Evaluation of Constituent Loading

Final Draft

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INTRODUCTION

The purpose of this task was to estimate the loads of key constituents into the lower Klamath River from Iron Gate Reservoir to its mouth and from point sources (i.e., wastewater discharges), the major tributaries (i.e., the Shasta, Scott, Salmon, and Trinity Rivers), and the approximately thirty minor tributaries to the mainstem. To manage water quality in this portion of the Klamath River to support existing and proposed uses, it is essential to know the sources of those constituents that potentially could have significant impacts on the dissolved oxygen, nutrients, and transparency of the River in space and time and subsequently on phytoplankton and other vegetation concentrations and on fish populations.

The focus of this report is the loading of nitrogen and phosphorus in and to the lower Klamath River during the CY2001 through CY2005 period, specifically the June through October sampling period in each year. Other constituents were of interest as well, namely dissolved inorganics, dissolved organics, suspended substances, and phytoplankton. Because the Arcata Fish and Wildlife Office (AFWO) grab sample database is the primary source of constituent concentration data used to estimate these loads and at the time this work was initiated it was limited mainly to these five years, these years were the logical ones of choice, and because sampling is limited mainly to the June through October period, those are the months of choice.

APPROACH

The area of study is that portion of the Klamath River watershed below Iron Gate Reservoir shown in Figure 1. It is referred to hereafter at the Study Area.

To estimate constituent loads to the Study Area, two key pieces of information were required – flows and constituent concentrations. The product of flow (volume per time) and concentration (mass per volume) is load (mass per time). Of interest next are the sources of those loads, and those sources fall into four major categories: (1) the upstream load into the Study Area (in this case the release from Iron Gate Reservoir which is the upper boundary condition for the Study Area); (2) major tributaries that are typically gauged for flows and monitored for constituent concentrations and for which constituent loads may be estimated; (3) point source loads that discharge directly to the River or that discharge to a tributary, in which case the point source load can be separated from the tributary load as appropriate; and (4) minor tributary loads again to the River directly or to the tributary. To the extent that the point source and non-point source loads are controllable, they need to be estimated separately from tributary loads for management purposes. For this report, loads attributed to releases from Iron Gate Reservoir and those that could be estimated for the four major tributaries, the Shasta, Scott, Salmon, and Trinity Rivers, and the minor tributaries are included. Point source loads may be needed at some point, and self-reporting data available from the U.S. Environmental Protection Agency or the appropriate California agency can be used to estimate loads directly or through Typical Pollutant Concentrations, i.e., typical concentrations of nitrogen and phosphorus in wastewater discharges based on levels of treatment provided and the nature of the raw wastewater being treated.

Flow information is of course available from the U.S. Geological Survey for gauged stations within the Study Area, and those flow data have been obtained and analyzed in Task 1, Hydrology Review, by Ward and Armstrong (2006). Constituent concentrations are available in the grab sample database compiled by the AFWO and processed for data quality by Armstrong and Ward (2005).

Several key constituents were to be included in these load estimates, namely dissolved inorganics, dissolved organics, suspended substances, nutrients, and measures of phytoplankton. The dissolved inorganics, measured by Total Dissolved Solids or TDS, provide information about the water quality environment and its suitability for intended uses such as drinking water, irrigation agriculture, and aquatic life support, but it also provides a means to determine how well mass balances are being achieved – its primary purpose as a conservative material in this study in the lower Klamath River. If mass balances for conservative materials are not being achieved, then it not likely that mass balances for non-conservative materials are being achieved either.

Concentrations of organic materials may indicate the load that oxygen demanding materials are having on dissolved oxygen resources of the River. These concentrations may be estimated in several ways, but the constituent to be used in this study total organic carbon (TOC) and the measurement technique is limited to dissolved or colloidal sized forms of organics. Materials suspended in the water column that may decrease water transparency are made up of inorganic and organic materials, and they may be measured as total suspended solids (TSS). The primary nutrients supporting the growth of phytoplankton and other vegetative forms are measured by total nitrogen and total phosphorus, although the bioavailable forms of these nutrients make up only a portion of the total concentrations. Total nitrogen is determined as the sum of organic (total Kjeldahl nitrogen minus ammonia nitrogen) and inorganic nitrogen (the bioavailable forms - ammonia nitrogen plus nitrite nitrogen plus nitrate nitrogen) and total phosphorus (with bioavailable phosphorus estimated as orthophosphorus). Finally, measures of living and dead phytoplankton and other vegetative forms that have become suspended are estimated from chlorophyll and pheophytin concentrations, respectively.

In water quality management, the most compelling way to determine relationships between in-stream concentrations of nutrients and point and non-point loads, a desired outcome of this study and the focus of Task 3, is through mass balances and through mass balance-based water quality modeling. Based on the principle of conservation of mass and continuity of flow, a mass balance for some constituent such as a nutrient assumes that the mass flux downstream from the confluence of two or more inputs is the sum of the individual mass fluxes from those inputs. Again, for water quality constituents, the mass flux is the product of flow times constituent concentration, so by determining flows and concentrations for the inputs as well as downstream, it is possible to estimate the influence of an input constituent concentration on the downstream concentration of that same constituent.

The practical application of this concept for the Klamath River is to determine concentrations of a constituent like phosphorus in the Klamath River below the confluence of a tributary and the mainstem or a waste discharge to a tributary. By determining the flows and concentrations of phosphorus in the tributary and in the Klamath River upstream of the confluence point, it is possible to calculate the phosphorus concentration downstream of that point. In addition to calculating downstream constituent concentrations immediately below the confluence of the mainstem and a tributary, it is also desirable to calculate the constituent concentrations at points downstream from the confluence. For substances like phosphorus that are known to interact with living and nonliving components of a riverine environment, there may be a net loss of phosphorus mass from the water column as it is taken up by vegetation, adsorbed to sediments and other surfaces, and perhaps lost in other ways from the water column. This mass lost must be accounted for in a mass balance-based model, and it is generally represented as a first order reaction unless the kinetics of the phenomena causing the losses are well known.

It is clear that mass loads of water quality constituents entering the lower Klamath River have major impact on the constituent loads in the River and that these loads translate into concentrations of these constituents which in turn can be judged to have impact on the uses of the River. The approach of this task is then to use constituent concentrations in the AFWO water quality database coupled with flows to estimate constituent loads to the Lower Klamath River from the Iron Gate Reservoir release and the major and minor tributaries and to track these loads downstream in the River.

METHODS

Nutrient loads were expressed as monthly average loads which were calculated as average monthly flows times average monthly concentrations. This is a rather simple yet effective way of estimating nutrient flux in the lower Klamath River mainstem as well as point source and major and minor tributary nutrient fluxes as well. Thus, for each month from June through October in calendar years 2001 through 2005, monthly average nutrient loads were estimated and presented in tabular form in a way that river segment mass balances could be performed. Load yields (i.e., load per unit drainage area) were also determined as a way to compare one drainage area to another in terms of nutrient yield. The detailed methodology used to perform these calculations is given below.

Flow Data

Flow data were available at the U.S. Geological Survey gaging stations listed in Table 1 and shown in Figures 1 and 2 for the lower Klamath River mainstem and for the major tributaries. Average monthly flows at these USGS stations were estimated by Ward and Armstrong (2006) over the period of record, but for this study only average monthly flows for the months (June through October) and years (CY2001 through CY2005) for which loads were estimated were used.

To estimate constituent loads in the mainstem of the Klamath River, average monthly flows for June through October of CYs 2001 through 2005 were used at the following USGS gaging stations:

Iron Gate Reservoir release (gage no. 11516530);
Klamath River near Seiad Valley (gage no. 11520500);
Klamath River near Orleans (gage no. 11523000); and

Klamath River at Klamath (gage no. 11530500).

For the major tributaries, average monthly flows for the same months and years at the following USGS gages were used:

Shasta River near Yreka (gage no. 11517500);
Scott River near Fort Jones (gage no. 11519500);
Salmon River (gage no. 11522500); and
Trinity River at Hoopa (gage no. 11530000).

For the minor tributaries in the lower Klamath River watershed, flows in each tributary watershed were estimated by translating the average monthly flow yields (in inches/month) determined by Ward and Armstrong (2006) for that tributary regions into flow/time per area period (cfs/mi^2), the equivalent of inches/month, and then multiplying that number times the watershed area to get the average flow (cfs) for that month. From the data given in Table 1 and Figure 2, it may be determined that the ungaged watershed areas are 854 mi^2 of ungaged tributaries between the Iron Gate Reservoir release point and the Scott River confluence with the Klamath River, 650 mi^2 between the Scott River confluence and the Salmon River confluence, and 1,772 mi^2 between the Salmon River confluence and the Klamath River at Klamath gage.

Constituent Concentration Data

Constituent data were available at the stations sampled by AFWO and contained in the ACCESS database analyzed by Armstrong and Ward (2005), and for the most part their stations were at or close to the USGS gaging stations. In some instances they were not; nevertheless, nutrient loads were estimated as if they were. For these gaged mainstem and tributary stations, nitrogen and phosphorus loads were estimated over the five year time period using monthly average flows for each month throughout the June through October period each year. Again, these flows were obtained from Ward and Armstrong (2006).

As a start, average monthly values were obtained for all constituents in the AFWO ACCESS database at all stations and at all months in which samples were taken using the Cross-tab query feature of ACCESS. Not only were monthly average values estimated, but counts of analytical results for each constituent were also obtained.

As this data gathering proceeded, it became evident that analytical detection limits had changed over the years for constituents of interest and that some of these detection limits were high enough that many of the values for some constituents were below those detection limits. A compilation of these detection limits by analyte, station, and year is given in Table 2, and it is clear that MDLs have varied over time and among stations for most of the analytes listed. Thus, a decision had to be made about how to handle non-detects in the database, i.e., whether to substitute a value for below detection entries and if so what should that value be.

Chapman (1992) and Berthouex and Brown (1994) note that frequently water samples contain concentrations of chemical constituents which are below the limit of detection of the technique being used. These results may be reported as “not detected” (ND), less-than values (< or LT), half limit-of-detection (0.5 LOD), or zeros. The resulting data sets are thus artificially curtailed at the low-value end of the distribution and are termed *censored*.

Censoring can produce serious distortion in the output of statistical summaries such as mean values that might be used for computation of nutrient loads. There is no one, best approach to this problem, and judgment is necessary in deciding the most appropriate reporting method for the study purposes. Possible approaches are:

i. compute statistics using all measurements, including all the values recorded as < or LT;
ii. compute statistics using only “complete” measurements, ignoring all < or LT values;
iii. compute statistics using only “complete” measurements, but with all < or LT values replaced by zero;
iv. compute statistics using only “complete” measurements, but with all < or LT values replaced by half the LOD value;
v. use the median which is insensitive to the extreme data;
vi. “trim” equal amounts of data from both ends of the data distribution and then operate only on the doubly truncated data set;
vii. replace the number of ND, or other limited data, by the same number of next greater values, and replace the same number of greatest values by the same number of next smallest data (termed Winsorization); and
viii. use “maximum likelihood estimator” (MLE) techniques.

To derive, as a minimum summary, measures of magnitude and dispersion, approach (iv) is simple and acceptable for mean and variance estimates; the biases introduced are usually small in relation to measurement and sampling errors. If < or LT values predominate, then use approach (i) and report the output statistics as “<” values (Chapman 1992). Berthouex and Brown (1994) caution that these methods may work for up to 15-25% censored data, but within that range and beyond the results suffer from increased bias and variability.

The effects of non-detects (NDs) on general statistics of the major nutrient concentrations for the stations used in the nutrient loading estimates were determined. While the results given below are for all measurements of each analyte in the AFWO Klamath River database, one should assume that the values used to estimate nutrient loads at a given station and for a given month would be a sample of this larger population and thus reflect the results found for the sample population.

If the analytes are aggregated by percent ND’s into three groups, those with less than 15% ND’s, those with 15 – 25% ND’s, and those with greater than 25% ND’s, the following results are obtained:

<15%	total N, organic N, nitrite N + nitrate N, total P
15 – 25%	orthophosphorus
>25%	total Kjeldahl N, ammonia N, nitrite N, nitrate N

Clearly, it is difficult to have much confidence in the TKN, ammonia N, nitrite N, nitrate N, and orthophosphorus data whereas one can have high confidence in the total N, organic N, nitrite N + nitrate N, and total phosphorus data. The latter three analytes have been used for only short periods between 2001 and 2005.

Relating this incidence of NDs to the effects on estimates of the mean and median values, one finds the following. In Table 3, mean values are given for total nitrogen, total Kjeldahl nitrogen, organic nitrogen, ammonia nitrogen, nitrate + nitrite nitrogen, nitrate nitrogen, nitrite nitrogen, total phosphate, and orthophosphate and for the condition in which the MDL is substituted for a ND, the MDL/2 is substituted for a ND, and zero is substituted for a ND. Also given are the number of data values, n, and the percent of values that are represented by ND's. For example, there are 28 values of total nitrogen available and, of those, 7.1% are ND's. The mean for the case of ND = MDL is 0.741 mg/L, for ND = MDL/2 it is 0.737 mg/L (a 0.5% decrease), and for ND = 0 it is 0.734 mg/L (a 0.9% decrease). Thus, with a low incidence of ND's, the measure of central tendency changes little. On the other hand, for ammonia nitrogen, n = 503 and 78.3% of those values are ND's. One would expect a significant effect of the assumptions about ND's on the mean, and there is. The mean for the case of ND = MDL is 0.118 mg/L, for ND = MDL/2 it is 0.078 mg/L (a 33.9% decrease), and for ND = 0 it is 0.038 mg/L (a 67.8% decrease) – significant changes for different assumptions about the ND values.

As results are examined for the other constituents and the influence of ND's noted, it is clear that the larger the number of ND's, the more impact on variation in the mean. Normalizing the effects of ND's on the means by calculating the percent change among the three combinations of the means (see Table 3) and graphing the results, it is clear that the higher the percent of ND's the higher the percent difference among the means as illustrated in Figure 3. The term "bias" used in the graph refers to the percent change in the mean caused by one of the substitutions for ND's. If it is assumed that 15 - 25% ND's is the range at which bias begins to be a problem (as noted above), then the bias is on the order of about 5 - 10% in the loading estimates based on estimated concentrations alone.

Based on these results, the following conclusions were drawn about how to deal with non-detects and their impact on nutrient analyte concentrations and loads derived from them:

1. Substitution for ND values should continue to be the MDL/2, for this is a conventional approach and recommended in the scientific literature and for the Klamath River data will provide a midpoint of loads between the other two assumptions;
2. High confidence can be placed in the total nitrogen data now being collected as long as a low MDL is used, but low confidence must be assumed for most of the nitrogen load estimates for the most of the years and months because of the high percentage of ND's; and
3. Highest confidence can be placed in the total P data because of the very small percentage of ND's.

Constituent Loads

Constituent loads were determined for Total Nitrogen (TN), Total Phosphorus (TP), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Organic Carbon (TOC), and Chlorophyll a. Because the calculation procedure is the same overall for all of the constituents, TN and TP will be used to show the calculation methodology.

To estimate nitrogen and phosphorus loads in the lower Klamath River, estimates of TN and TP were needed as opposed to component species of these two nutrients. This is true for the other constituents as well, but it was possible to determine their concentrations through direct measurement, whereas for TN it was necessary to estimate TN from component forms of nitrogen first before loads could be calculated. TP on the other hand was determined directly analytically.

Based on the nitrogen and phosphorus forms in the database, there are three ways to estimate TN concentrations and only one way to estimate TP concentrations. The nitrogen forms measured and in the AFWO database are: Ammonia Nitrogen; Nitrate (as Nitrogen); Nitrite (as Nitrogen); Nitrogen-Total Kjeldahl; Organic Nitrogen-N; and Total Kjeldahl Nitrogen. Clearly, Nitrogen-Total Kjeldahl and Total Kjeldahl Nitrogen are the same analyses but just have been given different names by the analytical laboratories; the latter is the name used in 2005 results, and the former for the rest of the years. Phosphorus is represented by Total Phosphate Phosphorus and by Orthophosphate Phosphorus, and it is assumed that the concentrations are expressed as phosphorus, not phosphate.

For TN, the estimating method is as follows:

$$TN = TON + TIN \tag{1}$$

where

TON = Organic Nitrogen-N <u>or</u> (Total Kjeldahl Nitrogen - Ammonia Nitrogen) <u>or</u> (Nitrogen Total Kjeldahl - Ammonia Nitrogen) (2)

and

TIN = [Ammonia Nitrogen + Nitrite (as Nitrogen) + Nitrate (as Nitrogen)] <u>or</u> (Nitrite + Nitrate). (3)

Thus, there are three ways to estimate TON (Equation 2) and two ways to estimate TIN (Equation 3); one involves addition, two involve subtraction, and two are direct. For one of the direct ways (i.e., use of Organic Nitrogen-N), the result was almost certainly obtained from a subtraction (i.e., TKN - Ammonia N) because there is no direct analytical method for organic-N, although it is difficult to confirm that this subtraction is based on the TKN and Ammonia-N data in every case.

For the purpose of this study, monthly average TON concentrations were estimated by each of the three ways possible and monthly average TIN concentrations by each of the two ways possible. If more than one result was obtained depending on values available for the analytes used in the ways to calculate TON and TIN, then the results were averaged to yield the value used in the mass loading calculations. If only one result was obtained, then it was used. In this way, as much of the data was used as possible for a single station. Now, using monthly averages rather than single values diminishes the effect of ND's except for the Nitrite (as Nitrogen) values; there are so many ND's for Nitrite that the DL values used as estimates of the actual nitrite values essentially represent most of the values used. Because nitrite nitrogen concentrations are normally very small, these DL estimates of concentrations will most certainly yield estimates of nitrite nitrogen and hence TIN and TN that are higher than they most likely are. This could skew comparisons of TIN values from one year to the next depending on the DL's used for nitrite-N.

In the final analysis, then, the following "business rules" were adopted to estimate TON, TIN, and TN and TN loading as well as TP and TP loading:

> Monthly average loads were calculated as monthly average flows multiplied by monthly average TN and TP concentrations. Monthly average TN and TP concentrations were based on monthly averages of nutrient forms available from AFWO field sampling. Concentrations below detection limits were assumed to be ½ the MDL and were set to MDL/2.
>
> Analyte form names in the AFWO database were assumed to be the following:

Ammonia Nitrogen	Assumed to be NH3-N
Nitrate (as Nitrogen)	Assumed to be NO3-N
Nitrate + Nitrite	Assumed to be NO3-N + NO2-N
Nitrite (as Nitrogen)	Assumed to be NO2-N
Nitrogen-Total Kjeldahl	Assumed to be TKN-N
Organic Nitrogen-N	Assumed to be Org-N
Orthophosphate Phosphorus	Assumed to be Ortho-P
Total Kjeldahl Nitrogen	Assumed to be TKN-N
Total Nitrogen	Assumed to be TN
Total Phosphate Phosphorus	Assumed to be Total P

> Total Nitrogen (TN) = Total Nitrogen (TN) or
> Total Nitrogen (TN) = Total Organic Nitrogen (TON) + Total Inorganic Nitrogen (TIN)
> Total Inorganic Nitrogen (TIN1) = Ammonia-N (NH3-N) + Nitrite-N (NO2-N) + Nitrate-N (NO3-N) or
> Total Inorganic Nitrogen (TIN2) = Ammonia-N (NH3-N) + Nitrite-N + Nitrate-N (NO3-N+NO2-N)
> Total Organic Nitrogen (TON1) = Organic-N (Org-N) or
> Total Organic Nitrogen (TON2) = Nitrogen-Total Kjeldahl (TKN) - Ammonia-N (NH3-N) or
> Total Organic Nitrogen (TON3) = Total Kjeldahl N (TKN) - Ammonia-N (NH3-N)
> Total Phosphorus (TP) = Total Phosphate Phosphorus
> Orthophosphorus (Ortho-P) = Orthophosphate phosphorus

These "business rules" were incorporated into the spreadsheets created from the Cross-tab queries for the AFWO water quality database so that for each station, each year of sampling at that station, and each month of each year a monthly average concentration of each analyte monitored at that station and that month was calculated. Then, for each Klamath River mainstem station and each major tributary station used in this study, monthly averages of TN and TP for the 2001 through 2005 years and the June through October months in each of those years were compiled into matrices with months representing columns and years representing rows. These matrices of monthly average concentrations for TN and TP were then copied into the nutrient loading spreadsheet.

In the nutrient loading spreadsheet, the average daily flow for the month for each Klamath River mainstem station and each major tributary were loaded in the same general format as the matrices of TN and TP concentrations. Also, flows for the minor tributary areas were compiled in a similar fashion but with flows calculated as described below.

Formulas were then created in the spreadsheet to calculate TN and TP loads for the mainstem, major tributary, and minor tributary stations. The equation used to calculate monthly constituent loads was:

$$\begin{aligned} W(\text{kg/mo}) &= Q\left[\frac{\text{ft}^3}{\text{sec}} \bullet \frac{28.32\text{L}}{\text{ft}^3} \bullet \frac{86{,}400\text{sec}}{\text{d}}\right] \bullet S\left[\frac{\text{mg}}{\text{L}} \bullet \frac{\text{kg}}{10^6\,\text{mg}}\right] \bullet n\left[\frac{\text{d}}{\text{mo}}\right] \\ &= 2.446848 \bullet Q(\text{cfs}) \bullet S(\text{mg/L}) \bullet n(\text{d/mo}) \end{aligned} \tag{4}$$

where monthly average flow values, Q, provided by Ward and Armstrong (2006) were obtained from daily average USGS flow values in units of ft^3/sec and monthly average constituent concentrations obtained in this study (as described below), S, are in units of mg/L. The constant value of 2.446848 is a unit conversion factor, and n is the number of days in each of the months of June through October. For example, for an average daily flow of 235 cfs, a monthly average total phosphorus concentration of 0.12 mg/L, and the month of say July, the load is calculated to be 2,139 kg/mo (2.446848 x 235 cfs x 0.12 mg/L x 31 d/mo).

To estimate constituent loads from the ungaged tributary areas, constituent yields from adjacent gaged areas were used as estimates of the yields from the ungaged areas, or

$$\begin{aligned} W(\text{kg/mo}) &= Y\left(\frac{\text{in}}{\text{mo}}\right) \bullet A_{ug}(\text{mi}^2) \bullet S\left(\frac{\text{mg}}{\text{L}}\right) \bullet \left(\frac{\text{kg}}{10^6\,\text{mg}}\right) \bullet n\left(\frac{\text{d}}{\text{mo}}\right) \\ &= Y\left(\frac{\text{cfs}}{\text{mi}^2}\right) \bullet A_{ug}(\text{mi}^2) \bullet S\left(\frac{\text{mg}}{\text{L}}\right) \bullet \left(\frac{\text{kg}}{10^6\,\text{mg}}\right) \bullet n\left(\frac{\text{d}}{\text{mo}}\right) \\ &= 2.446468 \bullet Q(\text{cfs}) \bullet S\left(\frac{\text{mg}}{\text{L}}\right) \bullet n\left(\frac{\text{d}}{\text{mo}}\right) \end{aligned} \tag{5}$$

where the Q (cfs) values were obtained from Ward and Armstrong (2006) and the values for constituent concentration were the average values over the five calendar years for a USGS gaging station considered to drain a watershed which represented the relatively undeveloped characteristics of the ungaged watershed throughout the lower Klamath River. For this study, that watershed was the Salmon River and the average concentration was determined at the gaging station near its mouth. This river was selected because of its relatively undeveloped nature and the assumption that constituent concentrations would represent background levels.

Once TN and TP loads were estimated, these monthly loads were arranged for each calendar year so that they reflected the geographic position of mainstem station or the location of the confluence of the major or minor tributaries. The order of the values for each month of each calendar year was as follows:

Calendar year 200_	**Gage No.**
Klamath at Iron Gate	11516530
Tributaries:	
Shasta near Yreka	11517500
Scott near Ft Jones	11519500
Total	
Nongauged	
Total intervening	
Klamath near Seiad Valley	11520500
Tributaries:	
Salmon at Somes Bar	11522500
Nongauged	
Total intervening	
Klamath at Orleans	11523000
Tributaries:	
Trinity at Hoopa	11530000
Nongauged	
Total intervening	
Klamath at Klamath	11530500

Similar analyses were performed for TDS, TSS, TOC, and Chlorophyll a.

