Memorandum CCL-UKHM-1

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To: Access Consulting Group – Dan Cornett (dan@accessconsulting.ca)

From: Clearwater Consultants Ltd. - Peter S. McCreath (pmccreath@shaw.ca)

Subject: United Keno Hill Mines – Hydrological Update and Assessment

1. Introduction

This Memorandum CCL-UKHM-1 prepared by Clearwater Consultants Ltd. presents a description of the results of the data processing carried out for streamflow data collected at and around the United Keno Hill Mine (UKHM) property. The purpose of the study was to update the site hydrologic parameters and ultimately refine the site-wide water balance and mass loading model for the site.

2. Background

The climate and hydrology of the UKHM property was characterized in 1996, as part of an investigation leading to the development of the first comprehensive closure plan for this mine development. At the time, the database of streamflows at the mine site was sparse, being largely limited to a few spot discharge measurements at some of the water quality monitoring stations. Owing to this dearth of site-specific data, the flow characteristics of the mine site streams were inferred from streamflow data collected at the network of government gauging stations operated in the region. The regional streamflow data were supplemented with climatic water balances, which were derived from data collected at climate stations at or near the UKHM property. The original climate and hydrology study is documented in Sections 3.6 and 3.7 of the Access Mining Consultants Ltd. Report No. UKH/96/01 entitled "United Keno Hill Mines Limited, Site Characterization".

A program was initiated in 2003 to improve the monitoring of streamflows at the mine site. In August 2003, Station KV7 on Christal Creek was equipped with a pressure transducer and datalogger to facilitate continuous monitoring of water level. The program was expanded in July 2004 with the installation of water-level monitoring equipment at Station KV9 on Flat Creek and Station KV41 on Lightning Creek. All stations were visited on a frequent basis to make direct measurements of discharge and to survey the staff gauges relative to bench marks. Winter measurements of discharge were made using salt dilution. This network of streamflow gauging stations has been operated over the years by both Laberge Environmental Services (LES) and by Elsa Reclamation & Development Company Ltd (ERDC).

ERDC is presently undertaking a program to develop a site-wide water balance and associated chemical load balances for the entire UKHM property. As part of this program, ERDC retained Clearwater Consultants Ltd. (Clearwater) to refine the understanding of the UKHM hydrology that was originally developed in 1996 and to provide guidance on developing hydrological inputs to the site-wide water balance. Clearwater adopted the following three-step approach for this assignment:

1) Process historical records of water level, direct discharge measurements and survey data collected at the mine's three streamflow gauging stations (KV7, KV9 and KV41);
2) Use streamflow records developed in Step 1 to assess accuracy of flow-estimation techniques documented in the 1996 climate and hydrology study; and,
3) Outline a proposed method for estimating flows at key locations around the UKHM property based on the original hydrology study and the streamflow records for the three mine site gauging stations.

These three steps are described below under separate headings.

3. Processing of Mine Site Streamflow Data

The procedure used to reduce the streamflow data at each station entailed the following general steps:

- Assemble all raw water level data collected since 2003 into a single spreadsheet. Over the years, water levels have been sampled at intervals of from 30 minutes to four hours. The typical sampling rate was hourly.
- Adjust the raw data so that all water levels are referenced to a common datum. The datum selected for this purpose was the zero of the station's staff gauge. Survey measurements demonstrated that shifts in the datum of each staff gauge has so far been minimal.
- Identify and eliminate water level data affected by backwater caused by ice conditions. This step was largely facilitated using the air temperature record from the Mayo Airport to identify periods of prolonged freezing.
- Develop a rating curve for the station using the record of direct discharge measurements. A three-parameter power relationship was fitted to the data to facilitate extrapolation of the rating curve.
- Convert water level readings into equivalent discharge rates using the rating curve.
- Aggregate computed discharges into a daily average discharge record.
- Patch periods of missing data in the daily discharge record. All patchings were done using linear interpolation. Only short periods of missing data were patched during the open water season. Patching of longer periods was considered valid during the winter months.
- Aggregate the patched daily record into a monthly average discharge record. (These last three steps were not applied to the data for Station KV9, for a reason outlined later in this section.)

Water level data collected at the four mine adits has not been processed at the time of preparation of this memorandum. The data appears to be unreliable and of dubious quality.

3.1. Christal Creek at KV7

The streamflow record for Station KV7 on Christal Creek is presented in Figures 1 to 5. Each figure covers a calendar year and comprises two plots. The top plot provides a comparison of the pressure transducer readings and the staff gauge readings. The bottom plot shows the continuous records of discharge computed from the pressure transducer readings and the derived rating curve. To confirm that the rating curve was applied correctly, the direct discharge measurements are superimposed on the computed discharge record. The blue lines on the bottom plots represent discharges at a range of intervals, depending on the interval at which the water level data were collected. For the most part, the blue lines represent hourly average discharge.

Table 1 presents the patched monthly average flow record for Station KV7 for the period 2003 to 2007. Averages were computed for each calendar month to provide an estimate of the average seasonal runoff distribution at this station. These average monthly flows were in turn averaged to derive an estimated value for the mean annual runoff (MAR) of Christal Creek at KV7. The resulting MAR was 0.304 m^3/s, or 221 mm equivalent depth of runoff distributed uniformly over the contributing catchment area of 43.5 km^2.

3.2. Flat Creek at KV9

Processing of the streamflow record for Station KV9 on Flat Creek had not been finalized at the time this memorandum was prepared. The raw water level record for an important period (the 2006 freshet) had not been located. Further searches for the computer file that contains these data will be undertaken. If unsuccessful, an alternative plan has been formulated for reconstructing the water level record for the missing period. A preliminary discharge record for this period and a preliminary rating curve were presented in a report prepared by LES entitled "Keno Valley Receiving Environment Monitoring – Freshet Survey 2006". The preliminary discharge record can be digitized from a graph of the data in that report. The water level record can then be back calculated using the preliminary rating curve. The 2006 freshet period is important to include in the KV9 streamflow record because of recommendations presented later in this memorandum and because the largest direct flow measurements were made during this period. Figure 6 presents the record of pressure transducer readings assembled to date. It also shows the complete record of direct discharge measurements taken since 2003.

Despite the missing 2006 freshet data, the remainder of the dataset could be productively used in estimating the long-term MAR of Flat Creek at KV9. This was accomplished by correlating the direct discharge measurements with coincidental daily flows at regional Water Survey of Canada (WSC) stations. Figure 7 is a graphical presentation of the correlations made with the data from four WSC stations. For each WSC station, a linear regression was fitted to the pairs of coincidental data. The intercept of the regression was forced through the origin to simplify the analysis and to minimize the influence of outliers at the low end of the data range. The slope of the regression was interpreted as approximating the ratio of the MAR of Flat Creek to the MAR of the regional stream monitored by the WSC station. Text boxes on the figure illustrate how the regressions were used to determine four independent estimates of the MAR of Flat Creek. The independent estimates range from 0.304 m^3/s to 0.352 m^3/s. Expressed as equivalent depths, this estimated range is 170 mm to 197 mm. The drainage area controlled by Station KV9 is 56.5 km^2. The correlations made use of direct discharge measurements at KV9 extending back to 1994.

3.3. Lightning Creek at KV41

The streamflow record for Station KV41 is presented in Figures 8 to 11. The format of these figures is the same as described above for Station KV7. Further investigation is proposed to investigate potential errors in the original computations of the direct flow measurements made on June 30 and July 20, 2005. These two flows are inconsistent with their corresponding staff gauge readings and pressure transducer readings. The water levels at this station were monitored on either a half-hourly or hourly basis.

Table 2 presents the patched average monthly discharge record for the period 2004 to 2007. As for Station KV7, averages of the monthly values were computed for each calendar month. These averages were in turn averaged to estimate the MAR for Lightning Creek at KV41. The resulting MAR was 0.645 m^3/s, or 344 mm equivalent depth of runoff water spread over the catchment area of 59.1 km^2.

4. Critique of 1996 Hydrology Study

The 1996 Hydrology Study provided a technique for estimating the average runoff hydrograph at ungauged locations in and around the UKHM property. Application of this technique involved the following procedure:

1) Draw catchment boundary for point of interest. Measure drainage area enclosed by this catchment boundary. Determine median elevation of catchment (i.e., the contour that divides the catchment in halves, where ground elevations are all greater than the contour level in one half and all below in the other).
2) Use regional relationship between MAR and median elevation (see Figure 3-8 of Report UKH/96/01) to provide an estimate of the MAR of the ungauged catchment.
3) Select a normalized streamflow distribution from one of the regional WSC stations to represent conditions at the ungauged point (see Figure 3-9 of Report UKH/96/01). Like the MAR relationship, the selection process is based on the median elevation of the study catchment.
4) Integrate information obtained from the above three steps to estimate the average flow for each calendar month of the year at the ungauged location. It should be noted that the resulting flow estimates are representative of pre-mining conditions. Further adjustments must be made to the resulting flows to make them representative of present-day conditions. For example, the measured releases from upstream adits should be added to the estimated pre-mining flow estimates. In determining the catchment area in Step 1, enclosed areas draining to open pits and glory holes should be excluded from the calculation. This avoids double accounting of flows because much of the runoff generated in these enclosed areas eventually reports to one of the adits.

