Technical Memorandum

March 19, 2010 Revised April 2, 2012

MEMORANDUM

To : File

From : Mike Heyl, Chief Environmental Scientist

Subject ; Estimation of Historical Chassahowitzka River Flows

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The following summary is adapted from an interchange among colleagues and peers during 2007 regarding selection of an appropriate methodology to extend the discharge record for the Chassahowitzka River. By way of background, the USGS estimates discharge (See Table 1 in USGS WRI 01-4230) at several springs along the west coast of Florida by way of regressions to the maximum daily water level in the Weeki Wachee Well (283201082315601). The USGS began reporting daily discharge at a point just downstream of the Chassahowitzka Main Spring (02310650) in February 1997. The stage record begins in 1999. In consideration of the sizable impact of the Atlantic Multidecadal Oscillation (AMO) on streamflow along the west coast of Florida (Kelly[1] 2004), it is desirable to have a flow record that bridges both the wet and the dry cycle, which are approximated by flows from 1940 – 1969 and 1970 – 1999 respectively.

In contrast to the Chassahowitzka observations, water levels in the Weeki Wachee Well were recorded at 10-11 day intervals from 1966 until 1974 when daily observations commenced. Thus, the Well record offers an attractive approach for long-term hind casting and efforts were undertaken to develop relationships between discharge in the Chassahowitzka River and water level in the Weeki Wachee Well.

The first step of the evaluation was to replicate the Chassahowitzka results reported in WRI 01-4230 using the raw data from Appendix B. Unfortunately the regression adopted by the USGS included two terms (Chassahowitzka River stage and average stage change) which are not available for long-term hind-casting. Daily stage (max, min and mean) for this site is available for 1999 – present) but the rate of change is apparently not reported by USGS.

Regardless, using the dataset provided in WRI 01-4230 it is informative to define the relative importance of the independent parameters used by the USGS. Again, using the data from Appendix B and linear step-wise regression the following results were obtained (In all cases, discharge (cubic feet per second, cfs) was the dependent variable and all parameters and regressions were significant at the 0.05 level):

Q as function of Weeki Wachee well level (WW_WL) : n= 56, $r^2_{adj} = 0.27$)

Q as function of WW_WL and Stage: n= 56, $r^2_{adj} = 0.35$ (WW_WL entered first)

[1] Kelly, M. 2004. Florida River Flow Patterns and the Atlantic Multidecadal Oscillation. Ecologic Evaluation Section. Southwest Florida Water Management District.

Q as function of WW_WL, Stage and Rate : n= 56, $r^2_{adj} = 0.926$
(Rate entered first followed by WW_WL and finally stage.)

Q as function of Rate; n= 56, $r^2_{adj} = 0.67$

In and attempt to improve the relationship with WW_WL in order to hind cast discharge, daily averages of the Appendix B data were used with the following results:

Q as function of WW_WL and Rate (stage was not significant): n =9, $r^2_{adj} = 0.96$

Q as function of WW_WL: n = 9, $r^2_{adj} = 0.40$

Discharge seems to be strongly related to rate. An attempt to develop a relationship with the daily 1999-20007 stage and discharge data reported for the Chassahowitzka River station was undertaken. [Note that the discharge reported by USGS is probably the result of a regression, so in effect the following attempts are modeling with modeled results.] In lieu of instantaneous rate, a pseudo-rate was developed as the difference between the daily maximum stage minus the daily minimum stage (G_range). The other independent variables were maximum daily stage (G_max) and minimum daily stage (G_min). Again, using multiple linear regression the following results were obtained:

Q as function of WW_WL and G_max; n = 2594, $r^2_{adj} = 0.84$
Q as function of WW_WL and G_min; n = 2591, $r^2_{adj} = 0.83$
Q as function of WW_WL and G_mean; n = 2588, $r^2_{adj} = 0.85$
Q as function of WW_WL and G_range; n = 2591, $r^2_{adj} = 0.81$
Q as function of WW_WL, G_mean and G_range; n = 2588, $r^2_{adj} = 0.85$

Residuals of all were generally similar. The following equation was used to fill the missing (157 values, 4 % of record) river discharge data from 1999 through Nov 2007 for all cases where G_max was available. Additional missing data without corresponding G_max between 2/1997 and 11/29/2007 were interpolated from the reported data. See Figure 1.

