# 3.0 ANNUAL SUSPENDED-SEDIMENT LOADS AND YIELDS

## 3.1 Introduction

Annualized data on suspended-sediment loads and yields (load per unit area) are a convenient means of interpreting sediment production and delivery. With regard to sediment delivery to Lake Tahoe, data expressed as annual loads (in T/y) provide a means of differentiating those watersheds that are particularly critical in terms of gross amounts of sediment delivered on an annual basis. This is of course essential in interpreting issues involving lake clarity. With other things being equal, however, larger watersheds will generally provide greater suspended-sediment loads than smaller watersheds, but this tells us little about differences in sediment production and delivery processes between watersheds. Suspended-sediment yields, expressed in $T/y/km^2$ do provide a mechanism to interpret differences in sediment production and delivery because they describe loads per unit of drainage area. Because suspended-sediment yields will vary with time as runoff conditions change, temporal trends of annualized data are also expressed as an annual concentration (load per unit of runoff; in $g/m^3$) to (1) interpret differences in sediment production and sources within watersheds and, (2) determine temporal trends over the past 40 years.

## 3.2 Availability and Reliability of Data

Annual suspended-sediment loads and yields are calculated for 32 sites using historical mean-daily flow data and sediment-transport rating relations. The length of record, depending on the number of complete calendar years of flow data, ranged from two to 40 years with a mean of 12 years (Table 3-1). Eleven sites had four years or fewer of mean-daily flow data. Most of these stations were sampled in the early 1970's (1970-1974) by the U.S. Geological Survey (Kroll, 1976; Glancy, 1988). Fortunately, the flow recorded over this period is reasonably representative of longer periods of record. Average, mean-daily flows for the period are only 3 – 5% less than those for the full period of record on Incline and Third Creeks. Annual peak flows on Third Creek are just 9% higher during this short period in the 1970s. Similar patterns are seen on the west side of the lake where a number of gages were operated only during the early 1970s.

First approximation rating relations are derived from linear regression of instantaneous flow and suspended-sediment concentration data plotted in log-log space. As is often the case, this single power curve is inadequate to describe the relation between discharge and sediment load over the entire range of flows. In these cases two- or three-linear segments (in log-log space) are used. The break point for each segment is determined by eye. An example is shown in Figure 2-6. Plots of all rating relations are shown in Appendix C. Where applicable and where sufficient data are available, rating relations are also calculated for transport conditions prior to, and after the January 1-2, 1997 rain on snow runoff event. Finally, the resulting power functions are all closely inspected to make sure that the maximum mean-daily flow that is used to calculate daily loads does not exceed the maximum sampled flow rate. This is particularly critical at high flow rates where a small increment in discharge can result in large errors in the calculated sediment load.

Suspended-sediment loads for each complete calendar year of flow data were calculated by applying the appropriate transport rating to the mean-daily flow for that day. Flow rates based on 15-minute gage readings would have been superior, however, most of the 15-minute gage record contains varying periods of missing data, making it impossible to obtain annual values.

It is important to keep in mind that for a given station, discharge and suspended-sediment loads may range over four to six orders of magnitude. Data scatter around a suspended-sediment transport rating with an $r^2$ value as high as 0.9 still has only order of magnitude accuracy in predicting loads at a given discharge. Thus, suspended-sediment loadings are not actually measured, but calculated from measured flow and concentration data. In general, caution should be exercised in using 95% prediction limits around rating relations and not 95% confidence limits. The difference is that the confidence limits reflect the reliability of the relation to describe the trend in load with discharge whereas prediction limits refer to the reliability of estimating suspended-sediment loads at a given discharge.

## 3.3 Basin Quadrants and Index Stations

Precipitation and other basin characteristics vary from one side of the lake to the other resulting in a broad range of sediment-transport rates. To partially account for these differences and to make interpretations of differences in suspended-sediment loads and yields to Lake Tahoe, watersheds are separated into the four principle directional quadrants; north, south, east, and west (Figure 3-1). Streams referred to as “northern” include First, Second, Third, and Incline Creeks. The major “southern” streams are the Upper Truckee River and Trout Creek. “Eastern” streams include Edgewood, Glenbrook and Logan House Creeks, while “western” streams include Blackwood, Ward, and General Creeks.