The estimation technique described above relied primarily on two empirical relationships contained in the 1996 Hydrology Study. The critique of this study largely involved determining how well these empirical relationships estimate the actual conditions at the three mine site gauging stations KV7, KV9 and KV41.

Figure 12 is a reproduction of Figure 3-8 from the original hydrology study. It is a graph of mean annual runoff (expressed as a depth) versus catchment median elevation. Two sources of data were used to help develop the empirical relationship between MAR and elevation. The first source was pairs of MAR and elevation data provided by the streamflow gauging stations operated in the region by the WSC and DIAND. The second set was based on climatic water balances calculated for two climate stations at UKHM, namely Elsa and Keno Hill. Point estimates of runoff were made for these two stations by subtracting estimated mean annual evapotranspiration from the observed mean annual precipitation.

After these two sets of data were plotted on the figure, a line was drawn on the figure that was believed to represent conditions at UKHM. The adopted line runs through the two point runoff estimates provided by the climate stations and the MAR/elevation pairing provided by the WSC gauging station on McQuesten River. Much of the mine development drains to this river.

The three streamflow gauging stations at UKHM offer an excellent basis for validating the adopted relationship between MAR and catchment median elevation. These three stations represent runoff from catchments with a wide range of elevation characteristics. The catchment median elevations for KV7, KV9 and KV41 are 970 m, 830 m and 1400 m, respectively. The estimated MAR values for these three stations, together with their corresponding median elevations, were plotted on Figure 12. As can be seen, the mine site data plot close to the original relationship. This indicates that the original relationship is reasonable and can continue to be used to estimate MAR at ungauged locations around the mine site.

Figure 13 is a reproduction of Figure 3-9 from Report UKH/96/01. This figure shows a range of seasonal runoff distributions from seven WSC gauging stations in the region. These stations were selected on the basis that they represent runoff from catchments with a wide range of elevations. To facilitate comparison, the distributions have been normalized to represent percentages of the average annual runoff volume. For example, the distribution for the Indian River suggests that 40% of the average annual runoff volume occurs in May for this river.

The average runoff distribution for Christal Creek at KV7 has been superimposed on this figure. Based on this station's catchment median elevation, the distribution for McQuesten River (yellow line) would be expected to best represent conditions on Christal Creek. As can be seen, these distributions both peak in May. However, the baseflows are relatively much greater in Christal Creek and the freshet flows are more drawn out on McQuesten River. It must be noted that this is not a complete comparison of the two distributions. As noted above, the estimation technique presented in the 1996 Hydrology Study provides only estimates of flows under pre-mining conditions. The releases from upstream adits should be added to the estimates of pre-mining flow to obtain an estimate of present-day conditions. The existence of adit flows explains, at least partly, why the normalized average runoff distribution for Christal Creek shows greater baseflows than the normalized distributions for the seven WSC stations.

Figure 14 compares the observed distribution for Lightning Creek with the distributions of the seven WSC stations. Based on catchment median elevation, the distribution for North Klondike River (dark blue line) should provide a reasonable approximation of the conditions at Lightning Creek. Both distributions peak in June and follow similar patterns throughout the year. However, the distribution for Lightning Creek exhibits higher flows in the fall than does the one for North Klondike River. This discrepancy may be partially due to the short record used to define the average runoff distribution for Lightning Creek. The sample of four years may have experienced higher fall flows than is typical for this region.

The comparisons made above indicate that the 1996 Hydrology Study provides good estimates of long-term average flow at an ungauged site. However, accuracy decreases when the method is used to determine average flows for a particular calendar month or season. Accounting for upstream adit releases can improve the estimation of the seasonal runoff distribution at an ungauged location.

5. Hydrological Inputs for Site-Wide Water Balance

ERDC are planning to develop a site-wide water balance representative of present-day conditions. This water balance would then form the basis for constructing load balances that examine the present-day generation, movement and attenuation of contaminants at the mine site and in the receiving environment. Tables 3 and 4, reproduced from the 1996 study, shows the details of the mine area catchments and the estimated mean annual runoff depth in millimeters and volume in m^3/year.

Based on the critique presented in the previous section, the hydrological inputs for the new water balance could be estimated using the original techniques presented in the 1996 Hydrology Study, provided the influences of adit flows on the local hydrology are accounted for. However, the availability of the streamflow records at KV7, KV9 and KV41 may offer a more accurate method of assessing chemical loads. Instead of constructing the water and load balances using estimates of average flows, these balances could be based on a specific period in which the flows at some of the key monitoring sites have already been measured. An examination of the streamflow records at the three mine site stations indicates that the most complete and accurate data are available for Water Years 2005 and 2006 (i.e. period October 1, 2004 to September 31, 2006).

Based on the above discussion, we recommend that the next set of water and load balances for the UKHM property be prepared on a monthly basis for the two-year period from October 2004 to September 2006. Sites KV7, KV9 and KV41 would be characterized by the actual flow records, but patched where data are missing. Flows at ungauged sites would be estimated by transposing one or more of the local streamflow records to the site of interest. The transposition process could be handled in a number of different ways. For example, if a site had a catchment with similar elevation characteristics as KV9, then the KV9 flow record could be transposed to this site based on the ratio of catchment areas. If a site had a catchment with an elevation intermediate to that of KV9 and KV41, then the flows for the ungauged site could be estimated by taking a weighted average of the flow records for KV9 and KV41. In this transposition process, allowance must be made for the effect of adit flows. For example, the flows at KV7 could potentially be used to represent conditions at another stream, provided that the influence of adits on the KV7 flow regime is first removed (probably by subtraction of the measured adit flows from the measured KV7 flows).

The observed flow record for WSC Station 09DD004 (McQuesten River near the mouth) could be scaled to represent the flows in the South McQuesten River at sites in the vicinity of the mine development. The scaling would be achieved using ratios of catchment areas and ratios of estimated mean annual runoff MAR.

6. Conclusions

This memorandum presents the results of streamflow data processing and evaluation for the United Keno Hill Mine site area. The following conclusions are made:

- Christal Creek at KV7 has a catchment area of 43.5 km^2 and over the 2003 to 2007 period the estimated mean annual runoff (MAR) was 0.304 m^3/s corresponding to an average runoff depth of 221 mm from the catchment area
- Flat Creek at KV9 has a catchment area of 56.5 km^2. Based on correlations with regional WSC streamflow data the estimated mean annual runoff (MAR) was from 0.304 m^3/s to 0.352 m^3/s corresponding to an average runoff depth of 170 mm to 197 mm from the catchment area
- Lightning Creek at KV41 has a catchment area of 59.1 km^2 and over the 2004 to 2007 period the estimated mean annual runoff (MAR) was 0.645 m^3/s corresponding to an average runoff depth of 344 mm from the catchment area
- The Flat Creek flow data may be improved if additional water level data during the 2006 freshet period can be located.
- Water level data collected with dataloggers for the adits appears to be of dubious quality. Spot flow measurements taken with buckets and stopwatches provide the most reliable indications of adit flows.
- Based on comparisons with the latest site flow data, the hydrological inputs for the new site-wide water balance could be estimated using the original techniques presented in the 1996 Hydrology Study, provided the influences of adit flows on the local hydrology are accounted for. Figure 12 provides the relationship between median catchment elevation and mean annual runoff.
- The seasonal flow distribution for McQuesten River on Figure 13 would be expected to best represent conditions on Christal Creek

- The seasonal flow distribution for North Klondike River (Figure 14) should provide a reasonable approximation of the conditions at Lightning Creek
- The next set of water and load balances for the UKHM property should be prepared on a monthly basis for the two-year period from October 2004 to September 2006 using actual and/or patched flow data for sites KV7, KV9 and KV41.
- A comprehensive quality assurance and quality control program should be instituted for the mine site area to ensure that all future water quantity and water quality data collected is reliable, representative of actual conditions, and of the highest quality and usable for on-going analyses and assessment of the site water balance and mass loading model.

CLEARWATER CONSULTANTS LTD.

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APPENDIX 1

United Keno Hill Mines
Hydrologic Update - Tables

Table 1 Monthly Average Discharge Record for Christal Creek at KV7 (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003								0.420	0.510			
2004			0.150	0.166	1.153	0.314	0.119	0.112	0.163	0.135	0.103	0.101
2005		0.122	0.112	0.391	1.540	0.264	0.294	0.398	0.335	0.259	0.189	0.150
2006	0.166	0.138	0.120	0.124	1.089	0.519	0.397	0.278	0.415	0.368	0.203	0.142
2007	0.151	0.120			0.757	0.327	0.540	0.218	0.335	0.154		
Average	0.159	0.126	0.127	0.227	1.135	0.356	0.337	0.285	0.352	0.229	0.165	0.131

Mean annual runoff = ~0.304 m^3/s, or 221 mm.

Table 2 Monthly Average Discharge Record for Lightning Creek at KV41 (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004								0.433	0.315	0.240	0.153	0.125
2005	0.098	0.067	0.056	0.130	1.802	1.418	0.989	1.111	0.958	0.637	0.452	0.299
2006	0.219	0.192	0.194	0.272	0.793	1.994	1.326	0.921	1.083	0.889	0.554	0.447
2007					1.231	1.926	1.193					
Average	0.159	0.129	0.125	0.201	1.275	1.779	1.169	0.821	0.785	0.589	0.386	0.290

Mean annual runoff = ~0.645 m^3/s, or 344 mm.