$Q_{est} = 23.672 + 2.765\ WW\_WL - 3.813\ G\_max$. [Equation 1]

Flow was not reported by the USGS from 1/28/99 until 6/8/99. Reported values on either side were 66 cfs. However, the following day a flow of 60 cfs was recorded followed by flow of 55 cfs on 6/10/99, suggesting that the return value of 66 may be a residual reading from the beginning of the missing record. Two interpolations are possible, with the first accepting the last and first reading of 66 cfs. This would result in a constant 66 cfs discharge for 141 days that is unlikely. An alternate interpolation from 1/28/99 until 6/10/99 (ignoring the reported flows on 6/8/99 and 6/9/99) is provided in Figure 2. The alternative interpolation results in a flow pattern that seems much more typical of the overall period of record but at the expense of arbitrarily ignoring two daily values reported by the USGS. The alternative interpolation was adopted for use.

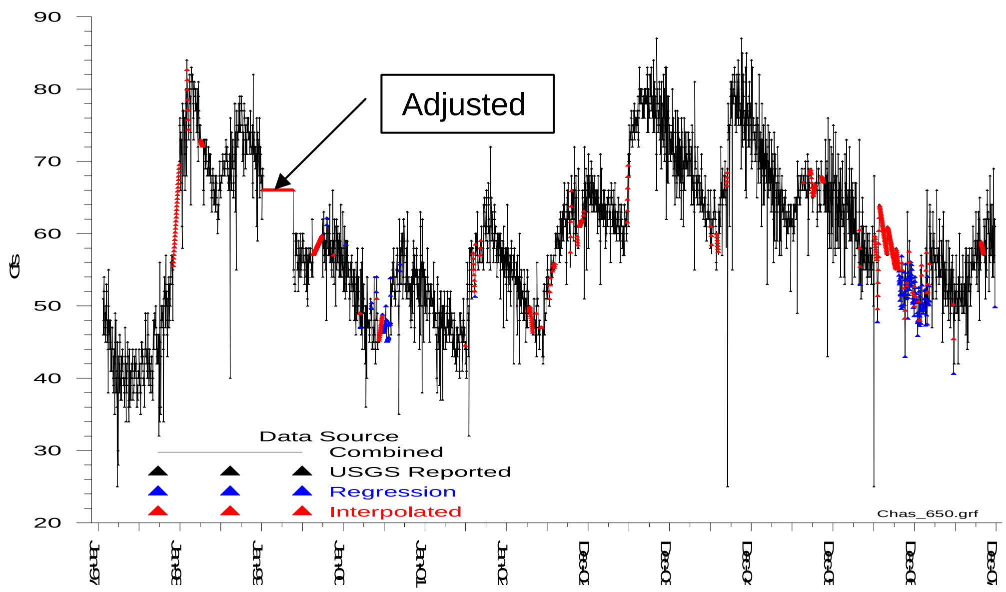

Figure 1. Adjusted Period interpolates data from 1/28/99 (66 cfs) to 6/8/1999 (66 cfs)

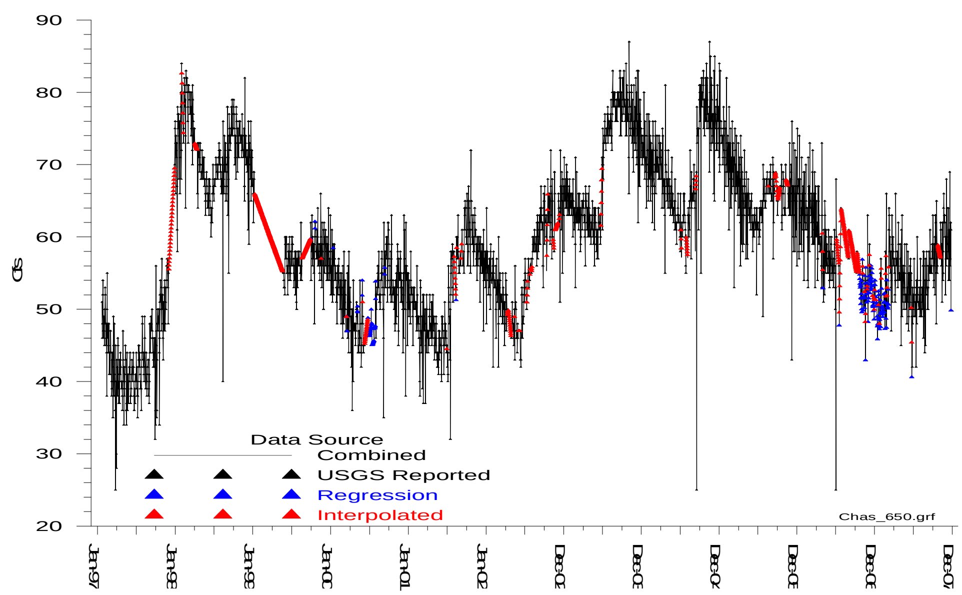

Figure 2. Adjusted period interpolates data from 1/28/1999 (66 cfs) to 6/10/1999 (55 cfs)

Two extreme low values (25 cfs) on September 6, 2004 and June 13, 2006 initially appeared to be outliers, but both are associated with extremely high stage events (e.g. 4.34 and 4.68 feet). The former corresponded with the passage of hurricane Frances. These are extreme events as the 99th percentile of G_max is 2.95 feet. On the other hand, a plot of reported discharge vs. G_max reveals a number of other days of high stage without the commensurate low discharge (Figure 3).

