Table 7. Coefficients and bias correctors for total-phosphorus load regressions for samples collected between 1988 and 2002

[Symbol: <, less than]

Site no. (see fig. 16)	Number of samples	Coefficient of determination (R^2)	F test (p value)	Slope coefficient (β_1)	Intercept coefficient (β_0)	Bias-corrector
1	75	0.88	p < 0.0001	1.39	-3.91	1.20
17	152	0.85	p < 0.0001	1.46	-3.89	1.35
34	112	0.89	p < 0.0001	0.926	0.41	1.11
39	132	0.94	p < 0.0001	1.027	-0.28	1.14
43	159	0.96	p < 0.0001	1.16	-1.20	1.21

Seasonal and annual loads of total phosphorus for WY 2001–02 at sampling sites 1, 17, 34, 39, and 43 were calculated by summing the daily loads for each season and for each year (table 8). Annual loads ranged from 1.33 tons at site 1 to 43.41 tons at site 34. Garcia and Carman (1986) estimated seasonal and annual loads of total phosphorus for 1980 at the same sites. Their value for annual load was based on the average of four different methods to estimate loads, using 12–14 measurements made at each site during WY 1980. Although the same general patterns are seen in the 1980 and 2001–02 data, annual loads were much greater in 1980 (table 8). The difference in loads is partly due to differences in streamflow; runoff during WY 1980 was much greater than during WY 2001–02. In addition, mean orthophosphate concentrations have decreased since the early 1970's (table 2; Garcia and Carman, 1986). Decreases in orthophosphate concentrations are most likely due to elimination of direct discharge of treated effluent to the Carson River by 1987. In 2002, estimated annual loads were greater at all sites than in 2001 (table 8), due to increased streamflow.

Estimated seasonal total-phosphorus loads for sampling sites 1, 17, 34, 39, and 43 are greatest during spring runoff, followed by fall and winter, and least during the summer (table 8), which corresponds with the amount of streamflow in the Carson River. Estimated seasonal loads ranged from 0.06 ton (site 1, summer) to 17.10 tons (site 34, spring) in 2001 and from 0.07 ton (site 1, spring and site 43, summer) to 28.20 tons (site 34, spring) in 2002. For each site and year, the greatest seasonal loads were in the spring from April to June.

Estimated daily mean total-phosphorus loads transported in streamflow at sampling sites 1, 17, and 34 were used to estimate the phosphorus load entering and leaving the Carson Valley subunit (fig. 24). Estimated daily mean loads for sites 1 and 17 were combined to estimate the mean load entering the Carson Valley subunit. Site 34 is located where the Carson River leaves the Carson Valley subunit. To show the uncertainty associated with the mean daily total-phosphorus loads estimated by the regression equations, the 95-percent confidence intervals were calculated (Helsel and Hirsh, 1992, p. 240) and shown for load leaving the Carson Valley subunit (site 34) in figure 24. The confidence intervals are not shown for the load entering Carson Valley subunit because the confidence intervals for the load from the East and West Forks cannot be combined.

The average estimated annual phosphorus load entering the Carson Valley (sites 1 and 17) for WY 2001–02 was 21.9 tons; whereas, the average estimated annual phosphorus load leaving the Carson Valley (site 34) was 37.8 tons (table 8), for an average estimated annual gain in load across Carson Valley of 15.9 tons. Thus, about 58 percent of the annual total-phosphorus load leaving Carson Valley could be attributed to headwater reaches upstream from Carson Valley during WY 2001–02. This value, 58 percent, is a maximum and assumes that the phosphorus load entering the valley passes through the valley and is not diverted from the Carson River system.

