

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 11	Oct-87	5.6	712	13										
SB 11	Dec-87	2.3	636	16										
SB 11	Feb-88	9.2	631	35	2	\	10	13	\	\	10	300	410	8400
SB 11	Apr-88	5.0	971	21	3	\		\	\	\	30	489	420	17900
SB 11	Jun-88	4.6	737	12	\	\	\	\	\	\	30	350	260	10200
SB 11	Aug-88	3.2	724	17	\		10	\	0.7	\	20	276	190	9900
SB 11	Oct-88	1.8	1120	18		\								
SB 11	Dec-88	8.5	1048	16	\	\	20	\	\	\	20	305	240	14400
SB 11	Feb-89	11.1	735	65	\	\	10	\	0.9	\	10	265	350	8900
SB 11	Apr-89	6.0	861	31	\	\	10	\	\	\	\	353	380	11700
SB 11	Jun-89	10.0	662	59	\	\	\	\	\	\	20	248	470	8800
SB 11	Aug-89	3.7	853	26	\	\	\	\	\	\	\	385	290	12800
SB 11	Oct-89	8.2	426	69	\	\	\	\	\	1	\	123	1100	4200
SB 11	Dec-89	6.8	935	29	\	\	\	\	\	\	10	370	590	13000
SB 11	Feb-90		900	63	\	\	\	\	\	\	\	315	930	12200
SB 11	Apr-90	4.6	1037	30	\	6	\	\	\	1	\	478	620	14400
SB 11	Jun-90		422	238	\	\	\	7	\	\	20	98	1260	3600
SB 11	Aug-90	4.2	492	87	\	\	\	\	\	\	\	144	890	5600
SB 11	Oct-90	2.9	1064	14	\	\	\	\	\	\	\	380	240	16200
SB 11	Dec-90	6.0	844	69	\	\	\	6	1.1	\	\	310	1400	11300
SB 11	Feb-91		750	56		\		6	\	\	\	370	1040	9900
SB 11	Apr-91	4.0	983	30	\	\	\	\	\	2	\	433	490	14500
SB 11	Jun-91		333	131	\	\	\	\	\	\	10	101	1750	3300

Table 20. (cont.)

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 12	Oct-87	7.3	513	22										
SB 12	Dec-87	3.5	269	11										
SB 12	Feb-88	5.5	446	46	1	\	10	10	\	\	10	180	290	4500
SB 12	Apr-88	2.0	984	21										
SB 12	Jun-88	4.9	432	16	\	\	\	\	\	\	10	200	250	4500
SB 12	Aug-88	1.0	279	86	\	\	\	\	1	\	10	140	420	1100
SB 12	Oct-88	0.4	251	16										
SB 12	Dec-88	2.8	383	34	\	\	\	\	\	\	20	123	270	3600
SB 12	Feb-89	3.6	365	39	\	\	10	\	\	\	10	71	170	1400
SB 12	Apr-89	1.8	400	48										
SB 12	Jun-89	4.5	502	83	\	\	\	\	\	\	10	130	420	3000
SB 12	Aug-89	0.6	372	58	\	\	10	\	\	\	10	65	560	1500
SB 12	Oct-89	8.3	252	33	\	\	\	6	\	\	\	51	570	1200
SB 12	Dec-89	6.2	253	15	\	\	\	\	\	\	10	49	500	1200
SB 12	Feb-90		601	43	\	\	\	\	\	\	10	325	1220	5500
SB 12	Apr-90	0.6	573	81	\	6	\	\	\	\	\	290	920	5200
SB 12	Jun-90	8.6	307	32	\	\	\	\	\	\	\	66	510	1500
SB 12	Aug-90	1.2	360	25	\	\	\	\	\	\	\	151	1180	3000
SB 12	Oct-90	0.0	440	76	\	\	\	9	2	\	\	91	1230	3800
SB 12	Dec-90	1.0	470	90	\	\	\	6	\	\	\	176	1450	3700
SB 12	Feb-91		272	51	\	\	\	\	\	\	10	72	930	1600
SB 12	Apr-91		329	61	\	\	\	\	\	2	\	102	1010	2500
SB 12	Jun-91		251	110	\	\	\	\	\	\	10	53	1770	1200

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 14	Oct-87	2.1	344	5	\	\	\	\	\	\	20	41	80	400
SB 14	Dec-87	1.8	226	11	\	\	\	\	\	\	10	14	90	200
SB 14	Feb-88	0.5	245	18										
SB 14	Apr-88	0.6	268	17										
SB 14	Jun-88	3.4	266	7	\	\	\	\	\	\	10	17	70	300
SB 14	Aug-88	3.5	279	14										
SB 14	Oct-88	3.3	270	23										
SB 14	Dec-88	1.7	296	12	\	\	10	\	\	\	20	23	50	400
SB 14	Feb-89	1.6	270	19	\	\	10	\	\	\	10	21	60	100
SB 14	Apr-89	1.1	248	33										
SB 14	Jun-89	1.4	308	7										
SB 14	Aug-89	2.0	349	8	\	\	\	\	\	\	\	25	60	300
SB 14	Oct-89	2.9	281	10	\	\	\	\	\	\	\	20	140	200
SB 14	Dec-89	1.1	273	8										
SB 14	Feb-90		264	19										
SB 14	Apr-90	1.7	267	14										
SB 14	Jun-90													
SB 14	Aug-90	2.3	328	21										
SB 14	Oct-90	0.9	301	62										
SB 14	Dec-90		266	16										
SB 14	Feb-91	1.6	259	14										
SB 14	Apr-91	0.7	292	13										
SB 14	Jun-91	0.7	310	12	\	\	\	\	\	\	\	26	70	300

Table 20. (cont.)

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 16	Oct-87	22.8	148	15	\	\	\	\	\	\	10	12	150	100
SB 16	Dec-87	8.5	343	25	\	\	\	\	\	\	10	270	170	300
SB 16	Feb-88	6.6	351	20	\	\	20	6	\	\	20	30	180	300
SB 16	Apr-88	6.0	379	36										
SB 16	Jun-88	28.6	213	35	\	\	70	\	\	\	40	12	230	200
SB 16	Aug-88	24.8	172	26										
SB 16	Oct-88	5.1	274	17										
SB 16	Dec-88	5.7	385	21	\	\	\	\	\	\	10	330	290	500
SB 16	Feb-89	6.0	365	19	\	\	10	\	\	\	20	36	160	200
SB 16	Apr-89	5.2	392	25	\	\	\	\	\	\	\	35	180	600
SB 16	Jun-89	34.0	214	23	\	\	\	\	\	\	20	15	60	200
SB 16	Aug-89	16.2	209	24	\	\	10	\	\	\	10	12	220	100
SB 16	Oct-89	19.4	200	8	\	\	\	\	\	\	\	11	220	100
SB 16	Dec-89	8.4	369	12	\	\	\	\	\	\	10	24	210	200
SB 16	Feb-90		380	25	\	\	\	\	\	\	10	30	410	400
SB 16	Apr-90	12.9	204	26	\	7	\	\	\	1	\	16	350	100
SB 16	Jun-90		198	15	\	\	\	\	\	\	\	10	300	\
SB 16	Aug-90	16.2	194	20	\	\	\	\	\	\	\	10	250	\
SB 16	Oct-90	2.1	374	7	\	\	\	\	1.4	\	\	21	160	100
SB 16	Dec-90	4.2	336	30	\	\	\	6	\	\	10	22	490	300
SB 16	Feb-91	4.7	289	47	\	\	10	11	\	1	30	14	1130	200
SB 16	Apr-91	6.3	268	57	\	\	\	6	\	2	\	30		300
SB 16	Jun-91	8.3	251	19	\	\	\	\	\	\	\	16	490	200

