Andrews Forest Streamflow Calculation and Rating Curve Summary

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Contents:

I. Steps involved in transforming raw streamflow data into discharge data

A. Raw stage height data
   1. Historically, raw data were collected from Stevens A-35 recording charts or from Fischer-Porter punched tapes (See weir history). Raw data was digitized or otherwise condensed to keep only "key (turning) points", that is, points where the slope or trajectory of streamflow height changes. Each day's midnight point reading was also kept. A critical aspect of this approach is that this raw stage data points were spaced irregularly in time, and there were more points for periods of more rapid change such as during storms or during wet periods.
   2. Data collection was moved to data loggers. Originally, this same type of algorithm was used briefly in the Campbell Scientific programs. However, the algorithm, which set a tolerance for slope change before outputting a new point, was found to be missing subtle diurnal behavior in v-notch readings on WS 2&3. In WY 2002 the Campbell logger algorithm was changed to check data every 5 minutes and points were output if *any* change of stage was detected. In WY 2012 all data loggers were reprogrammed to output data every 5 minutes.

B. All raw stage height data are corrected in processing.
   1. All values are linearly adjusted through time to be consistent with reference observations of stage measured at hook gages (or tape at Mack Creek) located adjacent to each gage house.
   2. Historically, when hook gages are not installed, direct measurement of gage height is made in the flume with a rule, and the raw data points are adjusted to these flume readings.
   3. Outlier data points are removed and missing data segments are estimated from paired gage data.

C. Stream discharge is calculated and summary data is created
   1. A rating curve is associated with all nine small watershed flumes. The rating curve converts stage height in feet to discharge in cubic feet per second.
   2. Summary output is generated for each data point and daily, monthly and annual summaries are also generated.
   3. Discharge data can be generated for any specific output interval (e.g., 15 minute, hourly, etc.), where points for the desired time interval are determined by interpolating between the key stage height points and the rating curves are applied. This process is handled interactively on the web-based FLOW program (first launched 18 Nov 2002).

II. Background on rating curves

A. A rating curve is developed for every weir (flume, v-notch, fish ladder) within the Andrews Forest

1. Typically a rating curve is a single log-linear equation or multiple piecewise log-linear equations that each operate over a specified water depth interval. The equation form is a power function:

$$Y = a\, b^x \quad \text{or} \quad \ln y = \ln a + b \ln x$$

(where y= flow as cfs and x = stage height in ft.

2. Each rating curve is customized for the specific weir by fitting the curve to a set of calibration points. (See HF002, Entity 2 for the raw calibration point data)
   a. Calibration points are collected to relate a specific stage height (either measured using a hook gage in a stilling well, or directly measured with a rule in the flume) to a determined measure of stream discharge (typically, calculated from velocity, dye dilution, or through volumetric measurement).
   b. The concrete trapezoidal flumes in use today at all Andrews' gages including the v-notches installed in summer have required the development of these custom-fit rating equations.
   c. Some of the early flumes (e.g. pre-built H-flumes installed at WS 6,7,8,9,10) came with a manufacturer's rating curve, and few or no calibration points were ever collected and no rating curves were developed.

3. The methods and technology for taking calibration points, and hence, possibly, their accuracy and precision, has changed over time at the Andrews. Calibration points consist of synchronous measures of stage height and velocity.
   a. *WS 1, 2, 3 main flumes*: Velocity measurements were taken with a velocity-head rod in the early years at WS 1, 2, 3 (1953-1958) in association with a direct stage height measurement in the flume. Rating tables were developed based on these measurements. After new hook gages were installed and properly adjusted, simultaneous direct flume and hook gage measurements (1957-1964) were used to generate calibration points using the hook gage stage height reading and discharge determined through these original rating tables from the corresponding flume reading. These generated calibration points served as input for generating the rating curves (~1966) still in use today (2018) at WS 1, 2 and 3.
   b. *WS 9, 10 main flume*: The dye dilution method was used to develop the WS 9 & 10 main trapezoidal flume rating curves from 1975-1977. Additional points were added from 1996 to 2002 before these rating curves were rebuilt. Additional points were collected with a velocity meter and with volumetric samples.
   c. *WS 9, 10 v-notch 1973-1979*: Volumetric or "bucket" samples were also used to directly measure discharge from 1973 to 1977 for the v-notch weirs in place during summers 1973-1979. Additional points were calculated based on using the main trapezoidal flume equation with v-notch stage height directly before or after removal of the v-notch.
   d. *All watersheds*: Velocity measurements have been regularly taken with a velocity meter starting after the February 1996 flood. Velocity meter measurements were also made at WS 8 from 1990-1995. Volumetric or "bucket" samples have also been used to measure velocity for the calibration of the v-notch weirs beginning in 1997.