The final step of this analysis was to check for a constituent mass balance between the main gaging stations on the Klamath River, i.e., between the Iron Gate and Seiad Valley gages, the Seiad Valley and Orleans gages, and the Orleans and Klamath gages. A flow balance existed because Ward and Armstrong (2006) estimated the intervening (i.e., ungaged or minor tributaries) flows assuming a flow balance. However, as noted above, the constituent loads were determined independently based on measured concentrations at the Klamath and major tributary stations and estimated minor tributary concentrations, so a mass balance may or may not exist. By calculating the difference between the downstream Klamath River constituent load and the upstream Klamath River constituent load from the major tributaries and nongauged areas, a mass balance was achieved if this difference was zero or very close to it. If the difference was negative, then there was a loss of mass in the river which would be typical for non-conservative substances, i.e., substances subject to decay, settling, or other mechanisms of loss from the water column. If the difference was positive, then there was a gain of mass presumably due to an instream source or growth in the case of vegetation represented by Chlorophyll a. Given the errors associated with substitution of values for NDs and the normal sampling and analytical errors, one must view these differences with caution, for unusual concentration variations can produce erratic mass balance results. This issue is addressed further in the Task 3 report, Coherence of Nutrient Loads and AFWO Klamath River Grab Sample Water Quality Database (Armstrong and Ward 2008).

RESULTS

Excel workbooks were created for each constituent (although a single workbook was used for TN and TP). These workbooks contained the following:

1. a set of "business rules" detailing the AFWO grab sample database constituents used and the equations used(if needed) to calculate the final constituent form used in the loading calculations;
2. a table containing the average monthly flows for the months of June through October for CYs 2001 through 2005 for each gauged station, the average monthly constituent concentrations as they were available and calculated as described above, the constituent loads (kg/mo) and their monthly yields (kg/mi^2) for the drainage area, and estimates of non-gauged tributaries using the Salmon River monthly average values of the five calendar years of sampling as the estimated monthly concentrations;
3. a table compiling the constituent loads into a table for all five calendar years and each of the five months in the order described above so that for each segment of the river (the distance between major gauging stations) the constituent loads at the gauging stations and the intervening major and minor tributary loads; and
4. final tables, one for each calendar year, containing the constituent loads by month from the previous table.

The contents of these workbooks are reproduced in the appendices and provide the basic information used for the results presented below.

Monthly Flows

Monthly average flows in the Klamath River and its tributaries are documented in Ward and Armstrong (2006) and Armstrong and Ward (2008). For the study area of the Klamath River, flows originate at Iron Gate Reservoir (RM 189.8 or 0 miles downstream from the reservoir) and increase downstream as measured at gages near Seiad Valley (RM 128.5 or 61.3 mi downstream), near Orleans (RM 59.1 or 130.7 mi downstream), and at Klamath (RM 6.7 or 183.1 mi downstream). Drainage areas and river miles are given in Table 1. Inflows from tributaries and adjacent areas reach the river from the drier portions of the drainage basin upstream to the wetter portions downstream. These same reports show the annual variation at Klamath with CY2001 having the lowest annual average flow at 252 cms, CY2003 and CY2005 the highest at 479 cms and 476 cms, respectively, CY2002 and CY2004 are close to being the same at 398 cms and 417 cms, respectively.

Flows in the lower Klamath River exhibited distinct downstream trends as well as seasonal patterns in 2001 through 2005, particularly in June through October, the months in which constituent loads were estimated and constituents modeled. Flows out of Iron Gate Reservoir averaged about 30 cms over the entire period modeled and changed little from month to month (see flows in Table 4). Downstream, flows were generally rather constant or increased only slowly for the first 230 km even with the entrance of the Shasta River 23.7 km downstream and the Scott River 86.7 km downstream. It was not until the Salmon River entered at 230 km and the Trinity River at 272 km downstream that significant flow changes were observed. This was especially true from August through October for each year of 2001 through 2005. Significantly greater increases were observed, however, downstream in June and to a lesser extent July due to high inflows from the tributaries.

Releases from Iron Gate Reservoir in June 2001 averaged 53.7 cms, the highest during the entire period modeled, and averaged about 35.5 cms from July through October (see Table 4 and Figure 4). Downstream flows in June increased significantly below the 230 km point where the Salmon River enters the Klamath River and at the 272 km point where the Trinity River enters reaching 170.1 cms near Klamath (considered to be same as Terwer here). Monthly flows from July through October in CY2001 averaged between 73.7 and 97.6 cms (see Table 1 and Figure 4). The higher rainfalls nearer the coast in June accounted for the increased runoff, particularly in the Trinity River.

The flows in 2002 were similar to 2001 although the June release from Iron Gate was about half that of June 2001 (Table 4). Again, major flow increases occurred downstream at the confluences with the Salmon and Trinity Rivers (Figure 5).

In 2003 these patterns were repeated except that June and July downstream flows increased significantly more than in 2001 and 2002 (see Table 4 and Figure 6). Inflows from the Scott, Salmon, and Trinity Rivers were particularly significant as were those from the minor tributaries due to high rainfalls. From August through October flows downstream were reduced and similar from month to month.

Flows in 2004 were close to those in 2003 except in June and July. Releases from Iron Gate in June were 27.0 cms while those in July were 19.1 cms, and flows at Terwer were almost 10 times those at Iron Gate in June and over just three times those at Iron Gate in August through October (Table 4). Clearly significant inflows occurred downstream in June and July (Table 4 and Figure 7).

In 2005, releases from Iron Gate Reservoir again averaged around 32 cms shown in Table 4 and Figure 8. The downstream flows in June increased dramatically with inflows from the major and minor tributaries, particularly the Salmon River and especially the Trinity River, reaching 409 cms near Klamath. As in 2003, flows were significantly reduced in July then from August through October were reduced and similar from month to month.

Monthly Nutrient Concentrations

Average monthly concentrations for CY2001 to CY2005 of TN and TP are presented in Figures 9a and 9b along with those for TDS, TSS, TOC, and Chlorophyll-a. All of these constituent concentrations tend to decrease downstream. Some of this decrease is due to dilution by the inflowing tributaries and some due to physical/chemical/biological kinetics that would account for the loss of both nutrients during transport downstream.

TN concentrations decrease from an average concentration of 0.97 mg/L at Iron Gate steadily downstream to 0.4 mg/L at Terwer (see Figure 9a). For comparison of these values to those found in the U.S. Environmental Protection Agency’s Ecoregion II (see USEPA 2000), in which the Klamath River basin lies, the median of the seasonal medians of TN is 0.28 mg/L, the median 75^{th} percentile is 0.54 mg/L, and the median 95^{th} percentile is 1.86 mg/L. Thus, the concentrations near Iron Gate are between the 75^{th} and 95^{th} percentiles while those at Terwer are between overall median and the 75^{th} percentile. In other words, these values are in the upper portion of the distribution of TN in Ecoregion II. Similarly, TP decreases from 0.14 mg/L to 0.03 mg/L at Terwer (see Figure 9a), and like TN the concentrations at Iron Gate are between the 75^{th} and 95^{th} percentiles, 0.055 mg/L and 0.173 mg/L, respectively. The concentration at Terwer is at the overall median of 0.03 mg/L.

TDS concentrations are relatively constant from concentrations averaging 130 mg/L from Iron Gate to Happy Camp and from there decreasing downstream to 94 mg/L at Terwer (see Figure 9a). As a conservative material, the TDS decreases reflect dilution effects of the lower TDS tributaries, the Salmon and Trinity Rivers, and the adjacent drainage areas inflowing to the Klamath River in the lower half of the basin. This dilution effect downstream means also that other constituents will also be diluted to the extent that their concentrations behave as conservative materials and that their concentrations in tributaries to the Klamath River are in proportion to TDS.

For TSS concentrations changes shown in Figure 9b are likely a combination of scouring and settling – net scouring in the region immediately below Iron Gate Reservoir as the river regains its normal sediment load after losing much of it in the Iron Gate Reservoir, and net settling as the concentrations decrease slowly downstream. Dilution could also be contributing to this decrease. The decrease in TOC also shown in Figure 9b reflects a loss of organic material through decay coupled with dilution. Finally, the Chlorophyll-a concentrations drop rapidly below Iron Gate Reservoir after an initial rise like the suspended solids. The decrease of Chlorophyll-a eventually to levels of about 0.001 mg/L (or 1 µg/L) is noteworthy as is the highest average concentration being below 0.01 mg/L (or 10 µg/L) – all very close to levels found throughout Ecoregion II. Comparing these values to those found in the U.S. Environmental Protection Agency’s Ecoregion II report (see USEPA 2000), the EPA reports a median of the seasonal medians of 0.002 mg/L while the median of the 25^{th} percentile values is 0.001 mg/L and the 75^{th} percentile median is 0.003 mg/L. Except for values in the first 50 km of the lower Klamath River below Iron Gate Reservoir, the Chlorophyll-a values are at the seasonal median reported by the EPA.

Monthly Loading Estimates

Estimates of Total Nitrogen, Total Phosphorus, TDS, TSS, TOC, and Chlorophyll-a average monthly loads for CY2001-2005 are given in Figures 10 through 14. In each figure the constituent loads are presented in three major sections of the lower Klamath River as described above. The upper section is the portion of the river between the Iron Gate and Seiad Valley gauges on the Klamath River, the middle section between the Seiad Valley and Orleans gauges, and the lower section between the Orleans and the Klamath gauges. Within each section, loads are presented for major tributaries above the gauges on those rivers, the nongauged portion of the major tributaries drainage area, and the intervening, nongauged drainage area between the upper and lower gauges on the Klamath River. If there were no losses of constituent loads from these sources after discharge, the sum of the load from upstream at the upstream gauge of the section plus the inflow loads from the tributaries and the two ungaged areas would equal the load at the lower gauge of the section.

While these section by section constituent mass balances are presented in Figures 10 through 14, so is an overall mass balance. That is, the constituent load at the Iron Gate gauge plus the loads from all the major tributaries and all the nongauged areas are summed, and this total is compared to the constituent load at the Klamath gauge. The difference between the measured load at Klamath and the sum of the inputs upstream is a measure of the losses (if the difference is negative) and gains (if the difference is positive). These loads are compiled under the “Aggregate Load (kg/mo)” heading towards the bottom of the figure with the Difference line representing the difference between the load at Klamath and the sum of the inflow loads. In the “Aggregate Load (%)” section are given the percentages that the various inflows comprise of the total of those inflows. Thus, it is possible to determine the percent contribution that loads at Iron Gate make of the total inflows between Iron Gate and Klamath. The Difference line in this case provides a measure of the load that is lost or unaccounted for. Finally, the “Balances (kg/mo)” section represents the net load in each of the three major sections of the study area and the amount for each section is calculated as the downstream load minus the constituent loads to that section (i.e., the upstream load plus the intervening load).

To illustrate the information provided by the aggregate loads and balances, consider the June CY2001 Total Nitrogen loadings shown in Figure 10a. Under the “Aggregate Loads (kg/mo)” heading are listed the various loads to the lower Klamath River starting with the load out of Iron Gate Reservoir at 112,116 kg/mo, the sum of the major tributaries at 20,385 kg/mo, the sum of the nongauged tributaries at 26,719 kg/mo, and the difference between the load at Klamath, 88,180 kg/mo, and the sum of the previous three loads or -70,040 kg/mo (i.e., 88,180 kg/mo – 112,116 kg/mo – 20,385 kg/mo – 26,719 kg/mo). The -70,040 kg/mo indicates a net loss of Total Nitrogen from the lower Klamath River. In the “Aggregate Loads (%)” section, the percentage that each source makes up of the total load is calculated, i.e., the load from Iron Gate Reservoir makes up 70.4% in June 2001, the major tributaries account for 12.8%, and the nongauged tributaries 16.8% and they sum to 100%. The percentage for the Difference is simply this net loss compared to the total load to give some idea of the magnitude; the percentage retains the sign of the load. In the “Balances (kg/mo)” section, the -19,262 kg/mo represents the net loss of TN in the segment of the river from Iron Gate to the Klamath River at Seiad Valley (i.e., 96,669 kg/mo – 112,116 kg/mo – 3,915 kg/mo), the -11,331 kg/mo represents the net loss of TN in the Seiad Valley to Orleans segment, and the -40,447 kg/mo represents the net loss in the Orleans to Klamath segment. These amounts are described as losses because of the negative sign; were the values positive then of course they would be described as gains. These amounts represents how much of the total net loss for the river, -71,040 kg/mo, was lost in each of these three major sections of the river.

Average monthly load estimates for CY2001-2005 for each constituent are given below along with comments on the proportion of the constituent loads coming from the various sources.

Nitrogen and Phosphorus

Total nitrogen (TN) and total phosphorus (TP) average monthly loads for CY2001-CY2005 are given in Figures 10a through 10e. Average monthly concentrations were available to estimate loads for all calendar years, and in those cases where one or more loads were absent the aggregate loads and load balances were not computed. There are also occasional negative loads shown, e.g., in CY2001. These loads are caused by the negative flows from Ward and Armstrong (2006), and those negative flows were produced as an artifact of flow balance estimates.

TN loads ranged from 32k kg/mo to 133k kg/mo while TP loads ranged from 7.6k kg/mo to 30.8k kg/mo at the Iron Gate gauge. At Klamath, these ranges were 34.3k kg/mo to 520.9k kg/mo for TN and 8.6k kg/mo to 54.9k kg/mo for TP.

Several patterns emerge from an examination of these loadings data. First, the TN and TP loads from Iron Gate Reservoir and measured at the Iron Gate gauge tend to dominate the loadings to the lower Klamath River. In CY2001 and CY2002, for example, loads at this station tend to make up more than 60 percent of the total inflows to the lower Klamath River. In other years, the amount is smaller, but Iron Gate remains as a significant source. Second, the Iron Gate loads become more dominate in August through October as compared to June and July in part due to increases in loading from Iron Gate but also because of decreases in gauged and nongauged tributary flows. Load tends to increase over the June through October months with increasing TN and TP concentrations even though flow releases are decreasing. Third, the difference between TN and TP loads at Klamath and the inflows upstream are almost always negative confirming that TN and TP are lost from the river water column between the Iron Gate and Klamath stations. This loss is due to a number of physical, chemical, and biological mechanisms that typically account for losses of these nutrients, and the amount lost is typically between 30 and 50 percent of the loads entering the river from the gauged and ungauged tributaries.

Total Dissolved Solids

Total Dissolved Solids (TDS) average monthly loads in the lower Klamath River for June through October of CY2001-CY2005 are given in Figures 11a through 11e. As for nitrogen and phosphorus, average monthly concentrations were available to estimate loads for all calendar years, and in those cases where one or more loads were absent in a given month the aggregate loads and load balances were not computed. There are also occasional negative loads shown, e.g., in CY2001. These loads are caused by the negative flows from Ward and Armstrong (2006), and those negative flows were produced by flow balance estimates. Because TDS concentrations tend to vary little over time and space in a river basin because of their conservative nature (see Figure 9a for the relatively small concentration variation from Iron Gate to Klamath), variations in loads are mostly due to changes in flows.

TDS loads ranged from 7,175k kg/mo to 13,927k kg/mo at the Iron Gate station and from 8,853k kg/mo to 78,607k kg/mo at Klamath. Loadings to the lower Klamath River were fairly evenly divided among Iron Gate Reservoir, the major tributaries, and the nongauged areas. The most interesting feature of the TDS load data is the lack of a mass balance throughout the lower Klamath River. The difference amounts were typically less than 30 percent of the total inflow load to the river, but these percentages could be higher if the TDS concentrations assumed for the nongauged drainage areas were more similar to those concentrations in adjacent drainage areas. (The values used for the nongauged areas are those of the Salmon River, as that was the procedure adapted for estimating nutrient loads. This may not be the appropriate procedure for TDS concentrations and should be examined further.) The cause for this difference in measured TDS loads at Klamath compared to the TDS loads upstream needs to be investigated further.

Total Suspended Solids

TSS concentrations in a river like the lower Klamath River are driven by external TSS loadings, i.e., loadings from upstream and the major and minor tributaries, and by internal sources and sinks. Like the other constituents, external loadings add flow and TSS mass to the river and increase or decrease river concentrations depending on the mass balance at the point of input. The internal sources and sinks have more to do with fluvial dynamics, i.e., the scour of sediments from the river channel bed and banks which increases TSS concentrations, and phytoplankton growth, scour and subsequent breakdown of periphyton and submerged rooted vegetation and the deposition of TSS including vegetation due to settling. Depending on the river's flow dynamics, the river may experience net scour or net settling at any given location and or time.

Construction of the Iron Gate and other reservoirs has undoubtedly altered the natural fluvial dynamics of the lower Klamath River. The reservoirs act as settling basins trapping sediment transported into them from upstream and lowering the TSS concentrations leaving them except on the rare occasion that flows are large enough that settled materials are resuspended and flushed downstream. Thus, it should not be surprising that the TSS concentrations leaving Iron Gate Reservoir are quite small as shown in Figure 9b. It should also not be surprising that the TSS concentrations increase immediately downstream as the river begins to pick up its normal suspended load through scour. Because Chlorophyll-a constitutes about 1% of phytoplankton on a dry weight basis and based on the Chlorophyll-a concentrations found in the lower Klamath River (see Figure 9b), the TSS concentration comprised of phytoplankton would be less than 1 mg/L a short distance below Iron Gate and less than 0.1 mg/L for most of the lower Klamath. Those concentrations then tend to decrease downstream as concentrations river velocities decrease which permits TSS settling rates to exceed resuspension rates.

Total Suspended Solids (TSS) loads ranged from 0.3k kg/mo to 387k kg/mo at the Iron Gate station and from 99.7k kg/mo to 6,724k kg/mo at Klamath as shown in Figures 12a through 12e. TSS loadings show that Iron Gate, major tributaries, and nongauged areas all contribute TSS in significant amounts and in fairly even proportions overall. The proportions change considerably from month to month and year to year. Of considerable significance are the differences between loads at Klamath and the sum of the inflows. In CY2001 for example, the differences are positive for all months suggesting internal sources of TSS (i.e., scour). In CY2002, the differences are initially negative (i.e., settling) and then turn positive (i.e., scour). Mixed results are seen thereafter.

Total Organic Carbon

Total Organic Carbon (TOC) loads are presented in Figures 13a through 13e for the months of June through October in CY2001 through CY2005. Loads in the Klamath River ranged from 286k kg/mo to 808k kg/mo at Iron Gate and from 337k kg/mo to 1,800k kg/mo at Klamath.

Loadings from Iron Gate Reservoir measured at the Iron Gate gage in the Klamath River were always above 50 percent of the total TOC loads to the lower Klamath except for June of CY2002-CY2005, and in June the major tributaries and nongauged areas were the larger contributors.

Mass balances over the lower Klamath River showed that there were net TOC load losses in every month for which data were available except October 2001, and for that month the net loss of only 0.5% of the total inflows. Losses were normally on the order of 20 to 40 percent of the loads into the river.

Chlorophyll-a

Like TSS, Chlorophyll-a loads are not only contributed to the lower Klamath River by the inflows from Iron Gate Reservoir and the tributaries but also by the growth of vegetation within the mainstem river. Losses are attributed to the death and settling of the vegetation.

Because of the very small monthly average Chlorophyll-a concentrations measured in the lower Klamath River, i.e., between 0.001 mg/L at Martin's Ferry and 0.0065 mg/L above Shasta (see Figure 9b), the loads are similarly quite small. Loads varied from 3 kg/mo to 1,229 kg/mo at Iron Gate and from 13 kg/mo to 1,411 kg/mo at Klamath (see Figures 14a through 14e).

Except for June of each year, Iron Gate Reservoir dominated the sources of Chlorophyll-a with percent contributions almost always above 50% and frequently exceeding 80 and 90 percent. There were also net losses of Chlorophyll-a in the river generally, and in CY2005 two months (July and August) in which there was considerable gain.

Monthly Constituent Yields

Monthly constituent yields are estimates of the amount of a constituent derived from a unit area of watershed over a period of time and determined by dividing the mass load of that constituent over that period of time by the watershed area. Yields are a way or normalizing the loads from different watersheds with different soil characteristics and rainfalls and comparing yields from different areas on a common basis. Yield factors are often used to estimate the mass load of a constituent from a watershed for which there has been no sampling as long as the yield factor used has been derived from a similar watershed with similar rainfall characteristics.

For this study, the calculated monthly constituent yields were determined by averaging the loads at a given station over the five months and five years of sampling and dividing by the drainage area for that station. These yields are expressed as kg of constituent mass per month per square mile or kg/mi^2 mo although other units could be used and this factor can easily be converted to other units.

Yields for the constituents used in this study in the Klamath River are given in Figures 15a and 15b. For TN, the yields decrease downstream from 16 kg/mi^2 mo at Iron Gate to about 10 kg/mi^2 mo as expected because of the overall decrease in concentrations downstream caused by the influx of low nitrogen content waters from the downstream watersheds and the losses of nitrogen from the water column due to decay mechanisms. Similarly, TP decreases, but less dramatically, from about 4 kg/mi^2 mo to about 2 kg/mi^2 mo.

TDS yield values are consistently around 2,000 kg/mi^2 mo from Iron Gate to Orleans before increasing to 2,700 kg/mi^2 mo at Klamath. TSS on the other hand increases downstream from about 40 kg/mi^2 mo at Iron Gate to over 120 kg/mi^2 mo at Klamath as would be expected due to the increase in suspended load due to scouring as the river picks up its normal sediment load after losing it in the reservoirs upstream. TOC yields like those for TN and TP decrease downstream from 105 kg/mi^2 mo at Iron Gate to about 60 kg/mi^2 mo at Klamath as the mass loads reflect the decay of organic material. Chlorophyll-a yields drop rapidly from 0.07 kg/mi^2 mo at Iron Gate to about 0.03 kg/mi^2 mo at Seiad Valley and stay relatively constant thereafter.

SUMMARY

Following is a summary of the work performed during the course of this study:

1. Average monthly loadings have been estimated for Total Nitrogen, Total Phosphorus, Total Dissolved Solids, Total Suspended Solids, Total Organic Carbon, and Chlorophyll-a (including Pheophytin) for the months of June through October for CY2001 through CY2005 as the availability of constituent data allowed.
2. These average monthly loadings have been estimated for:
    a. the Klamath River at the Iron Gate gage (as estimates of loads from Iron Gate Reservoir), at the Seiad Valley gage, at the Orleans gage, and at the Klamath gage (using flows measured at this gage and constituent concentrations measured at Terwer),
    b. the Shasta (near Yreka), Scott (near Ft. Jones), Salmon (at Somes Bar), and Trinity (at Hoopa) Rivers, i.e., the major tributaries, and
    c. the nongauged portions of the major tributaries and the nongauged drainage areas outside the major tributaries.
3. In addition to the monthly loadings at these various points, mass loadings were aggregated so that the contributions of each of the three major sources of constituent loadings (i.e., Iron Gate Reservoir, the major tributaries, and the nongauged watersheds) could be ascertained for the entire lower Klamath River and the primary sources identified.
4. Aggregate mass balances were also developed comparing total loadings to the lower Klamath River load at Klamath and comparing the loadings from one Klamath River station to another for the four stations used in this study.

5. Constituent yields were also developed based on their mass loadings and the area of the watershed from which they were derived.
6. Constituent loadings vary considerably in space and time depending on flows and concentrations, and there were relatively few patterns discernable among the loads for any one constituent although mass balances revealed constituent mass losses as expected for nonconservative materials like TN, TP, TOC, and Chlorophyll-a, mass gains for TSS, and surprising mass losses for the conservative substance TDS.
7. These constituent loads may be used in other efforts such as water quality modeling to estimate constituent concentrations in the lower Klamath River to compare to existing concentrations and to forecast constituent concentrations under future flow and loading conditions.

CONCLUSIONS

Conclusions have been developed in several areas related to estimating nutrient loading. These areas are dealing with constituent non-detects, flows, major sources of constituent loads in the lower Klamath Rive, and relations of flow to loading.

Constituent Non-Detects

1. Substitution for ND values should continue to be the MDL/2 for this is a conventional approach and recommended in the scientific literature, and for the Klamath River data will provide a midpoint of loads between the other two assumptions, namely ND = 0 and ND = MDL;
2. High confidence can be placed in the total nitrogen data now being collected as long as a low MDL is used, but low confidence must be assumed for most of the nitrogen load estimates for the most of the years and months because of the high percentage of ND’s;
3. Highest confidence can be placed in the total P data because of the very small percentage of ND’s for that constituent.