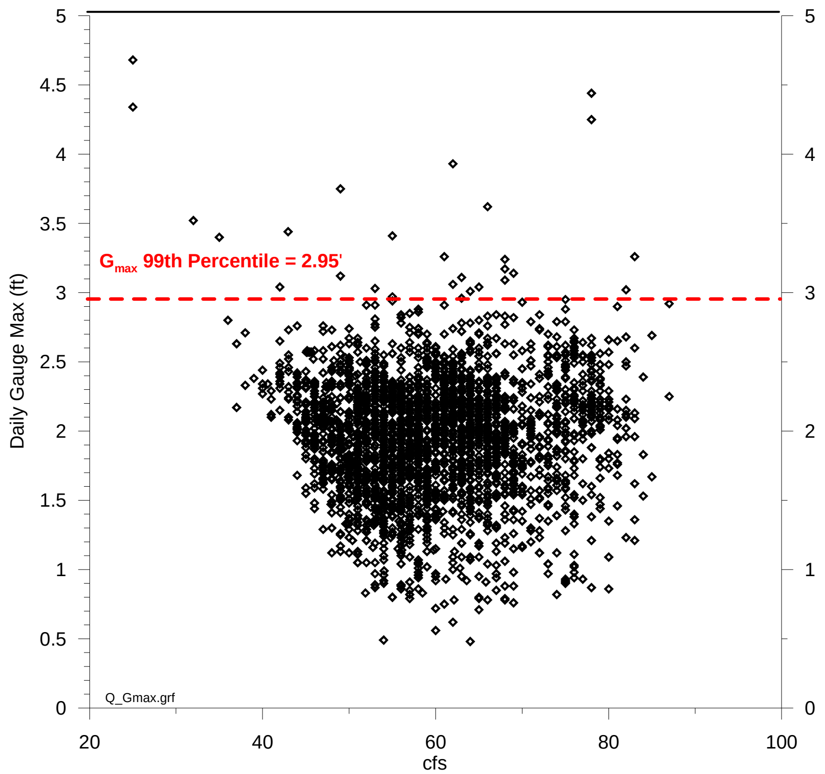

Figure 3. Gauge height vs. discharge.

Finally, the remaining period of record flows were estimated based solely on WW_WL using equation 2.

Q_{est} = 12.428 + 2.924 WW_WL; n = 3260, r^2_{adj} = 0.75 [Equation 2]

The results based on Equation 2 generally track the reported values reasonably well, but deviate substantially from the USGS reported flows for the period Feb – Dec 1997 and for the period Sept 2002 through May 2003. (See Figure 4).