4. Rating tables and rating curve equations
    a. In the late 1950s and early 1960s (prior to computerized statistical packages), stage height-discharge relationships were fitted by eye and rating tables were developed (WS 1, 2, 3).
    b. Subsequently curves have been fitted using regression techniques, typically with a log-linear or piecewise log-linear function. Piecewise functions have been used to account for bends in an otherwise straight log-linear relationship inferred from the calibration points; some rating curves have as many as seven equation segments (e.g., WS1).
    c. Other functional forms have been used (e.g., a reverse sigmoidal (cubic) curve for the main flumes at WS 9 and 10 in the 1970s)
    d. Rating curves for all Andrews flumes are now in log-linear or piecewise log-linear functional form (since Dec 2002).
    e. The USGS- maintained Lookout Creek gauge has no weir control structure and is still calibrated with annual surveys of cross-sectional channel area and velocity. Rating tables are modified as needed and stream discharge is calculated by the USGS. In 2012 the USGS selected AQUARIUS software by Aquatic Informatics to optimize workflows, consistency and data quality.

III. Summary of history and current status of rating curves, by gage

A. Watersheds 1, 2 and 3

1. Original rating curves:
    a. Rating tables for these basins were developed based on velocity-head rod measurements and stage height measured directly in the flume taken 1953-1958.
    b. Rating curve equations were developed for use with hook gage measurements in 1966 by PNW-Portland (Dorothy Martin, Sue Skinner, Floyd Johnson). In building these rating curves, rating points were generated using coinciding stage height measurements, both direct measurement in the flume and hook gage readings, in conjunction with the original rating table discharge based on the direct flume measurement. Approximate sets of calibrations points have been identified that were used to build these original equations.
    c. Note: WY 1953 to WY 1959 data was originally hand digitized with a minimum sketching of streamflow trace, and only daily discharge was calculated. These data charts were later electronically digitized and the discharge recalculated at a finer resolution. Caveat: There was no hookgage for most of these early years ~1953-1957 with only a flume measurement. While the recalculation of discharge would be most accurate using the original rating tables for WS 2 and 3, these watersheds were rerun and calculated using the rating curve developed based upon the hookgage. WS1 is not really affected because this original rating table was used from 1952 to 1956.
2. WS1, Equation Set A, version 1 (Oct 1952 - Aug 1956)
    a. Original flume (18” bottom) for WS 1 was operative for WY 1953 to WY1956 and was rebuilt in August 1956 after leaks were detected earlier that year. The curve built to calculate discharge for WS 1 was based on the early rating table derived from direct flume measurements and velocity-head rod rating points taken 1953-1956. There was no hook gage installed at this time. A rating table had been developed from a hand drawn curve through these velocity-head rod rating points. The rating curve currently used was created in 1988 based on this rating table.

b. **Status:** Checks made by plotting original rating points on this rating curve appear good. The curve was developed using summarized points from the rating table. The curve could be refit directly from the exact set of calibration points, but this seems unnecessary.