Flows

1. Flows during the CY2001-2005 period in the lower Klamath River exhibited distinct downstream as well as seasonal patterns with annual average flows ranging from 252 cms in CY2001 to 476 cms in CY2005.
2. While flows out of the Iron Gate Reservoir changed little from month to month during the CY2001-2005 period, downstream, flows were rather constant or increased slowly for the first 230 km even with the entrance of the Shasta River 23.7 km downstream and the Scott River 86.7 km downstream but significantly at the confluence with the Salmon River at 230 km downstream and the Trinity River at 272 km. Ratios of flows at Klamath to those at Iron Gate ranged from about 2.3 in low flow years to about 10 during high flow years indicating the significant flow increases that occur downstream from Iron Gate during high flow years.
3. Annual flow variations in the Klamath River at Klamath were primarily due to flow variations in the Salmon and Trinity Rivers.

Sources of Constituent Loads

1. Total Nitrogen and Total Phosphorus
    a. Total Nitrogen and Total Phosphorus loads from Iron Gate Reservoir tend to dominate the loadings to the lower Klamath River.
    b. The difference between Total Nitrogen and Total Phosphorus loads at Klamath and the inflows upstream are almost always negative confirming that Total Nitrogen and Total Phosphorus are lost from the river water column between the Iron Gate and Klamath stations.
2. Total Dissolved Solids
    a. Total Dissolved Solids loadings to the lower Klamath River were fairly evenly divided among Iron Gate Reservoir, the major tributaries, and the nongauged areas.
3. Total Suspended Solids
    a. Iron Gate, major tributaries, and nongauged areas all contribute TSS in significant amounts although the proportions change considerably from month to month and year to year.
    b. Of significance are the differences between loads at Klamath and the sum of the inflows from Iron Gate, the major tributaries, and the nongauged tributaries, for those differences are positive in some months suggesting internal sources of TSS (i.e., scour) and negative in others suggesting loss from the water column (i.e., settling).
4. Total Organic Carbon
    a. Loadings of Total Organic Carbon from Iron Gate Reservoir were always above 50 percent of the total TOC loadings to the lower Klamath except for June of CY2002-CY2005 when the major tributaries and nongauged areas were the larger contributors.
    b. Mass balances over the lower Klamath River indicated that there were net TOC load losses in every month for which data were available except October 2001, and for that month the net loss of only 0.5% of the total inflows.
5. Chlorophyll-a
    a. Except for June of each year, Iron Gate Reservoir dominated the sources of Chlorophyll-awith percent contributions frequently exceeding 80 and 90 percent.
    b. Generally there were net losses of Chlorophyll-a in the river except for a few months, such as June and October of 2001 and August 2005, in which there was a gain, sometime a considerable gain.

Constituent Loading and Flow

1. Average June through October constituent loads from nongauged tributaries were usually below 20% of the total and always below 40% with little variation with average annual flow at Klamath.
2. Total Phosphorus loads did not vary with average annual flow at Klamath.
3. For Total Nitrogen, Total Dissolved Solids, Total Suspended Solids, Total Organic Carbon, and Chlorophyll-a, constituent loads in major tributaries increased with Klamath flows, which were comprised primarily of flows from those major tributaries.

RECOMMENDATIONS

The following recommendations are made based on the results of this study:

1. Estimates of future nutrient loads can be more accurate as sampling and analytical procedures are more standardized, MDLs set low enough to detect the low concentrations of constituents in the Klamath River, and made more consistent over time.
2. Estimates of future nutrient loads can be made more accurate if there is more sampling of the nongauged portion of the lower Klamath River watershed and constituent concentrations and yield factors for those areas are determined and their comparison to the values assumed herein are verified.
3. Loading estimates can be extended to other constituents in the AFWO grab sample database as desired using the methodology described in this study.

REFERENCES

Armstrong, Neal E. and George H. Ward. 2005. Review of the AFWO Klamath River Grab Sample Water Quality Database. Prepared for Arcata Fish and Wildlife Office, U.S. fish and Wildlife Service, March 9.

Armstrong, Neal E. and George H. Ward. 2008. Coherence of Nutrient Loads and AFWO Klamath River Grab Sample Water Quality Database. Prepared for Arcata Fish and Wildlife Office, U.S. fish and Wildlife Service, January 12.

Berthouex, Paul Mac and Linfield C. Brown. 1994. Statistics for Environmental Engineers. Lewis Publishers, Ann Arbor.

Chapman, Deborah. 1992. Water Quality Assessments: A Guide to the Use of Biota, Sediments, and Water in Environmental Monitoring. Published on behalf of United Nations Educational, Scientific and Cultural Organization, World Health Organization, and United Nations Environmental Programme, Chapman & Hall, New York. Chapter 9 Data Handling and Presentation, pp. 482-483)

Miertschin, James D. and Neal E. Armstrong. 1986. "Evaluation of the Effects of Point and Nonpoint Source Phosphorus Loads Upon Water Quality in the Highland Lakes," CRWR Technical Report 215, Center for Research in Water Resources, September.

U.S. Environmental Protection Agency. 2000. Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion II. Office of Water, EPA 822-B-00-015, December.

Ward, George H. and Neal E. Armstrong. 2006. Hydrological features of Lower Klamath River and tributaries. Memorandum to U.S. Fish & Wildlife Service, Arcata Office, January 15.

Table 1

USGS Gages in the Lower Klamath River and Associated Data

Number	Name	Drainage Area at Gage (mi^2)	RM to Mouth (mi)	Drainage Area at Tributary Mouth (mi^2)
11516530	Klamath River below Iron Gate Dam	4,630	189.8	
11517500	Shasta River near Yreka	793	0.5	
11519500	Scott River near Fort Jones	653	21	808
11520500	Klamath River near Seiad Valley	6,940	128.5	
11522500	Salmon River at Somes Bar	751	1.01	
11523000	Klamath River at Orleans	8,475	59.1	
11530000	Trinity River at Hoopa	2,853	12.4	
11530500	Klamath River near Klamath	12,100	6.7	

Table 2

Minimum Levels of Detection for Nutrient Analytes in the AFWO Water Quality Database for the Lower Klamath River

Total Nitrogen (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)					0.1 AR
Klamath River at Seiad Valley (SV)					0.1 AR
Klamath River at Orleans (OR)					0.1 AR
Klamath River at Terwer (TG)					0.1 AR
Shasta River near Mouth (SH)					0.1 AR
Scott River near Mouth (SC)					0.1 AR
Salmon River near Mouth (SA)					0.1 AR
Trinity River near Mouth (TR)					0.1 AR

Total Kjeldahl Nitrogen (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.1 SEM	0.1 SEM 1 NCL	0.1 SEM 1 NCL	0.5 SA 0.5 NCL	0.2 AR
Klamath River at Seiad Valley (SV)	0.1 SEM	0.1 SEM 1 NCL	1 NCL	0.5 SA 0.5 NCL	0.2 AR
Klamath River at Orleans (OR)	0.1 SEM	0.1 SEM 1 NCL	1 NCL	0.5 SA 0.5 NCL	0.2 AR
Klamath River at Terwer (TG)	0.1 SEM	0.1 SEM	1 NCL	0.5 SA 0.5 NCL	0.2 AR
Shasta River near Mouth (SH)	0.1 SEM	0.1 SEM 1 NCL	0.1 SEM 1 NCL	0.5 SA	0.2 AR
Scott River near Mouth (SC)	0.1 SEM	0.1 SEM 1 NCL	0.1 SEM 1 NCL	0.5 SA 0.5 NCL	0.2 AR
Salmon River near Mouth (SA)	0.1 SEM	0.1 SEM 1 NCL	1 NCL	0.5 SA 0.5 NCL	0.2 AR
Trinity River near Mouth (TR)	0.1 SEM	0.1 SEM 1 NCL	1 NCL	0.5 SA 0.5 NCL	0.2 AR

Organic Nitrogen (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.1 SEM				
Klamath River at Seiad Valley (SV)	0.1 SEM				
Klamath River at Orleans (OR)	0.1 SEM				
Klamath River at Terwer (TG)	0.1 SEM				
Shasta River near Mouth (SH)	0.1 SEM				
Scott River near Mouth (SC)	0.1 SEM				
Salmon River near Mouth (SA)	0.1 SEM				
Trinity River near Mouth (TR)	0.1 SEM				

Ammonia Nitrogen (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.1 SEM 0.05 SEM	0.1 SEM 0.2 NCL	0.1 SEM 0.1 NCL 0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR
Klamath River at Seiad Valley (SV)	0.1 SEM 0.05 SEM	0.1 SEM 0.2 NCL	0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR
Klamath River at Orleans (OR)	0.1 SEM 0.05 SEM	0.1 SEM 0.2 NCL	0.1 NCL 0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR
Klamath River at Terwer (TG)	0.1 SEM 0.05 SEM	0.1 SEM	0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR
Shasta River near Mouth (SH)	0.1 SEM 0.05 SEM	0.1 SEM 0.2 NCL	0.1 SEM 0.1 NCL 0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR
Scott River near Mouth (SC)	0.1 SEM 0.05 SEM	0.1 SEM 0.2 NCL	0.1 SEM 0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR
Salmon River near Mouth (SA)	0.1 SEM 0.05 SEM	0.1 SEM	0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR
Trinity River near Mouth (TR)	0.1 SEM 0.05 SEM	0.1 SEM 0.2 NCL	0.1 NCL 0.2 NCL	0.05 NCL 0.1 NCL	0.01 AR

Nitrite Nitrogen + Nitrate Nitrogen (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)					0.01 AR
Klamath River at Seiad Valley (SV)					0.01 AR
Klamath River at Orleans (OR)					0.01 AR
Klamath River at Terwer (TG)					0.01 AR
Shasta River near Mouth (SH)					0.01 AR
Scott River near Mouth (SC)					0.01 AR
Salmon River near Mouth (SA)					0.01 AR
Trinity River near Mouth (TR)					0.01 AR

Nitrate Nitrogen (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL 0.1 NCL	
Klamath River at Seiad Valley (SV)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL	
Klamath River at Orleans (OR)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL 0.1 NCL	
Klamath River at Terwer (TG)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL 0.1 NCL	0.05 NCL	
Shasta River near Mouth (SH)	0.05 NCL 0.1 NCL	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL 0.1 NCL	
Scott River near Mouth (SC)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL	
Salmon River near Mouth (SA)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL	
Trinity River near Mouth (TR)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL 0.1 NCL	0.05 NCL	

Nitrite Nitrogen (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL 0.1 NCL	
Klamath River at Seiad Valley (SV)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL	
Klamath River at Orleans (OR)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.1 NCL	
Klamath River at Terwer (TG)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL 0.1 NCL	0.05 NCL	
Shasta River near Mouth (SH)	0.05 NCL 0.1 NCL 0.2 NCL 0.25 NCL	0.05 NCL 0.1 NCL 0.15 NCL 0.2 NCL	0.05 NCL 0.1 NCL	0.05 NCL	
Scott River near Mouth (SC)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL	
Salmon River near Mouth (SA)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL	0.05 NCL	
Trinity River near Mouth (TR)	0.05 NCL 0.1 NCL	0.05 NCL	0.05 NCL 0.1 NCL	0.05 NCL	

Total Phosphorus (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.02 NCL	0.02 NCL	0.02 NCL 0.04 NCL	0.02 NCL	0.002 AR
Klamath River at Seiad Valley (SV)	0.02 NCL	0.02 NCL	0.02 NCL	0.02 NCL	0.002 AR
Klamath River at Orleans (OR)	0.02 NCL	0.02 NCL	0.02 NCL	0.02 NCL	0.002 AR
Klamath River at Terwer (TG)	0.02 NCL	0.02 NCL	0.02 NCL	0.02 NCL	0.002 AR
Shasta River near Mouth (SH)	0.02 NCL	0.02 NCL	0.02 NCL	0.02 NCL	0.002 AR
Scott River near Mouth (SC)	0.02 NCL	0.02 NCL	0.02 NCL	0.02 NCL	0.002 AR
Salmon River near Mouth (SA)	0.02 NCL	0.02 NCL	0.02 NCL	0.02 NCL	0.002 AR
Trinity River near Mouth (TR)	0.02 NCL	0.02 NCL	0.02 NCL	0.02 NCL	0.002 AR

Orthophosphorus (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR
Klamath River at Seiad Valley (SV)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR
Klamath River at Orleans (OR)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR
Klamath River at Terwer (TG)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR
Shasta River near Mouth (SH)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR
Scott River near Mouth (SC)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR
Salmon River near Mouth (SA)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR
Trinity River near Mouth (TR)	0.01 NCL	0.01 NCL	0.01 NCL	0.01 NCL	0.001 AR

Total Dissolved Solids (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	10 NCL	10 NCL	10 NCL	10 NCL 20 NCL	10 SA
Klamath River at Seiad Valley (SV)	10 NCL	10 NCL	10 NCL	10 NCL	10 SA
Klamath River at Orleans (OR)	10 NCL	10 NCL	10 NCL	10 NCL 20 NCL	10 SA
Klamath River at Terwer (TG)	10 NCL	10 NCL	10 NCL	10 NCL 20 NCL	10 SA
Shasta River near Mouth (SH)	10 NCL	10 NCL	10 NCL	10 NCL	10 SA
Scott River near Mouth (SC)	10 NCL	10 NCL	10 NCL	10 NCL	10 SA
Salmon River near Mouth (SA)	10 NCL	10 NCL	10 NCL	10 NCL	10 SA
Trinity River near Mouth (TR)	10 NCL	10 NCL	10 NCL	10 NCL 20 NCL	10 SA

Total Organic Carbon (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.2 NCL 0.5 NCL 0.7 ESB	0.2 SEM 0.5 SEM 3.5 SEM	0.2 SEM 0.5 SEM	0.3 NCL 0.5 NCL 1.2 NCL	0.25 AR
Klamath River at Seiad Valley (SV)	0.2 NCL 0.5 NCL 0.7 ESB	0.2 SEM 0.5 SEM 3.5 SEM	0.2 SEM 0.5 SEM	0.3 NCL	0.25 AR
Klamath River at Orleans (OR)	0.2 NCL 0.5 NCL 0.7 ESB	0.2 SEM 0.5 SEM 3.5 SEM	0.5 SEM	0.3 NCL 0.5 NCL	0.25 AR
Klamath River at Terwer (TG)	0.2 NCL 0.5 NCL 0.7 ESB	0.2 SEM 0.5 SEM	0.2 SEM 0.5 SEM	0.3 NCL	0.25 AR
Shasta River near Mouth (SH)	0.2 NCL 0.5 NCL 0.7 ESB	0.2 SEM 0.5 SEM 3.5 SEM	0.2 SEM 0.5 SEM	0.3 NCL	0.25 AR
Scott River near Mouth (SC)	0.2 NCL 0.5 NCL 0.7 ESB	0.2 SEM 0.5 SEM 3.5 SEM	0.5 SEM	0.3 NCL	0.25 AR
Salmon River near Mouth (SA)	0.2 NCL 0.5 NCL 0.7 ESB	0.2 SEM 0.5 SEM 3.5 SEM	0.5 SEM	0.3 NCL	0.25 AR
Trinity River near Mouth (TR)	0.2 NCL 0.5 NCL	0.2 SEM 0.5 SEM	0.2 SEM 0.5 SEM	0.3 NCL	0.25 AR

Total Suspended Solids (mg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	1 NCL	1 NCL	1 NCL	1 NCL	10 SA
Klamath River at Seiad Valley (SV)	1 NCL	1 NCL	1 NCL	1 NCL	1 SA 10 SA
Klamath River at Orleans (OR)	1 NCL	1 NCL	1 NCL	1 NCL	10 SA
Klamath River at Terwer (TG)	1 NCL	1 NCL	1 NCL	1 NCL	1 SA 10 SA
Shasta River near Mouth (SH)	1 NCL	1 NCL	1 NCL	1 NCL	1 SA 10 SA
Scott River near Mouth (SC)	1 NCL	1 NCL	1 NCL	1 NCL	1 SA 10 SA
Salmon River near Mouth (SA)	1 NCL	1 NCL	1 NCL	1 NCL	10 SA
Trinity River near Mouth (TR)	1 NCL	1 NCL	1 NCL	1 NCL	1 SA 10 SA

Chlorophyll a (µg/L)

Station	2001	2002	2003	2004	2005
Klamath River at Iron Gate (IG)	0.1 ETS 0.8 ETS 2 SEM	0.1 ETS 0.1 SEM	0.1 ETS	0.1 ETS	0.1 AR 0.5 SA
Klamath River at Seiad Valley (SV)	0.1 ETS 0.2 ETS 0.5 ETS 0.8 ETS	0.1 ETS	0.1 ETS	0.1 ETS	0.5 SA
Klamath River at Orleans (OR)	0.1 ETS 0.2 ETS 0.8 ETS	0.1 ETS	0.1 ETS	0.1 ETS	0.5 SA
Klamath River at Terwer (TG)	0.1 ETS 0.2 ETS 0.8 ETS	0.1 ETS	0.1 ETS	0.1 ETS	0.5 SA
Shasta River near Mouth (SH)	0.1 ETS 0.2 ETS 0.8 ETS 2 SEM	0.1 ETS	0.1 ETS	0.1 ETS	0.5 SA
Scott River near Mouth (SC)	0.1 ETS 0.2 ETS 0.8 ETS	0.1 ETS	0.1 ETS	0.1 ETS	0.5 SA
Salmon River near Mouth (SA)	0.1 ETS 0.2 ETS 0.8 ETS	0.1 ETS	0.1 ETS	0.1 ETS	0.5 SA
Trinity River near Mouth (TR)	0.1 ETS 0.2 ETS 0.8 ETS	0.1 ETS	0.1 ETS	0.1 ETS	0.5 SA

AR – Aquatic Research
ESB – E. S. Babcock & Sons
ETS - ETS
NCL – NCL
SA – Sequoia Analytical
SEM – Sierra Environmental Monitoring

Table 3

Effects of Non-Detects on Statistical Measures of Nutrient Concentrations

Analyte	n	NDs	ND = MDL	ND = MDL/2	ND = 0	MDL to MDL/2	MDL/2 to 0	MDL to 0
Total Nitrogen	28	7.1%	0.741	0.737	0.734	0.54%	0.41%	0.94%
Total Kjeldahl Nitrogen	861	30.0%	0.587	0.499	0.411	14.99%	17.64%	29.98%
Organic Nitrogen	154	10.4%	0.492	0.487	0.482	1.02%	1.03%	2.03%
Ammonia Nitrogen	503	78.3%	0.118	0.078	0.038	33.90%	51.28%	67.80%
Nitrite N + Nitrate N	76	9.2%	0.107	0.107	0.106	0.05%	0.93%	0.93%
Nitrate Nitrogen	552	56.5%	0.17	0.153	0.136	10.00%	11.11%	20.00%
Nitrite Nitrogen	488	96.9%	0.0708	0.0338	0.0033	52.26%	90.24%	95.34%
Total Phosphorus	627	5.4%	0.173	0.172	0.172	0.58%	0.01%	0.58%
Orthophosphorus	621	17.7%	0.0913	0.0904	0.0896	0.99%	0.88%	1.86%

Table 4

Monthly average flows used for simplified water quality modeling in the lower Klamath River at Iron Gate and at Terwer for June through October of CY 2001 through 2005.

Year	Month	Monthly Average Flow at Iron Gate (cfs)	Monthly Average Flow at Iron Gate (cms)	Monthly Average Flow near Klamath (plotted as Terwer) (cfs)	Monthly Average Flow near Klamath (plotted as Terwer) (cms)	Ratio of Flows at Terwer and Iron Gate
2001	June	1,897	53.7	6,006	170.1	3.17
	July	1,012	28.7	3,271	92.6	3.23
	August	1,023	29.0	2,713	76.8	2.65
	September	1,026	29.1	2,601	73.7	2.54
	October	1,308	37.0	3,447	97.6	2.64
2002	June	993	28.1	6,528	184.9	6.57
	July	837	23.7	3,187	90.3	3.81
	August	666	18.9	2,327	65.9	3.49
	September	813	23.0	1,993	56.4	2.45
	October	1,047	29.7	2,405	68.1	2.30
2003	June	1,304	36.9	12,902	365.4	9.89
	July	827	23.4	5,201	147.3	6.29
	August	996	28.2	3,463	98.1	3.48
	September	1,254	35.5	3,383	95.8	2.70
	October	1,366	38.7	3,057	86.6	2.24
2004	June	953	27.0	9,473	268.3	9.94
	July	674	19.1	4,382	124.1	6.50
	August	752	21.3	2,964	83.9	3.94
	September	913	25.9	3,049	86.3	3.34
	October	926	26.2	3,087	87.4	3.33
2005	June	1,222	34.6	14,443	409.0	11.82
	July	925	26.2	6,487	183.7	7.01
	August	999	28.3	3,647	103.3	3.65
	September	1,179	33.4	3,123	88.4	2.65
	October	1,357	38.4	3,584	101.5	2.64

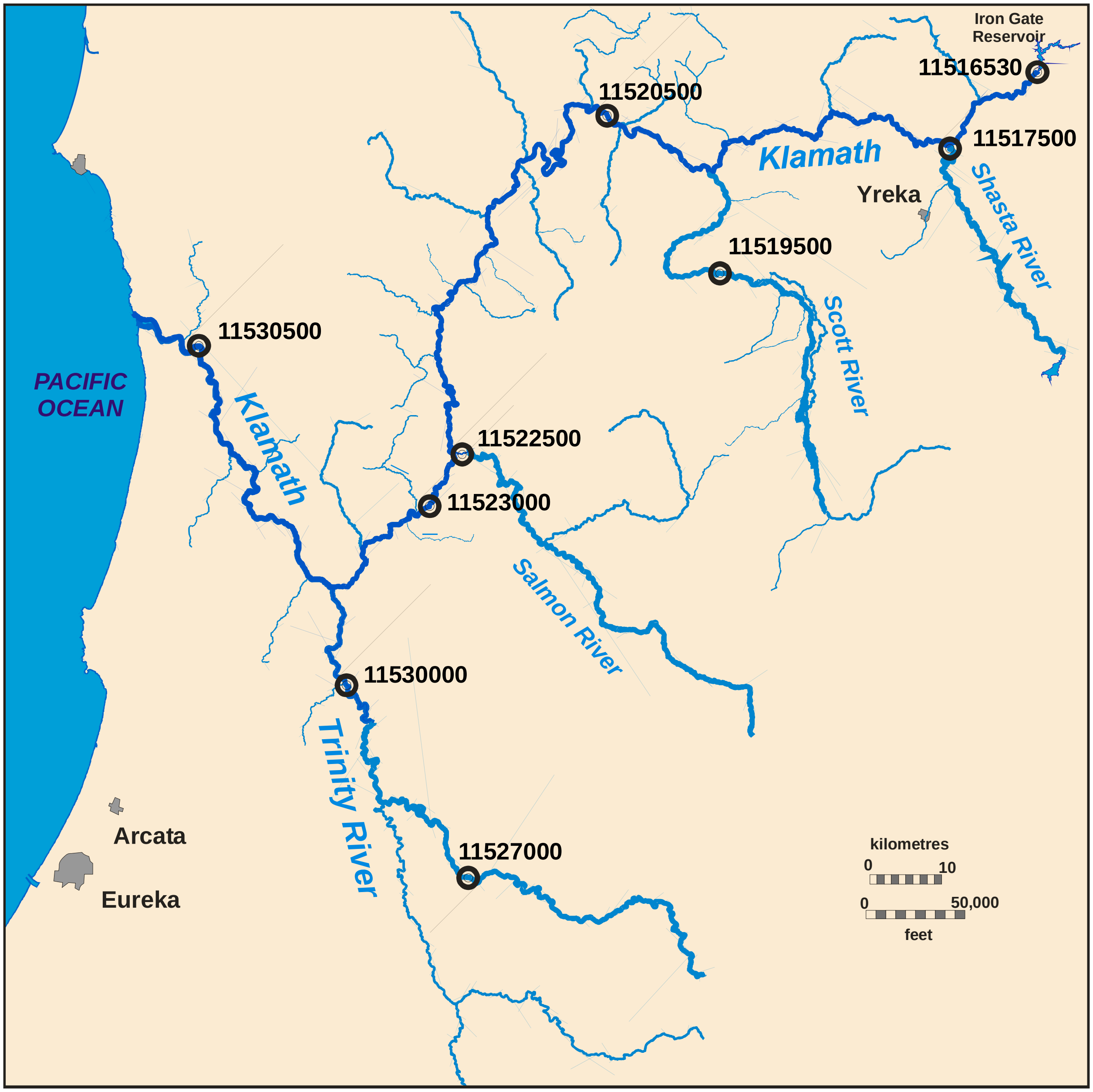


Figure 1. Study Area of the lower Klamath River and its major tributaries showing principal USGS streamflow gauges