Table 3 - Details of Minesite Catchments

Catchment Description	Catchment Area (km²)	Catchment Median Elevation (m)	Mean Annual Runoff (MAR)	
			Depth (mm)	Volume (m3/yr)
Christal Creek above Station KV6	7.7	990	240	1,848,000
Christal Creek between Stations KV6 and KV7	35.8	970	230	8,234,000
Sandy Creek above LES-63	2.3	1180	290	667,000
No Cash Creek above LES-21	1.5	1200	300	450,000
South McQuesten River above S10 and below LES-1, S 19, LES-21, and LES-63	32.9	650	150	4,935,000
South McQuesten River above LES-1	476	940	230	109,480,000
Catchment of Dam No. 3 of Elsa Tailings Impoundment	4.3	760	180	774,000
Porcupine Creek Diversion Channel above LES-47	10.1	1110	270	2,727,000
Galena Creek above the mouth	10.9	970	240	2,616,000
Flat Creek above S9 and below LES-57, LES-47, and S1	31.2	700	170	5,304,000
South McQuesten River above S11 and below S10 and S9	29.9	670	160	4,784,000
South McQuesten River above LES-5 and below S11 and LES-10	95	850	200	19,000,000
Haldane Creek above South McQuesten Road	88.8	830	200	17,760,000

Table 4 - Details of Enclosed Basins created by Open Pits:

Enclosed Basin Description	Catchment Area (km²)	Catchment Median Elevation (m)	Mean Annual Runoff (MAR)	
			Depth (mm)	Volume (m3/yr)
Open pits within catchment of Element 1 (Calumet "C" and Onek)	0.09	1180	290	26,100
Open pits within incremental catchment of Element 2 (Sime 6, Sime 4, 35 Vein, and Miller)	0.19	1280	320	60,800
Open pits within catchment of Element 3 (Western portion of Calumet 4-11 Veins)	0.05	1400	350	17,500
Open pits within catchment of Element 4 (Bermingham and Bermingham SW)	0.18	1350	340	61,200
Open pits within incremental catchment of Element 5 (Calumet 3, Calumet 2, and part of Calumet 4-11 Veins)	0.23	1380	350	80,500
Open pits within catchment of Element 8 (Silver King)	0.27	860	210	56,700

