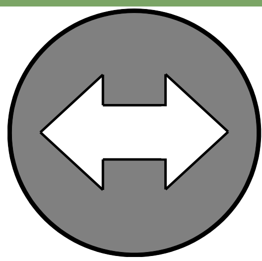
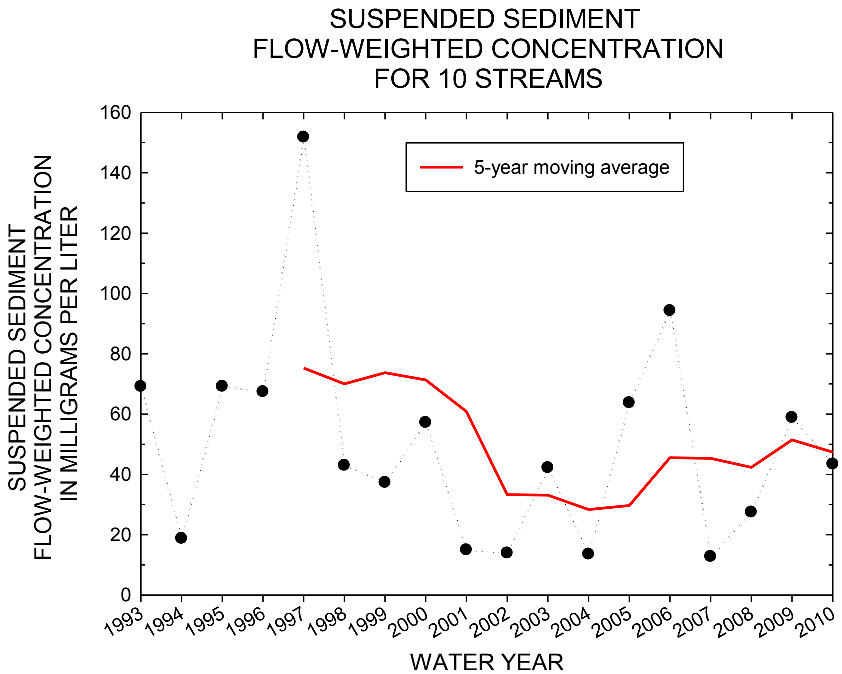
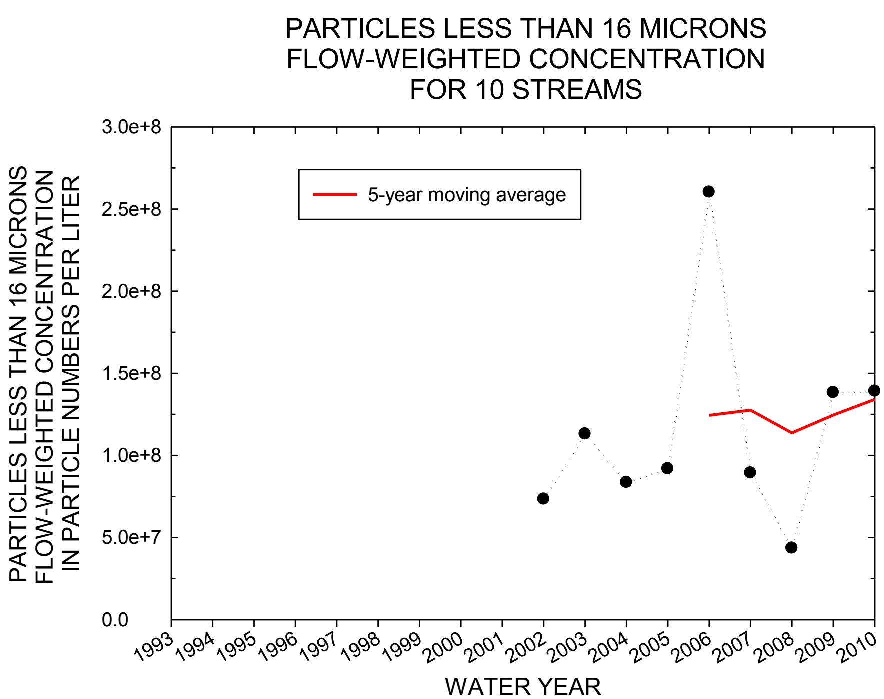
APPENDIX WQ-3. Indicator summaries for nutrient and sediment yearly flow-weighted concentrations (FWC) from 10 monitored streams in the Lake Tahoe Basin (1993 to 2010).