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 17	Oct-87	23.0	283	21	\	\	10	\	\	\	20	51	170	1900
SB 17	Dec-87	28.2	501	34	\	\	\	\	\	\	10	133	220	4600
SB 17	Feb-88	23.0	520	38	2	\	10	\	\	\	20	152	670	4800
SB 17	Apr-88	21.5	638	67	1	\	20	\	\	\	50	200	360	6400
SB 17	Jun-88	31.1	302	57	\	\	50	\	\	\	30	68	330	1700
SB 17	Aug-88	37.4	256	49	\	\	10	\	0.8	\	20	45	230	1400
SB 17	Oct-88	7.2	527	26										
SB 17	Dec-88	16.7	599	25	\	\	10	\	\	\	10	156	240	5900
SB 17	Feb-89	32.4	569	84	\	\	20	\	1.1	\	20	164	300	5000
SB 17	Apr-89	15.5	654	57	\	\	20	\	\	\	\	224	270	6900
SB 17	Jun-89	57.0	406	55	\	\	\	\	\	\	10	131	400	3400
SB 17	Aug-89	16.8	285	66	\	\	\	\	\	\	10	24	320	600
SB 17	Oct-89	47.2	329	40	\	\	\	\	\	1	10	85	1170	2400
SB 17	Dec-89	22.2	475	20	\	\	\	\	\	\	10	93	520	3000
SB 17	Feb-90		559	29	\	\	10	\	\	\	10	178	670	5400
SB 17	Apr-90	10.8	353	40	\	9	\	\	\	1	\	104	650	2500
SB 17	Jun-90		307	42	\	\	\	\	\	\	10	73	720	1500
SB 17	Aug-90	19.8	294	34	\	\	\	\	\	\	\	66	490	1300
SB 17	Oct-90	14.0	515	22	\	\	\	\	1.5	\	\	100	450	3600
SB 17	Dec-90	13.9	560	27	\	\	\	5	0.8	\	10	152	720	5000
SB 17	Feb-91	14.2	455	130	\	\	10	7	1	\	20	160	1680	3900
SB 17	Apr-91	8.1	526	71	\	\	\	\	0.7	1	\	165	1190	4900
SB 17	Jun-91	12.3	439	45	\	\	\	\	0.8	\	10	166	910	4100

Table 20. (cont.)

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 18	Oct-87	5.7	179	16	\	\	\	\	\	\	30	5	17	100
SB 18	Dec-87	3.1	348	27	\	\	\	\	\	\	10	8	18	200
SB 18	Feb-88	2.1	335	103	\	\	10	\	\	\	20	9	970	200
SB 18	Apr-88	1.3	341	35										
SB 18	Jun-88	2.9	198	14	\	\	40	\	\	\	30	5	190	200
SB 18	Aug-88	9.5	207	14										
SB 18	Oct-88	0.6	370	24										
SB 18	Dec-88	0.7	401	52	\	\	10	\	\	\	10	9	380	400
SB 18	Feb-89	0.6	332	68	\	\	10	\	\	\	20	7	220	100
SB 18	Apr-89	1.0	330	65										
SB 18	Jun-89	5.7	159	10										
SB 18	Aug-89	1.9	182	4	\	\	20	\	\	\	10	3	70	\
SB 18	Oct-89	4.0	228	7	\	\	\	\	\	1	\	6	270	\
SB 18	Dec-89		349	32										
SB 18	Feb-90		315	9										
SB 18	Apr-90	0.5	300	240	\	11	\	\	\	1	\	12	380	100
SB 18	Jun-90		195	14	\	\	\	\	\	\	\	5	270	\
SB 18	Aug-90	2.1	230	13	\	\	\	\	\	\	\	5	170	\
SB 18	Oct-90	0.4	304	8	\	\	\	\	1.4	\	\	5	200	\
SB 18	Dec-90	0.5	315	39	\	\	\	\	\	\	10	7	600	100
SB 18	Feb-91	0.1	256	67	\	\	10	7	\	\	20	6	860	100
SB 18	Apr-91	0.8	288	123	\	\	\	7	\	\	\	8	850	100
SB 18	Jun-91	2.4	149	10	\	\	\	\	\	\	\	5	250	100

STA	DATE	Flow	TDS	TSS	Cd	Cr	Cu	Pb	Hg	Se	Zn	As	Fe	B
SB 19	Oct-87	50.0	275	11										
SB 19	Dec-87	24.0	516	50										
SB 19	Feb-88	24.0	495	32										
SB 19	Apr-88	45.0	612	40										
SB 19	Jun-88	28.0	352	40	\	\	40	\	\	\	20	62	330	1500
SB 19	Aug-88	24.0	223	98										
SB 19	Oct-88	10.0	511	15										
SB 19	Dec-88	17.0	591	24	\	\	10	\	\	\	10	148	310	5300
SB 19	Feb-89	15.0	556	61	\	\	20	\	0.9	\	10	152	310	4900
SB 19	Apr-89	18.0	634	31										
SB 19	Jun-89	63.0	384	47										
SB 19	Aug-89	18.0	272	42										
SB 19	Oct-89	49.0	333	39										
SB 19	Dec-89	28.2	474	17										
SB 19	Feb-90		516	51										
SB 19	Apr-90	29.6	365	30	\	11	\	\	\	1	\	101	610	2300
SB 19	Jun-90	36.8	302	42										
SB 19	Aug-90	29.6	272	21										
SB 19	Oct-90		392	20										
SB 19	Dec-90		529	28	1	6	\	17	\	\	10	142	710	4700
SB 19	Feb-91		475	103	\	\	10	9	0.8	\	10	140	2110	3400
SB 19	Apr-91	20.0	513	55	\	\	\	12	\	2	\	126	1380	3500
SB 19	Jun-91	32.1	357	31	\	\	\	26	\	\	\	109	730	2700

Table 21. Summary of metals distribution in Steamboat Creek and sampled tributaries. WQ criteria based on Nevada State Code Chapter 445. Hardness data was not available; to be conservative, it was assumed that stations SB 4, SB 8 and SB 10 was at the high end of soft (H=50mg CaCO3/l) and the remaining stations were mid-range of moderately hard (H=150 mg CaCO3/l). AL=aquatic life, I=irrigation, LS=livestock watering. na=not applicable. Number in paraentheses below station ID is number of samples for which data is available. AL(x:y), x=number of samples where concentration exceeds 96-hr criterion and x=number of samples where concentration exceeds 1-hr criterion.

		As	Cd	Cr	Cu	Pb	Hg	Se	Zn	B
SB 3	# above detection	6	0	0	5	0	0	0	6	4
[8]	max concentration	7 µg/l	na	na	20 µg/l	na	na	na	20 µg/l	300 µg/l
	exceed WQ criteria	no	no	no	AL(1:0)	no	no	no	no	no
SB 4	# above detection	1	0	0	3	0	0	0	6	1
[6]	max concentration	3	na	na	10	na	na	na	20	100
	exceed WQ criteria	no	no	no	AL(3:3)	no	no	no	no	no
SB 5	# above detection	19	0	1	5	0	0	3	9	7
[20]	max concentration	24	na	7	30	na	na	2	30	100
	exceed WQ criteria	no	no	no	AL(2:1)	no	no	no	no	no
SB 6	# above detection	4	0	0	2	0	1	0	6	1
[8]	max concentration	6	na	na	20	na	0.8	na	10	100
	exceed WQ criteria	no	no	no	AL(1:0)	no	AL(1:0)	no	no	no
SB 7	# above detection	21	4	1	3	1	2	1	13	21
[21]	max concentration	1630	7	6	20	14	0.8	2	20	39800
	exceed WQ criteria	AL(21:11) I(21), LS(20)	AL(3:1)	no	AL(1:0)	AL(1:0)	AL(2:0)	no	no	AL(21:21) I(21), LS(21)
SB 8	# above detection	0	1	0	2	0	0	0	1	2
[3]	max concentration	na	na	na	20	na	na	na	10	100
	exceed WQ criteria	no	no	no	AL(2:2)	no	no	no	no	no
SB 10	# above detection	0	0	0	2	0	0	0	3	0
[3]	max concentration	na	na	na	40	na	na	na	30	na
	exceed WQ criteria	no	no	no	AL(2:2)	no	no	no	no	no
SB 11	# above detection	20	3	1	5	4	3	2	10	20
[20]	max concentration	489	2	6	2	13	1.1	2	30	16200
	exceed WQ criteria	AL(16:7) I(19), LS(16)	no	no	AL(1:0)	AL(4:0)	AL(3:0)	no	no	AL(20:20) I(20), LS(20)
SB 12	# above detection	18	1	1	3	4	2	1	11	18
[18]	max concentration	325	1	6	10	10	2.0	2	20	5500
	exceed WQ criteria	AL(3:0) I(10), LS(3)	no	no	no	AL(4:0)	AL(2:0)	no	no	AL(18:18) I(18), LS(18)
SB 14	# above detection	8	0	0	2	0	0	0	5	8
[8]	max concentration	41	na	na	1	na	na	na	20	400
	exceed WQ criteria	no	no	no	no	no	no	no	no	no
SB 16	# above detection	18	0	1	5	4	1	3	12	18
[20]	max concentration	330	na	7	70	11	1	2	40	600
	exceed WQ criteria	AL(1:0) I(1), LS(1)	no	no	AL(2:1)	AL(4:0)	AL(1:0)	no	no	AL(1:1), LS(1)
SB 17	# above detection	22	2	1	10	2	7	3	17	22
[21]	max concentration	224	2	9	50	7	1.5	1	50	6900
	exceed WQ criteria	AL(2:0) I(14), LS(1)	AL(1:0)	no	AL(4:0)	AL (1:0)	AL(7:0)	no	no	AL(22:22) I(22), LS(21)
SB 18	# above detection	16	0	1	6	2	1	2	9	11
[16]	max concentration	12	na	11	40	7	1.4	1	30	400
	exceed WQ criteria	n0	no	no	AL(2:0)	AL(2:0)	AL(1:0)	no	no	no
SB 19	# above detection	8	1	2	4	4	2	2	5	8
[8]	max concentration	152	1	11	40	26	0.9	2	20	5300
	exceed WQ criteria	I(7)	no	no	AL (2:1)	AL(4:0)	AL(2:1)	no	no	AL(8:8) I(8), LS(8)