APPENDIX 2

United Keno Hill Mines
Hydrologic Update - FIGURES

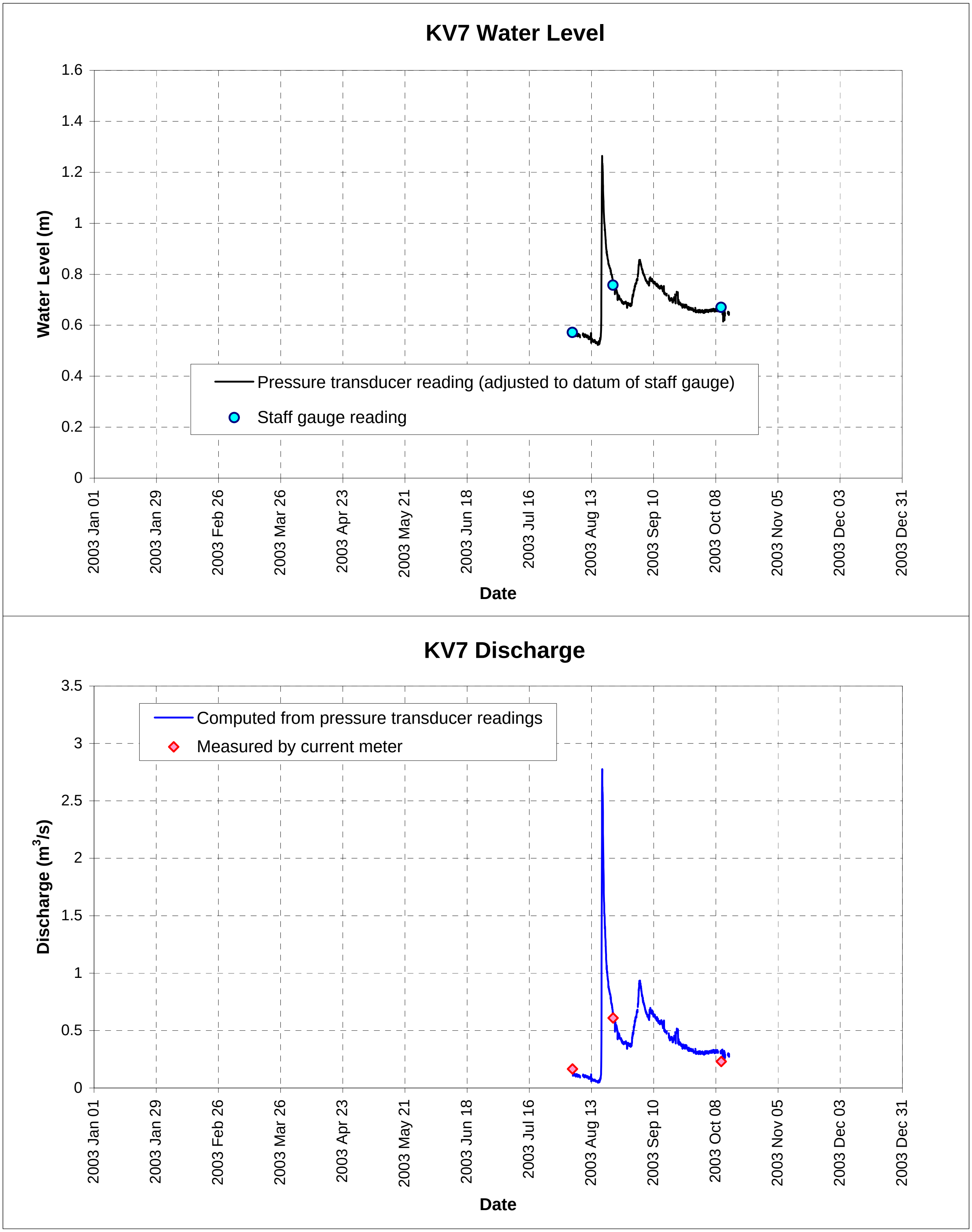


Figure 1 2003 Stage and Flow Records for Station KV7

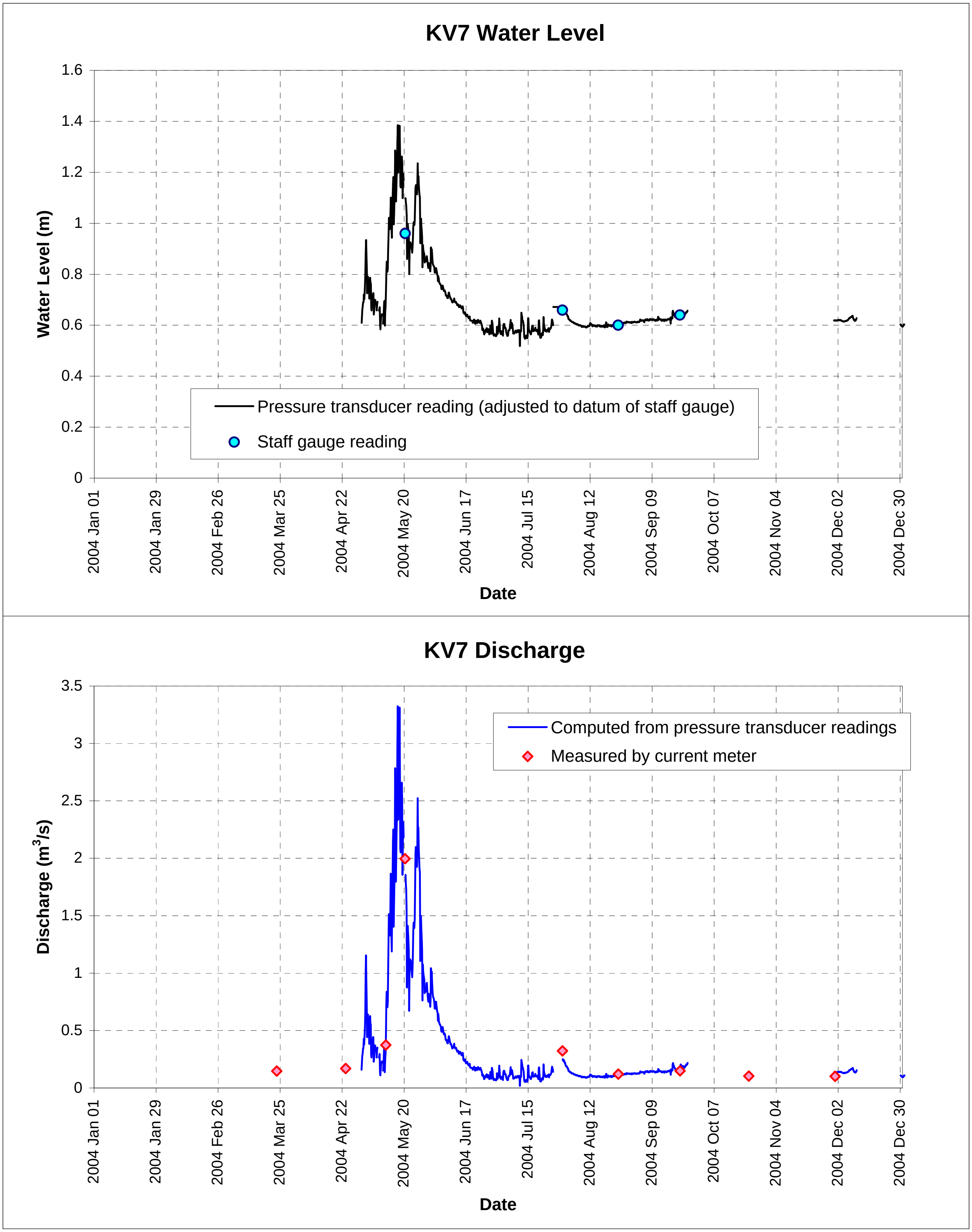


Figure 2 2004 Stage and Flow Records for Station KV7

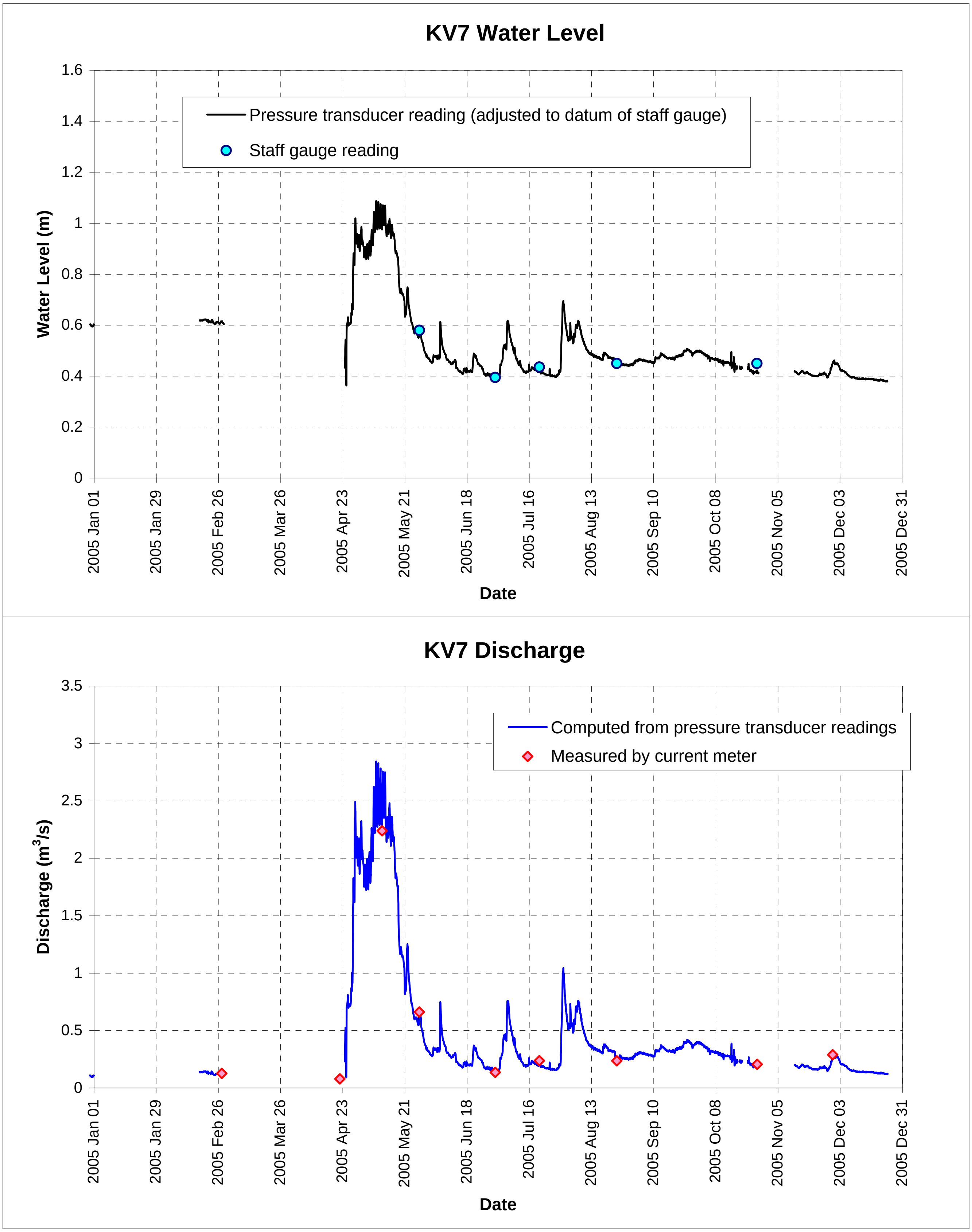
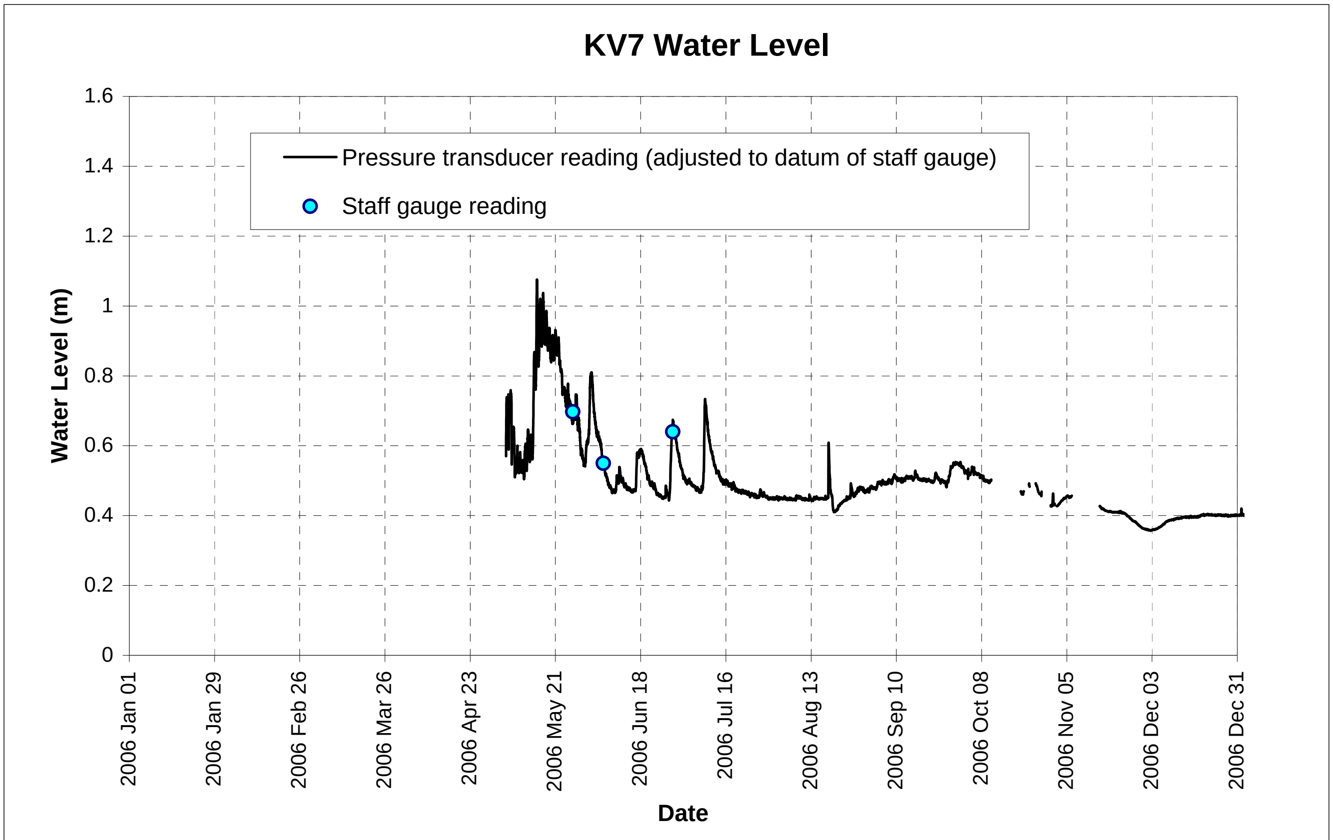


