ANALYSIS OF FY11 GRANITE CREEK TURBIDITY, SEDIMENT (TSS) AND FLOW DATA AND EFFECTS ON SEDIMENT MODELS AND LOAD CALCULATIONS

June 30, 2011

Task 5 of the FY11 Granite Creek project workplan calls for an analysis of turbidity and TSS data collected in FY11 for updating sediment load models and in-stream sediment load calculations developed annually in FY07, FY08, FY09 and FY10. This ensures that estimates of existing in-stream sediment loads (tons TSS/month and tons TSS/year) use all recently available water quality information. The newly calculated FY11 sediment loads allow for comparing against prior years' sediment loads and quantifying load reductions over time in compliance with the 2002 TMDL. Importantly, existing in-stream sediment loads must be below the allowable sediment stream load (the load capacity) in order to support delisting.

Over the last several years, simultaneous collection of TSS and turbidity data, along with stream staff gage height correlated to a stage-discharge curve, has allowed for determining the instantaneous sediment-flow relationship for the creek and, with extrapolation, to monthly and annual sediment loads. Sediment loads are directly proportional to flow rates. These analyses have provided quantifiable results on the effectiveness of sediment control BMPs in improving water quality of Granite Creek and a factual basis for recommending modifications to BMPs. The data also provides a basis for determining whether the TMDL has been met, i.e. when the in-stream sediment load is lower than the allowable sediment load. The FY11 simultaneous data sets provided thirteen (13) new data points for updating mathematical equations on the relationship of TSS-to-turbidity and the relationship of TSS-to-flow rate.

Monthly sampling conducted at Station GC1 since September 2007 was changed to a random day of the month, independent of weather conditions, to avoid preferentially targeting high rainfall/high flow events. This more random method understandably resulted in proportionally more low flows measured in 2007, 2008, 2009, 2010 and 2011 compared with the 2002-2007 period which often targeted high flows.

The Stepwise Process Used in FY11 Data Review

The FY07 comprehensive analysis of water quality data completed in June 2007 covered the period October 2002 through January 2007. The follow-up analysis completed in June 2008 addressed sixteen (16) additional monthly simultaneous TSS and turbidity data sets collected at Station GC1 at Granite Creek through May 2008. The FY09 analysis added another fourteen (14) data sets; FY10 added 17 more data sets. Stream gage height was also simultaneously documented, and later converted to flow rate (cfs) using the USGS stream rating table. The FY11 analysis is the fifth load update to be completed

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since 2007, and includes simultaneous TSS and turbidity data sets collected at Station GC1 from July 2010 through June 2011. *Table 1* includes a summary of all TSS, turbidity, gage height and flow rate data collected from July 2010 through June 2011. The reader is referred to the earlier reports for detailed data covering October 2002 through June 2010. Important excerpts and calculations from those reports are included in this analysis for continuity.

The process used to analyze the 2010-2011 data was identical to that used in the prior 2007 through 2010 water quality analyses, with a few additional calculations made for comparative purposes. A listing of sequential steps that needed to occur was prepared to guide the data analysis. Essential variables, parameters and relationships that needed examination were identified. As with the FY07/FY08/FY09/FY10 reports, data analysis focused on the monitoring results from Station GC1, the watershed integrator station at the Halibut Point Road bridge site. This station is the location of a USGS staff gage and the site of monthly monitoring of TSS and turbidity concentrations since October 2002.

In addition, comprehensive monitoring data collected throughout the watershed by the project consultant in FY11 were used to address time series of events over three day periods, and confirm source contributions of sediment within the watershed. The City and Borough of Sitka also completed comprehensive storm event monitoring in October 2010 to address these very high flow conditions. These results are discussed in the section *FY10 Watershed-Wide Water Quality Data and General Observations.*

The steps in the analysis included:

- Tabulate all new turbidity and TSS data using the 13 simultaneously collected data sets from July 2010 through June 2011, and add to the previous 97 data sets collected since 2002.

- Complete a new linear regression analysis on all 110 simultaneously-collected TSS and turbidity data sets from October 2002 through June 2011 and generate an updated "y = mx + b" equation representing that relationship.