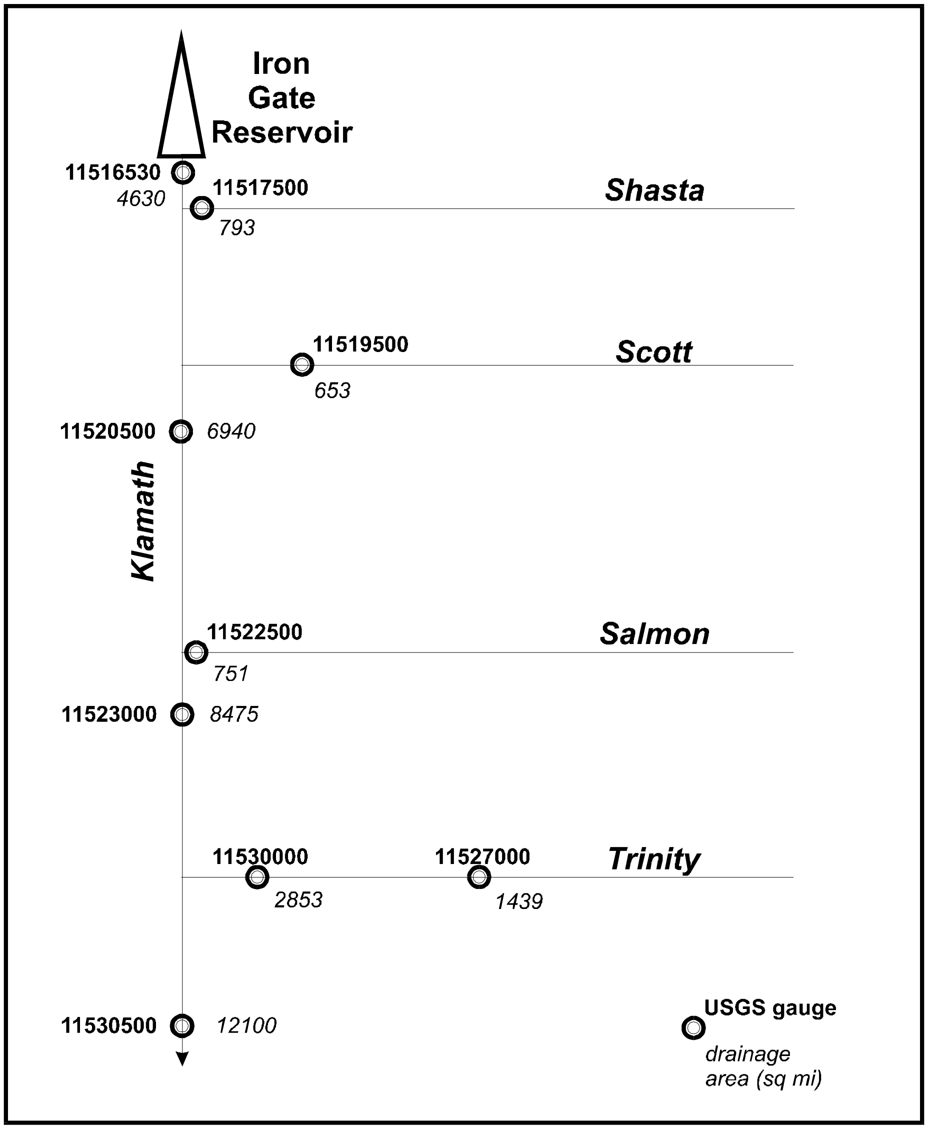


Figure 2. Stem Diagram of Study Area

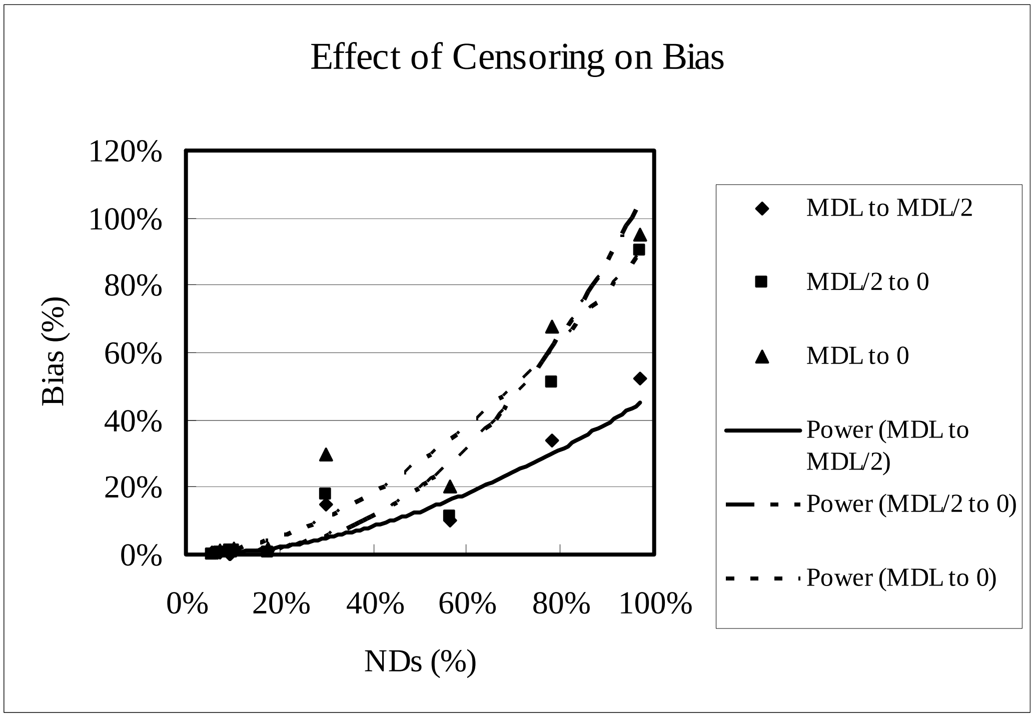
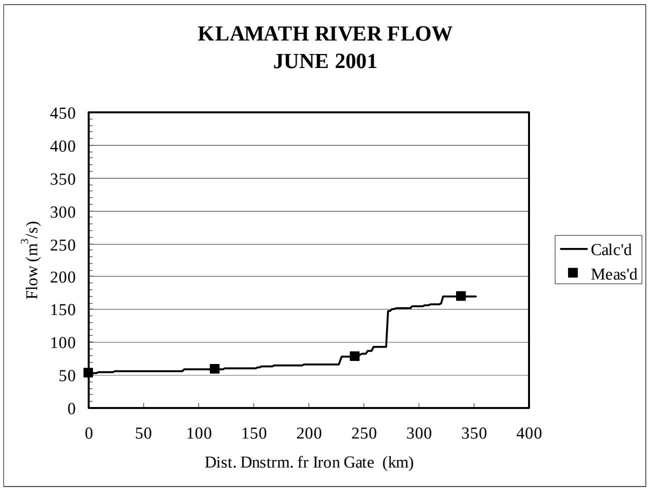
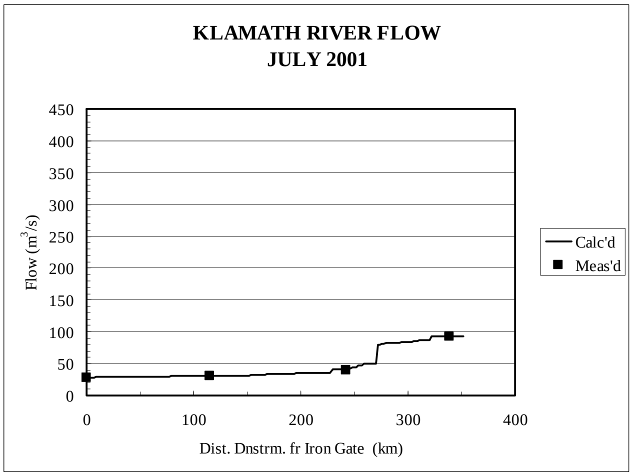
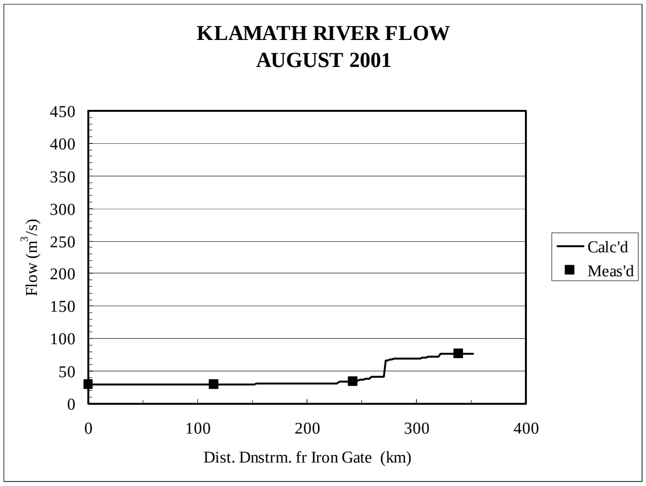
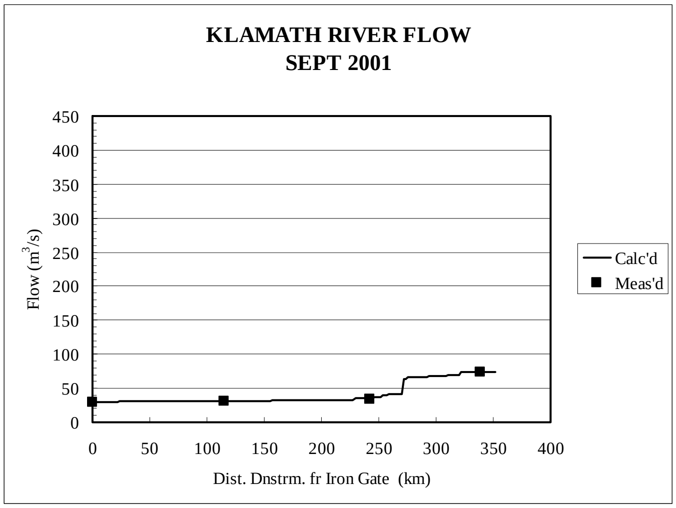


Figure 3. Relationship of bias (percent change in the mean caused by one of the substitutions for non-detects) to percent of non-detects in analyte database.


KLAMATH RIVER FLOW
JUNE 2001
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd


KLAMATH RIVER FLOW
JULY 2001
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd


KLAMATH RIVER FLOW
AUGUST 2001
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd



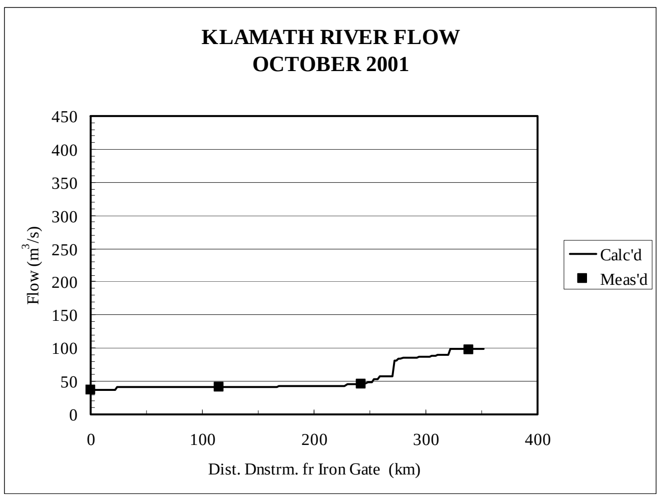
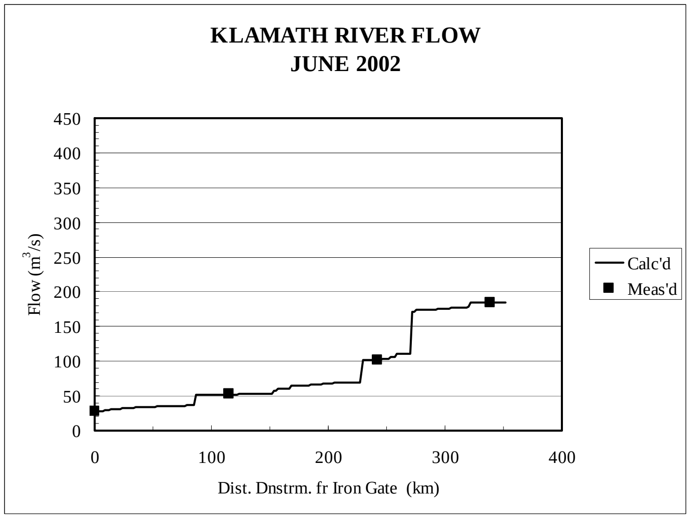
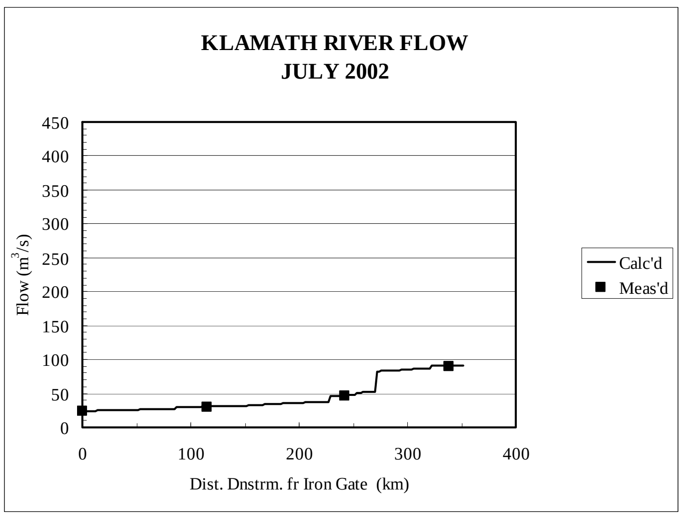
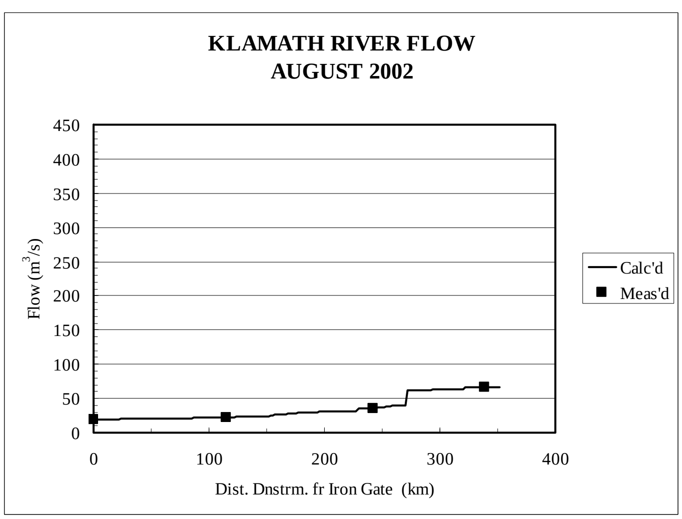
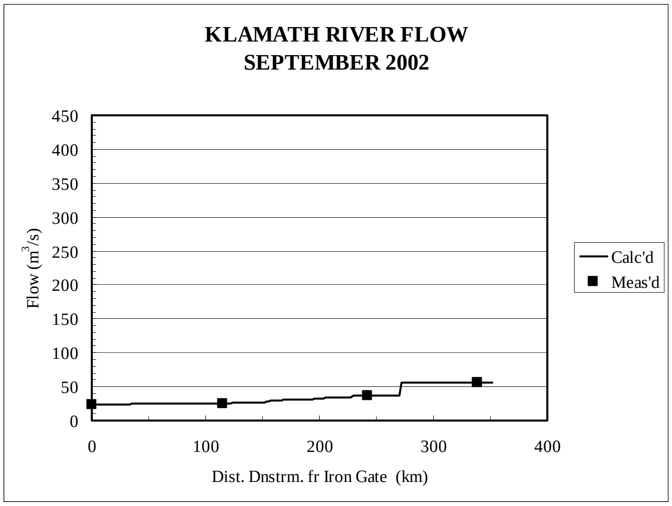


Figure 4. Measured and calculated flows in the Klamath River, June through October 2001.


KLAMATH RIVER FLOW
JUNE 2002
450
400
350
300
250
200
150
100
50
0
Flow (m3/s)
0
100
200
300
400
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd


KLAMATH RIVER FLOW
JULY 2002
450
400
350
300
250
200
150
100
50
0
Flow (m3/s)
0
100
200
300
400
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd


KLAMATH RIVER FLOW
AUGUST 2002
450
400
350
300
250
200
150
100
50
0
Flow (m3/s)
0
100
200
300
400
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd



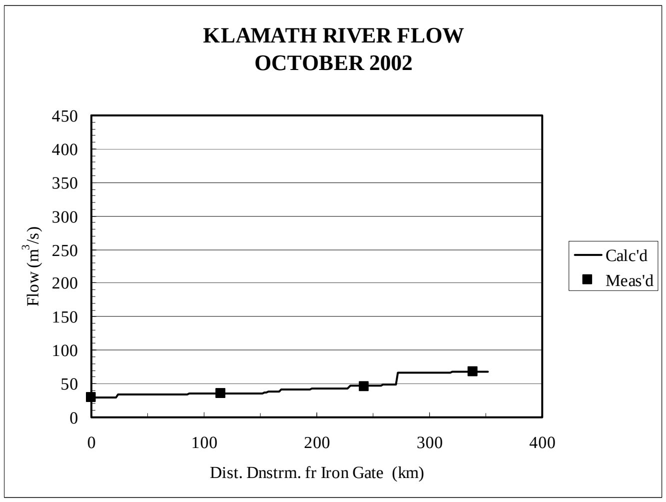
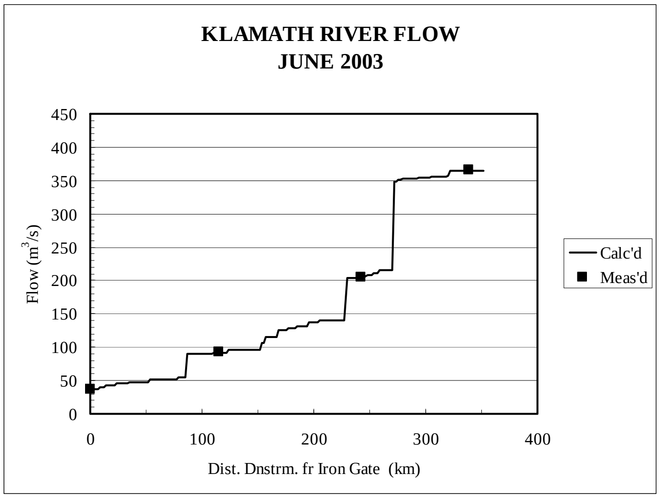
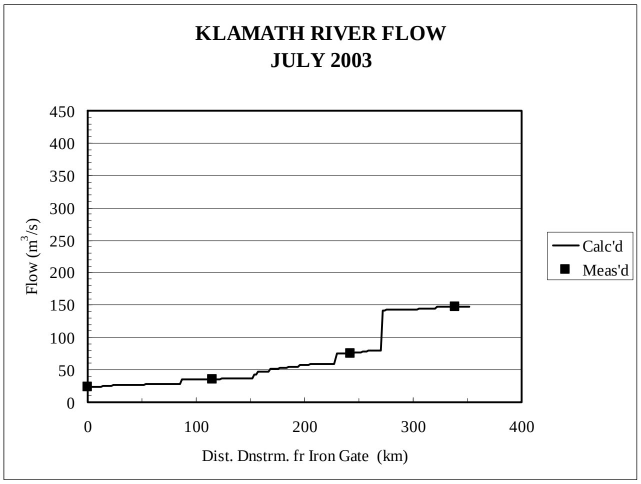
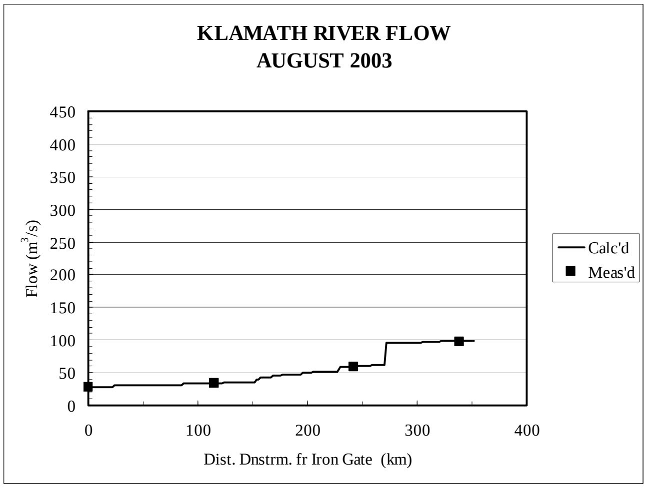
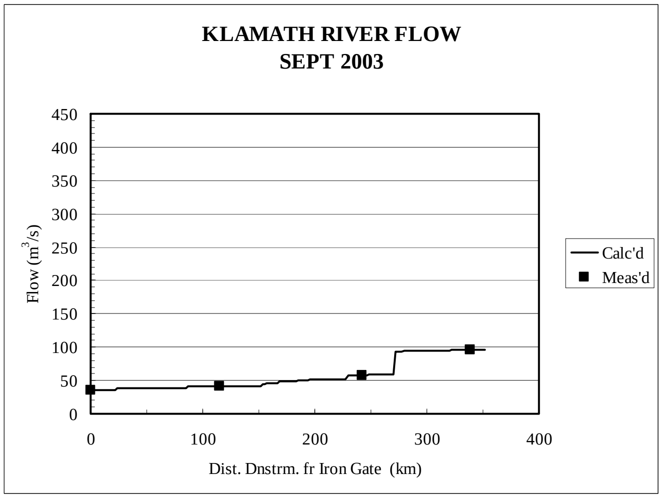


Figure 5. Measured and calculated flows in the Klamath River, June through October 2002.