The contribution from the headwater reaches changes throughout the year. The largest seasonal gain and most of the annual gain in phosphorus load across the Carson Valley occurs during the autumn and winter (October 1–March 31; fig. 24, table 8). During this period, an average of only 17 percent of the phosphorus load leaving Carson Valley could be attributed to headwater reaches upstream of Carson Valley. This means that the majority of load leaving the Carson Valley subunit is generated within the Carson Valley during October through March. During the period April 1–September 30, only a slight increase in load occurs across Carson Valley (table 8). During this period, the streamflow entering Carson Valley is much greater than the streamflow leaving, indicating that there are increases in phosphorus concentration. An average of 85 percent of the phosphorus load leaving Carson Valley could be attributed to headwater reaches during spring and summer. Based on the confidence intervals for phosphorus load shown in figure 24 this value is very uncertain.

During most of the 2-year study period, the estimated total-phosphorus load entering Eagle and Dayton–Churchill Valleys was greater than the amount leaving the valleys (figs. 25–26, table 8). For these valleys, the lower 95 percent confidence limit for the daily estimated phosphorus load entering the valleys exceeded the upper 95-percent confidence limit for the load leaving the Eagle Valley and Dayton–Churchill Valleys 54 and 63 percent of the time, respectively, during WY 2001–02. When the 95 percent confidence limits do not overlap, the estimated phosphorus loads at the upstream and downstream sites

Table 8. Estimated seasonal and annual loads, and average annual yields of total phosphorus at sites on the Carson River, water years 1980, 2001, and 2002

[Abbreviations: A, autumn (October 1–December 31); W, winter (January 1–March 31); Spr, spring (April 1–June 30); S, summer (July 1–September 30); lb/acre, pound per acre]

Site no. (see fig. 16)	Station name	Total-phosphorus load (tons)											2001–02 average annual yield (lb/acre)
		Water year 1980[a]	Water year 2001					Water year 2002					
		Annual	A	W	Spr	S	Annual	A	W	Spr	S	Annual	
1	West Fork Carson River at Woodfords, CA	6.1	0.08	0.16	1.04	0.06	1.33	0.07	0.18	2.13	0.09	2.46	0.091
17	East Fork Carson River near Dresslerville, NV	120	0.58	1.49	14.69	0.56	17.32	0.57	1.77	19.33	1.05	22.72	0.167
34	Carson River near Carson City, NV	230	5.63	8.82	17.10	0.62	32.17	4.26	9.75	28.20	1.19	43.41	0.133
39	Carson River at Deer Run Road, NV	250	4.39	7.41	16.21	0.15	28.16	3.48	8.97	25.54	0.37	38.36	0.108
43	Carson River near Silver Springs, NV	230	2.88	6.27	15.72	0.07	24.93	1.95	6.44	22.70	0.07	31.15	0.060

[a]From Garcia and Carman (1986).