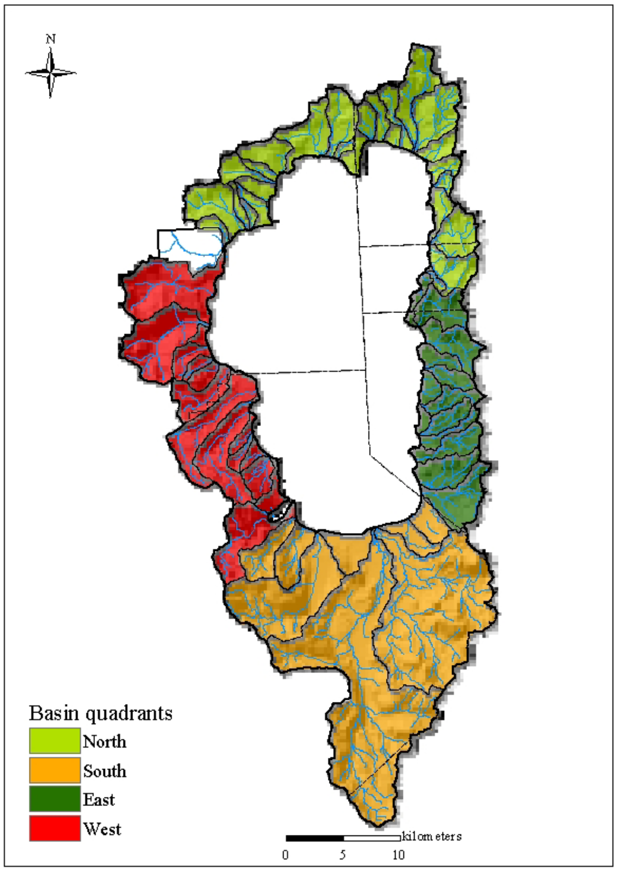


**Figure 3-1. Map of Lake Tahoe watershed showing designation of the four basin quadrants.**

Index stations were selected from the 32 sampling stations (Table 3-1). The concept of an index station is that sediment loadings and yields from a particular watershed to Lake Tahoe can be represented by sediment-transport data from a specific downstream location in the watershed. Selection of these stations are based on two criteria; (1) the station from a given stream with the longest period of record and, (2) the station has a downstream location. These stations are then used to interpret similarities and differences in sediment delivery to the lake.

**Table 3-1. List of index stations used to differentiate suspended-sediment loads and yields to Lake Tahoe from individual watersheds.**

| Stream | Station number | Basin quadrant | Distance above mouth (km) | Period of record (y) |
|---|---|---|---|---|
| First | 10336688 | N | 0.13 | 4 |
| Second | 10336691 | N | 0.52 | 4 |
| Third | 10336698 | N | 0.19 | 26 |
| Incline | 10336700 | N | 0.27 | 17 |
| Wood | 10336692 | N | 0.02 | 4 |
| Trout | 10336780 | S | 4.52 | 40 |
| Upper Truckee | 10336610 | S | 2.94 | 24 |

| | | | | |
|---|---|---|---|---|
| Edgewood | 103367585 | E | 3.81 | 11 |
| Glenbrook | 10336730 | E | 0.04 | 16 |
| Logan House | 10336740 | E | 0.66 | 17 |
| Eagle Rock | 103367592 | E | 2.99 | 10 |
| Blackwood | 10336660 | W | 0.31 | 40 |
| General | 10336645 | W | 0.65 | 20 |
| Meeks | 10336640 | W | 0.45 | 3 |
| Ward | 10336676 | W | 0.44 | 28 |
| Quail Lake | 10336650 | W | 0.07 | 3 |
| Eagle | 10336630 | W | 0.57 | 3 |

## 3.4 Total Annual Suspended-Sediment Loads

Annual suspended-sediment loads generally vary over about four orders of magnitude with time at a particular station, and from watershed to watershed. This variability can simply reflect differences in drainage area or, be a function of differences in precipitation, and basin and channel characteristics. Median annual suspended-sediment loads range from about 0.5 T/y on Logan House Creek (10336740) to about 2,200 T/y on the Upper Truckee River (10336610) (Table 3-2). Median values are used for comparison purposes in lieu of means because of the overriding influence of the large runoff events. To compare downstream loadings from individual watersheds, the median-annual loads for the 18 index stations are highlighted in green in Table 3-2. The greatest annual loads, in decreasing order emanate from the Upper Truckee River (2200 T/y), Blackwood (1930 T/y), Second (1410 T/y), Trout (1190 T/y), Third (880 T/y), and Ward Creeks (855 T/y). The lowest annual loads, in increasing order emanate from Logan House (0.5 T/y), Eagle Rock (4.6 T/y), Dollar (4.6 T/y), Quail Lake (6.4 T/y), Glenbrook (8.9 T/y), and Edgewood Creeks (21.3 (T/y).

**Table 3-2. Summary of total annual suspended-sediment loads calculated from measured data. Sites shaded in green are index stations.**