KLAMATH RIVER FLOW
JUNE 2003
Flow (m3/s)
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400


KLAMATH RIVER FLOW
JULY 2003
Flow (m3/s)
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400


KLAMATH RIVER FLOW
AUGUST 2003
Flow (m3/s)
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400



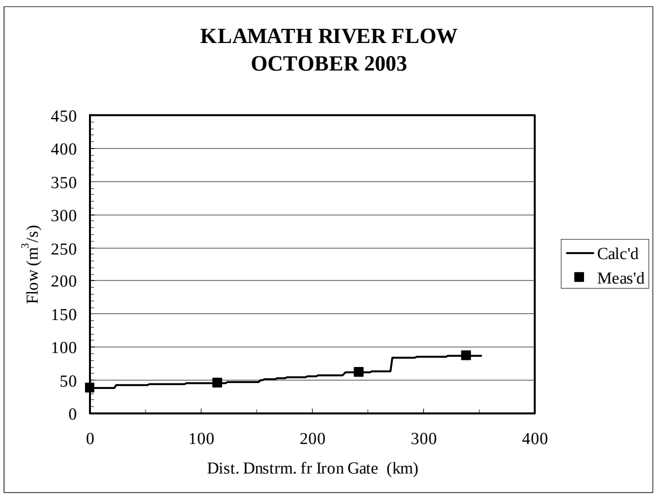
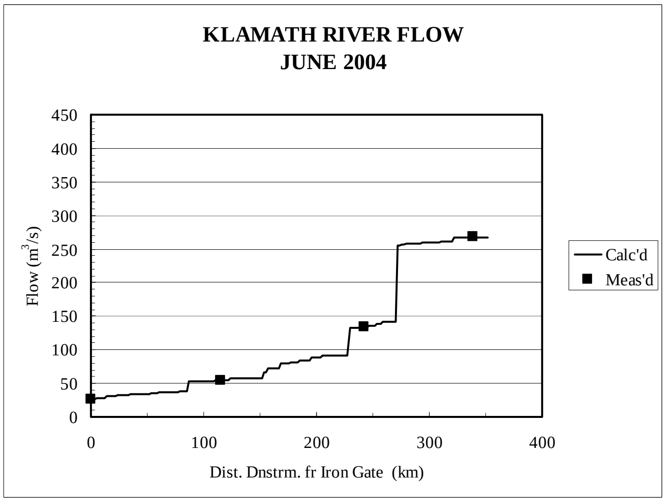
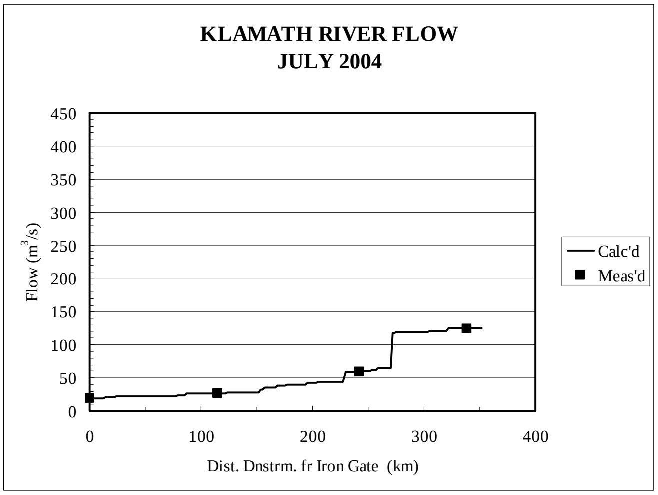
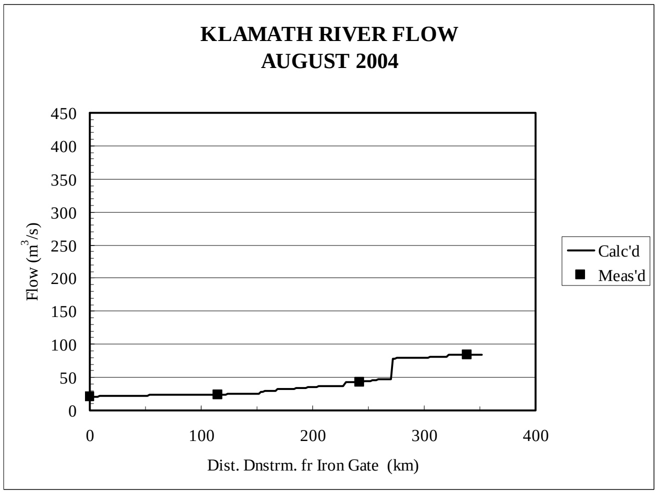
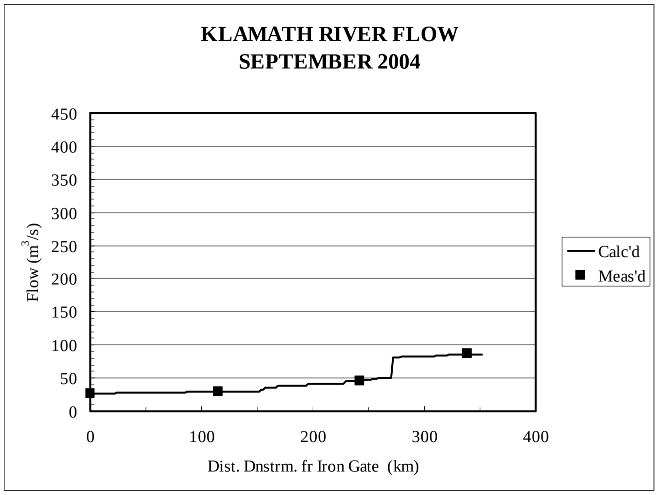


Figure 6. Measured and calculated flows in the Klamath River, June through October, 2003.


KLAMATH RIVER FLOW
JUNE 2004
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd


KLAMATH RIVER FLOW
JULY 2004
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd


KLAMATH RIVER FLOW
AUGUST 2004
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
Dist. Dnstrm. fr Iron Gate (km)
Calc'd
Meas'd



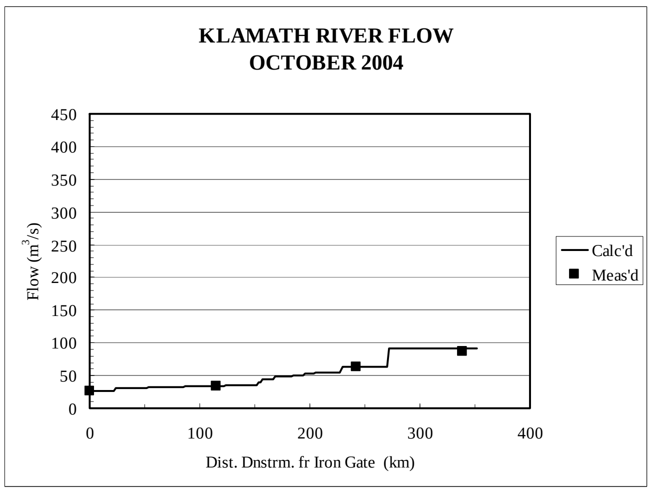
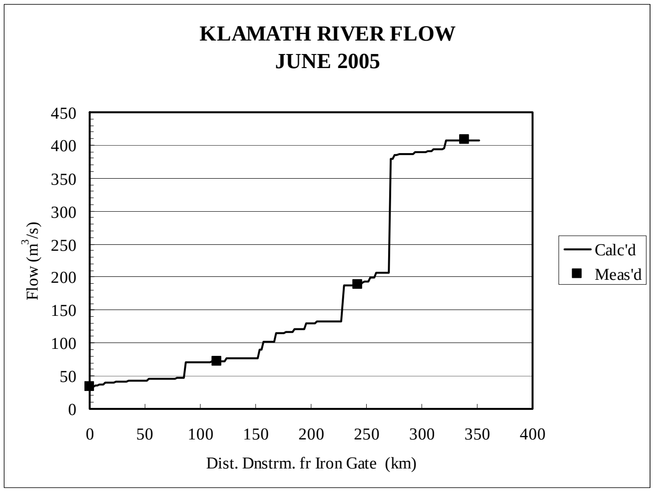
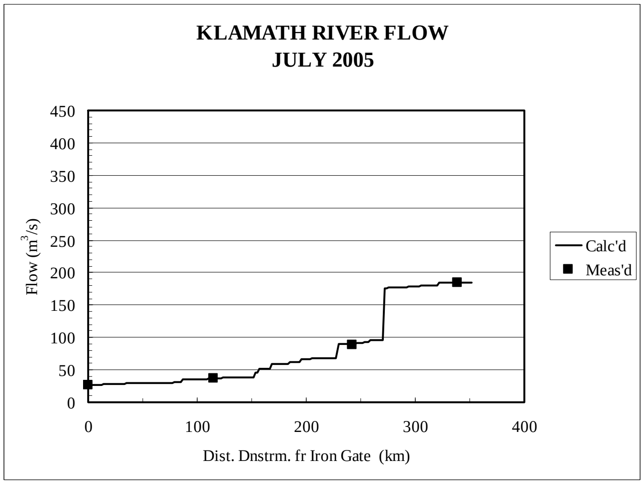
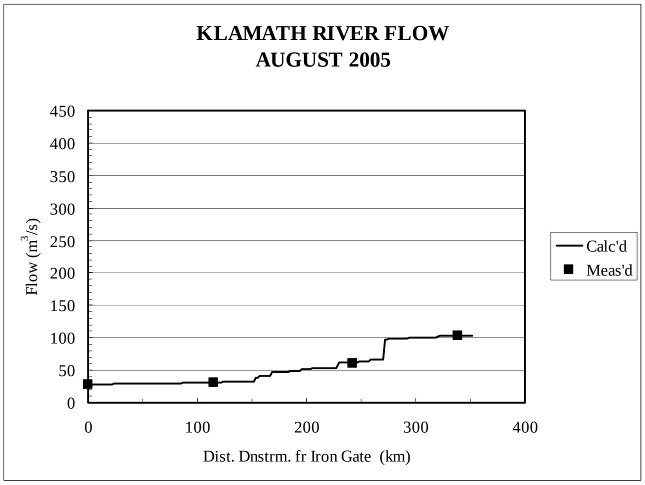
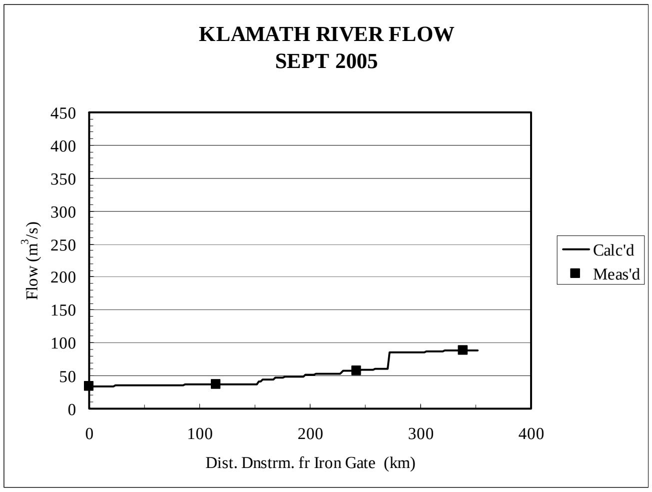


Figure 7. Measured and calculated flows in the Klamath River, June through October, 2004.


KLAMATH RIVER FLOW
JUNE 2005
Flow (m³/s)
Dist. Dnstrm. fr Iron Gate (km)
0
50
100
150
200
250
300
350
400
450
Calc'd
Meas'd


KLAMATH RIVER FLOW
JULY 2005
Flow (m³/s)
Dist. Dnstrm. fr Iron Gate (km)
0
100
200
300
400
Calc'd
Meas'd


KLAMATH RIVER FLOW
AUGUST 2005
Flow (m³/s)
Dist. Dnstrm. fr Iron Gate (km)
0
100
200
300
400
Calc'd
Meas'd



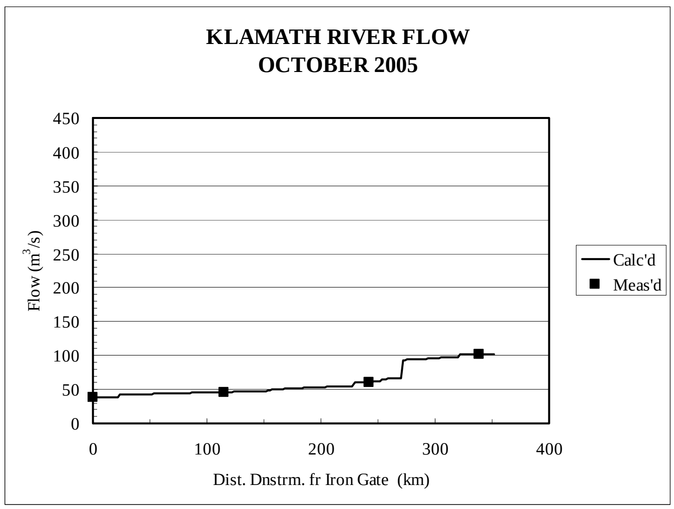
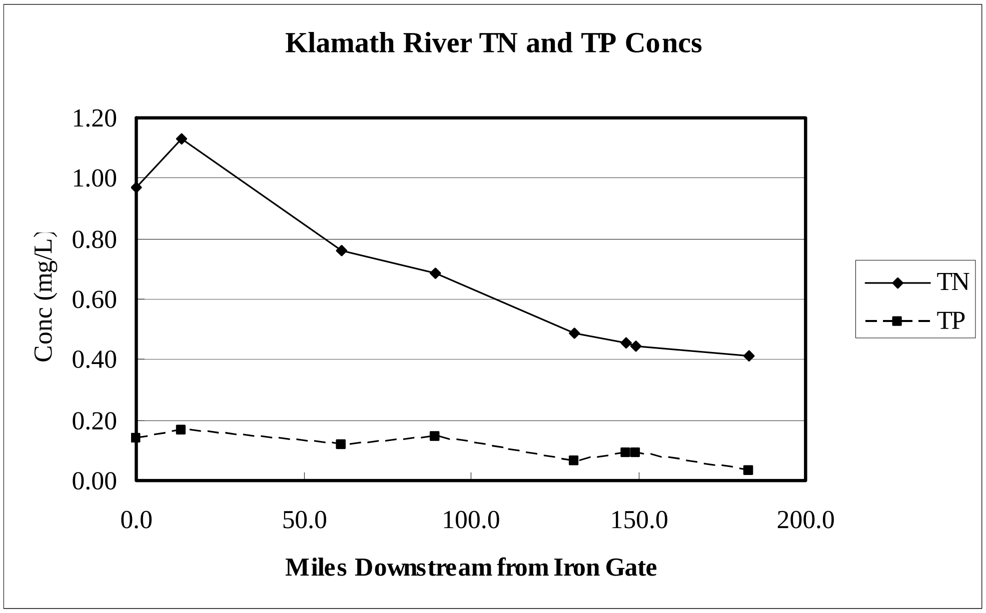


Figure 8. Measured and calculated flows in the Klamath River, June through October 2005.



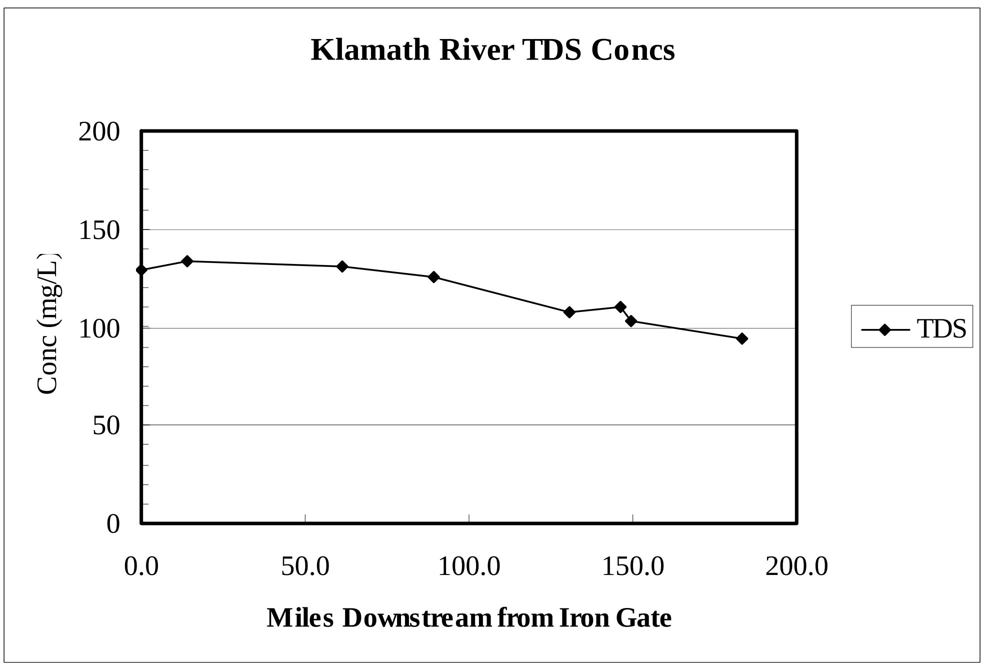
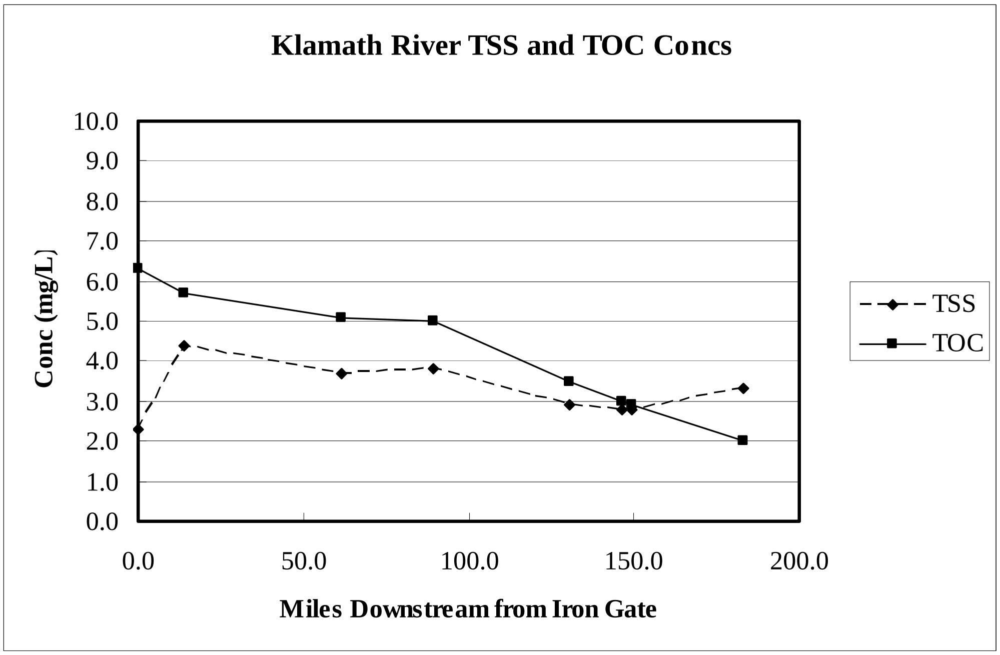


Figure 9a. Average concentrations (mg/L) of Total Nitrogen, Total Phosphorus, and Total Dissolved Solids in the lower Klamath River during June through October, CY2001-CY2005.



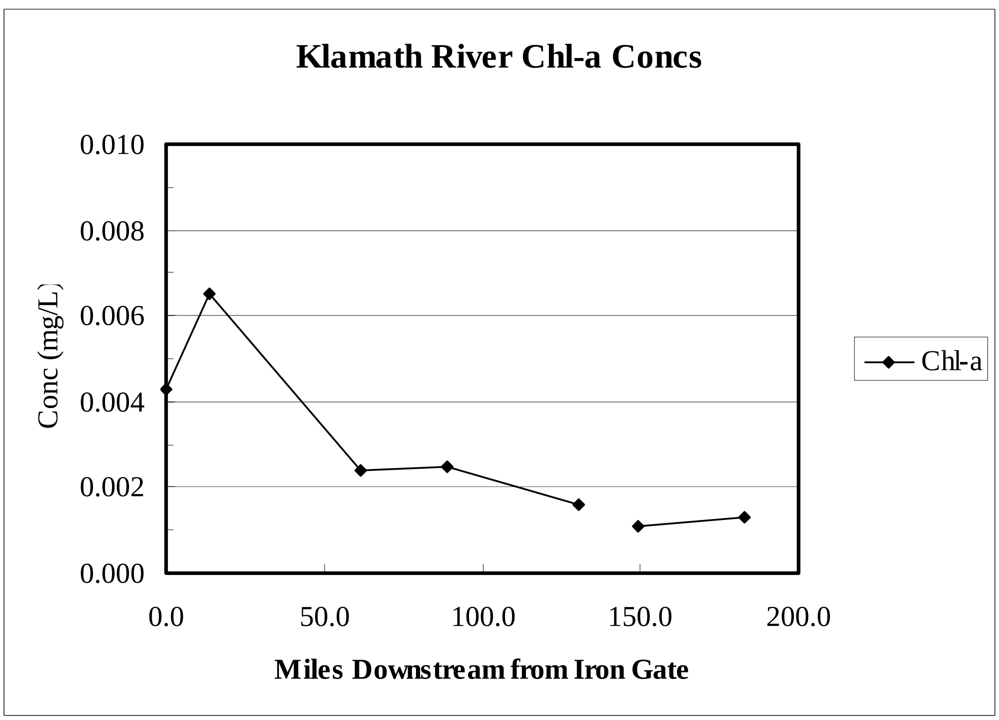
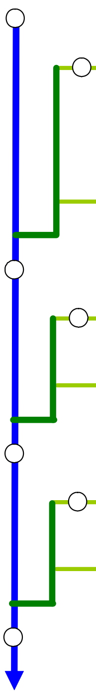


Figure 9b. Concentrations (mg/L) of Total Suspended Solids, Total Organic Carbon, and Chlorophyll-a in the Klamath River during June through October, CY2001-CY2005.

Nutrient Loads for Klamath main stem (ND = ½ MDL)
CY 2001

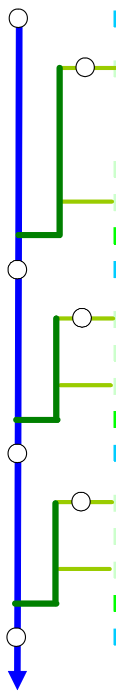


gauge	number	drainage area (mi^2)	Total Nitrogen Load (kg/mo) Jun	Jul	Aug	Sep	Oct	Total Phosphorus Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	112,116	86,975	133,441	100,700	189,226	17,827	13,824	30,824	19,199	18,526
Tributaries:												
Shasta near Yreka	11517500	793	1,636	1,605	1,238	2,330	7,050	772	778	939	1,122	2,738
Scott near Ft Jones	11519500	653	606	142	136	106	113	145	33	31	8	9
Total		1,446	2,242	1,747	1,374	2,436	7,163	917	811	970	1,130	2,747
Nongauged		864	1,572	868	-45	-98	379	115	96	-6	-14	82
Total intervening		2,310	3,815	2,615	1,329	2,339	7,542	1,032	907	964	1,115	2,829
Klamath near Seiad Valley	11520500	6,940	96,669	68,721	100,578	123,668	176,473	23,002	11,959	23,012	18,452	26,637
Tributaries:												
Salmon at Somes Bar	11522500	751	3,744	3,993	1,914	1,546	2,142	609	431	484	135	233
Nongauged		784	3,304	2,521	1,575	965	644	242	277	201	141	139
Total intervening		1,535	7,048	6,513	3,489	2,511	2,786	851	709	684	277	372
Klamath at Orleans	11523000	8,475	92,386	49,038	71,074	81,964	143,541	14,566	8,128	17,883	14,372	21,475
Tributaries:												
Trinity at Hoopa	11530000	2,853	14,399	21,026	17,672	17,428	18,641	21,311	2,900	2,746	1,394	1,374
Nongauged		772	21,842	17,272	17,412	9,731	21,488	1,599	1,901	2,220	1,427	4,649
Total intervening		3,625	36,241	38,298	35,084	27,159	40,130	22,910	4,802	4,966	2,821	6,023
Klamath at Klamath	11530500	12,100	88,180	80,636	293,202	114,557	172,788	44,090	17,244	26,748	19,284	30,505
Aggregate Loads (kg/mo)												
Klamath at Iron Gate			112,116	86,975	133,441	100,700	189,226	17,827	13,824	30,824	19,199	18,526
Major tributaries			20,385	26,766	20,960	21,410	27,946	22,837	4,143	4,199	2,659	4,354
Nongauged			26,719	20,660	18,942	10,598	22,511	1,956	2,274	2,415	1,554	4,870
Difference			-71,040	-53,766	119,858	-18,151	-66,895	1,470	-2,997	-10,690	-4,129	2,755
Aggregate Loads (%)												
Klamath at Iron Gate			70.4%	64.7%	77.0%	75.9%	78.9%	41.8%	68.3%	82.3%	82.0%	66.8%
Major tributaries			12.8%	19.9%	12.1%	16.1%	11.7%	53.6%	20.5%	11.2%	11.4%	15.7%
Nongauged			16.8%	15.4%	10.9%	8.0%	9.4%	4.6%	11.2%	6.5%	6.6%	17.5%
Difference			-44.6%	-40.0%	69.1%	-13.7%	-27.9%	3.4%	-14.8%	-28.6%	-17.6%	9.9%
Balances (kg/mo)												
Klamath near Seiad Valley			-19,262	-20,870	-34,192	20,630	-20,295	4,142	-2,772	-8,776	-1,862	5,283
Klamath at Orleans			-11,331	-26,196	-32,993	-44,214	-35,717	-9,287	-4,539	-5,813	-4,357	-5,534
Klamath at Klamath			-40,447	-6,700	187,044	5,433	-10,883	6,614	4,314	3,899	2,090	3,007

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 10a. Total Nitrogen and Total Phosphorus monthly average loading in the lower Klamath River and its major and minor tributaries for CY2001 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