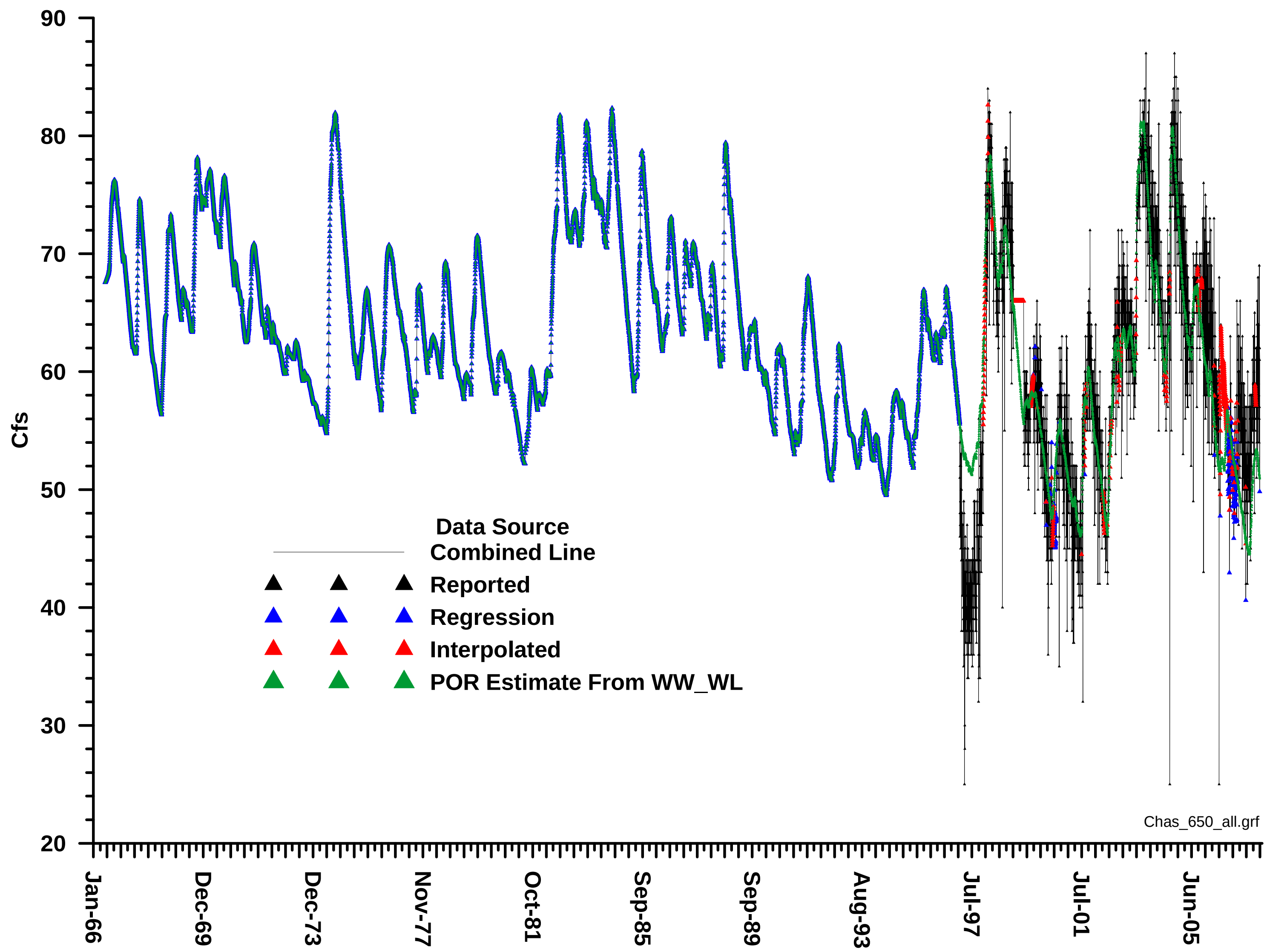

Figure 4. Recreated flow record illustrating source of values. Note extreme daily variability beginning July 1997.

In summary, the reconstructed flow record included the following steps.

1. The two aberrant low discharge values in 2004 are associated with abnormally high stage and were retained.

2. For flows prior to 2/20/97, equation 2 was used to estimate flows from the Weeki Wachee well.

3. For flows from 2/20/97 to present, flows reported by USGS on NWIS were used where present.

4. From 2/20/1997 to present and where the USGS did not report flows Equation 1 was used to estimate these flows from gage height and water levels in Weeki Wachee well.

Groundwater impacts for the Chassahowitzka were estimated to be approximately 1 cfs (Basso, 2008). Consequently; no corrections were applied for groundwater impacts. The reconstructed flow record used for the MFL determination is given in Figure 5.