3. WS1, Equation Set B (Sep 1956 – Present, except summers beginning WY1999)
   a. This rating curve is as described in III.A.1., developed in 1966 for the main flume
   b. Check calibration points have been taken WY 1996 to Present
   c. **Status:** A new curve fit to these new calibration check points show a distinct change in the curve equations. Initial checks of a new curve show that annual streamflow seems to drop by about 18%. Checks of the hook gage – flume relationship using a double mass plot indicate changes in 1962 and again after replacement of the hook gage in 1998.
4. WS1, Equation Set C (WY 1999 – Present, summers only)
   a. V-notch weir has been in place every summer since July, 1999
   b. Rating curves are based on volumetric samples taken from Oct 1999 to Oct 2001. The "bucket" collection method has been used consistently but the method and efficiency was improved after the 1999 summer. The 1999 points have not been used in the final rating equation.
   c. Check calibration points have been taken from WY 2002 – Present
   d. Status: Checks made by plotting new calibration points on this rating curve appear good. Continue collection of check points.
5. WS1, Equation Set D (WY 1999 – Present, pending)
   a. Calibration points taken 1996-2017 have been used to rebuild the original rating curve WS1 Equation Set B.
   b. These calibration points will correspond better with the v-notch calibration points with both sets being taken after 1996, and all but a few taken after replacement of the hook gage in 1998.
   c. **Status:** Curve will be used to rerun the historic WS1 streamflow data beginning in WY1999 to Present, where WY1999 is the year the v-notch is installed. There is still uncertainty in the reason why the curve deviates so much from the earlier curve, or why the hook gage measurements appear to have increased versus corresponding flume depth measurements made with a rule in the flume.
6. WS2, Equation Set A (Oct 1952 – Present, except summers beginning WY1999)
   a. This curve is as described in III.A.1., developed in 1966
   b. Check calibration points have been taken WY 1996 to Present
   c. **Status:** A new curve fit to these new calibration check points show differences from original curve at the low end. Initial checks of the new curve show that annual streamflow only seems to drop by about 2%.
7. WS2, Equation Set B (WY 1999 – Present, summers only)
   a. V-notch weir has been in place every summer since July, 1999
   b. Rating curves are based on volumetric samples taken from Oct 1999 to Oct 2001. The "bucket" collection method has been used consistently but the method and efficiency was improved after the 1999 summer. The 1999 points have not been used in the final rating equation.
   c. Check calibration points have been taken from WY 2002 – Present
   d. Status: Checks made by plotting new calibration points on this rating curve appear adequate. Continue collection of check points and monitor.
8. WS2, Equation Set C (WY 1999 – Present, pending)

a. Calibration points taken 1996-2017 have been used to rebuild the original rating curve WS2 Equation Set A.
b. These calibration points will correspond better with the v-notch calibration points with both sets being taken after 1996.
c. **Status:** Curve will be used to rerun the historic WS2 streamflow data WY 1999 to Present, where WY1999 is the year the v-notch is installed.

9. WS3, Equation Set A (Oct 1952 – Present, except summers beginning WY1999)
    a. This curve is as described in III.A.1., developed in 1966
    b. Check calibration points have been taken WY 1996 to Present
    c. **Status:** A curve fit to these more recent calibration check points show streamflow that is comparatively lower and higher in separate sections in the lower portion of the curve with the annual change about 3%.
10. WS3, Equation Set B (Nov 1964 – Sep 1966)
    a. Watershed 3 had no hook gage data to correct the discharge data (step I.B. above) for this period. Post 1964 flood streamflow data are calculated with a rating curve built from the original rating table or original velocity-head rod data points collected WY1953-WY1958, and is based on flume (rather than hook gage) measurements. Note: there was also no hook gage after the 1996 flood, Oct 1996 to October 1998 (both hook gages were destroyed by the floods), but post-1996 streamflow data have been calculated with the original hook gage-based equations to date.
    b. An approximate set of points have been identified that were used to build this original rating table and subsequently rating curve equations.
    c. **Status:** This curve is based on direct flume height measurement and is only used post-1964 flood. The curve seems reasonable based on plots of the original, approximate calibration points onto this curve. The curve could be applied to post-1996 flood data but never was applied due to the uncertainty in using this original rating curve. This curve could also be applied to the early years (1953-1957) before a hookgage was established, but only the rating curve based on the hookgage has been applied to these years.
11. WS3, Equation Set C (WY 1999 – Present, summers only)
    a. V-notch weir has been in place every summer since July, 1999
    b. Rating curves are based on volumetric samples taken from Oct 1999 to Oct 2001. The “bucket” collection method has been used consistently but the method and efficiency was improved after the 1999 summer. The 1999 points have not been used in the final rating equation.
    c. Check calibration points have been taken from WY 2002 – Present
    d. Status: Checks made by plotting new calibration points on this rating curve appear good. Continue collection of check points and monitor.
12. WS3, Equation Set D (WY 1999 – Present, pending)
    a. Calibration points taken 1996-2017 have been used to rebuild the original rating curve WS3 Equation Set A.
    b. These calibration points will correspond better with the v-notch calibration points with both sets being taken after 1996.
    c. **Status:** Curve will be used to rerun the historic WS3 streamflow data WY 1999 to Present, where WY1999 is the year the v-notch is installed.