Station SB 17 (just upstream of the Yori Drain) had the greatest number of mercury concentrations above the 0.5 µg/l limit of detection, i.e. seven dates. The range of concentrations at this station was 0.7-1.5 µg/l (Table 20). The maximum Hg concentration on any sampling date was found at SB 12 when a value of 2.0 µg/l was measured in October 1990 (Table 20). Six stations showed no detectable concentrations of this metal; SB 6, SB 16 and SB 18 had one date above detection; SB 7, SB 12 and SB 19 two dates above detection; and SB 11 had three dates with concentrations above detection. Lead was found either at or near the limit of detection at many of the stations , i.e. 7 of 14 stations. A maximum concentration of 26 µg/l was measured at SB 19 with the next highest values at SB 7, SB 11 and SB 16 (11-14 µg/l). Selenium was most frequently found at SB 5, SB 16 and SB 17 (three occasions above detection) followed by SB 11, SB 18 and SB 19 with two occasions each. A maximum concentration of 2 µg/l was found at SB 5, SB 7, SB 11, SB 12, SB 16 and SB 19.

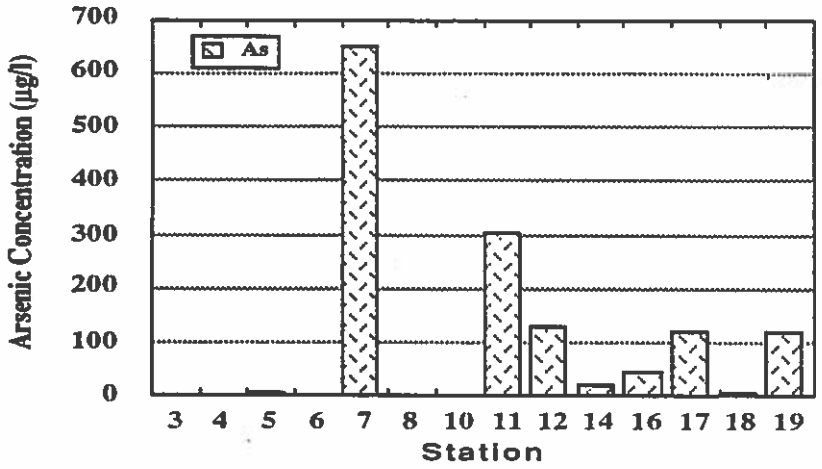
Copper was measured at above detection concentrations more frequently than these other metals. The combination of most sampling dates above detection and highest concentrations occurred at SB 5, SB 16, SB 17, SB 18 and SB 19. The maximum concentration during the period of record was 70 µg/l at SB 16 and copper was most frequently found at SB 17 when it was measured on 10 individual sampling dates (Table 21). The largest copper levels were measured in Jun-88. Concentrations of 70 and 50 µg/l on that date in Boynton Slough and Yori Drain were measurable downstream at SB 17 (50 µg/l) and SB 19 (40 µg/l), respectively. On all remaining dates when copper was measured at any station, the concentration was either 10 or 20 µg/l and just above the analytical limit of detection for this metal (10 µg/l). Except for the June 1988 period when copper was slightly elevated in the downstream tributaries, neither Cd, Cr, Hg, Pb, Se or Cu concentrations indicated a significant source of these metals. Zinc had a detection of 10 µg/l and while this metal was measured more frequently than the metals discussed above, the maximum concentration at any station never exceed 30-40 µg/l. Of the 97 occasions on which zinc was above detection, only ± 10% of these were greater than 20 µg/l.

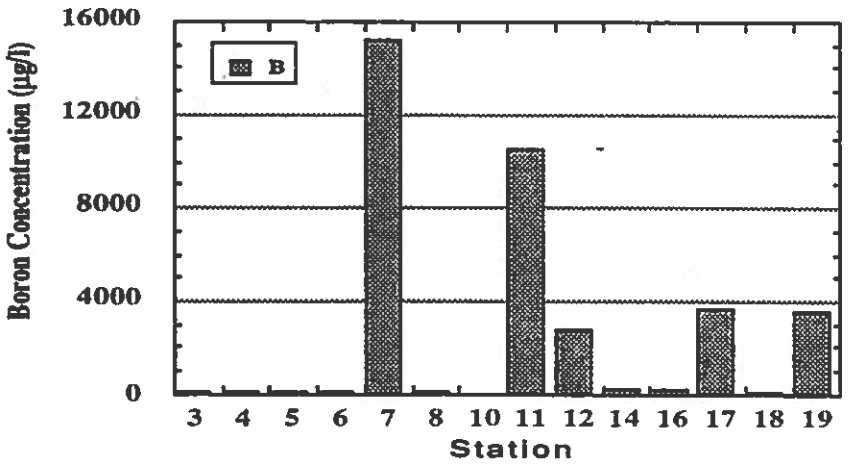
2.5.2. Arsenic, Boron and Iron

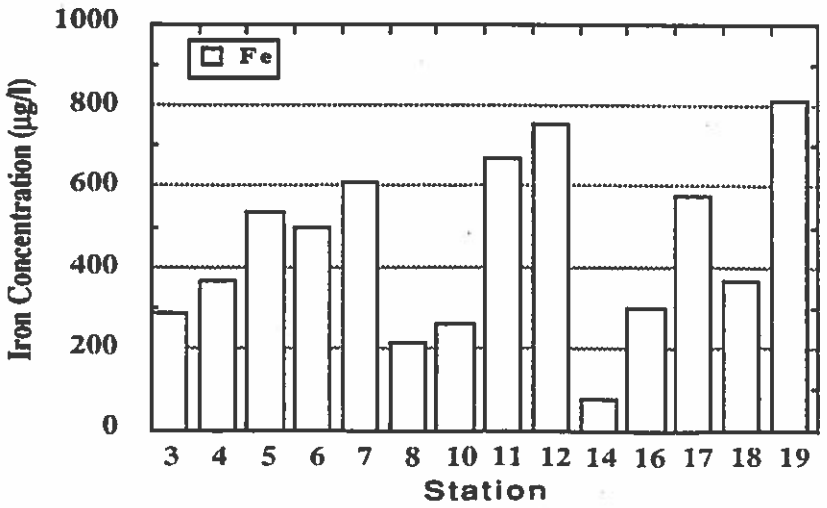
The distribution of arsenic and boron were in contrast to the other metals. Both these metals were found in low concentration and low frequency at SB 3, SB 4, SB 5, SB 6, SB 8, SB 10, SB 14 and SB 18 (Tables 20 and 21). At these stations the maximum concentrations for As and B were, 41 µg/l and 400 µg/l, respectively. Both of these higher concentrations were found at SB 14; the more upstream stations, including SB 8 and SB 10, were typically lower.