Figure 3 2005 Stage and Flow Records for Station KV7



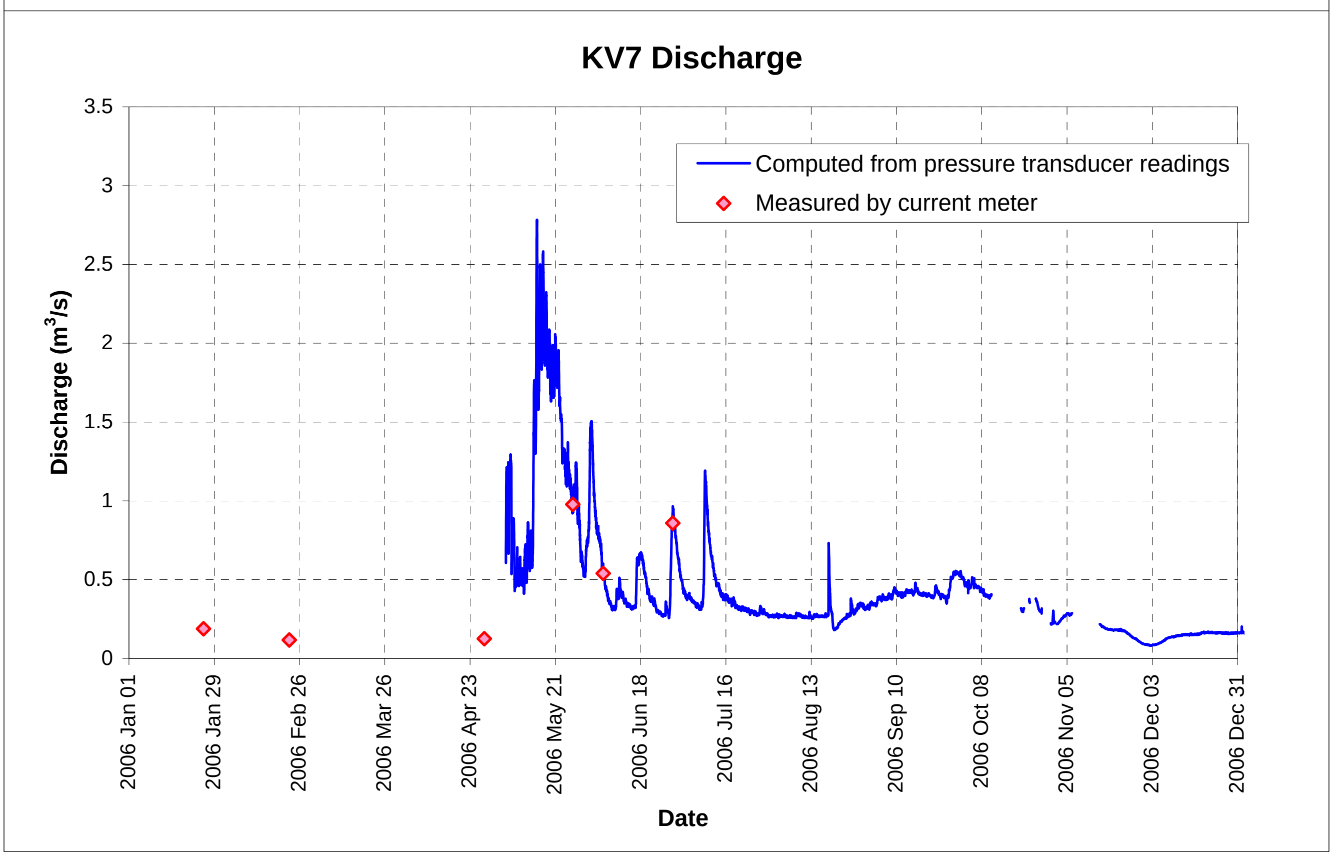


Figure 4 2006 Stage and Flow Records for Station KV7

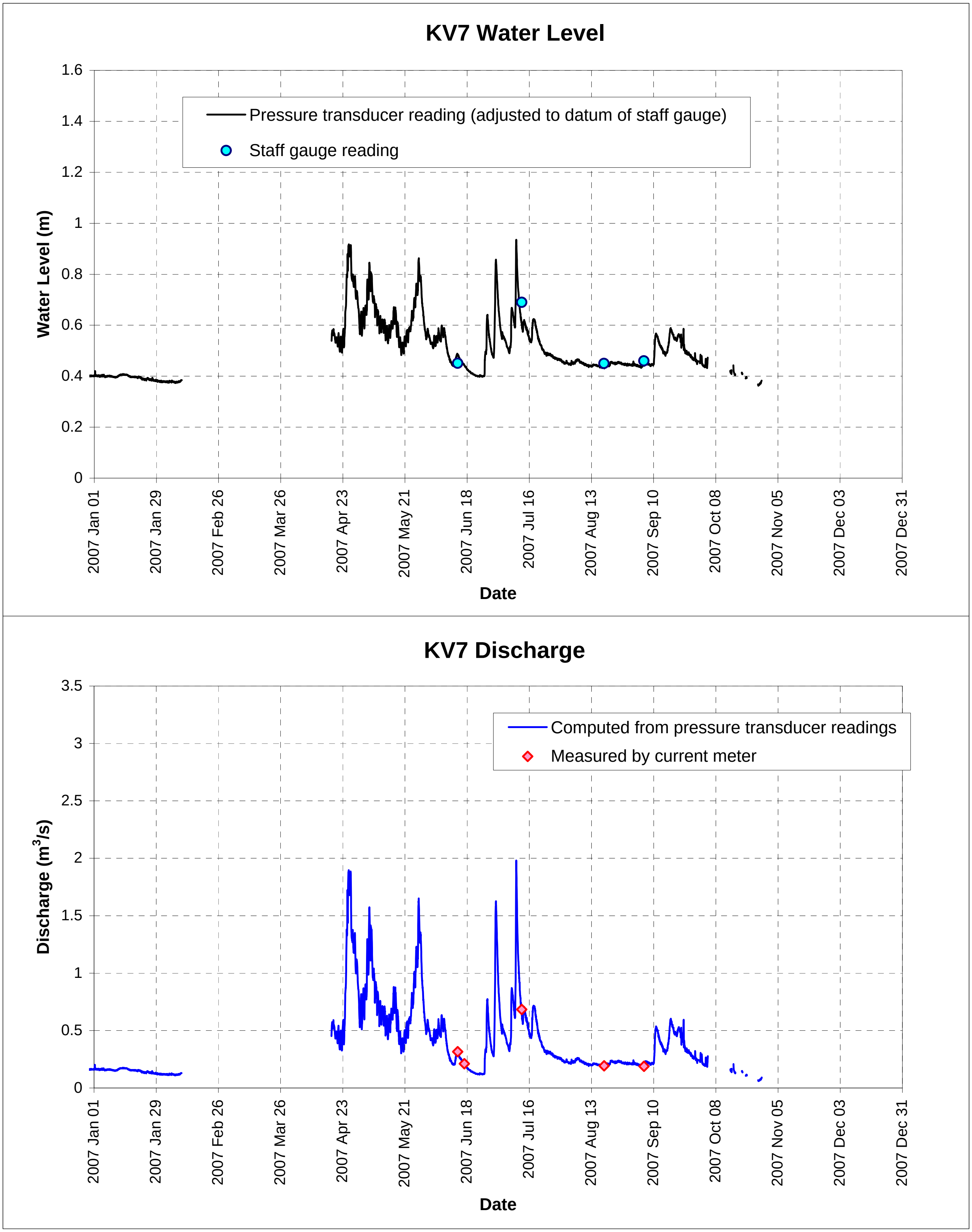
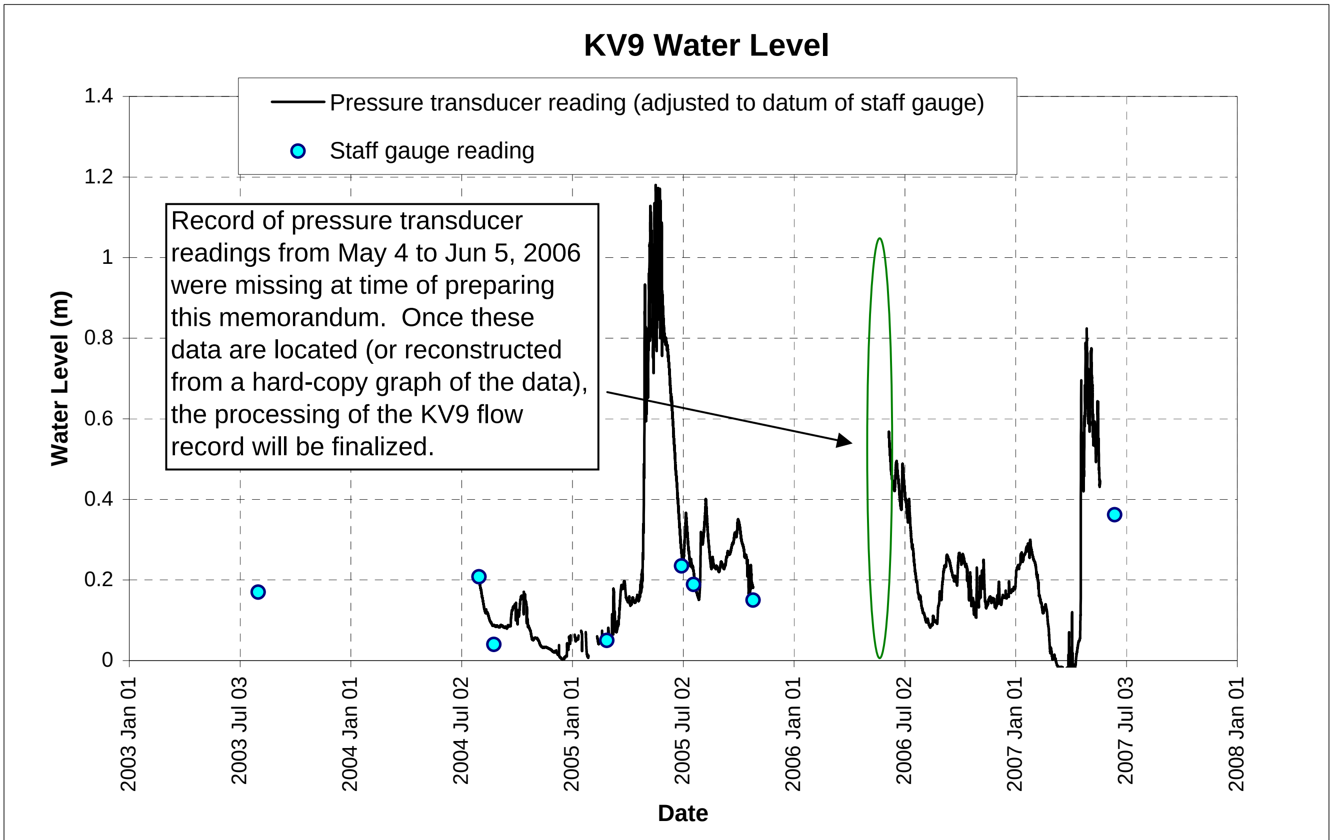