B. Watersheds 6, 7, and 8

1. Original flume rating curves
    a. These basins were originally instrumented with purchased H-flumes, and the accompanying manufacturer's rating curves were used without any attempt at

validation. The H-flume at Watershed 8 was replaced with a trapezoidal flume in 1988. During the 1990s questions about the accuracy of the H-flume rating curves led to calibration measurements being taken at Watersheds 6 and 7 in 1996-1997 prior to the removal of the H-flumes and their replacement with trapezoidal flumes in 1998.

   b. These original manufacturer rating curves used for the 1963-1997 periods can still be validated at Watersheds 6 (18 calibration points) and 7 (22 calibration points). Overlay of these points on the manufacturer's curve indicates that high and low discharges may be being overestimated at WS 6, and low discharges may be being underestimated at WS 7.

2. WS6 Equation Set A (Oct 1963 – Sep 1997)
   a. Manufacturer's rating equations were used. A custom rating curve was never developed.
   b. 18 calibration points were taken WY1996 and WY1997
   c. **Status:** It would be possible to develop a rating curve which could be used to rerun all or part of this streamflow data. Overlay of these points on the manufacturer's curve indicates that high and low discharges may be being overestimated at WS 6
3. WS6 Equation Set B (Oct 1997 – Present, except summers beginning WY1998)
   a. 22 calibration points taken with a velocity meter 1997-1999 have been used to build the rating curve
   b. Check calibration points have been taken from WY 2000 – Present
   c. Status: Checks made by plotting new calibration points on this rating curve appear good. An additional 33 points have been collected, mostly during low flow (<.15 ft.). Continue collection of check points.
4. WS6, Equation Set C (WY 1998 – Present, summers only)
   a. V-notch weir has been in place every summer since June, 1998
   b. Rating curves are based on volumetric samples taken from Jun 1998 to Oct 1999
   c. Check calibration points have been taken from WY 2000 – Present
   d. Status: Checks made by plotting new calibration points on this rating curve appear good although there are many more calibration points now. Continue collection of check points and monitor.
5. WS7 Equation Set A (Oct 1963 – Sep 1997)
   a. Manufacturer's rating equations were used. A custom rating curve was never developed.
   b. 22 calibration points were taken WY1996 and WY1997
   c. **Status:** It would be possible to develop a rating curve which could be used to rerun all or part of this streamflow data. Overlay of these points on the manufacturer's curve indicates that low discharges may be being underestimated at WS 7
6. WS7 Equation Set B (Oct 1997 – Present, except summers beginning WY1998)
   a. 19 calibration points taken with a velocity meter 1997-1999 have been used to build the rating curve
   b. Check calibration points have been taken from WY 2000 – Present
   c. Status: Checks made by plotting new calibration points on this rating curve appear good. An additional 35 points have been collected, mostly during low flow (<.16 ft.). Continue collection of check points.
7. WS7, Equation Set C (WY 1998 – Present, summers only)
   a. V-notch weir has been in place every summer since June, 1998
   b. Rating curves are based on volumetric samples taken from Jun 1998 to Oct 1999
   c. Check calibration points have been taken from WY 2000 – Present

d. Status: Checks made by plotting new calibration points on this rating curve appear good although there are many more calibration points now. Continue collection of check points and monitor.