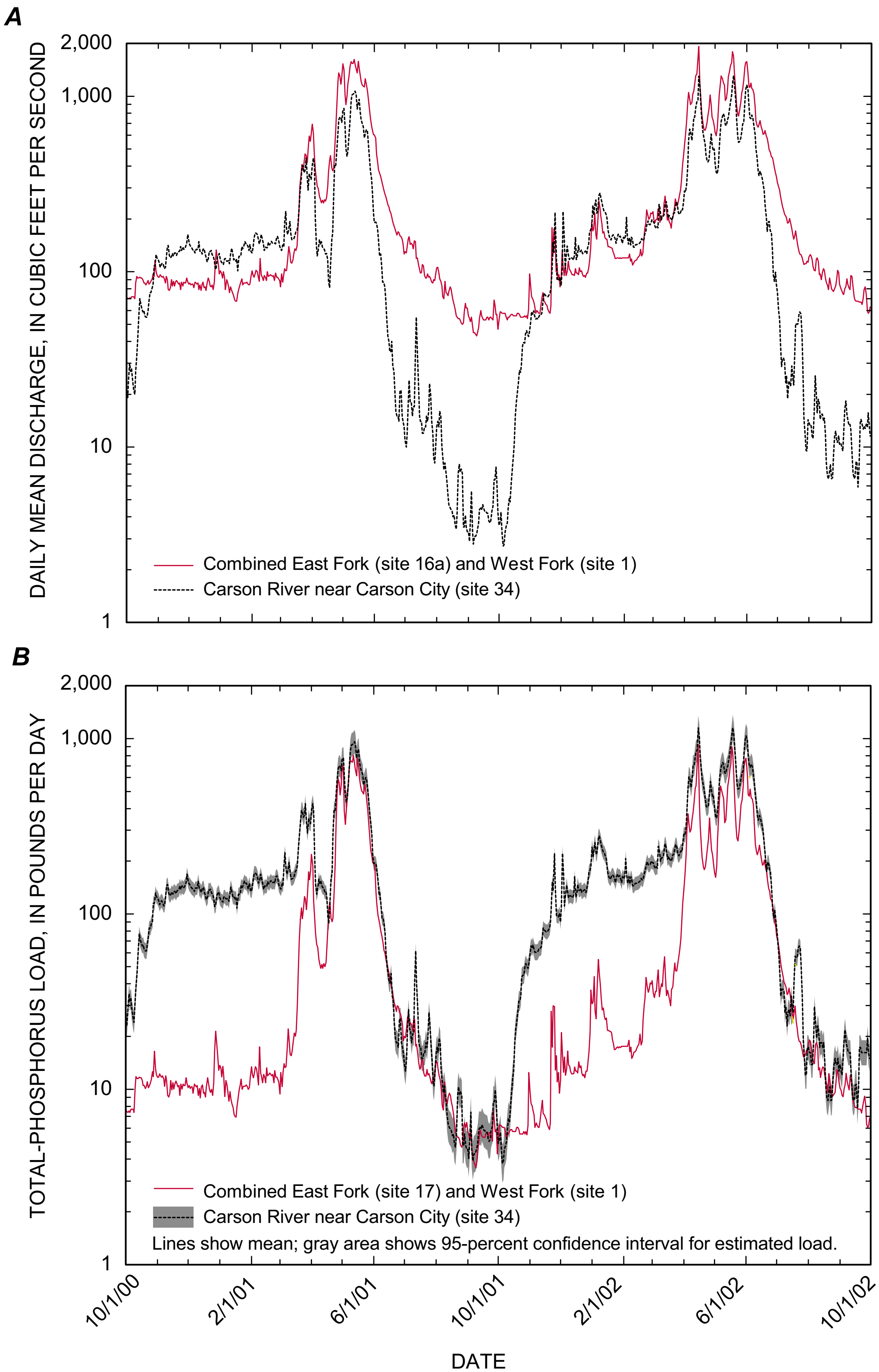

Figure 24. Comparison of (*A*) discharge and (*B*) total-phosphorus loads entering and leaving Carson Valley.