As shown in Figure 22, arsenic and boron increased dramatically between stations SB 5 and SB 7, and downstream of the confluence of Steamboat Ditch (SB 6). While the maximum measured concentration for As and B at SB 5 were 24 and 100 µg/l, respectively, maximum concentration of these two metals rose to 1,630 µg/l for arsenic and 39,800 µg/l for boron at station SB 7 (Table 21). The mean annual concentration of As at SB 7 exceeded 600 µg/l and B exceeded 15,000 µg/l. The source of the arsenic and boron laden water is commonly known to be the Steamboat Hot Springs which are located to the west of Steamboat Creek approximately 3/4 mile downstream from SB 5. In their discussion of thermal water of Nevada, Garside and Schilling (1979) comment that the thermal water of Steamboat Hot Springs is high in arsenic (2,700 µg/l) and boron (47-49 mg/l), but not in iron (50 µg/l). Given the reported discharge from the Steamboat Hot Springs (300, 825, 590 gpm; Garside and Schilling [1979]) which is in the range of 1.0-1.5 cfs, and the fact this discharge represents a significant portion of the total Steamboat Creek flow measured at SB 7 (Table 2), it appears that these hot springs can be a significant source of these metals, especially during the period of low summer flow at SB 7 following diversion. Indeed, the location of the Crane-Chandler Ditch upstream of these hot springs was intended to divert water from Steamboat Creek and Steamboat Ditch before it passed through this region which is geologically rich in arsenic and boron.

Figure 22 Mean annual concentration of arsenic, boron and iron at the Steamboat Creek sampling stations; Oct-87 to Jun-91.







Mean annual As and B concentrations typically declined as flow progressed in Steamboat Creek towards the Truckee River (Figure 22), however, concentrations were still elevated at SB 19 where mean annual concentration of As and B exceeded 120 µg/l and 3,500 µg/l, respectively. On-route downstream from SB 7 and SB 11, where values were maximum, relatively high concentrations were also found in the Alexander Ditch at SB 12 (maximum concentrations of 325 µg/l - As, 5,500 µg/l - B; mean annual concentrations of >125 µg/l - As and >2,700 µg/l - B). This area, which drains into Thomas Creek just upstream of Alexander Lake is known to have a shallow aquifer and be geologically rich in these elements. While both these metals were occasionally high in the Rio Pico Drain, Boynton Slough and Yori Drain, overall concentrations were much lower than measured in the Alexander Ditch.

The distribution of arsenic and boron on individual sampling dates throughout the period of record at stations SB 5, SB 7, SB 11, SB 17 and SB 19 is presented in Figures 23 and 24. This set of stations represents a transect along the main Steamboat Creek channel from just upstream of the hot springs to just upstream of the Truckee River confluence. As discussed above, the dramatic increase in arsenic between SB 5 and SB 7 as well as the downstream decline can be seen. Arsenic at SB 7 showed a high degree of seasonal fluctuation. For most of the record, arsenic was measured at 200-400 µg/l; the exceptions to this were Jun-88, Aug-89, Jun-90, Oct-90 and Dec-90 when concentrations peaked to 1040, 670, and 1180, 960 and 760 µg/l, respectively. Flow on these five dates was typically low at less than 0.5 cfs (Table 20). Oct-90 had a flow somewhat higher at 1.1 cfs. Since summer flow just upstream of SB 7 is typically diverted through the Crane-Chandler Ditch for agricultural irrigation, the hot springs make a larger contribution to total discharge at this station. Consequently, arsenic, and as presented below, boron concentrations are elevated during this season. Further downstream at SB 11, the seasonal distribution of As was relatively uniform and in the range of 300-400 µg/l. Interestingly, the large summer spikes observed at SB 7 were no longer present. The most likely explanation for this decline in peak summer As between SB 7 and SB 11 is dilution from irrigation return flows and perhaps to some extent groundwater inflow. In Aug-88 flow

Figure 23 Concentration of arsenic on individual dates at sampling stations in the main Steamboat Creek channel.

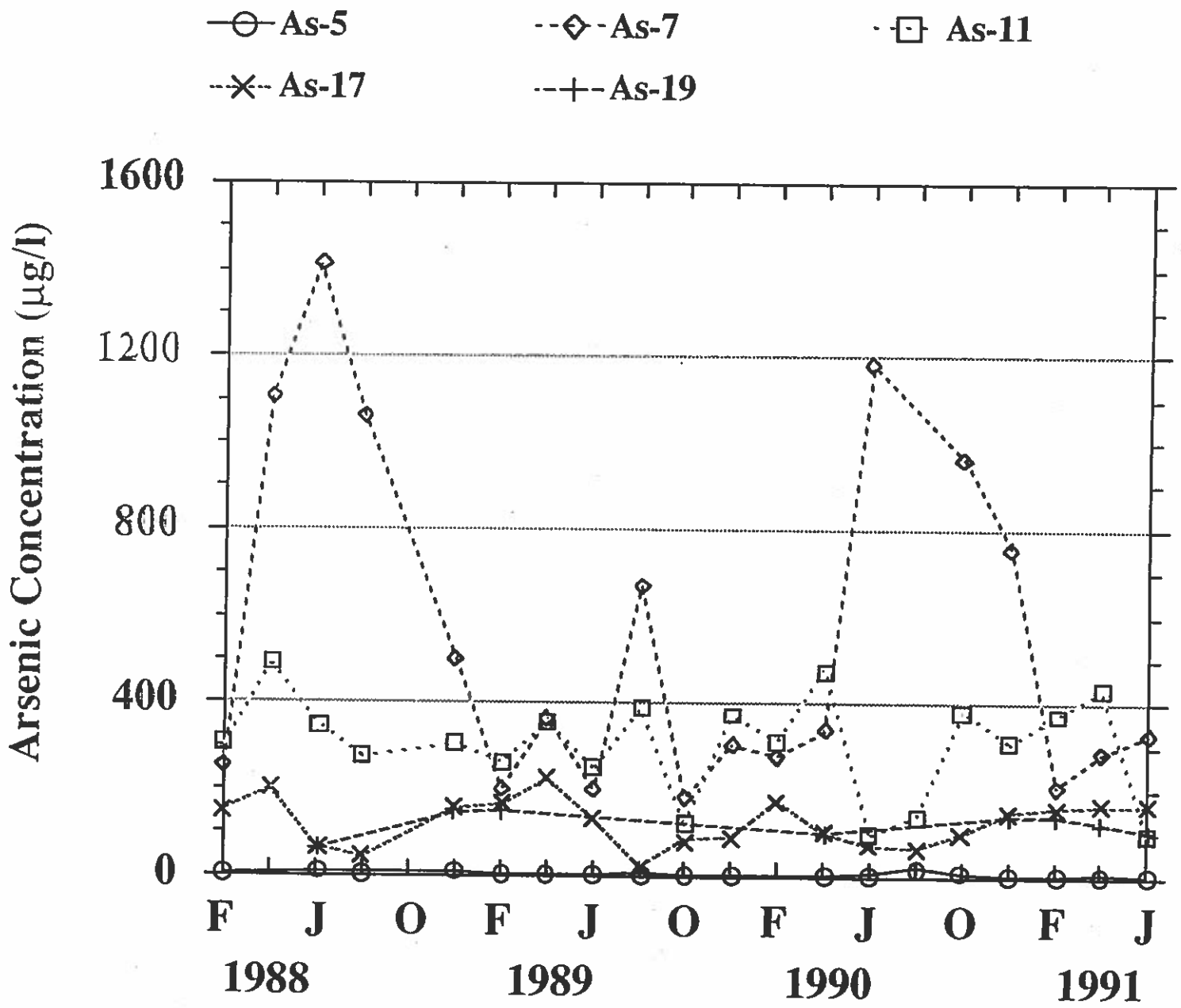
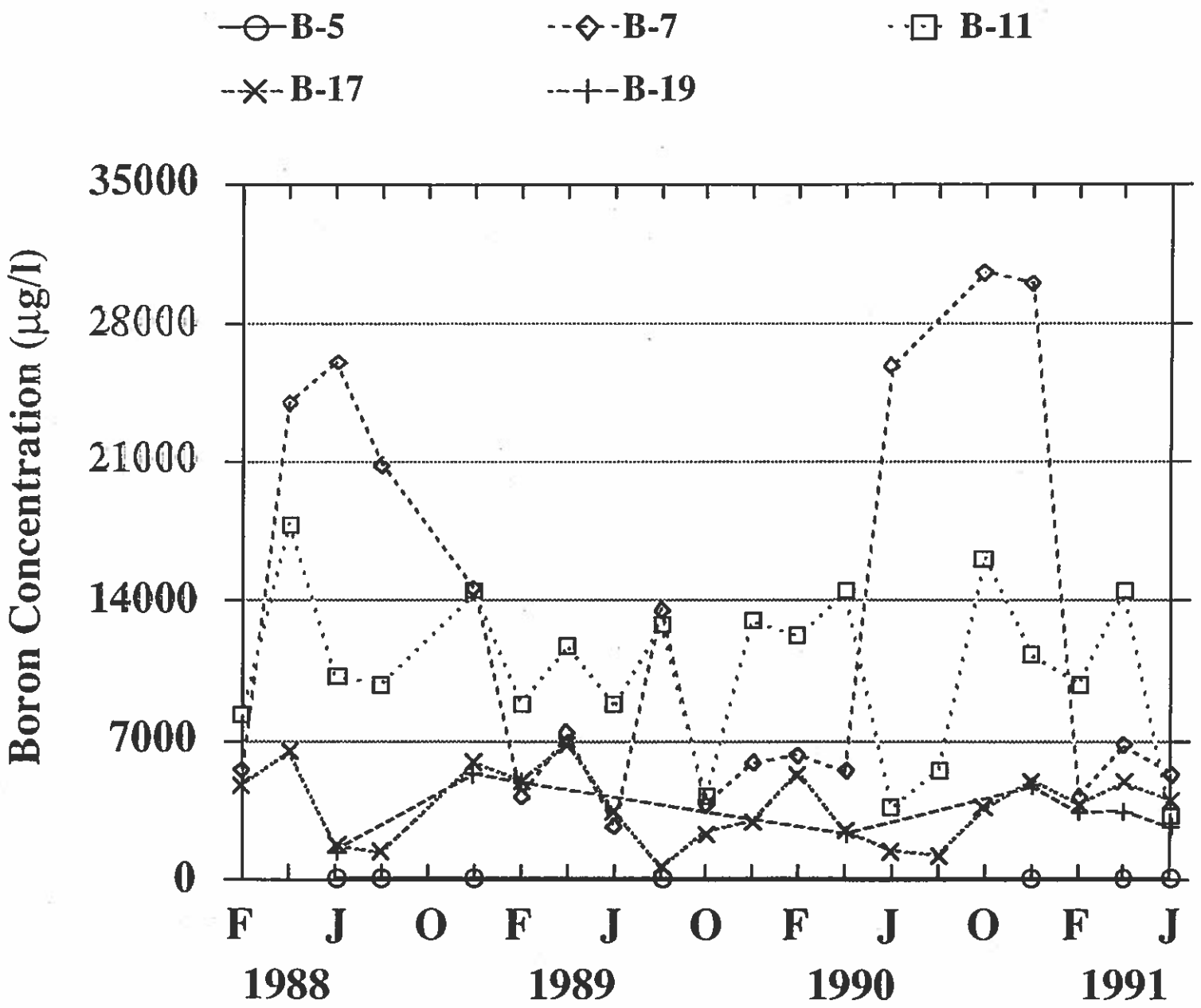