Suspended Sediment and Fine Particles – Combined LTIMP Streams (n=10)

Reporting Icon	Trend
 Status: Unknown - no standard or target has been established Trend: Little or no change Confidence: Moderate	

Map



The ten streams routinely monitored for suspended sediment include five streams in Nevada and five streams in California. Ninety percent of the cumulative total inflow from the monitored streams is from the five California streams, and ten percent is from the five Nevada streams. The sub-watersheds where stream monitoring occurs are colored in the figure above.

The figures show the combined yearly flow-weighted concentration of suspended sediment and

	fine particles in ten regularly monitored Lake Tahoe streams for each water year from 1993 to 2010. Data points represent the value for a single water year (October 1 – September 30) and are calculated as the combined yearly load from the ten streams divided by the combined total yearly inflow. The combined yearly load represents an estimate of the total mass of sediments or nutrients transported by the ten streams to Lake Tahoe during a single water year, based on periodic sampling during each water year. The red line on each plot is the 5-year moving average, a data smoothing technique, which helps to reveal long-term patterns and trends. Stream monitoring data used to calculate flow-weighted concentrations are from the sampling locations closest to where the tributaries discharge to Lake Tahoe.

Data Interpretation and Evaluation

Relevance – Sediment (particularly fine sediment) delivered to Lake Tahoe is known to directly affect the transparency of Lake Tahoe (Lahontan and NDEP 2010). The protection and restoration of the Lake's transparency is a central environmental goal, and Lake transparency is considered a key socioeconomic value. Particles in the water both scatter and absorb light thereby reducing its penetration depth. The Lake Tahoe Total Maximum Daily Load (TMDL) program identified four significant source categories of pollutants: upland watershed (streams), urban stormwater runoff, atmospheric deposition directly to the lake surface, and groundwater infiltration to the Lake (Lahontan and NDEP 2010). LTIMP data was used to evaluate the status and trend of loading of sediment and nutrients to Lake Tahoe from ten streams. As watershed restoration efforts carry on into the future, continued stream monitoring is important to detect changes in the response of stream water quality and provide data used to support management decisions.

Indicator (Unit of Measure) – Flow-weighted concentration (FWC) is calculated as the combined yearly load of sediment or fine particles divided by the combined total yearly stream inflow. Currently a total of 20-35 individual samples are collected each water year from each of the ten streams. FWC measurements are a useful way to better understand pollutant-loading data because it directly accounts for the influence of stream inflow, which can vary greatly among years. Indicators measured include suspended sediment FWC (expressed as milligrams/liter); and fine sediment particle FWC (expressed as number of particles/liter). Fine sediment particles are less than 16 microns in diameter.

Status – During water year 2010 the combined yearly flow-weighted concentration (FWC) for suspended sediment (SS) was 43 milligrams per liter (mg/L), and for fine particles less than 16 microns in diameter it was 1.39×10^8 particles per liter.