- Use the new TSS-turbidity mathematical equation to calculate the allowable "target" TSS concentration corresponding to 6.64 NTUs (= 5 NTUs above natural conditions). This TSS concentration is used to calculate the allowable load capacity (LC).

- Review new monthly flow rate data collected for July 2010 through June 2011 against the average monthly flows (AMF) calculated in June 2010 to see if any revisions to AMFs were warranted. Particular attention was paid to November.

- Run linear regression analysis on the 13 simultaneous TSS and flow rate measurements collected from July 2010 through June 2011 and generate an equation reflecting the TSS-flow rate relationship for that period. This equation then generates a TSS value for a given flow rate value. Run a linear regression analysis on all 110

TSS and flow rate data sets and generate an updated equation covering the period October 2002 through June 2011.

- Using the new FY11 TSS: flow rate equation, calculate average monthly in-stream TSS concentrations using data from the entire period of record, October 2002 through June 2011. Table 2 shows these results.

- For comparison, calculate annual in-stream sediment load and load capacity for the period July 2010 through June 2011 to compare with previously estimated annual in-stream sediment loads (in tons TSS/year).

Table 1. Relationship of Total Suspended Solids (TSS), turbidity, and flow rate at Station GC1, Granite Creek, Alaska, from July 2010 through June 2011. [1]

Date	**TSS (mg/l)**	**Mean turbidity (NTU)**	**Turbidity Replicates (NTU)**	**Flow rate (cfs)**	**USGS staff gage height (ft)**	**Comments and notes**
						USGS installed
7/14/10	1.0	2.05	2.10, 2.01	22.5	19.32	permanent stream
8/11/10	0.4	0.85	0.87, 0.84	2.4	18.84	staff gage on
9/09/10	2.3	2.03	2.06, 2.01	5.2	19.00	November 8, 2002
9/28/10	0.5	2.59	2.66, 2.53	5.7	19.02	
11/12/09	2.8	2.93	2.95, 2.92	82.9	19.66	
11/17/10				2.6	18.86	Additional Nov.
11/24/10				2.4	18.84	gage heights
12/15/10	0.1	0.42	0.39, 0.45	1.2	18.70	
1/12/11	0.2	0.41	0.39, 0.42	14.6	19.22	
2/07/11	0.1	0.48	0.49, 0.48	2.0	18.80	
3/09/11	0.2	0.90	0.91, 0.89	0.96	18.62	
4/13/11	0.6	1.86	1.84, 1.88	3.1	18.90	
5/18/11	0.3	0.39	0.38, 0.40	2.9	18.88	
5/31/11	0.1	2.30	1.85, 2.74	2.7	18.87	
6/09/11	0.2	0.35	0.34, 0.37	1.7	18.76	

[1] Flow rates are derived from staff gage height readings converted using the USGS stage discharge curve (SDC) and stream rating table.

1. TSS-to-turbidity relationship

Alaska water quality standards limit allowable turbidity to 5 NTUs above natural conditions to protect the drinking water use - the "default" designated use for Granite Creek. The turbidity criterion for the aquatic life use category may not exceed 25 NTUs above natural conditions.

The following assumptions were made in the TMDL and were upheld in analyses completed in 2007, 2008, 2009, 2010 and 2011.

1. Granite Creek has an average natural background turbidity of *1.64 NTU*.
2. A turbidity of 1.64 NTU + 5 NTU = *6.64 NTU* as the target turbidity water quality standard

Another important conversion was necessary to allow for a quantitative calculation of sediment loading capacity for Granite Creek. The majority of water quality data collected from Granite Creek through 2002 was turbidity. Turbidity is an optical property and is a measure of the amount of light-scattering particles in the water. However, loading capacities are most often expressed as a mass per unit time. Not being a measure of the weight of particles in water, turbidity cannot be used *directly* to calculate pollutant loads (in tons of sediment) or load allocations. The TMDL required conversion of turbidity values to an equivalent TSS value to estimate sediment loads gravimetrically (by weight, in tons). Total suspended solids (TSS) was selected to represent sediment loads in Granite Creek.

History of the statistical relationship of TSS –to -turbidity

For the TMDL in 2002, regression analysis was completed on the data sets to establish the TSS-turbidity relationship. Sixteen data sets were plotted. The following equation described the relationship between TSS and turbidity in the original 2002 TMDL:

$$\text{TSS (mg/l)} = [1.075\ (\text{turbidity in NTUs})] - 1.681$$

The correlation coefficient for the data was a highly significant 0.9676.