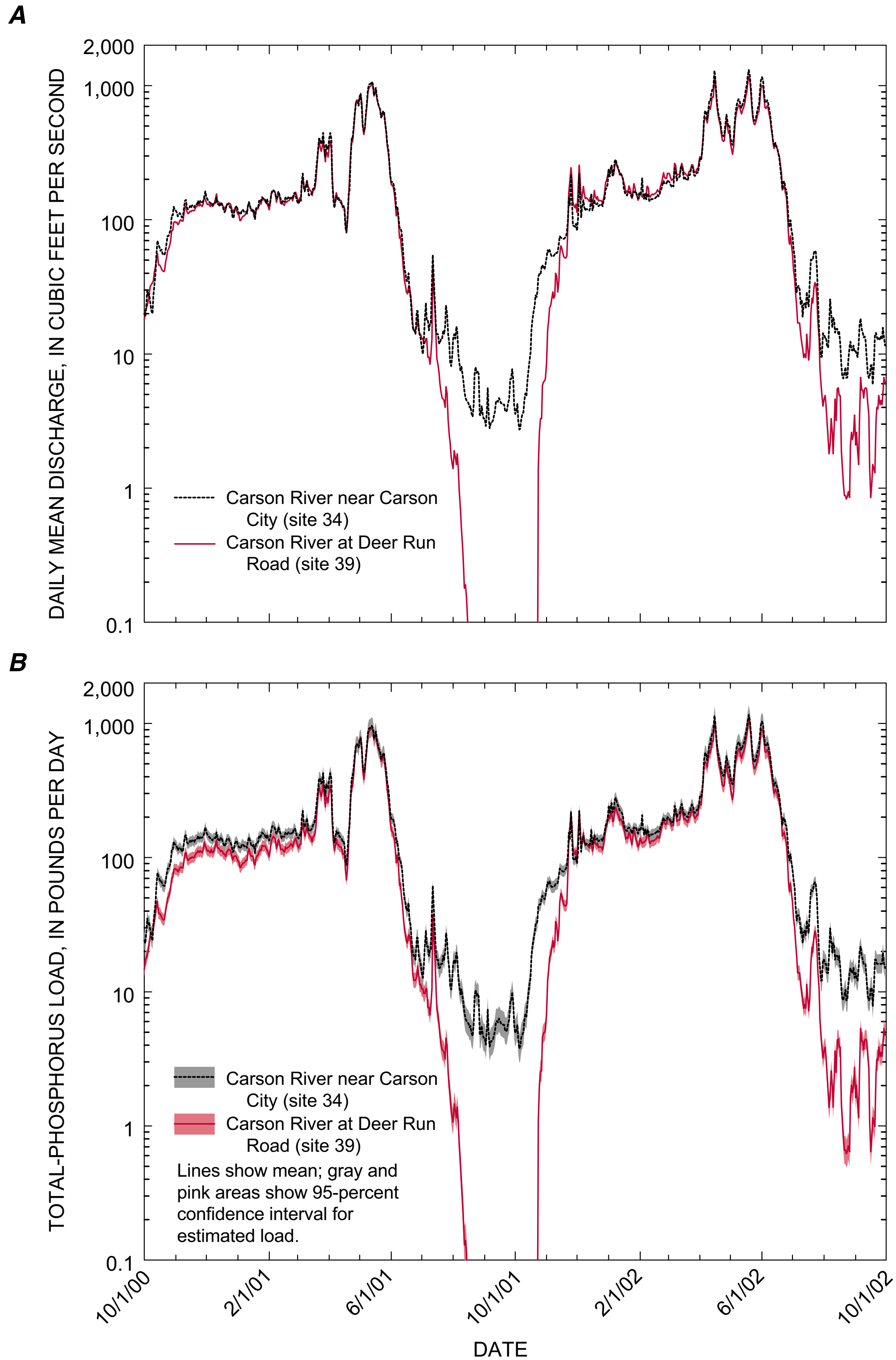

Figure 25. Comparison of (*A*) discharge and (*B*) total-phosphorus loads entering and leaving Eagle Valley.