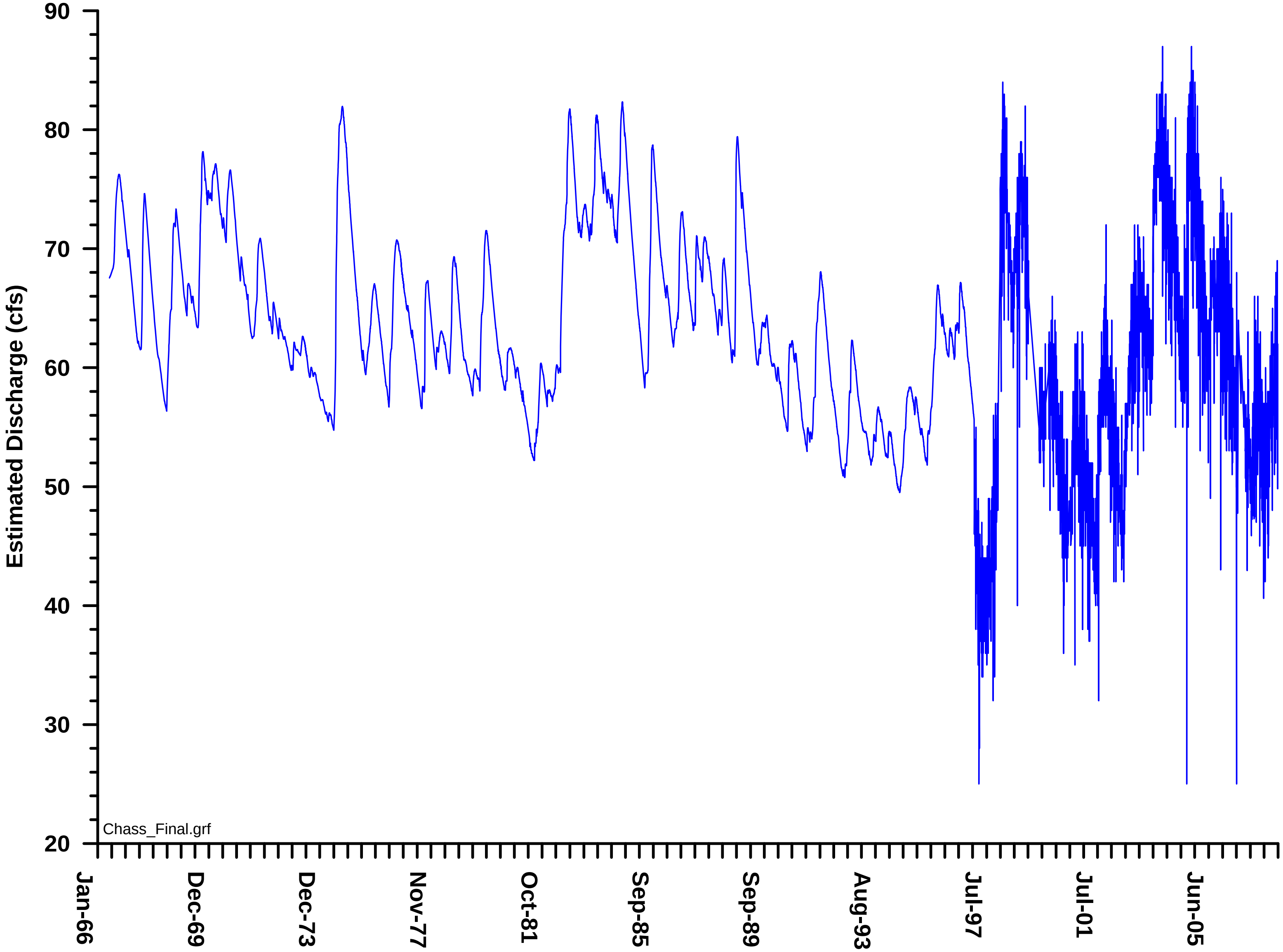

Figure 5. Final reconstructed flow record.

Errata

Updated April 2, 2012

In preparing a response to a citizen inquiry it was determined that one of the regression coefficients was incorrectly coded when developing the reconstructed flow record. Instead of coding "Q=23.672 + 2.765 WW_wl – 3.813 G_max", the following erroneous equation was coded "Q=23.672 + 2.765 WW_wl – 6.139 G_max." Application of the latter equation (termed Equation 1a), results in lower estimates of discharge than intended, i.e., lower than would be predicted using Equation 1. However, for the period of application (2/20/1997 through 11/28/2007), 96% of the daily flows utilized were obtained directly from USGS records. Equation 1a was erroneously used to fill-in the remaining 4% of the daily flows. The following table compares standard percentiles of flow for this period using Equation 1a (center column) and the intended Equation 1 (right-hand column). A statistical test (using the Kolmogorov-Smirnov two- sample test) indicates that the difference does not have a significant (p=0.232) impact on the discharge record for this site.

Table 1. Chassahowitzka River flow (cfs) percentiles for the period from 2/20/1997 through 11/28/2007. APPLIED FLOW RECORD is based on use of Equation 1a for in-filling of missing records and INTENDED FLOW RECORD is based on use of Equation 1 for data in-filling. (n=3,935)

Percentile	APPLIED FLOW_RECORD	INTENDED FLOW_RECORD
1.00%	38.0	38.0
5.00%	43.0	43.0
10.00%	46.5	47.0
20.00%	51.0	51.3
25.00%	52.0	53.0
30.00%	54.0	54.5
40.00%	57.0	57.0
50.00%	59.0	59.0
60.00%	62.0	62.0
70.00%	65.0	65.0
75.00%	66.0	66.0
80.00%	68.0	68.0
90.00%	74.0	74.0
95.00%	77.0	77.0
99.00%	81.0	81.0