Validating this relationship was an important task in the comprehensive analysis completed in FY07, as calculations for all in-stream sediment loads depend on it. In June 2007, cumulative analysis was completed on all 50 *simultaneously collected* TSS and turbidity data sets from October 2002 through January 2007. A new linear regression analysis was completed on the data collected from 2002 through early 2007. The following revised equation was generated:

$$\text{(2007 equation): TSS (mg/l)} = [1.2204\ (\text{turbidity in NTUs})] - 2.934$$

The correlation coefficient for the 2007 cumulative analysis remained a highly significant 0.9780. Similar analyses were completed in each of FY08, FY09 and FY10.

For FY11, all 13 new monthly data sets, together with the previous 97 data sets collected through June 2010, were run through linear regression analysis. The new FY11 equation generated was:

(2011 revised equation): TSS (mg/l) = [1.09579 (turbidity in NTUs)] – 2.22970

The correlation coefficient (r^2) for the new data analysis is a highly significant 0.95196.

The addition of 13 FY11 TSS-turbidity data sets helps to strengthen the statistical relationship between TSS and turbidity. Importantly, the revised equation yields TSS values that deviate from the original equation by only 2% to 7% over the range of normally encountered turbidity levels. For example, using the original 2002 equation, a turbidity concentration of 10 NTUs represented a TSS equivalent of 9.27 mg/l. Using the 2011 equation, a 10 NTU turbidity level predicts a TSS level of 8.73 mg/l, a 7% change from the original estimate. The new allowable target TSS concentration (equivalent to 6.64 NTUs) is 5.04 mg/l, compared to the 4.95 mg/l limit derived in 2010. The new "target" value for TSS is used in calculating the allowable monthly and annual sediment load capacity for Granite Creek in Table 3.

The bottom line is that the original TSS: turbidity regression equation was valid and acceptably accurate as confirmed from subsequent analysis of all 110 data sets collected from 2002 through June 2011. The most recent revised equation, however, should be used for further analysis since it is based on a larger number of data points and, hence, is expected to be more accurate and statistically supportable.

Confirming the close relationship between turbidity and TSS provides several benefits. First, water quality sampling could potentially rely on turbidity measurements alone, or a reduced number of TSS samples, in calculating TSS with a reasonable amount of accuracy. This is both cost-effective and provides real-time information without the need to await the results of laboratory analysis. Secondly, turbidity concentrations are more easily estimated and understood by gravel operators and other lease operators in conducting visual self-monitoring of the effects of their operations on water quality.

2. Sediment (TSS)-to-flow relationship

Of key importance in estimating monthly loading capacity and existing in-stream sediment loads in Granite Creek is creating a statistical model of the TSS-flow relationship. In 2002, data were insufficient to support a statistically significant regression equation. This was particularly true for higher flow-higher TSS conditions. Best available information was used.

In 2007, the cumulative analysis of TSS and flow data completed from October 2002 through January 2007 suggested that the original relationship of flow rate to average TSS concentration developed in 2002 for the TMDL was not entirely accurate for Granite Creek.

This latest load revision is much more accurate than the 2002 load calculations in that it recalculates annual in-stream sediment loads and load capacity using all project data.

From October 2002 through January 2007, 50 sets of simultaneous TSS-flow measurements (flow rates converted from gage height elevations) were collected. These data allowed for developing a Granite Creek sediment-rating curve from actual stream data. Given the unique environmental characteristics of each stream, the slope and characteristics of a sediment-rating curve typically apply only to that stream. The relationship is exponential at high flows. Sediment loads tend to increase as a square of flow.

The most common statistical method of analyzing sediment – discharge data is a power function (regression analysis) that relates TSS to flow rate. Typically, a common logarithmic transformation of both TSS and discharge data is done prior to analysis. Logarithmic transformation makes it easier to evaluate the relationship between two variables by linearizing the relationship, normalizing distribution of highly skewed data, and stabilizing variance. By transforming both variables, the log-log association becomes linear when plotted. The USGS used this identical method to plot Granite Creek gage height data and discharge data on a log–log scale, generating the stage-discharge curve for Granite Creek in 2005.