Trends – For water years 1993-2010, combined yearly FWC for SS for all ten LTIMP streams ranged between 13 and 152 mg/L, although yearly FWCs typically ranged between 15 and 70 mg/L. Combined yearly FWCs in 1997 and 2006 were uncharacteristically elevated as the result of large streamflow peaks caused by significant rain-on-snow events in those water years. There was no trend observed over the remaining water years. While the five-year moving average appears to decline after the early 2000s, this is more a function of the moving average being influenced by the large 1997 streamflow peak and the associated elevated FWC. Thus, visual inspection of the five-year moving average suggests no trend in FWCs of suspended sediment. Sampling for fine particles less than 16 microns in diameter (PSD) was initiated in water year 2002 when it was established that this particle size could substantially affect lake transparency. For water years 2002-2010, combined yearly FWC for PSD for all ten streams ranged between 0.44×10^8 and 2.60×10^8 particles per liter. Although it is difficult to ascribe a trend to the PSD combined yearly FWC data because of its short collection interval, PSD generally follows SS, with no observable trend. The water year 2006 rain-on-snow event caused a substantial increase in combined yearly FWC for PSD, which influenced the five-year moving average.

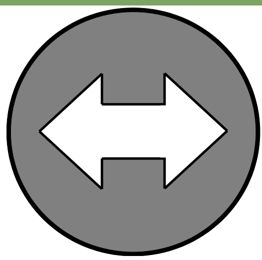
Confidence – There is high confidence in the reliability of the data used to calculate yearly flow-weighted concentrations as the data collection followed national and consistent field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All data, field and laboratory, are subject to extensive quality assurance requirements (USGS 2006). A total of 20-35 individual samples are collected each water year from each of the ten streams. This sampling frequency is considered sufficient to sample during different inflow conditions observed during the water year. The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring sediment, fine particles, and nutrients has been developed and customized for use in aquatic systems where concentrations can be extremely low ((Goldman et al. 2009).

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, there is a significant rain shadow across the lake from west to east where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including, but not exclusive to impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and long-term climate change are considered among the most important environmental drivers of tributary runoff.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s; five in California (Upper Truckee River and Trout, General, Blackwood, and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. Some of the ten streams have had multiple monitoring stations along the tributary and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently, a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The ten primary stations allow for the evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan and NDEP 2010). Reporting of combined yearly loads begins in water year 1993 because that was when the 10th stream was included in the monitoring program. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.
Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service – Lake Tahoe Basin Management Unit.

Total Phosphorus and Soluble Reactive Phosphorus – Combined LTIMP Streams (n=10)