Figure 5 2007 Stage and Flow Records for Station KV7



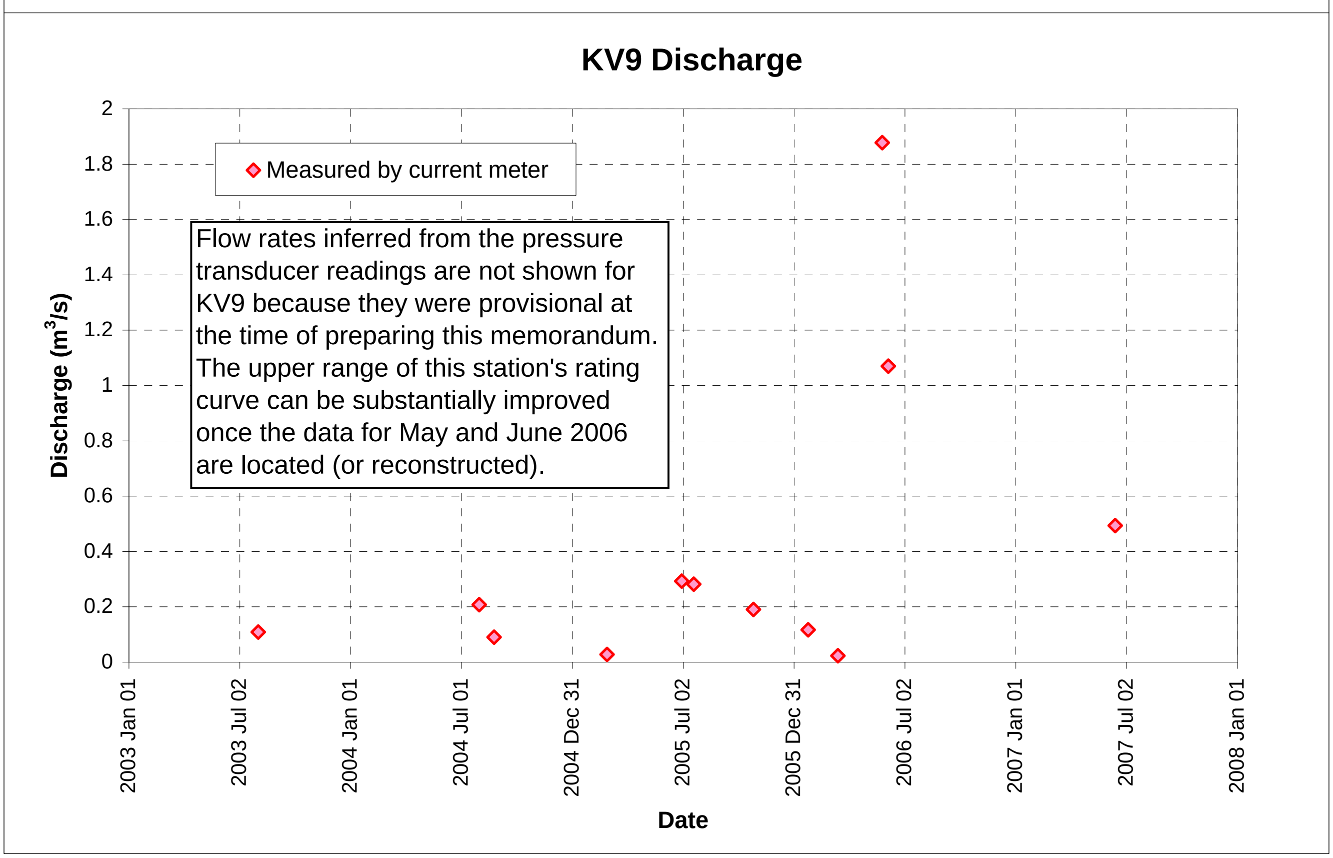


Figure 6 Stage and Flow Records for Station KV9

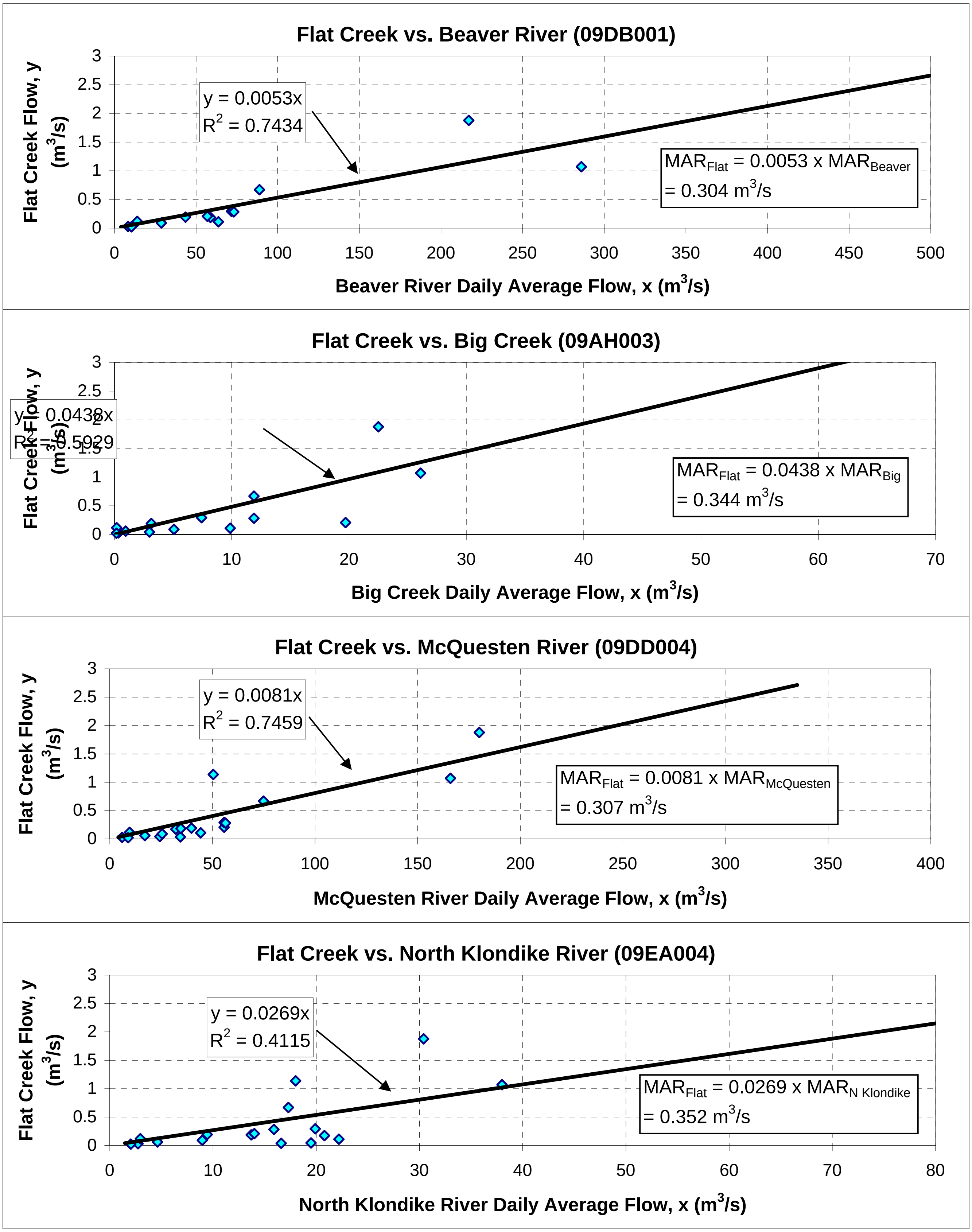
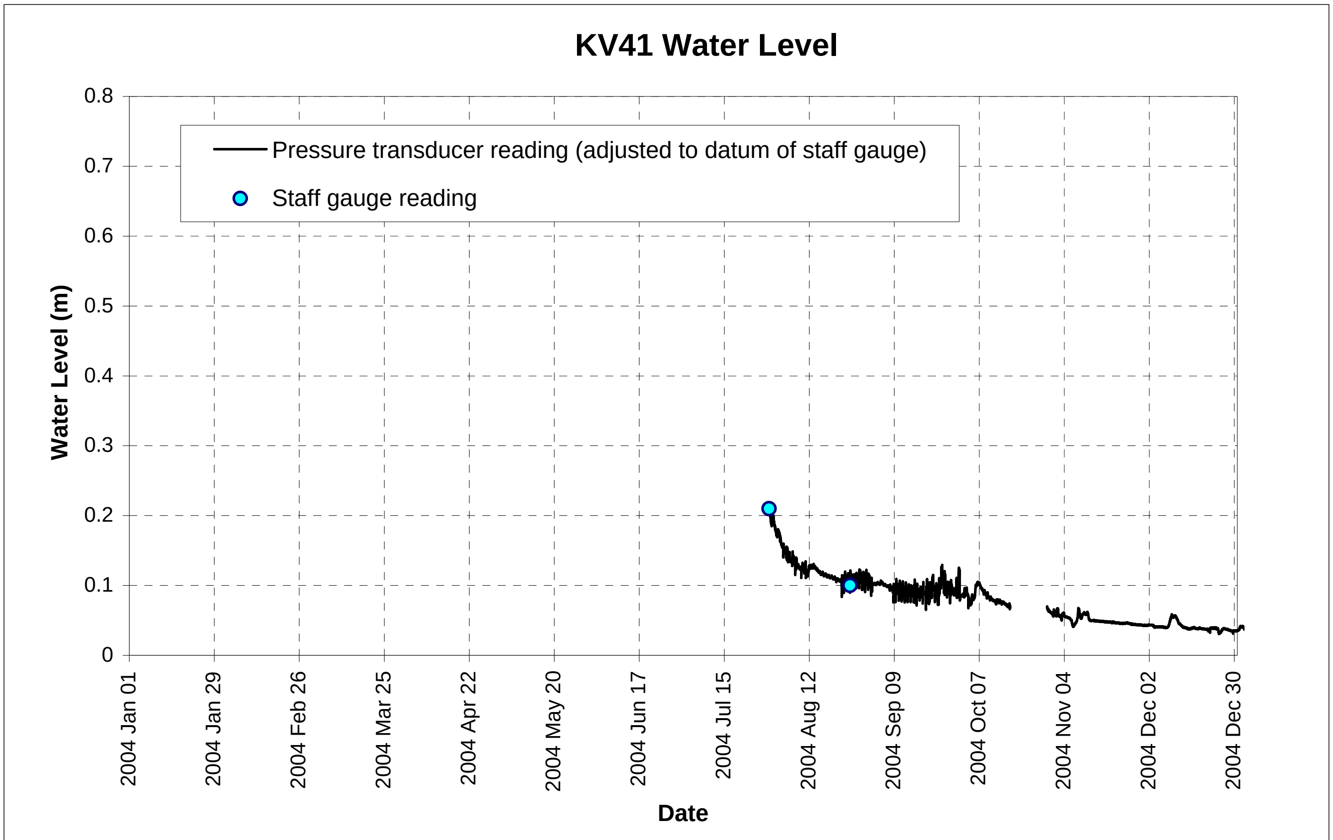