Figure 24 Concentration of boron on individual dates at sampling stations in the main Steamboat Creek channel.



increased from 0.3 cfs to 3.2 cfs between SB 7 and SB 11. A similar increase was observed in Aug 89; 0.1 cfs to 3.7 cfs. Flow was not measured at SB 11 in Jun-90; however, discharge also increased between SB 7 and SB 11 in Oct-90 (1.1 cfs to 2.9 cfs) and Dec-90 (0.4 cfs to 6.0 cfs).

Station SB 17 lies immediately downstream of the Boynton Slough confluence and as discussed in section 2.1., inflows from Boynton Slough were very large and showed a clear seasonal increase in the summer. Typically, arsenic at SB 17 was in the range of 100-200 µg/l; however, in the periods Jun-Aug 1988, Aug-89 and Jun-Aug 90 concentrations declined to less than 75 µg/l. These declines were the result of dilution by the relatively As-free high summer irrigation return flows in the Slough (Table 20, Figure 23). By SB 19, arsenic was uniform throughout the year at 100-150 µg/l. In support of the hypothesis that downstream arsenic concentrations were regulated by diluting flows, the seasonal pattern of boron at all these stations was nearly identical to that observed for arsenic (Figure 24).

The distribution of iron in Steamboat Creek was <u>not</u> influenced by the Steamboat Hot Springs. Concentrations at SB 5 and SB 7 ranged from approximately 400-700 µg/l and the mean annual values were nearly identical (Table 20, Figure 22). Inflow from the Alexander Ditch (SB 12) showed a high mean annual concentration of ±775 µg/l with six of the eighteen individual measurements greater than 1000 µg/l. All these higher Fe-concentrations occurred after January 1990. In 1988 and 1989 the maximum Fe-concentration was 570 µg/l. Station SB 11, just upstream from the Alexander Ditch confluence showed a similar distribution for iron with a mean annual concentration of ±670 µg/l and a maximum concentration of 1750 µg/l. Again, there was a predominance of higher values after January 1990. Water in the Rio Poco Drain (SB 14) had the lowest Fe-concentrations ranging from 50-140 µg/l. Natural background levels, as defined by the concentration at SB 8 and SB 10 were 200-300 µg/l.

Data presented in this report show that the Steamboat Hot Springs were a significant source of only arsenic, boron and chloride (plus TDS) to Steamboat Creek. The other measured constituents were not elevated by this nonpoint source. Other specific ions and metals may

have been high but were not measured as part of this survey.

2.5.3. Statistical Relationship to Flow, TDS and TSS

The complete data record for total suspended solids (TSS) and turbidity by date and station is given in Table 22a. In general, TSS concentration was low at SB 3, SB 4, SB 5, SB 8 and SB 10; values typically ranged from <5 to <25 mg/l, however, some exceptions were found, most notably Aug-90 and Jun-91 at SB 8 when TSS was 68 and 72 mg/l, respectively. Discharge at those times were intermediate and not high.

Inflow in Steamboat Ditch (SB 6) contained higher TSS and within the general range of 30-100 mg/l. Between SB 7 and SB 11 mean annual TSS-concentration increased from 11 mg/l to 50 mg/l. Mean annual TSS in the Alexander Ditch (SB 12) was nearly identical to that at SB 11, 50 mg/l. Despite the fact that the mean annual TSS at SB 17 was also 50 mg/l, concentration in Boynton Slough was lower at 22 mg/l. It is not unexpected to find elevated concentrations of TSS, especially at the downstream stations in this system. In addition to the contribution made by agricultural soils which are eroded and washed into both the irrigation return flows during the summer and natural rain runoff in the winter, the banks of the Steamboat Creek channel itself are not well armored and unstable at many locations. Turbidity values are given in Table 22b for comparison with TSS.

In the section above the case was made that arsenic and boron loading to Steamboat Creek was a direct result of discharge from the Steamboat Hot Springs and that downstream concentrations of these metals in the Creek proper was influenced by tributary dilution. Correlational relationships between these elements and TDS, TSS and flow further support this conclusion (Table 23). With only a few exceptions, As and B were very significantly correlated high TDS but not with TSS or flow. The significant negative correlation between As and B, and flow at SB 7 ($p<0.05$) again indicates that during periods of low flow at this station (when downstream water is diverted for irrigation) discharge of arsenic and boron-rich water from the hot springs was important. When all stations were combined, the only significant relations were As vs. TDS ($r=0.89$, $p<0.001$), B vs. TDS ($r=0.96$, $p<0.001$), Fe vs. TSS

Table 22a. Individual total suspended solids (mg/l) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Total Suspended Solids (mg/L)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	11	4	8	8	9	3	4	13	22	5	15	21	16	11
Dec-87	1	1	5		2	8	2	16	11	11	25	34	27	50
Feb-88	3	2	13		37		11	35	46	18	20	38	103	32
Apr-88	17	4	7		7		7	21	21	17	36	67	35	40
Jun-88	6	13	6	99	11		13	12	16	7	35	57	14	40
Aug-88	5	7	4	39	9	10	15	17	86	14	26	49	14	98
Oct-88	9	7	9		8	6	9	18	16	23	17	26	24	15
Dec-88	4	4	2		17	4	3	16	34	12	21	21	25	29
Feb-89	11	3	18		33	5	9	65	39	19	19	84	68	61
Apr-89	2	4	9		5	6	9	31	48	33	25	57	65	31
Jun-89	7	6	17	101	16	37	16	59	83	7	23	55	10	47
Aug-89	4	6	11	41	11	6	13	26	58	8	24	66	4	42
Oct-89	3	3	13	27	6	4	5	69	33	10	8	40	7	39
Dec-89	1	1	10		4	3	4	29	15	8	12	20	32	17
Feb-90	22	5	21		13	8	10	63	43	19	25	29	9	51
Apr-90	9	5	12		5	8	6	30	81	14	26	40	240	30
Jun-90	5	6	11	106	4	27	15	238	32		15	42	14	42
Aug-90	17	14	6	84		68	32	87	25	21	20	34	13	21
Oct-90	7	2	14		4	8	6	14	76	62	7	22	8	20
Dec-90	6	3	10		11	23	6	69	90	16	30	27	39	28
Feb-91	10	6	8		10	10	7	56	51	14	47	130	67	103
Apr-91	9	6	5		7	12	8	30	61	13	57	71	123	55
Jun-91	8	12	6	108	10	72	13	131	110	12	19	45	10	31