Nutrient Loads for Klamath main stem (ND = ½ MDL)
CY 2002

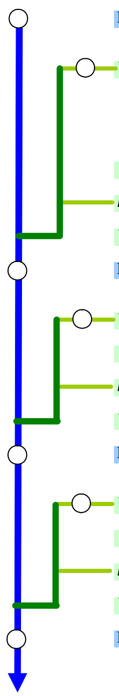


gauge	number	drainage area (mi^2)	Total Nitrogen Load (kg/mo) Jun	Jul	Aug	Sep	Oct	Total Phosphorus Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	40,085	72,173	55,534	59,972	72,106	9,475	12,064	9,845	15,515	22,227
Tributaries:												
Shasta near Yreka	11517500	793	2,031	1,739	1,589	1,112	5,753	1,251	728	735	876	3,679
Scott near Ft Jones	11519500	653	15,933	1,900	227	169	251	985	125	40	24	109
Total		1,446	17,963	3,639	1,815	1,281	6,004	2,236	853	775	900	3,789
Nongauged		864	5,473	2,643	1,830	597	592	401	291	233	88	128
Total intervening		2,310	23,436	6,282	3,645	1,878	6,596	2,637	1,144	1,008	987	3,916
Klamath near Seiad Valley	11520500	6,940	65,018	45,067	35,823	41,576	59,835	13,262	12,837	10,448	13,572	24,245
Tributaries:												
Salmon at Somes Bar	11522500	751	14,476	6,357	1,622	1,145	1,701	1,324	835	512	344	643
Nongauged		784	22,607	9,678	10,524	5,271	7,117	1,655	1,065	1,342	773	1,540
Total intervening		1,535	37,084	16,034	12,145	6,416	8,818	2,979	1,901	1,854	1,117	2,183
Klamath at Orleans	11523000	8,475	65,936	43,719	43,096	36,721	66,474	14,902	9,618	10,583	13,411	27,749
Tributaries:												
Trinity at Hoopa	11530000	2,853	18,094	14,013	9,244	13,124	4,347	3,474	1,471	1,056	1,529	1,435
Nongauged		772	12,512	10,539	8,155	750	3,367	916	1,160	1,040	110	728
Total intervening		3,625	30,606	24,552	17,399	13,873	7,714	4,390	2,632	2,096	1,638	2,163
Klamath at Klamath	11530500	12,100	83,858	68,502	70,616	43,896	54,716	16,772	11,283	10,504	15,510	17,874
Aggregate Loads (kg/mo)												
Klamath at Iron Gate			40,085	72,173	55,534	59,972	72,106	9,475	12,064	9,845	15,515	22,227
Major tributaries			50,534	24,008	12,681	15,550	12,052	7,034	3,160	2,344	2,772	5,866
Nongauged			40,592	22,860	20,509	6,617	11,076	2,972	2,517	2,615	970	2,396
Difference			-47,353	-50,540	-18,108	-38,243	-40,518	-2,708	-6,458	-4,299	-3,748	-12,616
Aggregate Loads (%)												
Klamath at Iron Gate			30.5%	60.6%	62.6%	73.0%	75.7%	48.6%	68.0%	66.5%	80.6%	72.9%
Major tributaries			38.5%	20.2%	14.3%	18.9%	12.7%	36.1%	17.8%	15.8%	14.4%	19.2%
Nongauged			30.9%	19.2%	23.1%	8.1%	11.6%	15.3%	14.2%	17.7%	5.0%	7.9%
Difference			-36.1%	-42.5%	-20.4%	-46.6%	-42.5%	-13.9%	-36.4%	-29.0%	-19.5%	-41.4%
Balances (kg/mo)												
Klamath near Seiad Valley			1,496	-33,389	-23,356	-20,274	-18,867	1,151	-371	-405	-2,931	-1,899
Klamath at Orleans			-36,165	-17,382	-4,872	-11,271	-2,179	-1,339	-5,120	-1,720	-1,277	1,322
Klamath at Klamath			-12,685	231	10,121	-6,698	-19,472	-2,520	-967	-2,175	460	-12,038

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 10b. Total Nitrogen and Total Phosphorus loading in the lower Klamath River and its major and minor tributaries for CY2002 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

Nutrient Loads for Klamath main stem (ND = ½ MDL)
CY 2003



gauge	number	drainage area (mi²)	Total Nitrogen Load (kg/mo) Jun	Jul	Aug	Sep	Oct	Total Phosphorus Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	62,697	42,331	56,288	90,694		18,187	19,441	15,111	22,098	
Tributaries:												
Shasta near Yreka	11517500	793	3,595	2,591	3,277	3,316		1,634	2,120	1,806	1,447	
Scott near Ft Jones	11519500	653			4,822					313		
Total		1,446	3,595	2,591	8,098	3,316	0	1,634	2,120	2,119	1,447	0
Nongauged		864	10,668	3,126	1,460	766	795	781	344	186	112	172
Total intervening		2,310	14,262	5,717	9,559	4,082	795	2,415	2,464	2,305	1,559	172
Klamath near Seiad Valley	11520500	6,940			66,967					15,703		
Tributaries:												
Salmon at Somes Bar	11522500	751			12,518					1,366		
Nongauged		784	22,599	13,744	12,615	5,367	6,601	1,654	1,513	1,608	787	1,428
Total intervening		1,535	22,599	13,744	25,133	5,367	6,601	1,654	1,513	2,974	787	1,428
Klamath at Orleans	11523000	8,475			87,098	92,817				14,411	30,086	
Tributaries:												
Trinity at Hoopa	11530000	2,853		86,358	48,022	51,056			8,793	1,281	3,999	
Nongauged		772	15,292	7,930	4,959	2,281	3,917	1,120	873	632	335	847
Total intervening		3,625	15,292	94,287	52,982	53,337	3,917	1,120	9,666	1,913	4,334	847
Klamath at Klamath	11530500	12,100	520,892	216,964	144,468	148,998		54,930	28,008	15,235	37,250	

	TN Aug	TN Sep	TP Aug	TP Sep
Aggregate Loads (kg/mo)				
Klamath at Iron Gate	56,288		15,111	
Major tributaries	68,639		4,765	
Nongauged	19,034		2,427	
Difference	507		-7,067	
Aggregate Loads (%)				
Klamath at Iron Gate	39.1%		67.8%	
Major tributaries	47.7%		21.4%	
Nongauged	13.2%		10.9%	
Difference	0.4%		-31.7%	
Balances (kg/mo)				
Klamath near Seiad Valley	1,121		-1,713	
Klamath at Orleans	-5,002		-4,266	
Klamath at Klamath	4,388	2,844	-1,089	2,829

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 10c. Total Nitrogen and Total Phosphorus monthly average loading in the lower Klamath River and its major and minor tributaries for CY2003 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

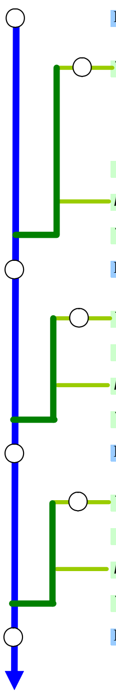
Nutrient Loads for Klamath main stem (ND = ½ MDL)
CY 2004

gauge	number	drainage area (mi^2)	Total Nitrogen Load (kg/mo) Jun	Jul	Aug	Sep	Oct	Total Phosphorus Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	45,840	43,485	52,336	32,159	57,612	8,398	9,209	14,126	18,089	10,890
Tributaries:												
Shasta near Yreka	11517500	793	3,927	1,616	873	1,371		832	801	952		
Scott near Ft Jones	11519500	653	14,043	2,665	290	274		757	59	116	120	
Total		1,446	17,970	4,281	1,163	1,646	0	1,589	860	1,068	120	0
Nongauged		864	6,498	2,547	704	397	1,338	476	280	90	58	289
Total intervening		2,310	24,467	6,828	1,867	2,042	1,338	2,065	1,140	1,158	178	289
Klamath near Seiad Valley	11520500	6,940	52,720	19,623	17,521	20,682		10,715	9,276	11,468	22,563	
Tributaries:												
Salmon at Somes Bar	11522500	751	32,630	11,793	5,360	3,366		1,088	1,372	195	465	
Nongauged		784	16,877	10,052	9,478	5,880	11,985	1,236	1,107	1,208	862	2,593
Total intervening		1,535	49,507	21,845	14,838	9,246	11,985	2,323	2,479	1,403	1,327	2,593
Klamath at Orleans	11523000	8,475	121,446	43,690	40,259	65,409		21,166	13,981	35,082	21,080	
Tributaries:												
Trinity at Hoopa	11530000	2,853	84,042	37,174	20,483	20,826		2,801	1,352	1,713	6,096	
Nongauged		772	12,079	8,626	10,103	4,920	-1,868	884	950	1,288	722	-404
Total intervening		3,625	96,121	45,800	30,586	25,747	-1,868	3,686	2,301	3,001	6,818	-404
Klamath at Klamath	11530500	12,100	208,611	91,398	61,818	86,840		18,775	8,641	10,565	32,453	
Aggregate Loads (kg/mo)												
Klamath at Iron Gate			45,840	43,485	52,336	32,159		8,398	9,209	14,126		
Major tributaries			134,642	53,248	27,005	25,838		5,478	3,584	2,976		
Nongauged			35,453	21,225	20,285	11,197		2,596	2,337	2,586		
Difference			-7,324	-26,560	-37,809	17,646		2,303	-6,488	-9,122		
Aggregate Loads (%)												
Klamath at Iron Gate			21.2%	36.9%	52.5%	46.5%		51.0%	60.9%	71.7%		
Major tributaries			62.4%	45.1%	27.1%	37.3%		33.3%	23.7%	15.1%		
Nongauged			16.4%	18.0%	20.4%	16.2%		15.8%	15.4%	13.1%		
Difference			-3.4%	-22.5%	-38.0%	25.5%		14.0%	-42.9%	-46.3%		
Balances (kg/mo)												
Klamath near Seiad Valley			-17,588	-30,690	-36,681	-13,519		253	-1,073	-3,815	4,296	
Klamath at Orleans			19,219	2,222	7,899	35,481		8,128	2,226	22,210	-2,810	
Klamath at Klamath			-8,956	1,907	-9,027	-4,316		-6,077	-7,641	-27,518	4,555	

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 10d. Total Nitrogen and Total Phosphorus monthly average loading in the lower Klamath River and its major and minor tributaries for CY2004 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

Nutrient Loads for Klamath main stem (ND = ½ MDL)
CY 2005

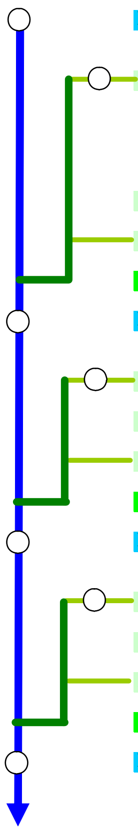


gauge	number	drainage area (mi²)	Total Nitrogen Load (kg/mo) Jun	Jul	Aug	Sep	Oct	Total Phosphorus Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	62,031	46,918	81,494	100,407	137,133	7,918	7,609	11,788	15,098	16,260
Tributaries:												
Shasta near Yreka	11517500	793	4,319	1,419	2,016	2,669	3,963	1,358	641	633	787	1,866
Scott near Ft Jones	11519500	653	13,870	2,555	185	127	264	722	61	10	7	29
Total		1,446	18,188	3,974	2,201	2,796	4,227	2,080	702	643	794	1,895
Nongauged		864	7,745	3,344	958	412	1,452	567	368	122	60	314
Total intervening		2,310	25,934	7,318	3,159	3,208	5,678	2,647	1,070	765	855	2,209
Klamath near Seiad Valley	11520500	6,940	80,418	106,594	106,581	90,976		10,748	8,793	13,270	14,863	
Tributaries:												
Salmon at Somes Bar	11522500	751	15,393	6,371	5,260	708		784	348	157	85	
Nongauged		784	28,246	18,591	16,909	7,439	5,044	2,068	2,047	2,156	1,091	1,091
Total intervening		1,535	43,639	24,963	22,170	8,146	5,044	2,852	2,394	2,313	1,176	1,091
Klamath at Orleans	11523000	8,475	62,560	25,008	93,089	80,259		14,720	9,765	13,931	14,606	
Tributaries:												
Trinity at Hoopa	11530000	2,853	47,327	147,331	9,127	3,106		5,026	1,209	400	373	
Nongauged		772	26,678	11,792	9,545	2,942	11,460	1,953	1,298	1,217	432	2,479
Total intervening		3,625	74,006	159,123	18,672	6,049	11,460	6,979	2,507	1,617	804	2,479
Klamath at Klamath	11530500	12,100	263,464	63,479	34,306	81,832		25,445	8,858	9,683	12,378	
Aggregate Loads (kg/mo)												
Klamath at Iron Gate			62,031	46,918	81,494	100,407		7,918	7,609	11,788	15,098	
Major tributaries			80,909	157,676	16,588	6,610		7,890	2,258	1,201	1,252	
Nongauged			62,670	33,728	27,412	10,793		4,588	3,713	3,495	1,583	
Difference			57,855	-174,842	-91,188	-35,978		5,049	-4,723	-6,800	-5,555	
Aggregate Loads (%)												
Klamath at Iron Gate			30.2%	19.7%	64.9%	85.2%		38.8%	56.0%	71.5%	84.2%	
Major tributaries			39.4%	66.2%	13.2%	5.6%		38.7%	16.6%	7.3%	7.0%	
Nongauged			30.5%	14.2%	21.8%	9.2%		22.5%	27.3%	21.2%	8.8%	
Difference			28.1%	-73.4%	-72.7%	-30.5%		24.8%	-34.8%	-41.3%	-31.0%	
Balances (kg/mo)												
Klamath near Seiad Valley			-7,546	52,358	21,928	-12,638		182	114	717	-1,089	
Klamath at Orleans			-61,498	-106,548	-35,661	-18,864		1,121	-1,422	-1,653	-1,433	
Klamath at Klamath			126,899	-120,653	-77,455	-4,475		3,746	-3,415	-5,864	-3,033	

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 10e. Total Nitrogen and Total Phosphorus monthly average loading in the lower Klamath River and its major and minor tributaries for CY2005 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TDS Loads for Klamath main stem (ND = ½ MDL)
CY 2001



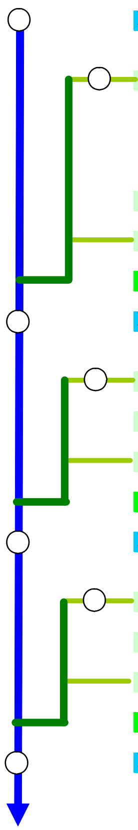
gauge	number	drainage area (mi^2)	Total Dissolved Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	13,927,459	7,603,123	9,313,682	9,411,189	13,894,182
Tributaries:							
Shasta near Yreka	11517500	793	715,948	688,629	581,836	1,294,688	3,198,077
Scott near Ft Jones	11519500	653	455,481	81,623	69,078	50,404	52,467
Total		1,446	1,171,428	770,252	650,914	1,345,092	3,250,544
Nongauged		864	419,770	247,590	-11,611	-48,211	140,305
Total intervening		2,310	1,591,198	1,017,842	639,304	1,296,882	3,390,849
Klamath near Seiad Valley	11520500	6,940	15,676,025	8,553,740	9,522,154	10,207,516	16,648,354
Tributaries:							
Salmon at Somes Bar	11522500	751	2,096,459	1,031,709	584,542	518,282	730,032
Nongauged		784	882,132	719,078	405,911	476,509	238,347
Total intervening		1,535	2,978,591	1,750,787	990,453	994,791	968,379
Klamath at Orleans	11523000	8,475	18,814,402	10,728,719	10,087,865	10,329,736	17,382,995
Tributaries:							
Trinity at Hoopa	11530000	2,853	11,980,042	5,485,170	4,567,609	4,136,313	3,982,999
Nongauged		772	11,273,479	8,978,262	8,576,378	8,897,131	11,892,415
Total intervening		3,625	23,253,521	14,463,432	13,143,988	13,033,444	15,875,414
Klamath at Klamath	11530500	12,100	49,821,422	24,066,708	19,958,278	21,956,668	32,160,832

	Jun	Jul	Aug	Sep	Oct
Aggregate Loads (kg/mo)					
Klamath at Iron Gate	13,927,459	7,603,123	9,313,682	9,411,189	13,894,182
Major tributaries	15,247,930	7,287,131	5,803,066	5,999,687	7,963,575
Nongauged	12,575,380	9,944,931	8,970,678	9,325,429	12,271,068
Difference	8,070,653	-768,476	-4,129,148	-2,779,637	-1,967,992
Aggregate Loads (%)					
Klamath at Iron Gate	33.4%	30.6%	38.7%	38.0%	40.7%
Major tributaries	36.5%	29.3%	24.1%	24.3%	23.3%
Nongauged	30.1%	40.0%	37.2%	37.7%	36.0%
Difference	19.3%	-3.1%	-17.1%	-11.2%	-5.8%
Balances (kg/mo)					
Klamath near Seiad Valley	157,368	-67,224	-430,832	-500,555	-636,677
Klamath at Orleans	159,785	424,192	-424,741	-872,570	-233,738
Klamath at Klamath	7,753,500	-1,125,444	-3,273,574	-1,406,512	-1,097,578

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 11a. Total Dissolved Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2001 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TDS Loads for Klamath main stem (ND = ½ MDL)
CY 2002

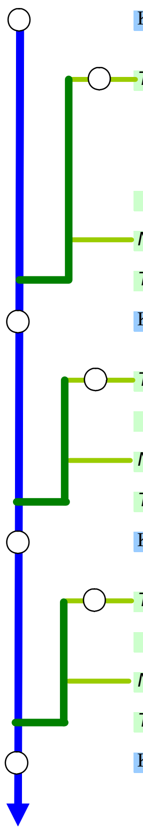


gauge	number	drainage area (mi^2)	Total Dissolved Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	9,839,045	7,175,015	6,815,585	8,354,322	10,557,951
Tributaries:							
Shasta near Yreka	11517500	793	1,251,024	636,792	680,835	887,961	3,080,599
Scott near Ft Jones	11519500	653	2,462,300	535,884	152,940	118,183	166,946
Total		1,446	3,713,324	1,172,676	833,776	1,006,144	3,247,545
Nongauged		864	1,461,009	754,136	471,600	294,777	219,005
Total intervening		2,310	5,174,333	1,926,813	1,305,375	1,300,921	3,466,550
Klamath near Seiad Valley	11520500	6,940	15,642,332	9,586,985	7,463,192	9,930,655	14,267,155
Tributaries:							
Salmon at Somes Bar	11522500	751	2,481,618	1,661,836	1,102,721	788,056	704,976
Nongauged		784	6,035,028	2,760,922	2,712,020	2,603,896	2,635,133
Total intervening		1,535	8,516,646	4,422,757	3,814,741	3,391,953	3,340,109
Klamath at Orleans	11523000	8,475	18,462,202	14,115,010	11,492,356	11,495,292	16,525,375
Tributaries:							
Trinity at Hoopa	11530000	2,853	9,119,598	3,923,531	4,384,272	3,983,420	2,217,131
Nongauged		772	10,179,775	7,508,349	6,073,938	4,446,412	4,941,654
Total intervening		3,625	19,299,373	11,431,879	10,458,210	8,429,832	7,158,785
Klamath at Klamath	11530500	12,100	37,376,876	17,649,433	18,536,709	14,632,151	18,056,417
Aggregate Loads (kg/mo)							
Klamath at Iron Gate			9,839,045	7,175,015	6,815,585	8,354,322	10,557,951
Major tributaries			15,314,540	6,758,042	6,320,769	5,777,620	6,169,651
Nongauged			17,675,812	11,023,407	9,257,557	7,345,085	7,795,792
Difference			-5,452,521	-7,307,031	-3,857,202	-6,844,876	-6,466,978
Aggregate Loads (%)							
Klamath at Iron Gate			23.0%	28.8%	30.4%	38.9%	43.1%
Major tributaries			35.8%	27.1%	28.2%	26.9%	25.2%
Nongauged			41.3%	44.2%	41.3%	34.2%	31.8%
Difference			-12.7%	-29.3%	-17.2%	-31.9%	-26.4%
Balances (kg/mo)							
Klamath near Seiad Valley			628,954	485,158	-657,768	275,412	242,654
Klamath at Orleans			-5,696,776	105,267	214,423	-1,827,316	-1,081,889
Klamath at Klamath			-384,700	-7,897,456	-3,413,857	-5,292,973	-5,627,743

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 11b. Total Dissolved Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2002 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TDS Loads for Klamath main stem (ND = ½ MDL)
CY 2003



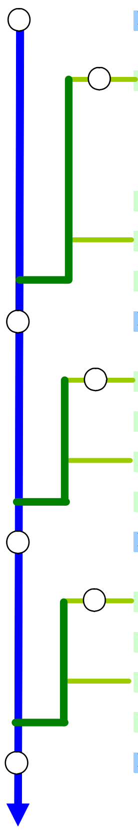
gauge	number	drainage area (mi^2)	Total Dissolved Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	12,443,690	8,152,653	9,066,453	11,509,361	
Tributaries:							
Shasta near Yreka	11517500	793	1,895,304	1,460,157	1,909,349	1,989,581	
Scott near Ft Jones	11519500	653			997,580		
Total		1,446	1,895,304	1,460,157	2,906,929	1,989,581	0
Nongauged		864	2,847,793	891,852	376,286	378,322	294,503
Total intervening		2,310	4,743,097	2,352,009	3,283,215	2,367,903	294,503
Klamath near Seiad Valley	11520500	6,940			12,931,592		
Tributaries:							
Salmon at Somes Bar	11522500	751			1,798,086		
Nongauged		784	6,032,716	3,921,131	3,250,964	2,651,267	2,443,789
Total intervening		1,535	6,032,716	3,921,131	5,049,050	2,651,267	2,443,789
Klamath at Orleans	11523000	8,475			19,003,200	19,556,188	
Tributaries:							
Trinity at Hoopa	11530000	2,853		11,462,039	7,770,886	6,552,241	
Nongauged		772	4,082,315	2,262,252	1,278,085	1,126,783	1,450,051
Total intervening		3,625	4,082,315	13,724,291	9,048,970	7,679,024	1,450,051
Klamath at Klamath	11530500	12,100	78,607,390	55,227,317	26,266,913	9,436,563	

	Jun	Jul	Aug	Sep	Oct
Aggregate Loads (kg/mo)					
Klamath at Iron Gate			9,066,453		
Major tributaries			12,475,900		
Nongauged			4,905,335		
Difference			-180,775		
Aggregate Loads (%)					
Klamath at Iron Gate			34.3%		
Major tributaries			47.2%		
Nongauged			18.5%		
Difference			-0.7%		
Balances (kg/mo)					
Klamath near Seiad Valley			581,924		
Klamath at Orleans			1,022,558		
Klamath at Klamath			-1,785,257	-17,798,649	

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 11c. Total Dissolved Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2003 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TDS Loads for Klamath main stem (ND = ½ MDL)
CY 2004



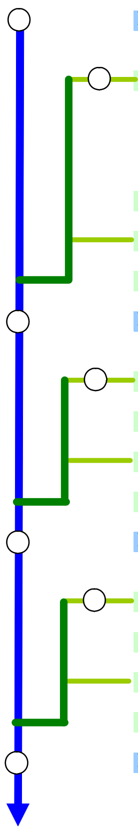
gauge	number	drainage area (mi^2)	Total Dissolved Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	9,098,017	8,185,392	8,161,400	9,379,600	9,836,231
Tributaries:							
Shasta near Yreka	11517500	793	1,570,681	1,008,297	1,079,011	1,645,603	
Scott near Ft Jones	11519500	653	2,745,459	828,992	147,609	139,661	
Total		1,446	4,316,140	1,837,289	1,226,620	1,785,264	0
Nongauged		864	1,734,550	726,625	181,445	196,008	495,413
Total intervening		2,310	6,050,690	2,563,914	1,408,065	1,981,273	495,413
Klamath near Seiad Valley	11520500	6,940	17,144,575	10,703,247	9,557,021	11,281,315	
Tributaries:							
Salmon at Somes Bar	11522500	751	5,873,434	2,701,658	1,520,344	1,101,522	
Nongauged		784	4,505,230	2,867,825	2,442,639	2,904,918	4,437,298
Total intervening		1,535	10,378,663	5,569,482	3,962,984	4,006,440	4,437,298
Klamath at Orleans	11523000	8,475	29,493,939	19,064,861	15,617,741	16,261,874	
Tributaries:							
Trinity at Hoopa	11530000	2,853	21,290,612	10,543,928	5,437,190		
Nongauged		772	3,224,462	2,460,965	2,603,642	2,430,777	-691,721
Total intervening		3,625	24,515,074	13,004,893	8,040,832	2,430,777	-691,721
Klamath at Klamath	11530500	12,100	57,020,318	33,235,536	22,479,193	23,500,385	

	Jun	Jul	Aug	Sep
Aggregate Loads (kg/mo)				
Klamath at Iron Gate	9,098,017	8,185,392	8,161,400	
Major tributaries	31,480,185	15,082,875	8,184,154	
Nongauged	9,464,242	6,055,414	5,227,727	
Difference	6,977,874	3,911,855	905,912	
Aggregate Loads (%)				
Klamath at Iron Gate	18.2%	27.9%	37.8%	
Major tributaries	62.9%	51.4%	37.9%	
Nongauged	18.9%	20.7%	24.2%	
Difference	13.9%	13.3%	4.2%	
Balances (kg/mo)				
Klamath near Seiad Valley	1,995,868	-46,058	-12,444	-79,558
Klamath at Orleans	1,970,701	2,792,131	2,097,737	974,120
Klamath at Klamath	3,011,305	1,165,782	-1,179,381	4,807,733