Figure 7 Estimation of MAR of Flat Creek at KV9



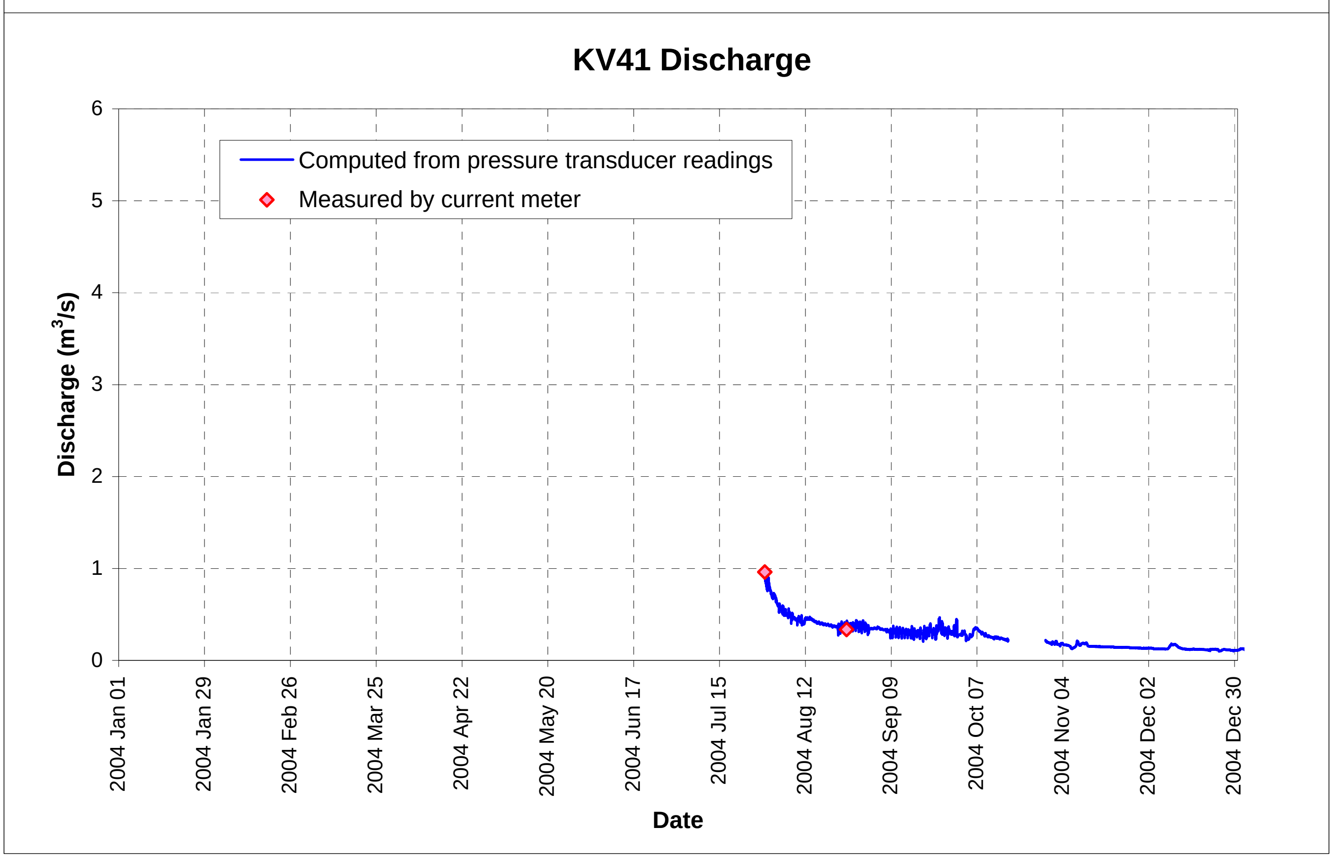
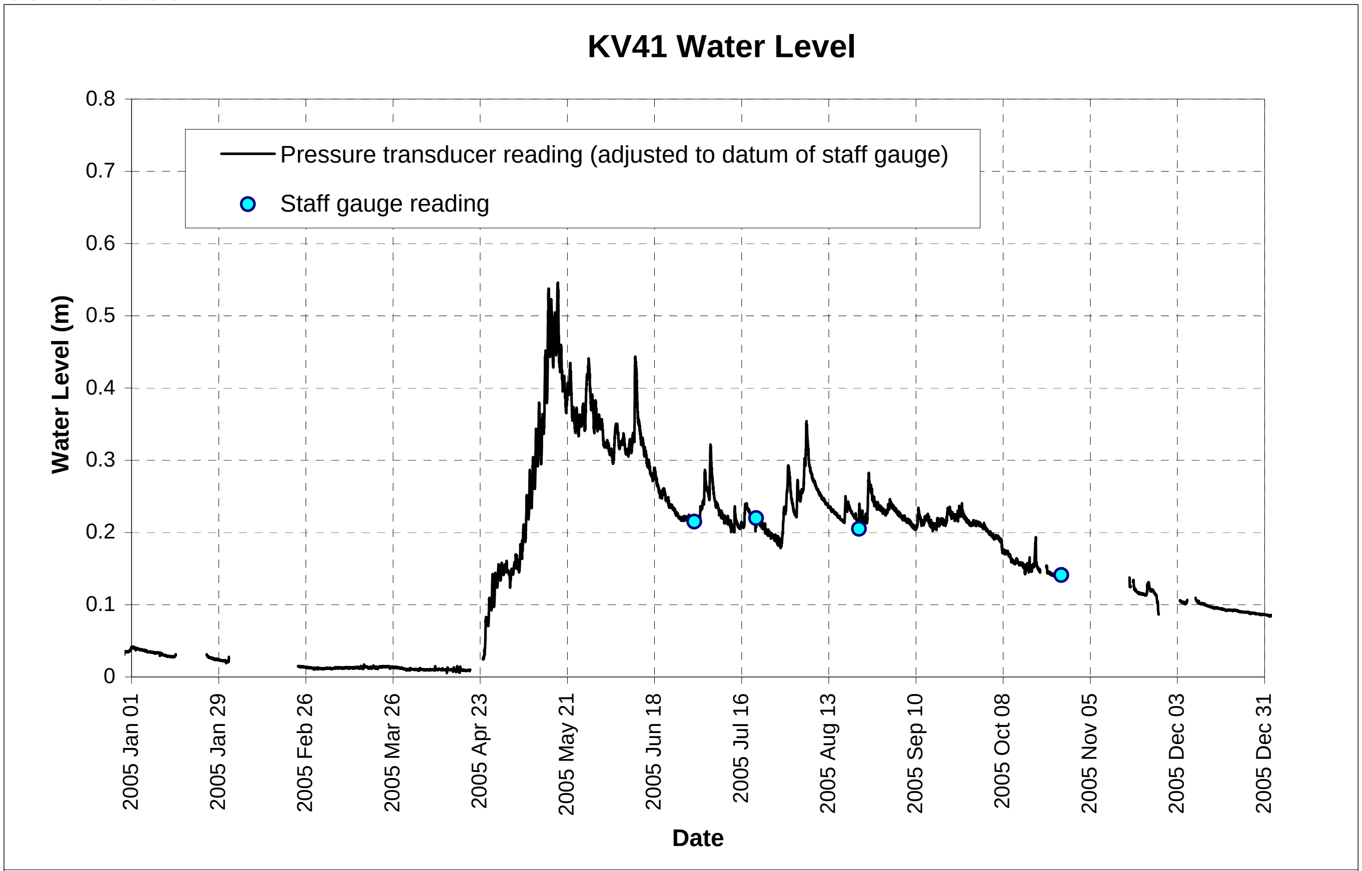