Reporting Icon

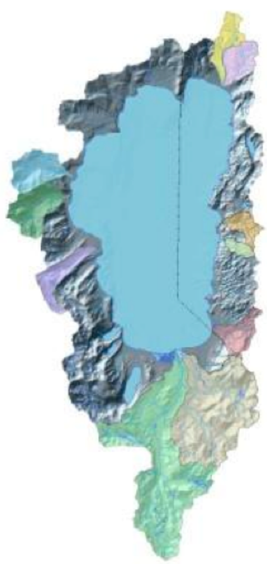


Status: Unknown - no standard or target has been established

Trend: Little or no change

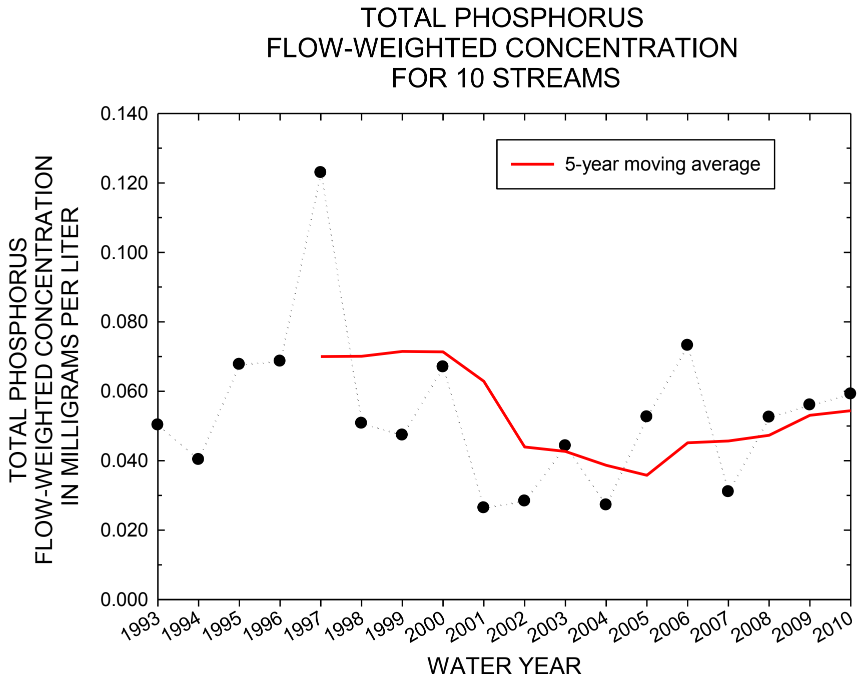
Confidence: Moderate

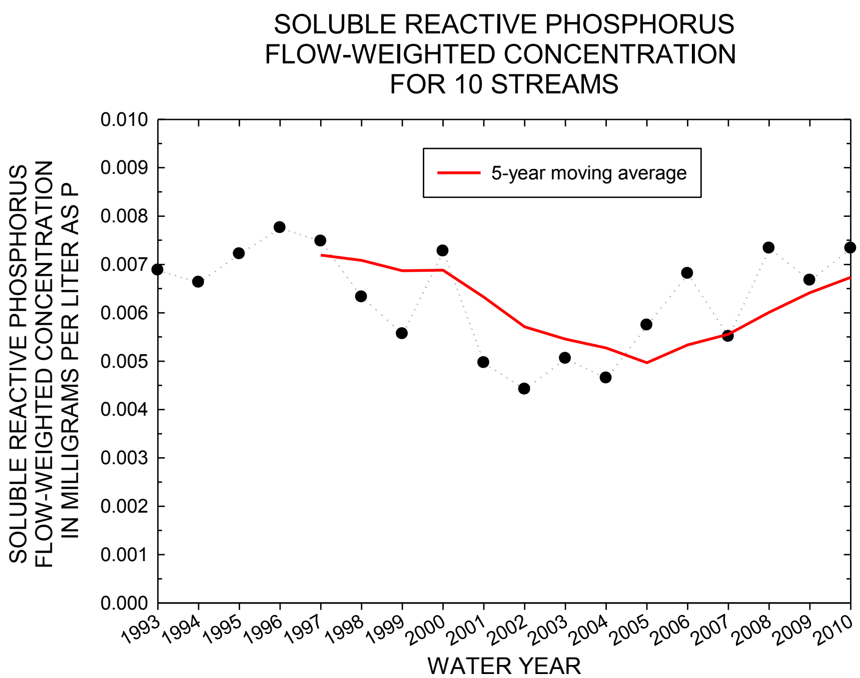
Map



The ten streams routinely monitored for phosphorus include five streams in Nevada and five streams in California. Ninety percent of the cumulative total inflow from the monitored streams is from the five California streams, and ten percent is from the five Nevada streams. The sub-watersheds where stream monitoring occurs are colored in the figure above.

Trend





The figures show the combined yearly flow-weighted concentration of total phosphorous and soluble reactive phosphorus for the ten regularly monitored Lake Tahoe streams for each water year from 1993 to 2010. Data points represent the value for a single water year (October 1 – September 30) and are calculated as the combined yearly load from the ten streams divided by the combined total yearly inflow. The combined yearly load represents an estimate of the total mass of sediments or nutrients transported by the ten streams to Lake Tahoe during a single

	water year, based on periodic sampling during each water year. The red line on each plot is the five-year moving average, a data smoothing technique, which helps to reveal long-term patterns and trends. Stream monitoring data used to calculate flow-weighted concentrations are from the sampling locations closest to where the tributaries discharge to Lake Tahoe.