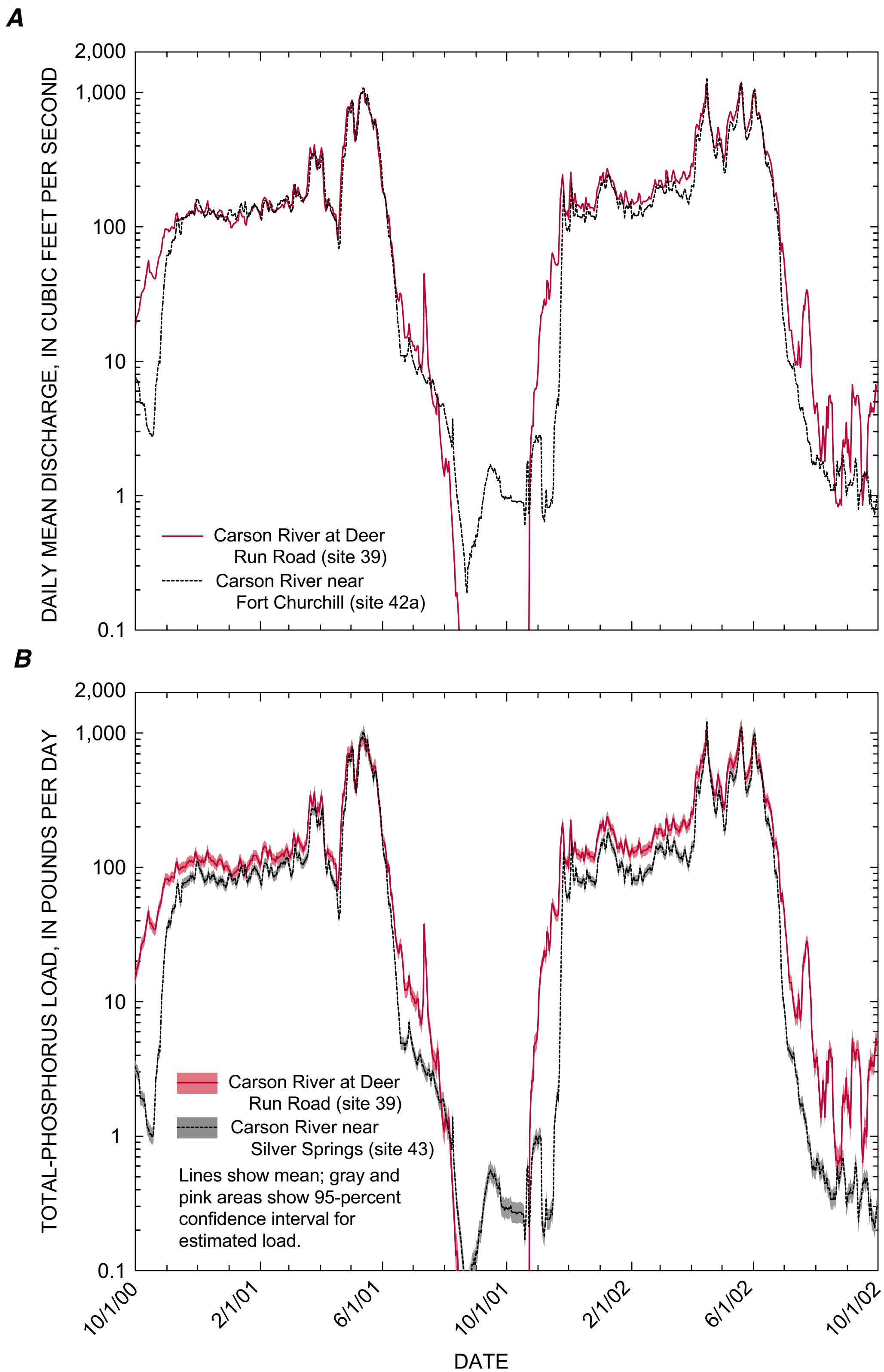

Figure 26. Comparison of (*A*) discharge and (*B*) total-phosphorus loads entering and leaving Dayton–Churchill Valleys.

statistically are different and indicates that the valleys may be acting as sinks, with more phosphorus entering them than is leaving them. On an annual basis (WY 2001–02), about 90 percent and 85 percent of the phosphorus entering Eagle Valley and Dayton–Churchill Valleys, respectively, left them. During flood events, however, the phosphorus may be mobilized and moved downstream.

Generally, sampling sites with the largest drainage areas are assumed to have the largest phosphorus loads (Pope and Milligan, 2000) because streamflow is directly related to drainage area and streamflow is assumed to increase moving downstream. However, for the Carson River system, the amount of annual streamflow generally decreases in a downstream direction (fig. 6). In addition, the total-phosphorus concentrations decrease between site 34 and site 43 (table 6). The combination of decreased flow and concentrations are the reasons the annual and seasonal loads decrease between site 34 and site 43.

The phosphorus yield indicates which sites have the largest annual phosphorus contribution per unit drainage area. Differences in mean annual phosphorus yields among sub-watersheds are related to several factors including water yield, precipitation, soil characteristics, topography, stream gradient, and land-use characteristics (Pope and Milligan, 2000). Site 17 has the largest annual yield with 0.167 lb/acre, followed by site 34 with 0.133 lb/acre (table 8). Yield from the headwaters of the East Fork (site 17) is nearly twice that for the West Fork (site 1). This difference may result from soils in the East Fork being more erodible and having a greater clay content than soils in the headwater reaches of the West Fork (fig. 3, table 5).