For the 2007 analysis, the TSS-to-flow rate equation was:

$$\log (\text{TSS (mg/l)}) = 0.92489 * \log (\text{flow (cfs)}) - 1.1521$$

Statistical analysis of TSS -flow rate data from February 2007 through May 2008 (FY08), June 2008 through June 2009 (FY09), and July 2009 through June 2010 (FY10) were completed in identical fashion. The resulting equations are found in prior year's reports.

Statistical analysis of TSS-flow rate including data from July 2010 through June 2011: an updated TSS – flow rate relationship

In June 2011, regression analysis was completed using on all 13 new TSS-flow rate data sets collected from July 2010 through June 2011, together with the 97 prior data sets covering October 2002 through June 2010. *Table 1* includes all simultaneous TSS and flow data collected from July 2010 through June 2011. Common (base 10) logarithmic transformation was completed on all 110 data sets for Granite Creek. The transformed data were then run through linear regression analysis.

The resulting 2011 equation used for generating the in-stream sediment loads in Table 2 was:

$$\log (\text{TSS (mg/l)}) = 0.68149 * \log (\text{flow (cfs)}) - 0.70386$$

The correlation coefficient for all logged data sets from 2002-2011 was 0.70535.

This equation represents the standard regression: y = mx + b

The "y" variable is TSS and the "x" variable is flow rate. The slope is "m'.
The y intercept on the graph is "b".

The strength of the statistical relationship of TSS-to-flow has varied annually over the period 2002-2011. The relationship of TSS to low-to-moderate flow rates may be best represented by a linear equation, whereas high-to-extremely high flows appear best represented by an exponential equation.

For comparison and consistency with all prior year's analyses, all monthly in-stream sediment loads and loading capacities were calculated using log transformed data and the resulting equation. To do otherwise would be comparing "apples and oranges" due to using different methods than those used in prior years. Tables 2 and 3 show the results with comparison to prior year's load calculations.

3. Average monthly flows, average monthly TSS concentrations, loading capacity and existing in-stream sediment loads

The fifteen monthly flow rate measurements recorded from July 2010 through June 2011 were compared against the average monthly flows (AMFs) calculated in 2007 using the original 208 data points. Given the relatively few number of monthly flow observations (15), the new data – except for November, where two additional flows were estimated - did not meaningfully alter the mean monthly flow values calculated in 2007. Average recorded flows during FY11 were low, but the effect on recalculating AMFs would have an equal "lowering" effect on both in-stream loads and load capacity calculations. The effect of overall lower average monthly flows would be to lower equally the calculations for both load capacity and in-stream sediment loads. New AMFs were therefore not calculated, *with the exception of the AMF for November*. November is a focus of attention for sediment control, as previous analyses suggest it is the only month with an in-stream sediment load exceeding the allowable load capacity for the creek. Therefore, three (3) flow measurements were recorded during November 2010 to get a more statistically accurate assessment of flow rate. The November AMF was updated and provided to ADEC as part of the Granite Creek delisting memorandum, along with revised sediment loads for November. The newly calculated AMF for November using the 38 observations is 102 cfs. An AMF of 68 cfs is calculated if the highest recorded outlier flow is excluded from the analysis. These values are used in Tables 2 and 3.

The total 38 measurements show that November's in-stream sediment load is below the allowable sediment load for the month. In summary, Granite Creek is in compliance with both the annual and the monthly allowable sediment load capacity for all months of the year.

It is worth noting that no November flows recorded over the last four years have exceeded 82.9 cfs**.** This suggest that several extremely high flows (863, 1390 cfs) measured in 2003 and 2005, respectively, have skewed the AMF higher than is supported by the vast majority (36 of 38 data points) of flow measurements in November. These high flows were not excluded from the calculation of November's AMF in order to allow comparison with and be consistent with all prior year's analyses, but excluding one or both of them would significantly lower the in-stream sediment load. For comparison in Tables 2 and 3, the highest November flow rate recorded (1390 cfs) was excluded from the calculation of November's AMF and shown in **(bold).**

It is also important to note that the flow data collected from July 2010 through June 2011 for the months of September, November and December measured lower flows than the average monthly flows calculated in 2007, suggesting drier conditions.