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 11d. Total Dissolved Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2004 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TDS Loads for Klamath main stem (ND = ½ MDL)
CY 2005



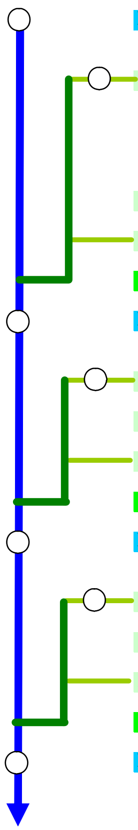
gauge	number	drainage area (mi²)	Total Dissolved Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	10,767,110				
Tributaries:							
Shasta near Yreka	11517500	793	2,038,420	852,678	838,926	1,769,879	3,402,734
Scott near Ft Jones	11519500	653	3,034,008	1,318,166	183,024	188,701	528,519
Total		1,446	5,072,428	2,170,844	1,021,951	1,958,579	3,931,253
Nongauged		864	2,067,633	953,950	246,932	203,372	537,426
Total intervening		2,310	7,140,062	3,124,794	1,268,883	2,161,952	4,468,679
Klamath near Seiad Valley	11520500	6,940	19,421,073	12,701,343	9,180,818	16,093,653	
Tributaries:							
Salmon at Somes Bar	11522500	751	4,988,511	3,475,307	1,123,960		
Nongauged		784	7,540,317	5,303,950	4,357,742	3,674,911	1,867,471
Total intervening		1,535	12,528,828	8,779,258	5,481,702	3,674,911	1,867,471
Klamath at Orleans	11523000	8,475	33,365,317	22,388,561	6,555,595		
Tributaries:							
Trinity at Hoopa	11530000	2,853	18,847,214	17,333,031	6,565,392	7,454,763	
Nongauged		772	7,121,796	3,364,294	2,459,752	1,453,643	4,242,834
Total intervening		3,625	25,969,010	20,697,324	9,025,144	8,908,406	4,242,834
Klamath at Klamath	11530500	12,100	65,733,593	44,287,704	8,853,283	29,798,694	

	Jun	Jul	Aug
Aggregate Loads (kg/mo)			
Klamath at Iron Gate	10,767,110		
Major tributaries	28,908,154		
Nongauged	16,729,746		
Difference	9,328,584		
Aggregate Loads (%)			
Klamath at Iron Gate	19.1%		
Major tributaries	51.3%		
Nongauged	29.7%		
Difference	16.5%		
Balances (kg/mo)			
Klamath near Seiad Valley	1,513,902		
Klamath at Orleans	1,415,416	907,960	-8,106,925
Klamath at Klamath	6,399,266	1,201,818	-6,727,456

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 11e. Total Dissolved Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2005 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TSS Loads for Klamath main stem (ND = ½ MDL)
CY 2001

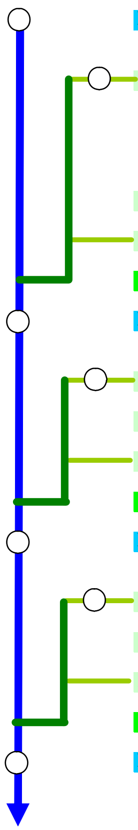


gauge	number	drainage area (mi^2)	Total Suspended Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	153,202	84,479	223,972	240,926	198,488
Tributaries:							
Shasta near Yreka	11517500	793	32,155	8,764	3,977	10,703	75,632
Scott near Ft Jones	11519500	653	4,130	302	523	163	1,016
Total		1,446	36,285	9,067	4,500	10,865	76,648
Nongauged		864	15,695	3,179	-216	-420	2,448
Total intervening		2,310	51,980	12,246	4,284	10,445	79,097
Klamath near Seiad Valley	11520500	6,940	686,466	78,894	214,248	243,410	732,528
Tributaries:							
Salmon at Somes Bar	11522500	751	31,946	7,066	3,479	4,417	12,685
Nongauged		784	32,983	9,233	7,557	4,151	4,159
Total intervening		1,535	64,929	16,300	11,036	8,569	16,844
Klamath at Orleans	11523000	8,475	438,328	108,371	220,099	148,209	494,342
Tributaries:							
Trinity at Hoopa	11530000	2,853	57,596	122,943	27,188	23,238	44,770
Nongauged		772	421,513	115,285	159,667	77,513	207,534
Total intervening		3,625	479,109	238,229	186,855	100,751	252,304
Klamath at Klamath	11530500	12,100	3,835,809	719,520	576,115	400,948	679,822
Aggregate Loads (kg/mo)							
Klamath at Iron Gate			153,202	84,479	223,972	240,926	198,488
Major tributaries			125,827	139,077	35,168	38,520	134,103
Nongauged			470,191	127,698	167,007	81,244	214,142
Difference			3,086,589	368,267	149,968	40,257	133,089
Aggregate Loads (%)							
Klamath at Iron Gate			20.4%	24.1%	52.6%	66.8%	36.3%
Major tributaries			16.8%	39.6%	8.3%	10.7%	24.5%
Nongauged			62.8%	36.4%	39.2%	22.5%	39.2%
Difference			412.0%	104.8%	35.2%	11.2%	24.3%
Balances (kg/mo)							
Klamath near Seiad Valley			481,285	-17,831	-14,008	-7,962	454,943
Klamath at Orleans			-313,067	13,177	-5,186	-103,769	-255,030
Klamath at Klamath			2,918,371	372,921	169,162	151,988	-66,824

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 12a. Total Suspended Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2001 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TSS Loads for Klamath main stem (ND = ½ MDL)
CY 2002



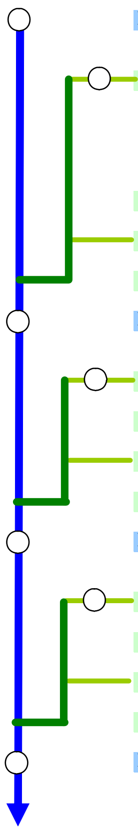
gauge	number	drainage area (mi^2)	Total Suspended Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	182,205	78,311	141,360	220,793	373,101
Tributaries:							
Shasta near Yreka	11517500	793	3,087	16,577	6,899	11,684	90,980
Scott near Ft Jones	11519500	653	133,254	6,171	566	422	1,297
Total		1,446	136,341	22,748	7,466	12,106	92,277
Nongauged		864	54,627	9,683	8,780	2,568	3,822
Total intervening		2,310	190,968	32,432	16,245	14,674	96,099
Klamath near Seiad Valley	11520500	6,940	863,729	161,149	214,940	172,131	845,461
Tributaries:							
Salmon at Somes Bar	11522500	751	41,360	13,622	6,487	9,622	12,368
Nongauged		784	225,648	35,452	50,490	22,685	45,986
Total intervening		1,535	267,009	49,073	56,976	32,307	58,354
Klamath at Orleans	11523000	8,475	632,990	141,566	196,328	143,691	612,971
Tributaries:							
Trinity at Hoopa	11530000	2,853	260,560	46,709	26,411	23,159	52,168
Nongauged		772	380,619	96,411	113,079	38,738	86,237
Total intervening		3,625	641,179	143,119	139,490	61,897	138,404
Klamath at Klamath	11530500	12,100	1,102,139	249,832	441,350	395,068	601,881

	Jun	Jul	Aug	Sep	Oct
Aggregate Loads (kg/mo)					
Klamath at Iron Gate	182,205	78,311	141,360	220,793	373,101
Major tributaries	438,261	83,078	40,363	44,887	156,813
Nongauged	660,895	141,546	172,348	63,991	136,044
Difference	-179,222	-53,103	87,278	65,397	-64,077
Aggregate Loads (%)					
Klamath at Iron Gate	14.2%	25.9%	39.9%	67.0%	56.0%
Major tributaries	34.2%	27.4%	11.4%	13.6%	23.5%
Nongauged	51.6%	46.7%	48.7%	19.4%	20.4%
Difference	-14.0%	-17.5%	24.6%	19.8%	-9.6%
Balances (kg/mo)					
Klamath near Seiad Valley	490,557	50,406	57,334	-63,335	376,262
Klamath at Orleans	-497,748	-68,655	-75,589	-60,747	-290,843
Klamath at Klamath	-172,031	-34,854	105,533	189,480	-149,495

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 12b. Total Suspended Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2002 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TSS Loads for Klamath main stem (ND = ½ MDL)
CY 2003



gauge	number	drainage area (mi^2)	Total Suspended Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	306,306	100,340	90,665	386,715	
Tributaries:							
Shasta near Yreka	11517500	793	14,378	10,362	51,604	14,470	
Scott near Ft Jones	11519500	653			18,621		
Total		1,446	14,378	10,362	70,226	14,470	0
Nongauged		864	106,478	11,452	7,005	3,296	5,139
Total intervening		2,310	120,857	21,814	77,231	17,766	5,139
Klamath near Seiad Valley	11520500	6,940			147,790		
Tributaries:							
Salmon at Somes Bar	11522500	751			11,380		
Nongauged		784	225,562	50,349	60,523	23,098	42,647
Total intervening		1,535	225,562	50,349	71,904	23,098	42,647
Klamath at Orleans	11523000	8,475			79,180	722,075	
Tributaries:							
Trinity at Hoopa	11530000	2,853		785,071	98,955		
Nongauged		772	152,637	29,048	23,794	9,817	25,305
Total intervening		3,625	152,637	814,120	122,749	9,817	25,305
Klamath at Klamath	11530500	12,100	6,724,247	1,025,650	315,203		

Aggregate Loads (kg/mo)	Aug
Klamath at Iron Gate	90,665
Major tributaries	180,561
Nongauged	91,323
Difference	-47,345

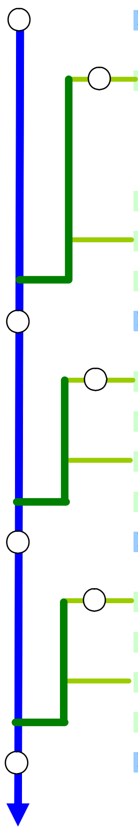
Aggregate Loads (%)	Aug
Klamath at Iron Gate	25.0%
Major tributaries	49.8%
Nongauged	25.2%
Difference	-13.1%

Balances (kg/mo)	Aug
Klamath near Seiad Valley	-20,106
Klamath at Orleans	-140,513
Klamath at Klamath	113,274

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 12c. Total Suspended Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2003 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TSS Loads for Klamath main stem (ND = ½ MDL)
CY 2004



gauge	number	drainage area (mi^2)	Total Suspended Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	111,976	66,506	126,987	214,391	168,621
Tributaries:							
Shasta near Yreka	11517500	793	7,391	9,786	6,982	11,968	
Scott near Ft Jones	11519500	653	138,851	11,843	527	499	
Total		1,446	146,242	21,629	7,509	12,467	0
Nongauged		864	64,854	9,330	3,378	1,708	8,645
Total intervening		2,310	211,097	30,959	10,887	14,174	8,645
Klamath near Seiad Valley	11520500	6,940	571,486	21,406	127,427	195,543	
Tributaries:							
Salmon at Somes Bar	11522500	751	54,384	12,865	9,746	6,120	
Nongauged		784	168,449	36,824	45,475	25,308	77,435
Total intervening		1,535	222,833	49,689	55,220	31,428	77,435
Klamath at Orleans	11523000	8,475	971,565	47,662	465,640	517,971	
Tributaries:							
Trinity at Hoopa	11530000	2,853	1,232,614	40,554	37,241	87,092	
Nongauged		772	120,562	31,600	48,472	21,177	-12,071
Total intervening		3,625	1,353,176	72,154	85,713	108,269	-12,071
Klamath at Klamath	11530500	12,100	2,781,479	99,707	224,792	805,727	

Aggregate Loads (kg/mo)	Jun	Jul	Aug	Sep
Klamath at Iron Gate	111,976	66,506	126,987	214,391
Major tributaries	1,433,240	75,048	54,496	105,679
Nongauged	353,866	77,754	97,325	48,193
Difference	882,397	-119,602	-54,015	437,465

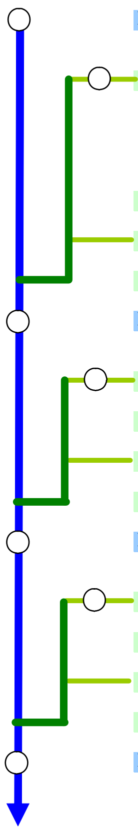
Aggregate Loads (%)	Jun	Jul	Aug	Sep
Klamath at Iron Gate	5.9%	30.3%	45.5%	58.2%
Major tributaries	75.5%	34.2%	19.5%	28.7%
Nongauged	18.6%	35.5%	34.9%	13.1%
Difference	46.5%	-54.5%	-19.4%	118.8%

Balances (kg/mo)	Jun	Jul	Aug	Sep
Klamath near Seiad Valley	248,414	-76,059	-10,447	-33,023
Klamath at Orleans	177,246	-23,434	282,993	291,000
Klamath at Klamath	456,738	-20,109	-326,561	179,487

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 12d. Total Suspended Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2004 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TSS Loads for Klamath main stem (ND = ½ MDL)
CY 2005



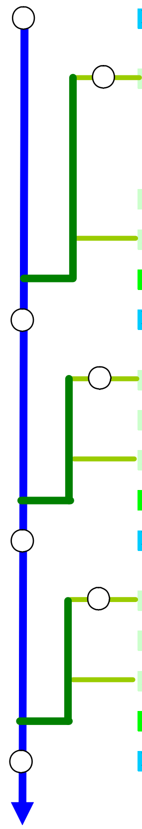
gauge	number	drainage area (mi^2)	Total Suspended Solids Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	265				
Tributaries:							
Shasta near Yreka	11517500	793	34,549	12,919	13,531	16,767	59,273
Scott near Ft Jones	11519500	653	240,794	50,699	8,319	590	1,321
Total		1,446	275,344	63,618	21,850	17,357	60,595
Nongauged		864	77,308	12,249	4,597	1,772	9,379
Total intervening		2,310	352,652	75,867	26,447	19,129	69,973
Klamath near Seiad Valley	11520500	6,940	942,771	488,513	417,310	312,406	
Tributaries:							
Salmon at Somes Bar	11522500	751	712,644	115,844	112,396		
Nongauged		784	281,931	68,105	81,128	32,016	32,589
Total intervening		1,535	994,575	183,949	193,524	32,016	32,589
Klamath at Orleans	11523000	8,475	2,453,332	1,190,881	819,449		
Tributaries:							
Trinity at Hoopa	11530000	2,853	2,094,135	1,007,734	400,329	31,062	
Nongauged		772	266,282	43,199	45,793	12,664	74,042
Total intervening		3,625	2,360,417	1,050,933	446,122	43,726	74,042
Klamath at Klamath	11530500	12,100	5,301,096	2,460,428	1,383,326	1,054,415	

	Jun	Jul	Aug
Aggregate Loads (kg/mo)			
Klamath at Iron Gate	265		
Major tributaries	3,082,123		
Nongauged	625,521		
Difference	1,593,187		
Aggregate Loads (%)			
Klamath at Iron Gate	0.0%		
Major tributaries	83.1%		
Nongauged	16.9%		
Difference	43.0%		
Balances (kg/mo)			
Klamath near Seiad Valley	589,854		
Klamath at Orleans	515,986	518,419	208,615
Klamath at Klamath	487,347	218,614	117,754

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 12e. Total Suspended Solids monthly average loading in the lower Klamath River and its major and minor tributaries for CY2005 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TOC Loads for Klamath main stem (ND = ½ MDL)
CY 2001

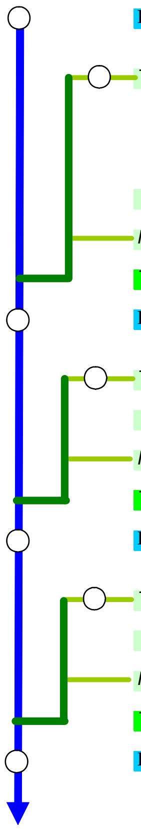


gauge	number	drainage area (mi²)	Total Organic Carbon Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	807,793	349,436	426,877	511,969	641,779
Tributaries:							
Shasta near Yreka	11517500	793	16,957	13,773	10,164	18,989	40,424
Scott near Ft Jones	11519500	653	5,587	1,058	733	406	429
Total		1,446	22,544	14,831	10,896	19,395	40,854
Nongauged		864	10,913	3,011	-225	-430	1,736
Total intervening		2,310	33,456	17,841	10,671	18,965	42,590
Klamath near Seiad Valley	11520500	6,940	870,890	323,879	388,821	400,449	773,224
Tributaries:							
Salmon at Somes Bar	11522500	751	35,740	8,126	5,706	5,654	8,750
Nongauged		784	22,932	8,744	7,881	4,249	2,949
Total intervening		1,535	58,672	16,870	13,587	9,903	11,699
Klamath at Orleans	11523000	8,475	802,478	292,601	343,904	377,260	611,849
Tributaries:							
Trinity at Hoopa	11530000	2,853	143,991	48,862	53,833	43,919	58,664
Nongauged		772	293,071	109,171	166,509	79,341	147,139
Total intervening		3,625	437,062	158,034	220,342	123,260	205,804
Klamath at Klamath	11530500	12,100	1,212,468	421,788	483,525	448,680	906,430
Aggregate Loads (kg/mo)							
Klamath at Iron Gate			807,793	349,436	426,877	511,969	641,779
Major tributaries			202,274	71,819	70,435	68,969	108,268
Nongauged			326,916	120,926	174,165	83,161	151,824
Difference			-124,514	-120,394	-187,952	-215,418	4,559
Aggregate Loads (%)							
Klamath at Iron Gate			60.4%	64.5%	63.6%	77.1%	71.2%
Major tributaries			15.1%	13.2%	10.5%	10.4%	12.0%
Nongauged			24.5%	22.3%	25.9%	12.5%	16.8%
Difference			-9.3%	-22.2%	-28.0%	-32.4%	0.5%
Balances (kg/mo)							
Klamath near Seiad Valley			29,641	-43,398	-48,727	-130,485	88,855
Klamath at Orleans			-127,084	-48,148	-58,504	-33,092	-173,074
Klamath at Klamath			-27,071	-28,847	-80,721	-51,841	88,777

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 13a. Total Organic Carbon monthly average loading in the lower Klamath River and its major and minor tributaries for CY2001 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TOC Loads for Klamath main stem (ND = ½ MDL)
CY 2002

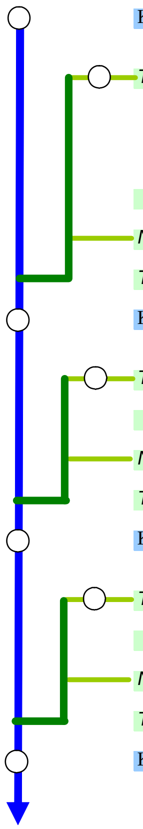


gauge	number	drainage area (mi^2)	Total Organic Carbon Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	455,511	446,586	449,324	522,145	658,880
Tributaries:							
Shasta near Yreka	11517500	793	23,071	14,192	14,524	18,811	58,869
Scott near Ft Jones	11519500	653	57,936	6,333	1,586	1,097	1,590
Total		1,446	81,007	20,525	16,111	19,908	60,459
Nongauged		864	37,981	9,170	9,156	2,629	2,710
Total intervening		2,310	118,988	29,695	25,267	22,537	63,169
Klamath near Seiad Valley	11520500	6,940	544,081	404,238	405,998	499,843	593,688
Tributaries:							
Salmon at Somes Bar	11522500	751	103,401	26,426	13,622	8,889	9,060
Nongauged		784	156,889	33,572	52,654	23,221	32,603
Total intervening		1,535	260,290	59,997	66,275	32,109	41,663
Klamath at Orleans	11523000	8,475	632,990	370,571	383,079	584,344	745,506
Tributaries:							
Trinity at Hoopa	11530000	2,853	166,469	76,836	66,028	62,530	91,294
Nongauged		772	264,638	91,298	117,925	39,651	61,141
Total intervening		3,625	431,107	168,134	183,953	102,182	152,434
Klamath at Klamath	11530500	12,100	910,462	467,428	432,523	358,488	629,239
Aggregate Loads (kg/mo)							
Klamath at Iron Gate			455,511	446,586	449,324	522,145	658,880
Major tributaries			350,877	123,787	95,761	91,327	160,812
Nongauged			459,509	134,039	179,734	65,501	96,454
Difference			-355,435	-236,985	-292,296	-320,485	-286,907
Aggregate Loads (%)							
Klamath at Iron Gate			36.0%	63.4%	62.0%	76.9%	71.9%
Major tributaries			27.7%	17.6%	13.2%	13.5%	17.6%
Nongauged			36.3%	19.0%	24.8%	9.6%	10.5%
Difference			-28.1%	-33.6%	-40.3%	-47.2%	-31.3%
Balances (kg/mo)							
Klamath near Seiad Valley			-30,419	-72,044	-68,593	-44,839	-128,361
Klamath at Orleans			-171,382	-93,664	-89,195	52,392	110,155
Klamath at Klamath			-153,635	-71,277	-134,508	-328,038	-268,701

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 13b. Total Organic Carbon monthly average loading in the lower Klamath River and its major and minor tributaries for CY2002 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TOC Loads for Klamath main stem (ND = ½ MDL)
CY 2003



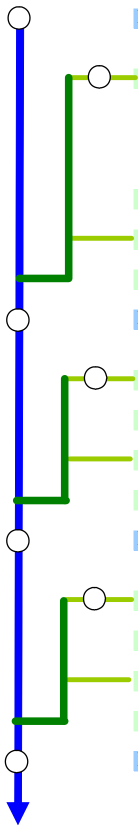
gauge	number	drainage area (mi²)	Total Organic Carbon Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	670,045	401,361	423,101	787,240	
Tributaries:							
Shasta near Yreka	11517500	793	32,024	29,203	41,283	37,380	
Scott near Ft Jones	11519500	653			15,296		
Total		1,446	32,024	29,203	56,579	37,380	0
Nongauged		864	74,033	10,845	7,306	3,374	3,644
Total intervening		2,310	106,057	40,048	63,885	40,754	3,644
Klamath near Seiad Valley	11520500	6,940			397,185		
Tributaries:							
Salmon at Somes Bar	11522500	751			47,797		
Nongauged		784	156,829	47,679	63,117	23,643	30,236
Total intervening		1,535	156,829	47,679	110,914	23,643	30,236
Klamath at Orleans	11523000	8,475			443,408	571,642	
Tributaries:							
Trinity at Hoopa	11530000	2,853		188,417	126,895		
Nongauged		772	106,126	27,508	24,814	10,048	17,941
Total intervening		3,625	106,126	215,925	151,709	10,048	17,941
Klamath at Klamath	11530500	12,100	1,799,446	710,066	446,538		

	Jun	Jul	Aug	Sep	Oct
Aggregate Loads (kg/mo)					
Klamath at Iron Gate			423,101		
Major tributaries			231,272		
Nongauged			95,237		
Difference			-303,072		
Aggregate Loads (%)					
Klamath at Iron Gate			56.4%		
Major tributaries			30.9%		
Nongauged			12.7%		
Difference			-40.4%		
Balances (kg/mo)					
Klamath near Seiad Valley			-89,802		
Klamath at Orleans			-64,691		
Klamath at Klamath			-148,580		

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 13c. Total Organic Carbon monthly average loading in the lower Klamath River and its major and minor tributaries for CY2003 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TOC Loads for Klamath main stem (ND = ½ MDL)
CY 2004