Phosphorus in Sediment

Suspended Sediment

The relation between suspended-sediment and phosphorus concentrations in water was evaluated using data collected during this investigation. A relation is expected because phosphorus is a structural component of some minerals in sediments (for example, apatite), and is bound to other minerals in sediment (for example, iron oxyhydroxide). A plot of total-phosphorus against suspended-sediment concentrations (fig. 27*A*) shows that only 28 percent of the variance in total-phosphorus concentration is explained by suspended-sediment concentration.

When total-phosphorus concentrations are corrected for the amount of orthophosphate, the relation between phosphorus and suspended-sediment concentrations improves (fig. 27*B*). The amount of phosphorus bound to particulate matter, particulate phosphorus, is estimated by subtracting orthophosphate from total phosphorus. Particulate phosphorus, as defined here, is an estimate because it includes an unknown amount of dissolved phosphorus that is not orthophosphate. A plot of particulate-phosphorus concentration against suspended-sediment concentration (fig. 27*B*) shows 57 percent of the variance in particulate-phosphorus concentration is explained. These data indicate that phosphorus from particulate phosphorus alone may exceed the water-quality standard for phosphorus when suspended-sediment concentrations exceed about 50 mg/L.

The relation between particulate-phosphorus and suspended-sediment concentrations is improved slightly (R^2 = 0.63) when suspended-sediment concentration is corrected for the contribution from sand-sized particles (fig. 27*C*). These data show that phosphorus from particulate phosphorus alone may exceed the State phosphorus standard when concentrations of clay and silt in suspended sediment exceed about 30 mg/L.

Much of the variance shown in figure 27 is related to the source of the suspended sediment. For example, a water sample from Williams Slough (site 29) had a particulate-phosphorus concentration of 0.29 mg/L and a suspended-sediment concentration of 13 mg/L (app. 1). This sample, which is the largest outlier in figure 27*C*, corresponds to a phosphorus concentration in suspended sediment of 2.2 percent. A water sample from the East Fork Carson River near Dresslerville (site 17), which also had a particulate-phosphorus concentration of 0.29 mg/L, had a suspended-sediment concentration of 195 mg/L (app. 1). In this sample, the phosphorus concentration in suspended sediment was 0.15 percent. Sediment in Williams Slough at site 29 likely originates in fields irrigated with treated effluent (fig. 13) where cattle may have access to the slough. Sediment in the East Fork at site 17 originates in forest and rangeland (fig. 9).

Streambank and Streambed Sediments

Phosphorus concentrations in streambank sediment typically were low (less than 0.07 percent) throughout the study area (fig. 28). The phosphorus concentration in samples of streambank sediment from 19 sites ranged from 220 to 1,200 mg/kg (from 0.02 to 0.12 percent) and the median concentration was 590 mg/kg (0.06 percent; app. 2). The greatest phosphorus concentrations (greater than 0.08 percent) were found in Carson Valley, with the greatest at site 33 on Clear Creek.

The phosphorus concentration in samples of streambed sediment from 39 sites ranged from 220 to 1,600 mg/kg (from 0.02 to 0.16 percent) and the median concentration was 810 mg/kg (0.08 percent; app. 2). Phosphorus concentrations greater than 0.08 percent were commonly found in samples from Carson Valley (fig. 29), but also were found in tributaries to the Carson River in Eagle Valley (sites 37 and 38) and in the Carson River in Dayton Valley. Phosphorus concentrations exceeding 0.1 percent were restricted to Carson Valley.