Data Interpretation and Evaluation

Relevance – Phosphorus is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP 2010). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (TERC 2011a). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis and scattering light. Attached algae coat rocks in the near shore, adversely impacting near shore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). Soluble reactive phosphorus approximates the amount of orthophosphate that is directly available for use by plants, whereas total phosphorus includes all forms of phosphorus that are directly and indirectly available to plants. Phosphorus occurs naturally in the soils of the Lake Tahoe Basin, and is delivered to surface waters and Lake Tahoe through soil erosion and fertilizer runoff (Lahontan and NDEP 2010). LTIMP data was used to evaluate the status and trend of loading of sediment and nutrients to Lake Tahoe from ten streams. As watershed restoration efforts carry on into the future, continued stream monitoring is important to detect changes in the response of stream water quality and provide data used to support management decisions.

Indicator (Unit of Measure) – Flow-weighted concentration (FWC) is calculated as the combined yearly load of total phosphorus (TP) or soluble reactive phosphorus (SRP) divided by the combined total yearly stream inflow. Currently, a total of 20-35 individual samples are collected each water year from each of the ten streams. FWC measurements are a useful way to better understand pollutant-loading data because it directly accounts for the influence of stream inflow, which can vary greatly among years. Indicators measured include total phosphorus FWC (expressed as milligrams/liter); and soluble reactive phosphorus FWC (expressed as milligrams/liter).

Status – During water year 2010 the combined yearly flow-weighted concentration (FWC) for TP was 0.059 milligrams per liter (mg/L), and for SRP it was 0.007 mg/L.

Trends – For water years 1993-2010, combined yearly FWC for TP for all ten streams ranged between 0.026 and 0.123 mg/L. The combined yearly FWC for TP followed a similar pattern to suspended sediment. Phosphorus adsorbs to soils and the two are typically transported together. Even though there are periods over the 1993-2010 record where the five-year moving average shows signs of either improvement or degradation, there is no observable overall trend. For water years 1993-2010, combined yearly FWC for SRP for all ten LTIMP streams ranged from 0.004 to 0.008 mg/L. SRP combined total yearly FWC was not influenced by the peaks in TP. The five-year moving average showed a decline between 1997 and 2005, an increase from 2006 to 2010, but no observable overall trend.

Confidence – There is high confidence in the reliability of the data used to calculate yearly flow-weighted concentrations as the data collection followed national and consistent field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All field and laboratory data are subject to extensive quality assurance requirements (USGS 2006). A total of 20-35 individual samples are collected each water year from each of the ten streams. This sampling frequency is considered sufficient to sample during different inflow conditions observed during the water year. The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring sediment, fine particles, and nutrients has been developed and customized for use in aquatic systems where concentrations can be extremely low ((Goldman et al. 2009).

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, there is a significant rain shadow across the lake from west to east where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including, but not exclusive to impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and long-term climate change are considered among the most important environmental drivers of tributary runoff.

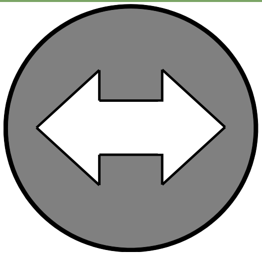
Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s; five in California (Upper Truckee

River and Trout, General, Blackwood, and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. Some of the ten streams have had multiple monitoring stations along the tributary and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently, a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The ten primary stations allow for the evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan and NDEP 2010). Reporting of combined yearly loads begins in water year 1993 because that was when the 10th stream was included in the monitoring program. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.