Table 22b. Individual turbidity (NTU) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Turbidity
(NTU)

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	7.5	1.6	3.4	3.0	2.6	0.7	1.5	7.4	13.0	2.1	3.0	4.7	5.2	3.4
Dec-87	2.4	1.4	2.4		3.5	0.9	1.9	6.9	5.9	3.0	6.0	11.0	12.0	13.0
Feb-88	2.4	1.0	2.5		3.8		2.5	6.3	7.5	2.5	3.9	9.2	14.0	12.0
Apr-88	5.2	1.9	3.4		4.4		2.1	6.2	7.0	48.0	1.1	2.2	1.2	7.3
Jun-88	1.9	1.6	4.0	6.6	2.2		1.2	4.8	5.8	1.1	1.8	3.4	2.0	6.0
Aug-88	1.7	1.4	3.0	5.1	2.3	0.8	1.6	4.9	20.0	2.2	3.3	4.8	1.8	17.0
Oct-88	1.6	1.0	1.4		2.1	0.6	1.1	3.3	7.2	1.6	3.5	4.7	4.6	2.5
Dec-88	1.7	1.6	2.0		3.3	0.9	2.1	5.2	8.9	1.2	2.7	2.7	6.1	7.2
Feb-89	3.2	1.9	4.6		6.3	1.1	3.7	13.0	9.3	3.1	4.8	18.0	12.0	15.0
Apr-89	1.6	1.1	1.8		2.6	1.7	3.8	7.2	15.0	3.3	3.5	13.0	4.8	8.2
Jun-89	3.0	4.0	3.0	31.0	11.0	9.0	7.0	18.0	17.0	5.0	10.0	18.0	7.0	17.0
Aug-89	1.7	2.1	4.6	19.0	2.4	1.8	3.9	13.0	95.0	3.8	5.2	27.0	1.6	7.6
Oct-89	1.7	2.2	3.4	7.6	3.4	1.6	3.2	27.0	15.0	3.3	3.3	20.0	4.5	13.0
Dec-89	1.5	1.8	3.9		2.9	1.5	3.2	14.0	9.3	3.0	5.9	10.0	15.0	10.0
Feb-90	6.8	1.9	7.8		5.7	2.3	3.3	23.0	19.0	5.3	9.1	13.0	3.1	38.0
Apr-90	3.5	2.8	4.2		3.7	2.8	3.3	15.0	33.0	4.4	8.2	16.0	48.0	17.0
Jun-90	2.1	2.4	4.4	24.0	2.4	6.0	4.5	140.0	14.0		6.5	17.0	5.4	16.0
Aug-90	6.3	5.4	2.1	32.0		16.0	8.4	33.0	36.0	6.2	5.6	13.0	3.4	9.2
Oct-90	2.4	2.5	6.0		2.1	2.0	2.8	5.0	38.0	8.0	3.5	12.0	4.0	7.8
Dec-90	2.6	2.0	4.2		5.6	3.7	2.8	28.0	38.0	4.4	14.0	15.0	13.0	17.0
Feb-91	2.5	3.1	3.3		5.1	2.6	3.9	23.0	21.0	4.0	26.0	49.0	23.0	54.0
Apr-91	4.9	3.4	4.9		6.3	5.3	6.7	15.0	30.0	4.9	22.0	30.0	45.0	33.0
Jun-91	3.2	3.9	3.5	38.0	4.4	27.0	4.8	56.0	58.0	3.4	8.5	18.0	4.3	11.0

Table 23. Statistical relationship between arsenic, boron and iron, and TDS, TSS and flow. Numerical values represent correlation coefficient. * = p<0.05, ** = p<0.01 and *** = p<0.001. (-) denotes inverse relationship.

		All stations combined	SB 7	SB 11	SB 12	SB 16	SB 17	SB 18	SB 19
Arsenic vs.	TDS	0.89***	0.89***	0.89***	0.85***	0.84***	0.90***	0.71**	0.87**
	TSS	0.14	0.36	0.73***	0.06	0.08	0.30	0.86***	0.26
	Flow	0.16	0.65* (-)	0.41	0.40	0.25	0.25	0.35	0.79 (-)
Boron vs.	TDS	0.96***	0.98***	0.97***	0.89***	0.66***	0.97***	0.54	0.95***
	TSS	0.16	0.36	0.72***	<0.01	0.23	0.10	0.18	0.01
	Flow	0.15	0.65** (-)	0.41	0.34	0.38	0.25	0.02	0.87* (-)
Iron vs.	TDS	0.23**	0.44**	0.60**	0.09	0.04	<0.01	<0.01	0.02
	TSS	0.49***	0.03	0.72***	0.54*	0.67**	0.47*	0.47*	0.79*
	Flow	<0.01	0.02	0.10	0.52	0.35	0.21	0.21	0.11
Flow vs.	TDS	0.03	0.68*** (-)	0.32 (-)	0.19 (-)	0.77*** (-)	0.34 (-)	0.58** (-)	0.35 (-)
	TSS		0.37	0.47*	0.43	0.08	0.04	0.39	0.08

(r=0.49, p<0.001) and Fe vs. TDS (r=0.23, p<0.01). Iron was typically not well correlated with either TDS or flow; however, it did show a significant correlation with TSS at SB 11, SB 12, SB 16, SB 17, SB 18 and SB 19. This is not unexpected since iron, when present, is typically associated with soils.

Finally, it is noteworthy that there was a general lack of correlation between TSS and flow; the only exception to this was SB 11 where these two parameters were correlated at the p<0.05 level of significance. Given the artificial flow regime of most of the major tributaries to Steamboat Creek, i.e. carrying summertime agricultural irrigation flows taken from the relatively clean Truckee River, it is not surprising that a strong positive relationship was not found for these two parameters.

2.6. Fecal Bacteria

Fecal coliform and fecal streptococci bacteria are often used as indicators of wastewater (sewage) contamination. Since other animals including livestock and waterfowl also contribute to the fecal coliform count, the source is often difficult to distinguish. Using a fecal coliform concentration of greater than 400 per 100 mls as a relatively high count, it can be seen that with the exception of SB 16 and SB 18, the remaining tributaries to Steamboat Creek were low in fecal coliforms (Table 24a). This was especially true for SB 8 and SB 10 where the concentrations never exceeded 50 per 100 mls. SB 3, just downstream from the outlet of of Little Washoe Lake had elevated fecal coliforms (500-6000 per 100 mls) during the summer of 1988, 1989, 1990 and 1991. It is most likely that these were either washed in from Little Washoe Lake and related to waterfowl, or the result of creek-side livestock. Fecal coliform were also higher during the summer at SB 5; at this station 10 of the 21 observations showed a concentration of greater than 400 per 100 mls. Again, this suggests the importance of livestock input. The presence of fecal coliforms at SB 7, SB 11 and indeed further downstream at SB 17 and SB 19 indicates livestock inputs at multiple locations along the creek. SB 16 (Boynton Slough) supported concentrations of 200-600 per 100 mls during the summer; the 8800 per 100 mls value in Dec-90 appeared anomalous when viewed in light of the complete data base.