Relation Between Suspended-Sediment Concentration and Total-Suspended Solids

Although suspended-sediment concentration (SSC) and total-suspended solids (TSS) are used to measure the amount of suspended matter being carried by rivers and streams, analytical

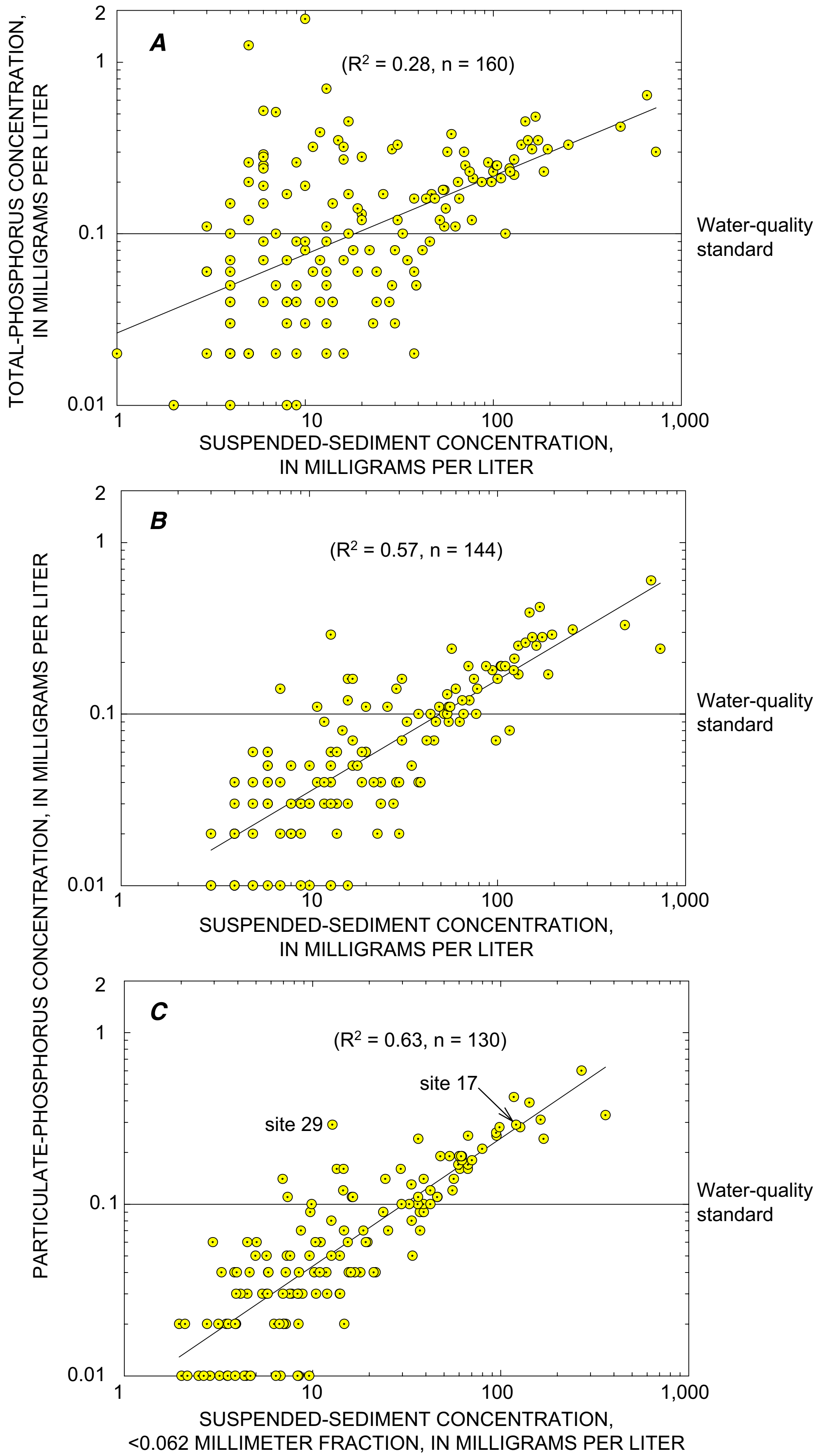

Figure 27. Relation between phosphorus and suspended-sediment concentrations in samples from the Carson River Basin upstream from Lahontan Reservoir, 2000–02.