8. WS8 Equation Set A (Oct 1963 – Sep 1987)
    a. Manufacturer's rating equations were used. A custom rating curve was never developed.
    b. **Status:** No calibration points were collected. Rating curve is static.
9. WS8 Equation Set B (Oct 1987 – Sep 2016, except summers beginning WY1998)
    a. Curve will be replaced with Equation Set D, and all data rerun beginning Oct 1987
    b. 27 calibration points taken with a velocity meter and bucket points 1990-1996 have been used to build the rating curve
    c. Calibration points taken Jan 1990 to Nov 1991 were used to fit the original version of this curve, which was a single equation curve. This curve was operative until Feb 1996 but replaced with version 2 and all data was rerun through the newer version 2.
    d. Check calibration points have been taken from WY 1997 – Present, plus an additional point from 1989
    e. Status: Checks made by plotting new calibration points on this rating curve are generally good but the curve could be improved at the very low end. An additional 47 points have been collected, a combination of low flow checks and velocity meter points at higher flows. A new rating curve is built from the full collection of points including the original 27 plus the additional 47 points to replace this curve.
10. WS8 Equation Set C (summers only, 1997 – Present)
    a. V-notch weir has been in place every summer since June, 1997
    b. Rating curves are based on volumetric samples taken from Jun 1997 to Oct 1999
    c. Check calibration points have been taken from WY 2000 – Present
    d. Status: Checks made by plotting new calibration points on this rating curve appear good although there are many more calibration points now. Continue collection of check points and monitor.
11. WS8 Equation Set D (Oct 1987 – Present, except summers beginning WY1998)
    a. The original 27 calibration points taken with a velocity meter and bucket points 1990-1996 and 47 additional points (WY 1997-2017) taken with a velocity meter, bucket, or derived from bucket collection through the v-notch flume have been used to rebuild the rating curve to replace Equation Set B. Three points were eliminated due to suspect collection conditions and outlier values – 71 points used.
    b. This curve will be used to rerun all data from WY1988 through WY 2016 and continue use with WY 2017.
    c. Status: The new curve tends to raise annual totals by 1.5 to 2 inches (~3-4%) with the new curve returning higher flow in the range of .3 to .7 cfs. More data points collected in the .25 to .40 ft. range would help to verify this curve. The low flow calibration points should improve the low end of the curve.

C. Watersheds 9 and 10

1. Original flume rating curves
    a. Similarly to WS 6, 7, and 8, these basins were originally instrumented with purchased H-flumes, and the accompanying manufacturer's rating curves were used without any attempt at validation from 1968 to August of 1973, when they were replaced with trapezoidal flumes.
    b. The rating curves for the trapezoidal flumes were originally based upon a reverse sigmoidal (cubic) curve, which were used until December 2002. The calibration points were collected with a dye dilution method and obtained between Nov 1975

and Dec 1977. Additional calibration points were obtained from 1996 to 1999, and the overlay of these points on the cubic rating curve indicated that low discharges in Watersheds 9 and 10 were being greatly underestimated, and apparently peak flows were over-estimated. Consequently, the rating curves for WS 9 and 10 were redeveloped in December 2002 and based on the dye dilution and velocity meter calibration points in log-linear form.

   c. V-notch weirs in Watersheds 9 and 10 were originally in place in summers 1973 to 1979. Calibration points were collected (volumetric samples) for the early v-notch at both watersheds. For unknown reasons, the rating curve developed for Watershed 10 was used for both Watershed 9 and 10, and the WS 9 calibration points were never used. In 2002, the original WS 9 volumetric sampling points were combined with derived points (based on calculated flows from the new regular flume equation at times when the v-notch was added or removed) and a new curve developed.

2. WS9 Equation Set A (Oct 1968 – Aug 1973)
   a. Manufacturer's rating equations were used. A custom rating curve was never developed.
   b. **Status:** No calibration points were collected. Rating curve is static.
3. WS9 Equation set B (summers only, 1973-1979)
   a. Original rating curve used the same equation as WS10 for this early v-notch, which was based on WS10 calibration points
   b. This rating curve was developed based on v-notch stage height after/before v-notch installation/removal and calculated discharge determined from corresponding main flume stage height (immediately before/after v-notch installation/removal) using rating equations (Equation Set C, version 2)
   c. Bucket points collected 1973-1977 were suspect and not used.
   d. **Status:** No additional calibration points are available. Rating curve is likely best guess possible.
4. WS9 Equation set C
   a. A reverse sigmoidal (cubic) curve with cubic and quadratic parameters was Version 1 and used until December 2002. Subsequently the curve was refit and all data was rerun through the Version 2 rating curve.
   b. Rating curve Version 2 was redeveloped in the standard log-linear form in December 2002 based on the dye dilution points (collected 1975-1977) and velocity meter and bucket calibration points (collected 1996-2002).
   c. **Status:** No additional calibration points are available. Rating curve is likely best guess possible
5. WS9 Equation set D
   a. A v-notch weir in Watershed 9 has been in place since 1997 with curve based on volumetric bucket samples taken from 1997 to 1999.
   b. Check bucket sample points have been collected from 2002 to 2017.
   c. **Status:** Checks made by plotting new calibration points on this rating curve appear good. Continue collection of check points and monitor.
6. WS10 Equation Set A (Oct 1968 – Aug 1973)
   a. Manufacturer's rating equations were used. A custom rating curve was never developed.
   b. **Status:** No calibration points were collected. Rating curve is static.
7. WS10 Equation set B (summers only, 1973-1979)
   a. This rating curve was based on a combination of bucket points and calculated points (collected 1973 to 1977). Calculated points were determined using v-notch stage