Table 24a. Individual fecal coliform bacteria (colonies/100 ml) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

Fecal Coliforms

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	70	280	150	130	10	10	10	10	150	80	20	600	80	120
Dec-87	130	50			10	10	10	10	40	130	300	410	300	210
Feb-88	10	10	20		10	10	10	10	10	10	10	40	20	10
Apr-88	10	20	420		100	10	10	30	20	40	30	90	100	40
Jun-88	770	90	1400	100	360	10	10	70	50	60			530	400
Aug-88	80	130	680	360	30	30	50	120		120	280	340	80	
Oct-88	600	10	500		450	10	10	50	270	290	600	300	40	130
Dec-88	10	10	10		20	10	10	10	170	10	10	10	50	20
Feb-89	30	10	70		100	10	10	40	80	20	60	600	600	220
Apr-89	10	10	200		120	10	10	200	600	10	10	130	40	120
Jun-89	600	180	590	170	540	10	10	220	600	110	360		480	
Aug-89	2400	360	900	230	50	10	10	90	50	180	100	140	50	300
Oct-89	510	140	350	90	100	10	30	230	260	150	110	160	50	110
Dec-89	80	20	270		10	10	10	50	30	10	10	10	100	10
Feb-90	20	20	100		80	10	10	10	10	10	10	10	10	10
Apr-90	10	50	600		30	10	10	170	100	120	520	10	190	20
Jun-90	970	410	580	120	330	10	10	1050	440		1200	60		340
Aug-90	7600	110	1000	100		10	40	400	200	480	180	90	40	80
Oct-90	160	40	50		40	10	10	30	110	350	10	10	50	50
Dec-90	40	10	90		40	10	10	170	10	10	8800	10	80	10
Feb-91	810	130	30		10	10	10	300	80	50	960	100	250	100
Apr-91	10	10	600		290	10	10	10	10	30	50	70	540	60
Jun-91	6000	50		120	380	10	10	340	200	30	390	400	600	490

Table 24b. Individual fecal streptococci bacteria (colonies/100 ml) observations for Steamboat Creek project. Missing data denotes no sample taken, no flow, or no data available.

FST

	SB3	SB4	SB5	SB6	SB7	SB8	SB10	SB11	SB12	SB14	SB16	SB17	SB18	SB19
Oct-87	120	210	1000	220	80	40	40	220	1000	290	180	220	590	150
Dec-87	10	50	290		30	40	10	150	110	510	740	460	1500	470
Feb-88	10	10	140		140	10	10	30	10	30	140	80	100	60
Apr-88	120	60	1000		390	10	10	80	150	110	300	100	280	150
Jun-88	860	130	2900	860	190	70	90	730	740	150	1000	1000	950	720
Aug-88	1000	180	1000	1000	70	670	880	1000	1000	520	980	630	1000	1000
Oct-88	1000	20	3000		1200	190	180	370	240	540	1000	310	260	360
Dec-88	10	10	80		230	10	10	30	4	30	30	30	120	160
Feb-89	340	30	430		760	10	90	160	300	60	540	180	240	570
Apr-89	50	10	510		920	10	20	190	290	10	220	150	100	210
Jun-89	850	260	1000	1000	1000	40	50	1000	1000	580	870	1000	1000	1000
Aug-89	280	380	3800	220	70	520	470	120	40	110	640	50	40	50
Oct-89	170	70	630	210	270	420	110	270	310	250	140	430	250	370
Dec-89	30	30	60		40	30	30	150	120	150	650	10	470	110
Feb-90	20	300	300		100	10	10	900	660	110	60	420	90	420
Apr-90	230	120	1000		390	30	10	1000	1000	520	1000	130		220
Jun-90	170	250	2800	740	230	1000	1260	4200	800		1000	130	860	570
Aug-90	7000	220	500	1000		560	760	1500	160	400	2500	200	210	190
Oct-90	160	200	560		310	40	100	460	300	1000	430	20	260	190
Dec-90	20	40	280		30	10	10	380	300	630	290	190	520	90
Feb-91	100	160	240		210	20	120	1200	300	110	1100	260	250	420
Apr-91	90	10	760		140	10	10	170	70	120	260	60	390	100
Jun-91	100	80		480	380	50	10	1400	290	90	3200	180	100	540

On only seven individual samplings or (1-2% of the time) did fecal coliform bacteria exceed 1,000 per 100 mls. While it is clear from comparison with counts taken at SB 8 and SB 10 that during the summer, fecal coliforms were elevated throughout the entire system, and that this was most likely the result of livestock activity along Steamboat Creek, that there were no single sources of large amount of contamination. As mentioned below, no State water quality standard for fecal coliform bacteria was exceeded.

Fecal streptococci bacteria data are presented in Table 24b. The quantities of fecal coliform (FC) and fecal streptococci (FS) bacteria discharged by humans are significantly different from those discharged by animals. It has been suggested, albeit not universally accepted, that an FC/FS ratio greater than 4.0 suggests human waste while a FC/FS ratio less than 1.0 indicates waste from domestic animals. Because of the wide fluctuation in the FC/FS ratio even within a given station at similar times of the year, we were very hesitant to give an interpretation to the calculated FC/FS values (e.g. FC/FS ratio at SB 3 Aug-88 = 0.08, Aug-89 = 8.6 and Aug-90 = 1.1).

2.7. Comparison of Program Monitoring Data to Water Quality Standards

2.7.1. Class C Waters

Class C waters are defined by the State of Nevada to include waters or portions of waters which are located in areas of moderate-to-urban human habitation, where industrial development is present in moderate amounts, agricultural practices are intensive and where the watershed is considerably altered by man's activity. Materials such as floating solids, sewage and other wastes, and toxics have narrative standards. Dissolved oxygen, pH, temperature, fecal coliform bacteria, total phosphates and total dissolved solids have been given numerical standards; these are presented in Table 25. Steamboat Creek is classified as a Class C Water from Little Washoe Lake to gaging station number 10-349300 located in the S 1/2, section 33, T. 18 N., R. 20 E., M.D.B. & M. This downstream location is the U.S.G.S. gaging station on the left bank 250 feet upstream from Steamboat Ditch. The lower reaches of Galena Creek is also specifically classified as a Class C Water. For the purpose of this report we have included stations SB 3, SB 4, SB 5, SB 6, SB 8 and SB 10 as Class C Waters.

Table 25. Water quality standards for Steamboat Creek and tributaries. Taken from Nevada State Code, Chapter 445. Assumed that waters at SB 4, SB 8 and SB 10 had hardness of 50 mg CaCO3/l; remainder of stations had hardness of 150 mg CaCO3/l. Demarcation between Class C and Class D Waters is just upstream of the confluence of Steamboat Ditch. n/a denotes that no standard has been set.
Values for metals are expressed in µg/1.

METALS

Aquatic Life		As	Cd	Cr	Cu	Hg	Pb	Se	Zn	B	Fe
Hardness											
50 mg/l CaCO3	1-hr	360	1.8	982	9	2.4	34	20	65	550	1000
	96-hr	190	0.7	117	7	0.01	1.3	5	59	550	1000
150 mg/l CaCO3	1-hr	360	6	2416	26	2.4	137	20	166	550	1000
	96-hr	190	1.6	287	17	0.01	5.3	5	150	550	1000
Irrigation		100	10	100	200	n/a	5000	20	2000	750	5000
Livestock		200	50	100	500	10	400	50	25000	500	n/a

Table 25. Continued. Parameters for which numerical standards have been set. Taken from Nevada State Code, Chapter 445.

GENERAL WATER QUALITY STANDARDS

Parameter	Class C Water [SB 3, 4, 5, 6, 8 & 10]	Class D Water [All other stations]
pH	6.5-8.5	6.0-9.0
Dissolved Oxygen	≥6.0 mg/l (assumes trout habitat)	≥3.0 mg/l
Temperature	<20 °C (assumes trout habitat)	none
Total Phosphates	<1.0 mg/l	none
TDS	<500 mg/l or 1/3 above natural background	none
Fecal Coliform	Geometric mean <1000 per 100 ml nor 20% of samples <2400 per 100 ml	none

Neither dissolved oxygen, pH, fecal coliform bacteria, total phosphates or total dissolved solids exceeded their numerical standard on any of the sampling dates. Assuming that trout are supported in these waters and that temperature should remain less than or equal to 20°C, the temperature standard was exceeded only on a single date; SB 5 in Jun-88 when a temperature of only 21.0°C was measured. However, it should be noted that the monitoring program was not designed to measure temperature at the hottest period of the day, i.e. mid-afternoon.

2.7.2. Class D Waters

Class D Waters include waters or portions of waters located in areas of urban development, highly industrialized or intensively used for agriculture or a combination of all the above and where effluent sources include a multiplicity of waste discharges from the highly altered watershed. Steamboat Creek, between the U.S.G.S. gaging station near Steamboat Ditch and its confluence with the Truckee River downstream is classified as a Class D Water. For the purpose of this report stations SB 7, SB 11, SB 12, SB 14, SB 16, SB 17, SB 18 and SB 19 are considered to be Class D Waters.

The narrative standards for these waters is identical to those for Class C waters; however, only pH and dissolved oxygen have numerical standards for Class D Waters. Dissolved oxygen did not exceed its standard during the present study and the pH standard was only exceeded once, SB 18 Jun-90 when a value of 9.17 was measured.