To calculate monthly in-stream sediment loads, the average monthly flows listed in *Table 2* were converted to common logarithmic values and a logarithmic value for TSS was generated for that particular month using the 2011 updated TSS: flow rate equation above. The antilogarithm was then calculated from this value to yield the TSS concentration corresponding to the average monthly flow. This calculation was completed for all months, January through December. This calculation method was also used in the June 2007 comprehensive analysis and all subsequent analyses**.**

For example, January has an estimated average monthly flow of 44.5 cfs. Log transformation of 44.5 gives a value of 1.648. Using the 2011 updated TSS: flow equation, (0.68149) (1.648) - 0.70386 = 0.41924. The antilogarithm of 0.41924 is 2.63 mg/l TSS. This represents the newly-calculated average monthly TSS concentration for January for the period October 2002 through June 2011.

Using the 2011 regression equation found at the bottom of page 6, the average monthly TSS concentrations calculated for each month using all 110 data sets from the period October 2002 through June 2011 were as follows:

January: 2.63 mg/l
February: 1.96 mg/l
March: 1.51 mg/l
April: 0.94 mg/l
May: 1.16 mg/l
June:1.28 mg/l

July: 0.89 mg/l
August: 3.31 mg/l
September: 3.90 mg/l
October: 3.46 mg/l
November: 4.62 mg/l (3.51 @ 68cfs)
December: 4.20 mg/l

Existing in-stream sediment loads *(Table 2)* for each month are then calculated by the following equation:

> Average monthly flow (cfs) * 0.0027 * average TSS concentration (mg/l) correlated to that monthly flow rate * number of days in the month = tons of sediment (TSS) for that month

Using this method, the monthly and annual existing in-stream sediment loads were then calculated (*Table 2*) using the revised equation at the bottom of page 6. *The annual estimated in-stream sediment load, updated with the July 2010 through June 2011 data, was calculated at 152.00 tons TSS/year. This value represents a reduction of 35.06 tons TSS/year below the five-year average load of 187.06 tons TSS/year calculated in June 2007 and a 14.15 ton decrease from the 166.15 tons TSS/year calculated for June 2010.*

Methods used to calculate annual in-stream sediment loads demonstrate that during the period July 2010 through June 2011, Granite Creek experienced a decrease in annual in-stream sediment load estimated at 14.15 tons TSS/year compared to the prior year's sediment load. Existing in-stream loads still remained below the five-year annual average in-stream sediment loads calculated in June 2007, at 152.00 tons TSS/year compared to 166.15 tons TSS/year, respectively**.** November's estimated in-stream sediment load is now calculated as being below the allowable sediment loading capacity for that month, using *either* the 102 or 68 cfs AMF for calculation. Improved sediment controls have resulted in existing sediment loads being below allowable loads for all 12 months of the year. *If the highest recorded November flow rate measured during the ten years of monitoring (1390 cfs) is removed from the average monthly flow calculations, an AMF of 68 cfs is calculated, and the November in-stream load is far lower than the allowable sediment load for November.*

For purposes of comparison, the highest November flow rate (1390 cfs recorded in November 2005) was excluded from the 38 total flow observations for that month. November's in-stream sediment load and load capacity were recalculated and those values shown in **( )** in Tables 2 and 3. Using this method, the monthly in-stream sediment load for November is 19.33 tons compared to the allowable load capacity for November of 27.76 tons. *This recalculation to account or one outlier data point, which is statistically appropriate, results in November's sediment loads easily complying with the load capacity for that month*. The rationale for deleting extreme "outlier" data points was further explored with the USGS to confirm that the practice is supported in calculations of AMF to avoid high bias when relatively few data points are available. USGS confirmed that, in cases where a stage discharge curve is based on relatively few high flow measurements, when the estimated flow rate using the stage discharge curve is greater than twice the highest directly measured stream flow, that estimated flow rate is suspect. The flow of 1390 cfs estimated in November 2005 was 15 times higher than the 90.2 cfs maximum measured flow rate that was used to develop the stage discharge curve for Granite Creek. It is accepted practice by professional hydrologists to question such flows as no calibration flows exist. This adds further creedance to throwing out the 1390 cfs value in recalculating November's average monthly flow.