| Stream | Station number | Annual load | | Quadrant | Complete years of data | Drainage area ($km^2$) |
|---|---|---|---|---|---|---|
| | | Average (tonnes) | Median (tonnes) | | | |
| Upper Truckee | 10336610 | 2850 | 2200 | S | 24 | 142 |
| Blackwood | 10336660 | 3060 | 1930 | W | 40 | 29.0 |
| Upper Truckee | 103366092 | 1410 | 1410 | S | 10 | 88.8 |
| Second[2] | 10336691 | 1500 | 1410 | N | 4 | 4.7 |
| Trout | 10336780 | 1790 | 1190 | S | 40 | 95.1 |
| Third | 10336698 | 1680 | 880 | N | 26 | 15.7 |
| Ward | 10336676 | 1730 | 855 | W | 28 | 25.1 |
| Ward | 10336670 | 641 | 638 | W | 3 | 5.2 |
| Wood[2] | 10336692 | 467 | 490 | N | 4 | 5.3 |
| Ward | 10336675 | 551 | 449 | W | 9 | 23.2 |
| First[2] | 10336688 | 402 | 413 | N | 4 | 2.8 |
| Ward | 10336674 | 427 | 356 | W | 9 | 12.9 |
| Trout | 10336790 | 360 | 355 | S | 5 | 105 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Upper Truckee | 10336580 | 363 | 334 | S | 10 | 36.5 |
| Trout | 10336775 | 376 | 331 | S | 10 | 61.4 |
| Incline | 10336700 | 612 | 217 | N | 17 | 18.1 |
| Grass[1] | 10336593 | 181 | 181 | S | 3 | 16.6 |
| General | 10336645 | 283 | 176 | W | 20 | 19.3 |
| Incline | 103366995 | 174 | 163 | N | 11 | 11.6 |
| Trout | 10336770 | 158 | 109 | S | 10 | 19.1 |
| Incline | 103366993 | 80.1 | 90.5 | N | 10 | 7.2 |
| Meeks[1] | 10336640 | 79.8 | 79.8 | W | 3 | 22.2 |
| Eagle[1] | 10336630 | 69.9 | 69.9 | W | 3 | 20.4 |
| Edgewood | 10336760 | 34.7 | 44.8 | E | 8 | 14.2 |
| Edgewood | 103367585 | 24.5 | 21.3 | E | 11 | 8.1 |
| Edgewood | 10336765 | 9.5 | 9.5 | E | 2 | 16.2 |
| Glenbrook | 10336730 | 11.3 | 8.9 | E | 16 | 10.5 |
| Quail Lake[1] | 10336650 | 6.4 | 6.4 | W | 3 | 4.2 |
| Dollar[1] | 10336684 | 4.6 | 4.6 | N | 3 | 4.7 |
| Eagle Rock | 103367592 | 5.6 | 4.6 | E | 10 | 1.5 |
| Logan House | 10336740 | 5.6 | 3.0 | E | 17 | 5.4 |
| Edgewood Trib. | 10336756 | 0.5 | 0.5 | E | 2 | 0.6 |

[1] = Mean values from Kroll (1976)
[2] = Data from Glancy (1988)

The spatial distribution of mean annual suspended-sediment loads (in T/y) are shown broken into five classes and mapped in Figure 3-2 with the darker colors indicating higher suspended-sediment loads. Note that the index stations on Blackwood Creek (10336660) and the Upper Truckee River (10336610) show the greatest values while the eastern streams in general have the lowest. The latter is in part due to the smaller watershed areas on the east side of the lake as well as lower runoff rates. Whereas high loadings rates are expected from large watersheds such as Trout Creek and the Upper Truckee River, the index stations on Blackwood, Ward (10336676) and Third Creeks (10336698) show relatively high loadings for their drainage area, indicating past and or present disturbances and the potential for high rates of channel erosion.

To compare loadings from sampled watersheds, data from Table 3-2 is perhaps better displayed graphically as in Figure 3-3 where median annual suspended-sediment loads are shown in descending order for the 18 index stations (Figure 3-3a) and by basin quadrant (Figure 3-3b). One of the most striking aspects of Figure 3-3b are the exceptionally low loadings rates for the eastern streams including those that have experienced significant urbanization, such as Edgewood Creek, and on Glenbrook Creek where construction of roads and road cuts has been listed as a cause of heightened loads (Kroll, 1976). Median annual water yields for the three main index stations in the east (Glenbrook, Edgewood, and Logan House Creeks) range from 0.09 $m^3/m^2$ to 0.20 $m^3/m^2$ for Logan House and Edgewood Creeks, respectively. In contrast, median annual water yields from the three main western index stations range from 0.80 $m^3/m^2$ to 1.17 $m^3/m^2$ for General and Ward Creeks, respectively. Still, because of greatly different rates of runoff in comparison with the larger and wetter western streams, suspended-sediment loads from disturbed watersheds in the eastern quadrant do not approach those from the western quadrant.

It is the relatively high water yields of the western streams that make them particularly sensitive to disturbance. Note the vastly greater suspended-sediment loads produced from the Blackwood and Ward Creek watersheds in comparison to the relatively undisturbed General, Meeks, and Eagle Creek watersheds.

Streams draining the northern quadrant of the Lake Tahoe Watershed have relatively high loads of suspended-sediment. This is one of the most intensely developed parts of the basin. Data for streams such as First, Second and Wood Creeks are only from the early 1970's and although they reflect representative flows, the period comes at the end of a decade of intense development that continued into the sampling period. Glancy (1988) lists 34 development projects in the Incline Village area between 1960 and 1970, and refers to this as a period of "dynamic non-equilibrium" for the streams draining to Crystal Bay. Both Third and Second Creeks also experienced thunderstorm-induced flash floods in 1965 and 1967 respectively that caused large changes in channel characteristics (Glancy, 1988). As such, suspended-sediment loads (per unit amount of water) should be at their highest during this period and attenuate with time (Simon, 1992). Thus, care should be used in interpreting long-term suspended-sediment transport for the northern streams based on data collected only in the early 1970's.