2.7.3. Metals

Water quality standards for metals used by the State of Nevada are generally taken from the US EPA water quality criteria for these compounds and apply to all waters within the Steamboat Creek study area (Note: criteria apply to total recoverable metals). Concentrations of cadmium, chromium (+3), copper, lead, selenium and zinc which are considered to have a negative impact on aquatic life are dependent on hardness; the harder the water the higher concentration of metal, biota can withstand. Arsenic, boron, mercury and iron are not affected by hardness. Numerical standards for aquatic life, irrigation and livestock watering which have been used for the purpose of comparison with Steamboat Creek data are given in Table

25. Both the 1-hr exposure and 96-hr exposure levels are provided. Since hardness was not measured, we assumed that stations SB 4, SB 8 and SB 10 had a hardness of 50 mg CaCO3/l and that the remaining stations had a hardness of 150 mg CaCO3/l.

A summary of the water quality exceedences is in Table 21. As expected from the high concentrations of arsenic and boron which entered Steamboat Creek from the Steamboat Hot Springs just upstream of SB 7, these two constituents frequently exceeded the established water quality standards for aquatic life, irrigation and livestock. These occurred at SB 7, SB 11, SB 12, SB 16, SB 17, SB 18 and SB 19 For arsenic, the maximum number of exceedences was at SB 7, SB 11, SB 12 and SB 17. The 1-hr aquatic life criteria of 190 µg/l for As was exceeded only at SB 7 and SB 11; however, this condition existed on the majority of the sampling dates. Downstream, only the irrigation and livestock watering standards were exceeded (with the exceptions of SB 14 and SB 18). Boron demonstrated the same general pattern except that the aquatic life standard was routinely violated at SB 7, SB 11, SB 12, SB 17, and SB 19.

Neither chromium (+3), selenium or zinc exceeded their respective aquatic life protection concentrations. Mercury, cadmium, copper and lead were only higher than the aquatic life standards (not irrigation or livestock) and on most of these occasions the measured value was very close to the analytical limit of detection. Similarly, iron exceeded only the aquatic life standard of 1000 µg/l. Iron concentrations over 1000 µg/l occurred at SB 5 (2 times), SB 11 (5 times), SB 12 (6 times), SB 16 (1 time), SB 17 (3 times) and SB 19 (2 times). The maximum iron concentration at these stations ranged from 1130-2110 µg/l and therefore did not go above the irrigation standard.

For all the constituents for which water quality standards have been established in the Steamboat Creek study area, only arsenic and boron routinely and significantly exceeded these standards. Given the rich geologic nature of the Steamboat Hot Springs and its thermal discharge to the creek it is not unexpected to find these high downstream concentrations. Nor is it unexpected to find occasional elevated concentrations of the other priority pollutant metals

(i.e. Cd, Cu, Pb, and Hg). With respect to aquatic life, all the metals in the Steamboat Creek can be considered natural and not the result of human development. Indeed, detection of urban derived metals from the Reno Metropolitan area could be more difficult to identify given this elevated background. We assume that metals discharge to Steamboat Creek from the Hot Springs will not be altered and expect that a biotic community of tolerant species has become established. The use of water at SB 7, SB 11, SB 12, SB 17 and SB 19 for irrigation or livestock watering is not recommended.

2.7.4. Unionized Ammonia

Unionized ammonia was measured eight (8) times during the study and all at SB 19.

Date	mg/l unionized NH_3
Oct-87	0.0156
Dec-87	0.0024
Feb-88	0.0012
Apr-88	0.0000
Jun-88	0.0036
Aug-88	0.0021
Oct-88	0.0060
Dec-88	0.0000

According to US EPA National Ambient Water Quality Criteria to protect freshwater aquatic life, and corrected for temperature and pH, none of these values are considered dangerous to salmonids or other sensitive coldwater fish species for either a 1-hr or 96-hr exposure time.

3. RECOMMENDATIONS

3.1. Control Strategies

3.1.1 Use of Wetlands for Nitrogen Removal

The reduction in nitrate load in the 1.1 mile reach of Steamboat Creek between the confluence of Yori Drain (SB 17 & SB 18) and the most downstream station sampled (SB 19) may be do to removal in the riparian,wetland and submerged portions of this system. Steamboat Creek is characterized by a greater degree of channel meandering downstream of Boynton Slough and Yori Ditch thereby increasing the potential for bottom contact. It is our understanding that in 1991 the USDA/Soil Conservation Service prepared a mitigation, enhancement and recreation plan as part of a larger flood control project on the Truckee Meadows for the U.S. Army Corps of Engineers. Featured elements of this overall plan include establishment of 46 acres of new riparian forest along the Truckee River and Steamboat Creek and 128 acres of emergent wetlands in the Steamboat Creek area. Even though the Corps flood control project was terminated, it is clear from the N-loading analysis presented above that 1) TN and especially NO3-loading to Steamboat Creek from regional agricultural return water is high and 2) this N-loading is significant when viewed in the context of other regional point and nonpoint sources. Any modification such as wetland creation and riparian restoration which would increase the capacity of this system to remove nitrate and total-N is highly recommended.

Nichols (1983) published a review article on the capacity of natural wetlands to remove nitrogen and phosphorus from wastewater. In this study he took data from nine wetland systems in predominantly cold-climate regions (e.g. Michigan, Wisconsin, Massachusetts and Ontario) and presented an empirical model plotting %N and %P removal versus N and P-loading as $g/m^2/yr$. Below we use Nichols basic model to estimate the N-removal capacity of the proposed 128 acre wetland. Assuming a mean loading of 185 lbs N/day (refer to Table

15b) and an area of 128 acres, the N-loading rate to the wetland would be 59 g $N/m^2/yr$. Applying the empirical data of Nichols which is best fit by the equation with an r-value of 0.99:

$$\% \text{ N-removal} = 83.3442 \times 10^{(-0.0045[\text{N-loading as } gN/m^2/yr])}$$

it is estimated that this size wetland would removal 45% of the TN-load in Steamboat Creek at SB 19. Reduction of wetland area to 64 acres yields a 24% removal while an increase to 192 acres results in a 55% removal. While caution must be used in over interpreting these results which are based on a very simplified model, albeit empirical model, it does appear that a 128 acre wetland could potentially provide significant reduction in TN-load to the Truckee River. Since nitrate comprises such a large component of the TN pool at SB 19, i.e. ±25%, and wetlands have such a great capacity to remove nitrate via denitrification (e.g. Gersberg et al. 1983; Reuter et al 1992), a 35-55% TN-removal for this system would not be unexpected. Of course, the proper stream channel and bank grading would be needed to successfully plant such a vegetative community.

3.1.2. Feasibility of Other Control Strategies

Given the overall range of concentration and load of phosphorus in the Steamboat Creek system, and the observation that downstream water quality and algal growth is not regulated by this nutrient, we believe that the soundest approach would be to focus on N-removal and not P-removal. Depending on the nature of the inflows in the irrigation return flows, i.e. diffuse versus centralized, small wetlands or modified riparian buffer zones could be created at strategic locations along the major tributaries where N-concentration and N-load is high. It is also our opinion at this time that while efforts to educate regional agricultural concerns regarding over fertilization with nitrogen and its potential downstream impacts should begin immediately, the first step would be to focus on N-removal. Achieving a reduction in N-addition system-wide could require a large effort which may take years to implement. In the interim, creation of wetlands and riparian buffer zones should proceed. Eventually, the

combination of decreased addition and increased removal as an effective nonpoint source control strategy will be in place.

3.2. Future Studies

1. Locate sources of nitrogen to the downstream tributaries (SB 12, SB 14, SB 16 and SB 18) by establishing a more focused monitoring study along the length of these tributaries
2. Determine the importance of groundwater flow to Steamboat Creek as a source of soluble nitrogen.
3. Determine the importance of cattle excreta to TN and TKN loads.
4. Conduct a more comprehensive quantitative evaluation for capacity of wetlands and riparian buffer zones to remove nitrogen from surface flow.
5. Conduct a comprehensive evaluation to determine the cost-benefit of implementing streambank erosion control measures.
6. Conduct expanded sampling of other regional nonpoint sources of nitrogen (e.g. North Truckee Drain, irrigation return flows, etc.).
7. Conduct a comprehensive evaluation of all data bases containing information on NPS N-loading to the Truckee River or its tributaries.

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