height after/before v-notch installation/removal and calculated discharge determined from corresponding main flume stage height (immediately before/after v-notch installation/removal) using rating equations (Equation Set C, version 2)

b. Additional points were calculated using method described in C.7.a from original data in 2002, and these points were used as a check on this original equation.
c. **Status:** No additional calibration points are available. Rating curve is good.

8. WS10 Equation set C
    a. A reverse sigmoidal (cubic) curve with cubic and quadratic parameters was Version 1 and used until December 2002. Subsequently the curve was refit and all data was rerun through the Version 2 rating curve.
    b. Rating curve Version 2 was redeveloped in the standard log-linear form in December 2002 based on the dye dilution points (collected 1975-1977) and velocity meter and bucket calibration points (collected 1996-2002).
    c. **Status:** Very low flow bucket calibration points collected 2003 to 2017 indicate that a new rating segment could be developed to better represent this very low flow. A new rating curve Set E
9. WS10 Equation set D
    a. A v-notch weir in Watershed 10 has been in place since 1997 with curve based on volumetric bucket samples taken from 1997 to 1999.
    b. Check bucket sample points have been collected from 2002 to 2017.
    c. **Status:** Checks made by plotting new calibration points on this rating curve appear good. Continue collection of check points and monitor.
10. WS10 Equation set E
    a. An additional 28 calibration points (bucket and derived points) were collected from 2002 to 2017 mostly at very low flow levels. These 28 points were added to 76 existing points used to build Eq Set C, ver.2 to build this curve.
    b. The annual total flows from this new curve are nearly identical to those from EQ. Set C as the high flow equation segment remains exactly the same. Only noted changes are at extremely low levels
    c. This curve is intended to replace the existing data from WY 1997-WY2016.
    d. **Status:** New curve is developed by adding 28 new low flow calibration points. Continue collection of check points and monitor.

D. **Mack Creek**

1. Mack Creek Equation set A
    a. Mack Creek was instrumented with a trapezoidal flume in 1980.
    b. Earlier versions of this rating curve were developed in 1994 and 2001. Data made available before 1994 had been run using a linear curve, which are considered invalid.
    c. At present, the discharge record is calculated from a piecewise log-linear rating curve, version 3, based upon 52 calibration points collected between 1983 and 2002.
    d. **Status:** Checks made by plotting new calibration points taken in 2002 and 2003 on this rating curve appear good. Continue collection of check points and monitor.
2. Mack Creek Fish Ladder Equation set A
    a. In 1996, when the Mack culvert was removed and replaced with a bridge, a fish ladder was added to the Mack Gage. The rating curve for the fish ladder's compound weir (there is a rectangular cross-section above a v-notch) was originally derived using theoretical relationships.

b. Calibration points collected with the velocity meter and by differencing the flow change in the main flume when the fish ladder is opened/closed were never used in developing rating curves likely due to suspect accuracy of these points.
c. The fish ladder rating equations were recreated (version 2) in 2001. Additional rating bucket points taken in 2001 are used to fit equation 1, but theoretical curve equations are used to generate points for the upper stage levels within the rectangular section above .8 foot depth (equations 2 and 3).
d. **Status:** No check measurements have been made since this equation version was established. Should the fish ladder be consistently opened at higher flows, new calibration points should be captured to check the theoretical portion of the rating curve.