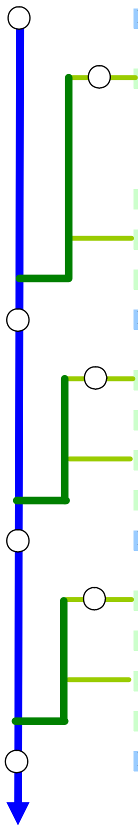


gauge	number	drainage area (mi²)	Total Organic Carbon Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	300,934	286,489	301,059	365,134	330,216
Tributaries:							
Shasta near Yreka	11517500	793	21,712	14,531	19,359	18,949	
Scott near Ft Jones	11519500	653	44,180	5,152	907	718	
Total		1,446	65,892	19,683	20,265	19,668	0
Nongauged		864	45,092	8,835	3,523	1,748	6,130
Total intervening		2,310	110,984	28,518	23,788	21,416	6,130
Klamath near Seiad Valley	11520500	6,940	385,753	278,284	312,196	353,481	
Tributaries:							
Salmon at Somes Bar	11522500	751	106,592	33,878	12,864	6,609	
Nongauged		784	117,120	34,871	47,424	25,905	54,901
Total intervening		1,535	223,712	68,749	60,288	32,514	54,901
Klamath at Orleans	11523000	8,475	555,180	333,635	384,659	415,581	
Tributaries:							
Trinity at Hoopa	11530000	2,853	232,516	93,273	53,627	62,101	
Nongauged		772	83,825	29,924	50,549	21,677	-8,558
Total intervening		3,625	316,341	123,197	104,177	83,777	-8,558
Klamath at Klamath	11530500	12,100	681,462	398,826	337,188	380,482	
Aggregate Loads (kg/mo)							
Klamath at Iron Gate			300,934	286,489	301,059	365,134	
Major tributaries			405,000	146,834	86,757	88,377	
Nongauged			246,037	73,631	101,496	49,330	
Difference			-270,509	-108,127	-152,124	-122,359	
Aggregate Loads (%)							
Klamath at Iron Gate			31.6%	56.5%	61.5%	72.6%	
Major tributaries			42.5%	29.0%	17.7%	17.6%	
Nongauged			25.8%	14.5%	20.7%	9.8%	
Difference			-28.4%	-21.3%	-31.1%	-24.3%	
Balances (kg/mo)							
Klamath near Seiad Valley			-26,166	-36,723	-12,651	-33,069	
Klamath at Orleans			-54,285	-13,399	12,175	29,586	
Klamath at Klamath			-190,058	-58,006	-151,648	-118,876	

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 13d. Total Organic Carbon monthly average loading in the lower Klamath River and its major and minor tributaries for CY2004 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

TOC Loads for Klamath main stem (ND = ½ MDL)
CY 2005



gauge	number	drainage area (mi^2)	Total Organic Carbon Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	573,797	401,854	454,849	497,493	668,944
Tributaries:							
Shasta near Yreka	11517500	793	46,296	15,684	17,942	28,458	30,844
Scott near Ft Jones	11519500	653	98,485	11,458	2,030	1,090	3,488
Total		1,446	144,781	27,142	19,972	29,548	34,332
Nongauged		864	53,751	11,600	4,794	1,814	6,649
Total intervening		2,310	198,532	38,742	24,766	31,361	40,982
Klamath near Seiad Valley	11520500	6,940	760,816	469,950	480,741	551,918	
Tributaries:							
Salmon at Somes Bar	11522500	751	212,368	45,758	60,019	9,466	
Nongauged		784	196,022	64,494	84,605	32,771	23,105
Total intervening		1,535	408,390	110,252	144,625	42,238	23,105
Klamath at Orleans	11523000	8,475	1,133,439	585,913	511,336	621,891	
Tributaries:							
Trinity at Hoopa	11530000	2,853	466,992	131,005	78,384	58,334	
Nongauged		772	185,142	40,908	47,756	12,963	52,495
Total intervening		3,625	652,134	171,914	126,140	71,297	52,495
Klamath at Klamath	11530500	12,100	1,802,373	703,682	525,664	538,669	

Aggregate Loads (kg/mo)	Jun	Jul	Aug	Sep
Klamath at Iron Gate	573,797	401,854	454,849	497,493
Major tributaries	824,141	203,906	158,376	97,347
Nongauged	434,914	117,001	137,155	47,548
Difference	-30,480	-19,078	-224,717	-103,720

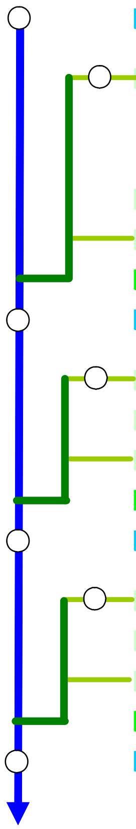
Aggregate Loads (%)	Jun	Jul	Aug	Sep
Klamath at Iron Gate	31.3%	55.6%	60.6%	77.4%
Major tributaries	45.0%	28.2%	21.1%	15.2%
Nongauged	23.7%	16.2%	18.3%	7.4%
Difference	-1.7%	-2.6%	-29.9%	-16.1%

Balances (kg/mo)	Jun	Jul	Aug	Sep
Klamath near Seiad Valley	-11,514	29,354	1,125	23,063
Klamath at Orleans	-35,766	5,712	-114,029	27,736
Klamath at Klamath	16,800	-54,145	-111,813	-154,519

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 13e. Total Organic Carbon monthly average loading in the lower Klamath River and its major and minor tributaries for CY2005 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

Chlorophyll a Loads for Klamath main stem (ND = ½ MDL)
CY 2001



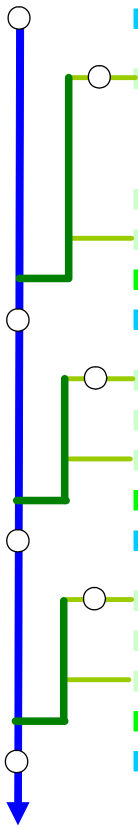
gauge	number	drainage area (mi^2)	Chlorophyll a Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	10	44	1,229	343	69
Tributaries:							
Shasta near Yreka	11517500	793	3	0	2	3	17
Scott near Ft Jones	11519500	653	3	0	0	0	0
Total		1,446	6	0	2	3	17
Nongauged		864	4	1	0	0	1
Total intervening		2,310	10	1	2	3	18
Klamath near Seiad Valley	11520500	6,940	297	291	349	98	351
Tributaries:							
Salmon at Somes Bar	11522500	751	12	2	5	6	4
Nongauged		784	9	3	2	3	1
Total intervening		1,535	21	5	6	9	5
Klamath at Orleans	11523000	8,475	67	73	426	38	203
Tributaries:							
Trinity at Hoopa	11530000	2,853	46	11	45	14	17
Nongauged		772	109	32	33	47	62
Total intervening		3,625	155	43	77	61	79
Klamath at Klamath	11530500	12,100	33	99	844	305	444

	Jun	Jul	Aug	Sep	Oct
Aggregate Loads (kg/mo)					
Klamath at Iron Gate	10	44	1,229	343	69
Major tributaries	65	14	52	24	38
Nongauged	121	36	34	49	64
Difference	-164	6	-471	-110	273
Aggregate Loads (%)					
Klamath at Iron Gate	5.3%	47.2%	93.5%	82.4%	40.6%
Major tributaries	33.0%	14.6%	3.9%	5.7%	22.2%
Nongauged	61.6%	38.2%	2.6%	11.9%	37.2%
Difference	-83.2%	6.1%	-35.8%	-26.5%	159.6%
Balances (kg/mo)					
Klamath near Seiad Valley	276	245	-882	-248	264
Klamath at Orleans	-251	-223	71	-69	-154
Klamath at Klamath	-189	-17	340	206	163

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 14a. Chlorophyll-a monthly average loading in the lower Klamath River and its major and minor tributaries for CY2001 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

Chlorophyll a Loads for Klamath main stem (ND = ½ MDL)
CY 2002

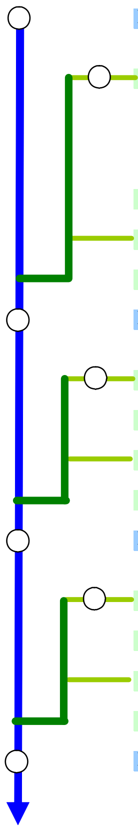


gauge	number	drainage area (mi^2)	Chlorophyll a Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	204	165	573	239	508
Tributaries:							
Shasta near Yreka	11517500	793	1	3	2	2	18
Scott near Ft Jones	11519500	653	12	5	0	0	1
Total		1,446	13	7	3	2	19
Nongauged		864	14	3	2	2	1
Total intervening		2,310	27	10	4	3	20
Klamath near Seiad Valley	11520500	6,940	75	67	167	60	298
Tributaries:							
Salmon at Somes Bar	11522500	751	58	12	1	0	4
Nongauged		784	58	10	10	14	14
Total intervening		1,535	116	22	11	14	17
Klamath at Orleans	11523000	8,475	112	175	67	134	292
Tributaries:							
Trinity at Hoopa	11530000	2,853	43	33	3	6	2
Nongauged		772	98	27	23	24	26
Total intervening		3,625	142	60	26	30	28
Klamath at Klamath	11530500	12,100	503	181	124	198	264
Aggregate Loads (kg/mo)							
Klamath at Iron Gate			204	165	573	239	508
Major tributaries			115	52	6	8	25
Nongauged			170	40	35	39	41
Difference			14	-76	-490	-88	-309
Aggregate Loads (%)							
Klamath at Iron Gate			41.7%	64.2%	93.3%	83.5%	88.7%
Major tributaries			23.4%	20.3%	0.9%	2.9%	4.3%
Nongauged			34.8%	15.4%	5.7%	13.6%	7.1%
Difference			2.9%	-29.5%	-79.9%	-30.9%	-53.9%
Balances (kg/mo)							
Klamath near Seiad Valley			-157	-108	-410	-182	-229
Klamath at Orleans			-79	86	-111	60	-24
Klamath at Klamath			249	-53	31	34	-55

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 14b. Chlorophyll-a monthly average loading in the lower Klamath River and its major and minor tributaries for CY2002 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

Chlorophyll a Loads for Klamath main stem (ND = ½ MDL)
CY 2003



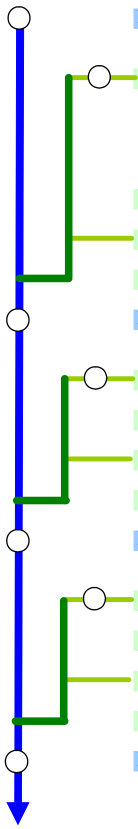
gauge	number	drainage area (mi²)	Chlorophyll a Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	354	3	4	631	
Tributaries:							
Shasta near Yreka	11517500	793	2	0	2	7	
Scott near Ft Jones	11519500	653			5		
Total		1,446	2	0	7	7	0
Nongauged		864	27	3	1	2	2
Total intervening		2,310	29	3	8	9	2
Klamath near Seiad Valley	11520500	6,940			5		
Tributaries:							
Salmon at Somes Bar	11522500	751			1		
Nongauged		784	58	14	12	14	13
Total intervening		1,535	58	14	13	14	13
Klamath at Orleans	11523000	8,475			8	241	
Tributaries:							
Trinity at Hoopa	11530000	2,853		8	32	4	
Nongauged		772	39	8	5	6	8
Total intervening		3,625	39	16	37	10	8
Klamath at Klamath	11530500	12,100	47	20	13	74	

	Jun	Jul	Aug	Sep	Oct
Aggregate Loads (kg/mo)					
Klamath at Iron Gate			4		
Major tributaries			40		
Nongauged			19		
Difference			-49		
Aggregate Loads (%)					
Klamath at Iron Gate			6.1%		
Major tributaries			64.1%		
Nongauged			29.8%		
Difference			-78.9%		
Balances (kg/mo)					
Klamath near Seiad Valley			-7		
Klamath at Orleans			-10		
Klamath at Klamath			-32	-176	

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 14c. Chlorophyll-a monthly average loading in the lower Klamath River and its major and minor tributaries for CY2003 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

Chlorophyll a Loads for Klamath main stem (ND = ½ MDL)
CY 2004



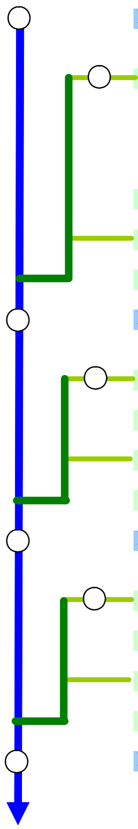
gauge	number	drainage area (mi^2)	Chlorophyll a Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630		220	233	375	47
Tributaries:							
Shasta near Yreka	11517500	793		0	7	4	
Scott near Ft Jones	11519500	653		0	0	0	
Total		1,446	0	0	7	4	0
Nongauged		864	17	3	1	1	3
Total intervening		2,310	17	3	8	5	3
Klamath near Seiad Valley	11520500	6,940		4	51	98	
Tributaries:							
Salmon at Somes Bar	11522500	751		2	1	4	
Nongauged		784	43	10	9	15	23
Total intervening		1,535	43	12	10	19	23
Klamath at Orleans	11523000	8,475		8	81	193	
Tributaries:							
Trinity at Hoopa	11530000	2,853		41	37	32	
Nongauged		772	31	9	10	13	-4
Total intervening		3,625	31	49	47	45	-4
Klamath at Klamath	11530500	12,100		17	11	515	

	Jul	Aug	Sep
Aggregate Loads (kg/mo)			
Klamath at Iron Gate	220	233	375
Major tributaries	43	45	40
Nongauged	22	20	29
Difference	-268	-286	70
Aggregate Loads (%)			
Klamath at Iron Gate	77.2%	78.2%	84.4%
Major tributaries	15.1%	15.2%	9.0%
Nongauged	7.6%	6.7%	6.6%
Difference	-94.2%	-96.2%	15.8%
Balances (kg/mo)			
Klamath near Seiad Valley	-219	-189	-282
Klamath at Orleans	-8	20	76
Klamath at Klamath	-41	-117	277

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 14d. Chlorophyll-a monthly average loading in the lower Klamath River and its major and minor tributaries for CY2004 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)

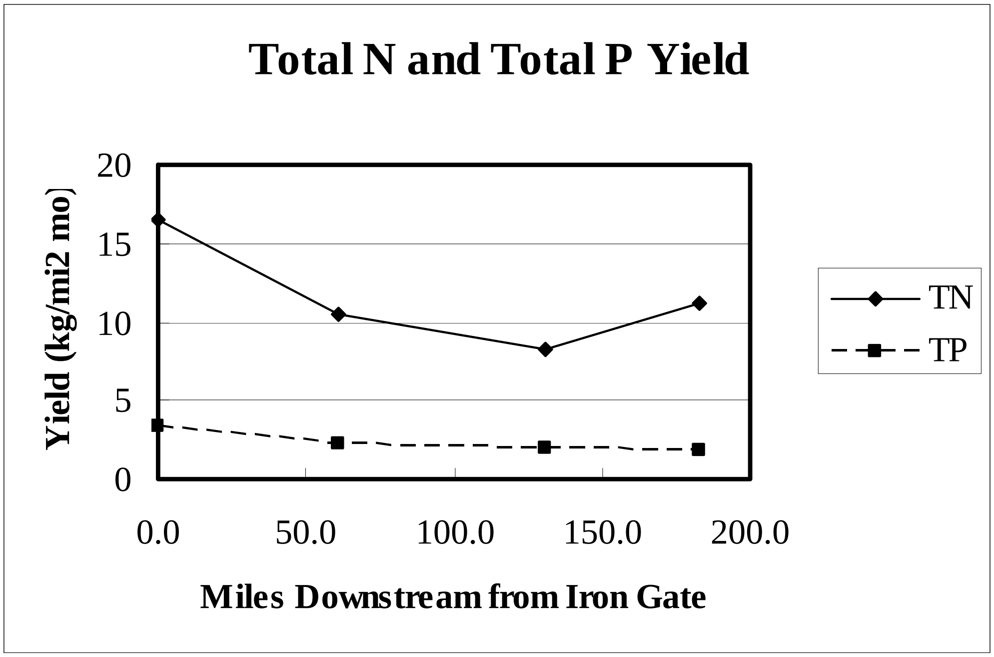
Chlorophyll a Loads for Klamath main stem (ND = ½ MDL)
CY 2005



gauge	number	drainage area (mi^2)	Chlorophyll a Load (kg/mo) Jun	Jul	Aug	Sep	Oct
Klamath at Iron Gate	11516530	4,630	265	347	84	1,224	232
Tributaries:							
Shasta near Yreka	11517500	793	5	4	3	7	12
Scott near Ft Jones	11519500	653	98	10	1		3
Total		1,446	102	14	4	7	16
Nongauged		864	20	3	1	1	3
Total intervening		2,310	122	17	5	8	18
Klamath near Seiad Valley	11520500	6,940	184	107	1,085	407	
Tributaries:							
Salmon at Somes Bar	11522500	751	36	14	13		
Nongauged		784	73	19	17	19	10
Total intervening		1,535	108	34	30	19	10
Klamath at Orleans	11523000	8,475	380	191	1,409		
Tributaries:							
Trinity at Hoopa	11530000	2,853	178	50	20	37	
Nongauged		772	69	12	9	8	22
Total intervening		3,625	247	62	29	45	22
Klamath at Klamath	11530500	12,100	716	935	1,411	986	
Aggregate Loads (kg/mo)							
Klamath at Iron Gate			265	347	84		
Major tributaries			316	79	38		
Nongauged			161	35	27		
Difference			-26	474	1,262		
Aggregate Loads (%)							
Klamath at Iron Gate			35.7%	75.4%	56.6%		
Major tributaries			42.6%	17.1%	25.4%		
Nongauged			21.7%	7.5%	18.0%		
Difference			-3.5%	103.0%	849.1%		
Balances (kg/mo)							
Klamath near Seiad Valley			-203	-257	996	-825	
Klamath at Orleans			88	49	294		
Klamath at Klamath			89	682	-28		

Amount = Downstr Klamath Sta - (Upstream Klamath Sta + Total Intervening)

Figure 14e. Chlorophyll-a monthly average loading in the lower Klamath River and its major and minor tributaries for CY2005 with ND level set to ½ MDL. (See text for explanation of Aggregate Loads and Balances.)



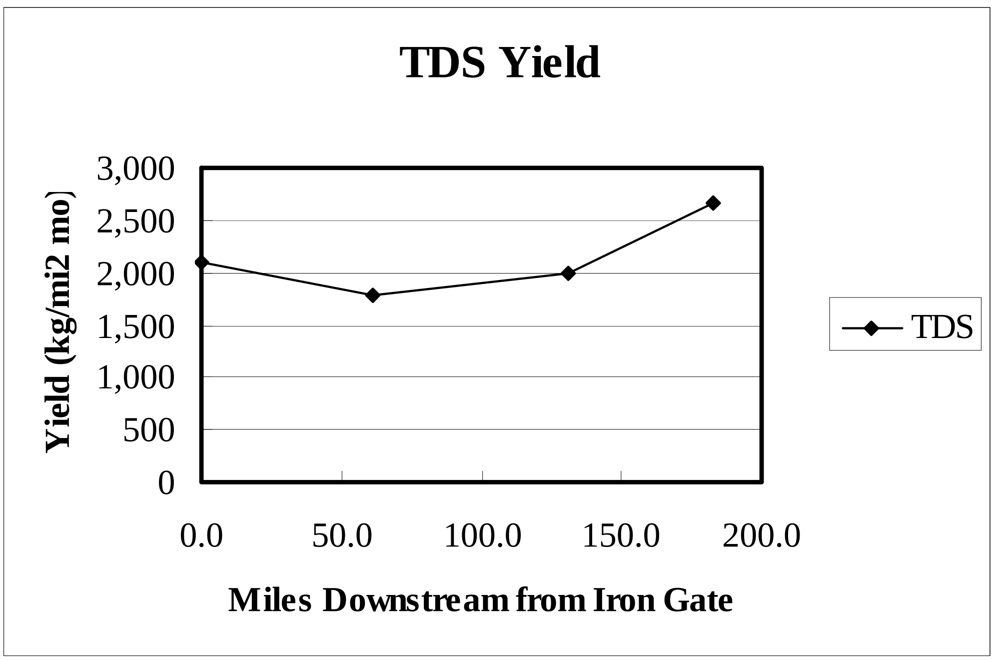
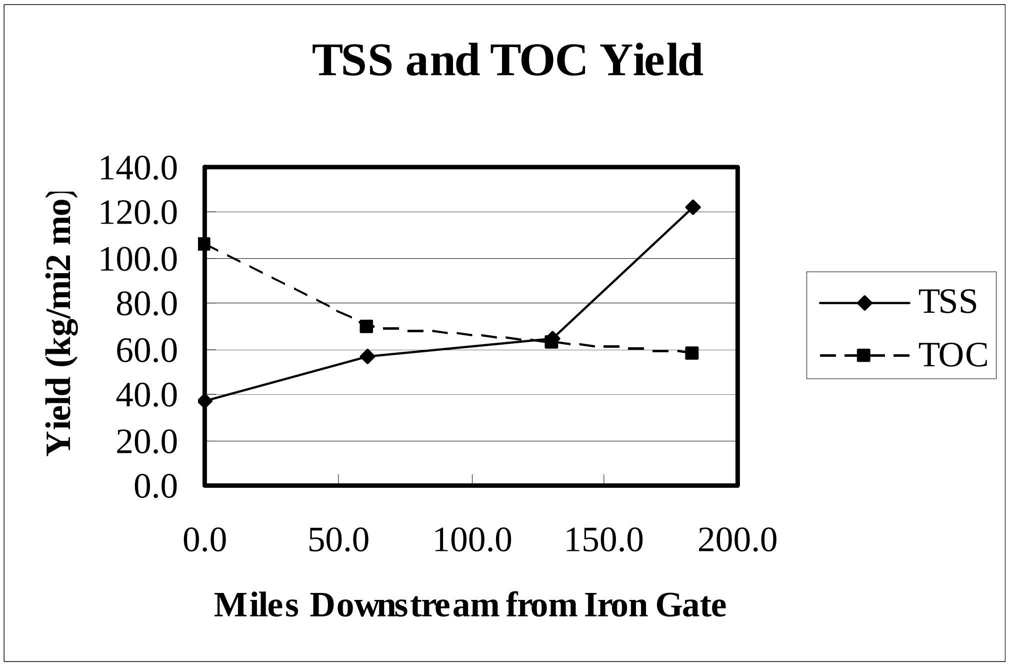


Figure 15a. Yields (kg/mi^2 mo) of Total Nitrogen, Total Phosphorus, Total Dissolved Solids, Total Suspended Solids, Total Organic Carbon, and Chlorophyll-a in the Klamath River during CY2001-CY2005.



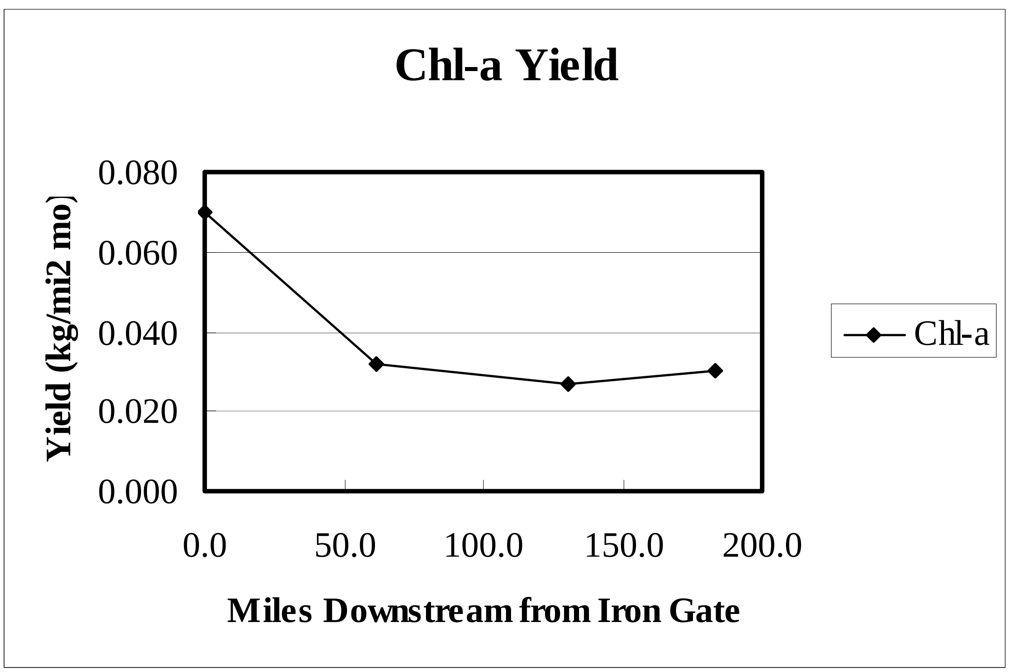


Figure 15b. Yields (kg/mi^2 mo) of Total Nitrogen, Total Phosphorus, Total Dissolved Solids, Total Suspended Solids, Total Organic Carbon, and Chlorophyll-a in the Klamath River during CY2001-CY2005.