Table 2. Monthly existing (in-stream) suspended sediment loads in Granite Creek, updated with July 2010 – June 2011 data and compared with the 2010, 2009, 2008 and (2007) load estimates. Calculations were made using all 110 data sets from 2002-2011.

Month	**Average Monthly Flow (cfs)**	**Existing In-Stream Suspended Sediment (TSS) Load (tons)[2]**				
		2011	**2010[3]**	**2009**	**2008**	**(2007)**
January	44.5	9.80	10.47	10.65	9.72	(8.79)
February	29.0	4.29	4.65	4.93	4.32	(3.51)
March	19.8	2.50	2.73	3.02	2.54	(1.86)
April	9.9	0.75	0.84	0.99	0.77	(0.47)
May	13.4	1.30	1.44	1.64	1.32	(0.87)
June	15.5	1.61	1.82	2.00	1.63	(1.12)
July	9.1	0.68	0.75	0.90	0.69	(0.41)
August	62.4	17.29	18.33	18.07	17.08	(16.82)
September	79.5	25.11	26.47	25.44	24.73	(25.95)
October	66.7	19.32	20.49	20.04	19.04	(19.15)
November	102 [4] (68)[5]	38.17 (19.33)	39.99 (20.58)	60.25	61.82	(75.00)
December	88.7	31.18	32.81	31.26	30.59	(33.11)
Annual Total		**152.00 tons/ (133.16)[6] /**	**166.15 tons/ (144.24 tons)[7]**	**179.19 tons/**	**174.25 tons/**	**(187.06 tons)**

[2] Tons of TSS/month = monthly average Q (cfs) * average TSS (mg/l) concentration corresponding to the average monthly flow (see text on using the TSS-flow regression equation) * 0.0027 * # of days in the month.

[3] Recalculated in December 2010 with new November flow information.
[4] Newly-calculated using additional flow data gathered from 2007-Nov 2010. November average includes 2 of the 3 highest flow rates recorded at Granite Creek from October 2002 through June 2011. Throwing out one or both of these flows (863 cfs and 1390 cfs) from the average calculation would result in significantly lower existing in-stream sediment load estimates for November. They are both left in here to provide a worst case scenario.
[5] November average monthly flow calculated with highest recorded outlier flow (1390 cfs in Nov 2003) excluded from the 38 observations used to calculated AMF.
[6] Existing sediment load calculated using an AMF of 68 cfs.
[7] Instream sediment load calculated using November AMF of 68 cfs calculated in December 2010.

Monthly sediment load capacity (*Table 3*) is calculated by the following equation:

> Average monthly flow (cfs) * (5.04 mg/l TSS allowable target) * 0.0027 * number of days in the month = loading capacity in tons of sediment (TSS) for that month

In FY11, the allowable target TSS value was 5.04 mg/l, based on the results of the newly-calculated TSS: turbidity statistical relationship using all project data from 2002-2011. This level corresponds to a turbidity allowable target level of 6.64 NTUs. This is a slight increase (1.8%) from the 4.95 mg/l target TSS concentration calculated in FY10 and results in slightly higher monthly and annual load capacity. *The FY11 estimated annual allowable sediment load capacity is estimated at 224.01 tons TSS/year as compared to the 2010 estimate of 223.02 tons TSS/year and the 2009 estimate of 226.39 tons TSS/year.* Table 3 includes a comparison of monthly and annual loading capacities for 2011 and prior years.

In summary, the annual in-stream sediment load (152.00 tons) is significantly below the allowable annual sediment load capacity (224.01 tons). This suggests compliance with the prescribed loads in the approved TMDL. For November, depending on whether an average monthly flow of 102 cfs (using all 38 flow measurements) or 68 cfs (one high flow excluded) is used, the November in-stream sediment load is 3.47 tons or 8.43 tons below the allowable load capacity, respectively.

Table 3. Monthly suspended sediment Loading Capacity (LC) for Granite Creek, showing 2011 and prior years' revised load capacity and 2007 load estimates in ( ).