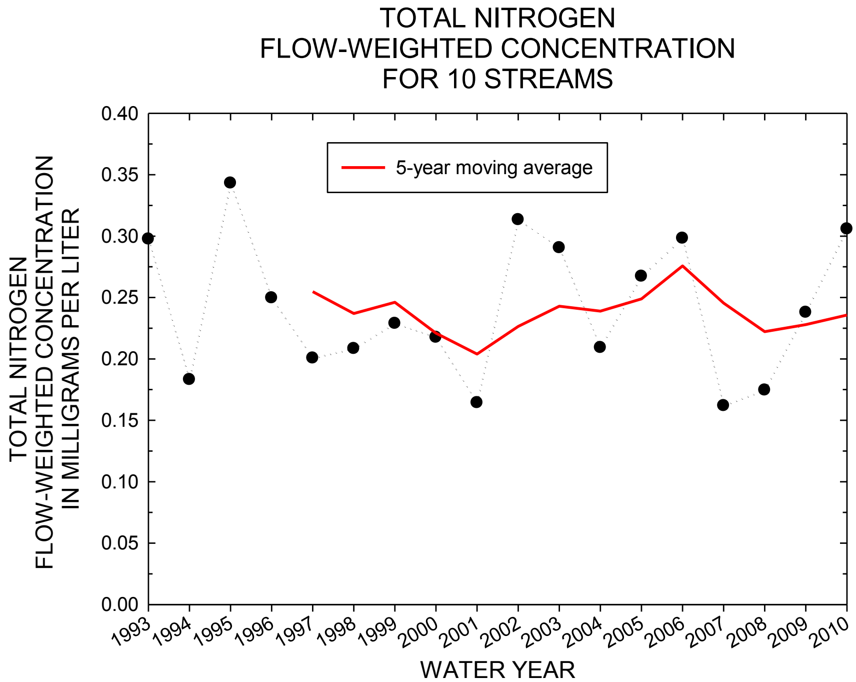
Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service – Lake Tahoe Basin Management Unit.

Total Nitrogen and Nitrate Plus Nitrite – Combined LTIMP Streams (n=10)

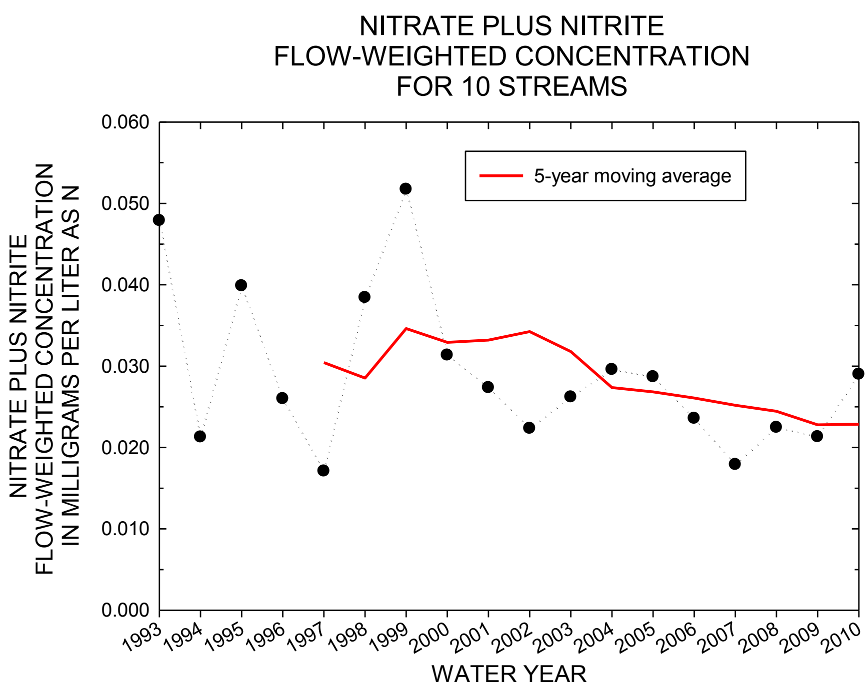
Reporting Icon	Trend



Status: Unknown - no standard or target has been established
Trend: Little or no change
Confidence: Moderate



Map



The ten streams routinely monitored for phosphorus include five streams in Nevada and five streams in California. Ninety percent of the cumulative total inflow from the monitored streams is from the five California streams, and ten percent is from the five Nevada streams. The sub-watersheds where stream monitoring occurs are colored in the figure above.