IV. HJA Flume Rating Curve Summary – June 2018 Update

WS	Eqn. Set	Water Years	Description	Status
1	A	1953-1956	Original trapezoidal flume (18" floor) - Damaged and replaced in 1956	Rating curve based on a rating table developed from flume measurement calibration points with velocity-head rod method
1	B	1956-Present (pending replacement beginning WY1999)	Rebuilt trapezoidal flume (9" floor)	A new curve fit to these new calibration check points show a distinct change in the curve equations
1	C	1999-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks good. Continue to monitor
1	D	Oct 1999- Present (pending)	Rebuilt trapezoidal flume (9" floor)	Curve may be used to rerun WS1 streamflow data beginning WY1999
2	A	1953-Present (pending replacement beginning WY1999)	Trapezoidal flume	A new curve fit to these new calibration check points show differences from original curve at the low end. Early years (~1953-1956) could be rerun based on early rating table since there are only flume-based stage measurements and no hookgage
2	B	1999-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks marginal. Continue to monitor
2	C	Oct 1999- Present (pending)	Trapezoidal flume	Curve may be used to rerun WS2 streamflow data beginning WY1999
3	A	1953-Present (pending replacement beginning WY1999)	Trapezoidal flume	A new curve fit to these new calibration check points show differences from original curve at the low end. Early years (~1953-1956) could be rerun based on early rating table since there are only flume-based stage measurements and no hookgage
3	A	Post-1996 flood (until October 1998)	Trapezoidal flume -channel changes may alter existing curve	Original hook gage-based equations still used. Consider getting flume-based calibration points to build alternate curve
3	B	Post-1964 flood (1+ year until September 1966)	Same flume with only flume measurements and no hook gage measures	Curve is based on flume measurements – used because no hook gage
3	C	1999-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks good. Continue to monitor
3	D	Oct 1999- Present (pending)	Trapezoidal flume	Curve may be used to rerun WS3 streamflow data beginning WY1999
6	A	1964-1997	Factory H-flume	Manufacturer's equation used - Overlay of check points on this curve indicates that low discharges may be overestimated – new curve could be developed to rerun
6	B	1998-Present	Trapezoidal flume	Curve based on velocity meter sampling points looks good. Continue to monitor
6	C	1998-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks good. Continue to monitor
7	A	1964-1997	Factory H-flume	Manufacturer's equation used - Overlay of check points on this curve indicates that high and low discharges may be overestimated – curve could be developed to rerun this data
7	B	1998-Present	Trapezoidal flume	Curve based on velocity meter sampling points looks good. Continue to monitor
7	C	1998-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks good. Continue to monitor
8	A	1964-1987	Factory H-flume	Manufacturer's equation used – no calibration points available to check

8	B	1988-Present (pending, may be replaced w/ Set D)	Trapezoidal flume	Curve based on velocity meter sampling points are generally ok, but potentially rebuild the curve with the inclusive, newer set of calibration points.
8	C	1997-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks good. Continue to monitor
8	D	1988- Present (pending)	Trapezoidal flume	Curve is based on all 71 calibration points. Improves low end but increases flow in mid-section of curve
9	A	1969-1973	Factory H-flume	Manufacturer's equation used – no calibration points available to check
9	B	1973-1979 (summers only)	Trapezoidal flume with v-notch (early style)	Curve based on volumetric sampling and calculated points is best guess
9	C	1973-Present	Trapezoidal flume	Curve based on dye-dilution and velocity meter sampling points looks good
9	D	1997-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks good. Continue to monitor
10	A	1969-1973	Factory H-flume	Manufacturer's equation used – no calibration points available to check
10	B	1973-1979 (summers only)	Trapezoidal flume with v-notch (early style)	Curve based on volumetric sampling and calculated points is best possible
10	C	1973-Present (pending replacement beginning WY1997)	Trapezoidal flume	Curve based on dye-dilution and velocity meter sampling points. A new rating segment could be developed to better represent very low flow
10	D	1997-Present (summers only)	Trapezoidal flume with v-notch	Curve based on volumetric sampling points looks good. Continue to monitor
10	E	1997-Present (pending)	Trapezoidal flume	New curve is developed. Annual flows stay nearly identical with improvement at the very low end. Propose using WY1997-Present
Mack Main	A	1980-Present	Trapezoidal flume	Curve based on velocity meter sampling points looks good. No new check points
Mack Fish	A	1996-Present	Compound weir: V-notch w/ rectangular section above	Curve based on volumetric sampling points and theoretical points (rectangular section) – no check points available for upper rectangular section