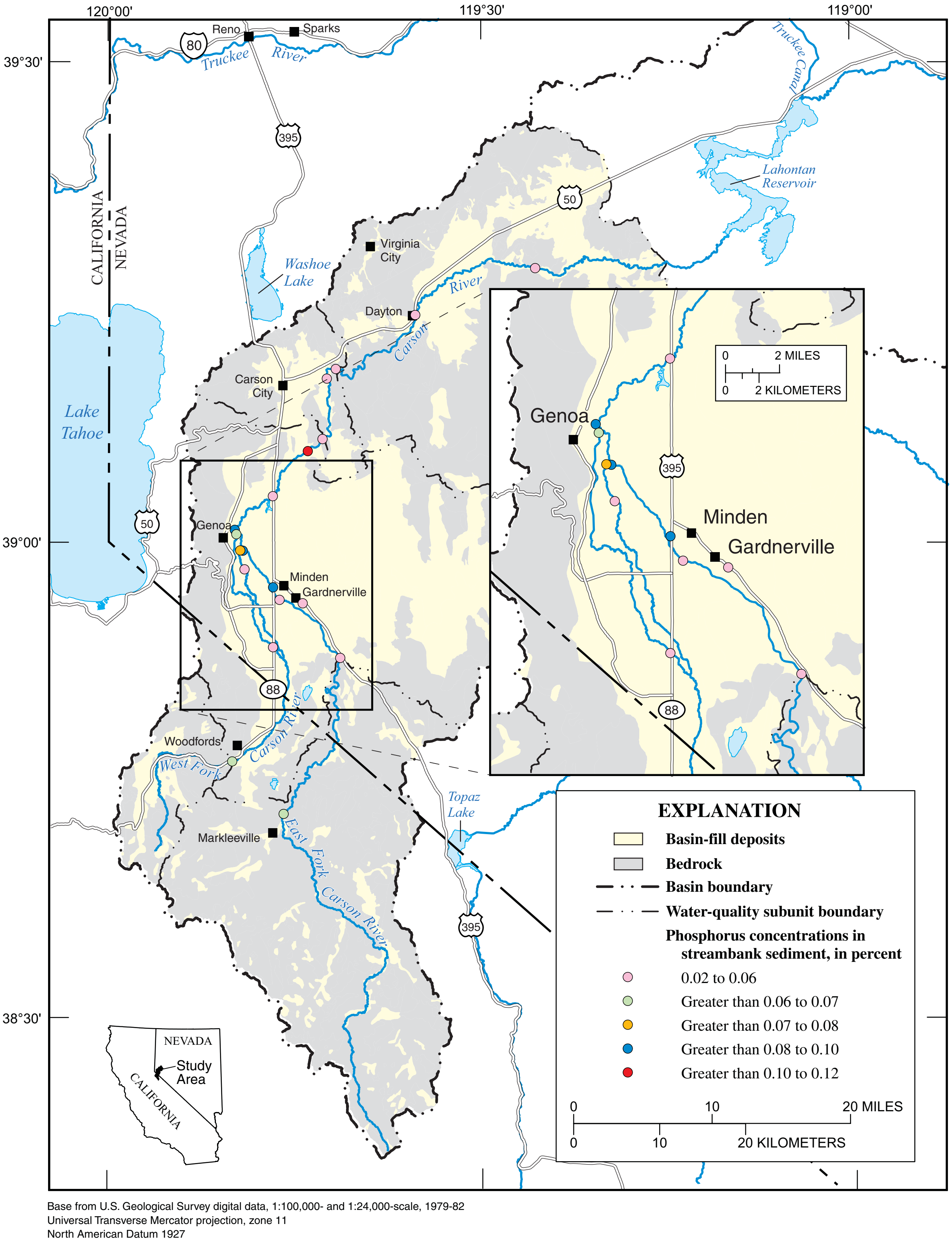

Figure 28. Phosphorus concentrations in streambank-sediment samples in the Carson River Basin upstream from Lahontan Reservoir, 2001–02.