The figures show the combined yearly flow-weighted concentration of total nitrogen and nitrate plus nitrite (as nitrogen) for the ten regularly monitored Lake Tahoe streams for each water year from 1993 to 2010. Data points represent the value for a single water year (October 1 – September 30) and are calculated as the combined yearly load from the ten streams divided by the combined total yearly inflow. The combined yearly load represents an estimate of the total mass of sediments or nutrients transported by the ten streams to Lake Tahoe during a single water year, based on periodic sampling during each water year. Total nitrogen flow-weighted

	concentrations are determined by adding the flow-weighted concentrations of total Kjeldahl nitrogen and dissolved nitrate plus nitrite-nitrogen. The red line on each plot is the five-year moving average, a data smoothing technique, which helps reveal long-term patterns and trends. Stream monitoring data used to calculate flow-weighted concentrations are from the sampling locations closest to where the tributaries discharge to Lake Tahoe.

Data Interpretation and Evaluation

Relevance – Phosphorus is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP 2010). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (TERC 2011a). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis and scattering light. Attached algae coat rocks in the near shore, adversely impacting near shore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). Soluble reactive phosphorus approximates the amount of orthophosphate that is directly available for use by plants, whereas total phosphorus includes all forms of phosphorus that are directly and indirectly available to plants. Phosphorus occurs naturally in the soils of the Lake Tahoe Basin, and is delivered to surface waters and Lake Tahoe through soil erosion and fertilizer runoff (Lahontan and NDEP 2010). LTIMP data was used to evaluate the status and trend of loading of sediment and nutrients to Lake Tahoe from ten streams. As watershed restoration efforts carry on into the future, continued stream monitoring is important to detect changes in the response of stream water quality and provide data used to support management decisions.
Indicator (Unit of Measure) – Flow-weighted concentration (FWC) is calculated as the combined yearly load of total nitrogen (TN) or dissolved nitrate plus nitrite (N+N) as nitrogen divided by the combined total yearly stream inflow. Total nitrogen flow-weighted concentrations are determined by adding the flow-weighted concentrations of total Kjeldahl nitrogen and dissolved nitrate plus nitrite-nitrogen. Currently, a total of 20-35 individual samples are collected each water year from each of the ten streams. FWC measurements are a useful way to better understand pollutant-loading data because it directly accounts for the influence of stream inflow, which can vary greatly among years. Indicators measured include total nitrogen FWC (expressed as milligrams/liter); and nitrate plus nitrite as nitrogen FWC (expressed as milligrams/liter).
Status – During water year 2010, the combined yearly flow-weighted concentration (FWC) for total nitrogen (TN) was 0.31 milligrams per liter (mg/L), and for dissolved nitrate plus nitrite-nitrogen (nitrate) it was 0.029 mg/L as nitrogen (N).
Trends – For water years 1993-2010, combined yearly FWC for TN for all ten streams ranged from 0.16 to 0.34 mg/L. While combined yearly FWC for TN exhibited inter-annual variability, there is no observable overall trend. For water years 1993-2010, combined yearly FWC for N+N for all ten LTIMP streams ranged from 0.017 to 0.052 mg/L as N. There was considerable inter-annual variability in the N+N combined yearly FWC between water years 1993-1999; however, since 2000 the variability has declined with the five-year moving average dropping from 0.35 mg/L as N prior to 2000, to 0.023 mg/L as N in 2010.
Confidence – There is high confidence in the reliability of the data used to calculate yearly flow-weighted concentrations as the data collection followed national and consistent field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All field and laboratory data are subject to extensive quality assurance requirements (USGS 2006). A total of 20-35 individual samples are collected each water year from each of the ten streams. This sampling frequency is considered sufficient to sample during different inflow conditions observed during the water year. The stream monitoring program focuses on event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring sediment, fine particles, and nutrients has been developed and customized for use in aquatic systems where concentrations can be extremely low ((Goldman et al. 2009).
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Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service – Lake Tahoe Basin Management Unit.