Month	**Average Monthly Flow (cfs)**	**Natural Background Load (tons)**[8]	**Loading Capacity TSS (tons)**[9] **2011 2010**[10] **2009 2008 (2007)**
January	44.5	1.86	18.77 18.44 17.80 18.40 (19.26)
February	29.0	0.56	11.05 10.85 10.48 10.82 (11.33)
March	19.8	0.93	8.35 8.20 7.92 8.18 (8.57)
April	9.9	1.50	4.04 3.97 3.83 3.96 (4.15)
May	13.4	2.17	5.65 5.37 5.36 5.54 (5.80)
June	15.5	1.80	6.33 6.21 6.00 6.20 (6.49)
July	9.1	1.24	3.84 3.77 3.64 3.76 (3.94)
August	62.4	0.93	26.32 25.85 24.97 25.79 (27.00)
September	79.5	3.00	32.46 31.88 30.78 31.79 (33.29)
October	66.7	4.34	28.14 27.63 26.69 27.56 (28.86)
November	102 (68)	1.20	41.64 40.89 53.43 55.19 (57.79) (27.76) (27.38)
December	88.7	3.10	37.42 36.75 35.49 36.65 (38.38)
Annual Total		**22.63 tons**	**224.01 tons/ 223.02 tons /226.39 tons/ 233.84 tons/** **(210.13 tons)/ (207.59 tons)** [11] **(244.86 tons)**

[8] Natural background turbidity and sediment loads used in the original 2002 TMDL remain accurate and unchanged based on eight years of water quality data collection.

[9] FY11 monthly load capacity based on analysis of in-stream data. Includes natural background sediment load. Calculated as: (Monthly Q (cfs)) * (5.04 mg/liter TSS) * (0.0027) * (# days in month).

[10] Revised in December 2010 with inclusion of new November flow measurements.

[11] Instream sediment load calculated using November AMF of 68 cfs.

4. FY11 Watershed-Wide Water Quality Data and General Observations

Comprehensive water quality data collected throughout the watershed is valuable in identifying time series of events, BMP cause-and-effect relationships, and documents site-specific sources of turbidity and sediment. Eight permanent monitoring stations plus a number of opportunistic stations including drainage ditches, settling ponds, and road culvert discharges were monitored in FY11. Of immediate note is the rapidity with which runoff from unpaved roads, and associated turbidity spikes, will occur after heavy rains and truck traffic. Additionally, bedload resuspension and bank erosion during very high creek flows are also known to contribute to elevated turbidity levels, although how much is not known precisely. Of equal note is the rapidity with which the system restores to normal with cessation of heavy rains. The exception is the residence time of turbidity levels in the CBS series of settling ponds receiving significant road runoff. Time series measurements over several days confirm that it typically takes 2 to 3 days for the ponds to "clear" to pre-heavy rain conditions. Ponds are working effectively the vast majority of time. Smaller ponds at the Tisher and, to a lesser extent, the Dormand McGraw leases experience periods where significant runoff exceeds their capacity to effectively treat turbidity, resulting in a turbid discharge from the ponds and into the tributaries. Retrofits are planned for both lease sites by the operators under their SWPPPs to increase volume and improve retention time.

The City and Borough of Sitka completed comprehensive water quality monitoring at ten stations along Granite Creek during a storm event in October 2010. Similar monitoring was done in November 2009. The purpose was to both isolate individual turbidity sources and also get more information on natural background conditions during storm events. The results indicated that natural background turbidity levels vary little from normal levels during such events.

From October 2008 through June 2011, monthly turbidity monitoring at GC1 has shown only two instances where the 6.64 NTU target level was exceeded. The November 12, 2009 replicate turbidity levels recorded were 12.5/12.9 NTUs and the November 25, 2009 values were 7.66/7.77 NTU. This information, coupled with sediment load calcuations, suggests a high level of compliance with both the TMDL and Alaska water quality standards for turbidity.

A couple of observations have focused attention on the need for revisions to several BMPs for FY11. These are included in the updated Action Plan. Check dams in the roadside ditch adjacent to the Granite Creek Road were rebuilt and hydroseeded, along with shoulders. This increased the retention time for treatment of stormwater and reduced flows to the creek from the main road culvert. The catch basin at the uphill portion of the ditch was deepened to provide improved sediment retention. Additional culverting and sediment controls in the area are being explored, including possibly paving the steep access road to the McGraw lease to better accommodate future development and runoff. Flash flooding through the area can carry high sediment loads.

Winter road sanding and maintenance pushes gravel into the Granite Creek roadside shoulder and ditch, smothering the grass fringe. This drainage ditch was reseeded in June 2008 to reestablish grasses through its length, but further seeding is not justified. The existing pond and segments of the drainage ditch are cleaned annually of sediment.

5. Conclusions and Recommendations

- *The annual in-stream sediment load – and the sediment loads for each month of the year - remain below the allowable annual sediment load capacity.*

- *Granite Creek's annual in-stream sediment load calculated for July 2010 through June 2011 was lower than the June 2009 – June 2010 period and remained much lower than the five-year average annual sediment load calculated in 2007. The annual estimated in-stream sediment load, updated with July 2010 through June 2011 data, was calculated at 152.00 tons TSS/year. This value represents a reduction of 35.06 tons TSS/year below the five-year average load of 187.06 tons TSS/year calculated in June 2007 and a 14.15 ton decrease from the 166.15 tons TSS/year calculated for 2010.*

- *November's in-stream sediment load was reduced compared to 2009 and 2010. At an AMF of 102 cfs, it is slightly below the allowable load capacity for the month. At an AMF of 68 cfs, it is well below the allowable load capacity. The AMF for November still seems artificially high when evaluating flow data over the last four years. Three additional flow measurements in FY11 allowed for recalculating the AMF and loads in December 2010.*

- *The TSS-to-turbidity mathematical relationship has been updated and improved with the addition of 13 new simultaneous data sets to the 97 data sets available in 2010. The 110 data sets were run through linear regression analysis and a new equation generated.*

- *Average monthly flows were not modified, with the exception of November's, as the meager data did not substantially change the other month's average monthly flows calculated in 2009 and 2010.*

- *A small 0.4% increase in the annual allowable sediment load capacity was calculated in comparison to the load capacity calculated in 2010. This is due to the recalculated allowable target TSS limit of 5.04 mg/liter compared to the 4.95 mg/l limit used in the 2010 calculations and the recalculation of November's AMF using additional 2008-2010 flow data.*

- *Updating and recalculating the TSS-to-flow rate relationship with each year's new data improves the statistical strength and validity of sediment load estimates, recognizing that the original 2002 TMDL loads are the formally prescribed loads.*

- *Since October 2008, random monthly turbidity monitoring at GC1 (38 samples) has shown only two instances where the 6.64 NTU target level was exceeded. This information, coupled with TMDL sediment load calculations, suggests a high level of compliance with both the TMDL and Alaska water quality standards for turbidity.*

EPA and ADEC have formally adopted the 2002 TMDL in-stream sediment loads and load capacity as the regulatory benchmark against which recovery is evaluated. Annual updates to Granite Creek's sediment load have been completed each year since 2007. Given that Granite Creek's existing sediment load is considerably below the allowable load capacity on an annual basis, the recommended future focus should be on ensuring that in-stream loads during the fall months (September through December) remain below the allowable monthly load capacity for those months.

Beginning in early 2011, the CBS and its contractor have worked closely with ADEC in drafting a delisting determination for Granite Creek. The Alaska Department of Environmental Conservation currently recommends that Granite Creek be moved from Category 4a (Impaired Waters) to Category 2 in the 2012 Integrated Water Quality Monitoring & Assessment Report based on consistent compliance with both the prescribed TMDL sediment load reductions and the turbidity criteria of the Alaska water quality standards. Ten years of continuous monitoring (2002-2011) support this decision and has allowed for a more complete statistical analysis and validation of loading estimates.

Ongoing implementation of BMPs (including installation of 21 settling ponds, protected and expanded streamside vegetated buffers, and road improvements) current analysis of water quality monitoring data, and other recommendations provided in the TMDL have demonstrated that the waterbody is meeting state water quality standards and the required TMDL sediment load reductions. Through the development and rigorous implementation of institutionalized BMPs, continuous monitoring, and active management of resource extraction activities, water quality in Granite Creek is expected to continue meeting Alaska water quality standards into the future.

In conclusion, Granite Creek is considered to be in compliance with the TMDL and warrants re-categorization as Category 2 since compliance activity and water quality data from the past 10 years confirm attainment of water quality standards.