Figure 8 2004 Stage and Flow Records for Station KV41



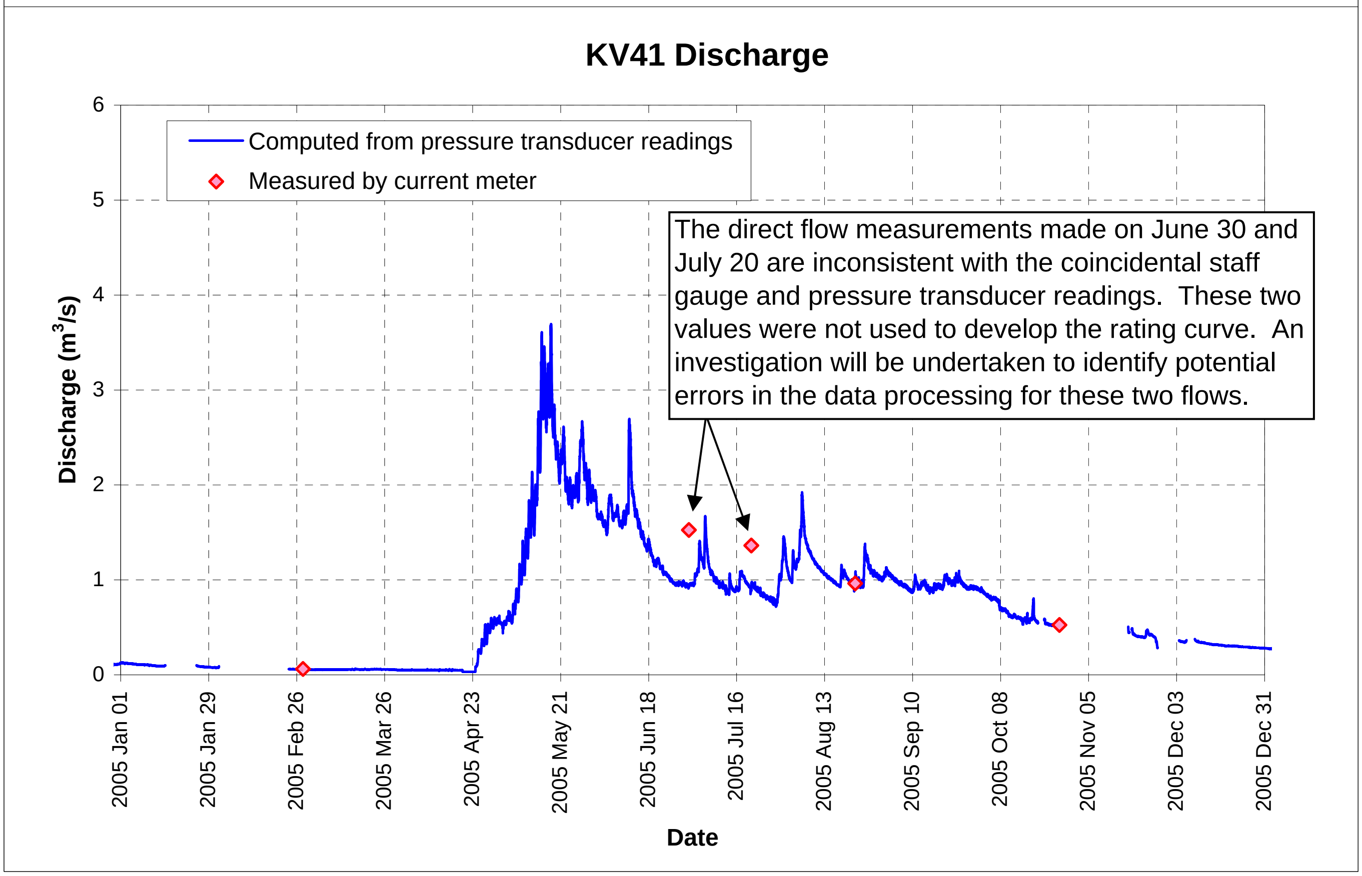
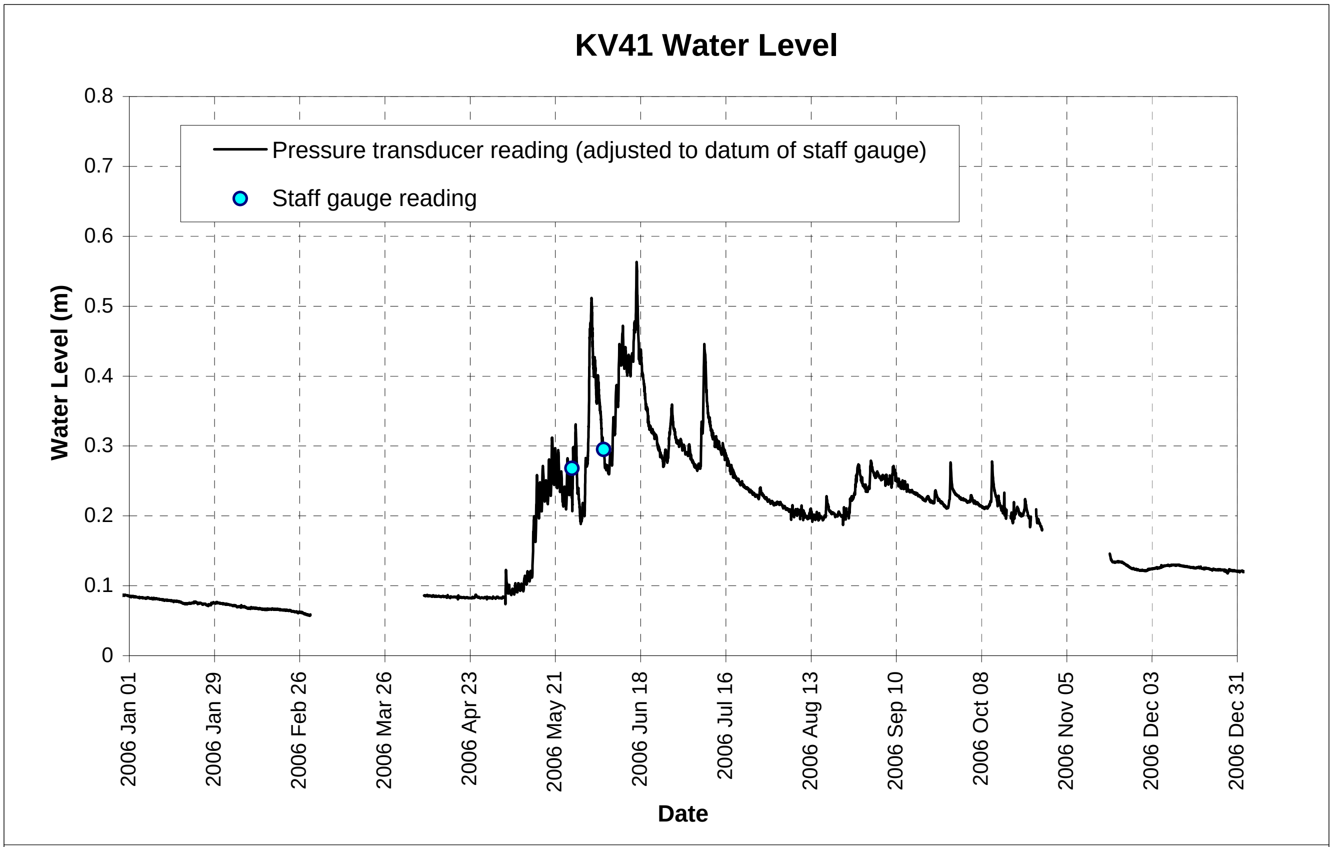


Figure 9 2005 Stage and Flow Records for Station KV41



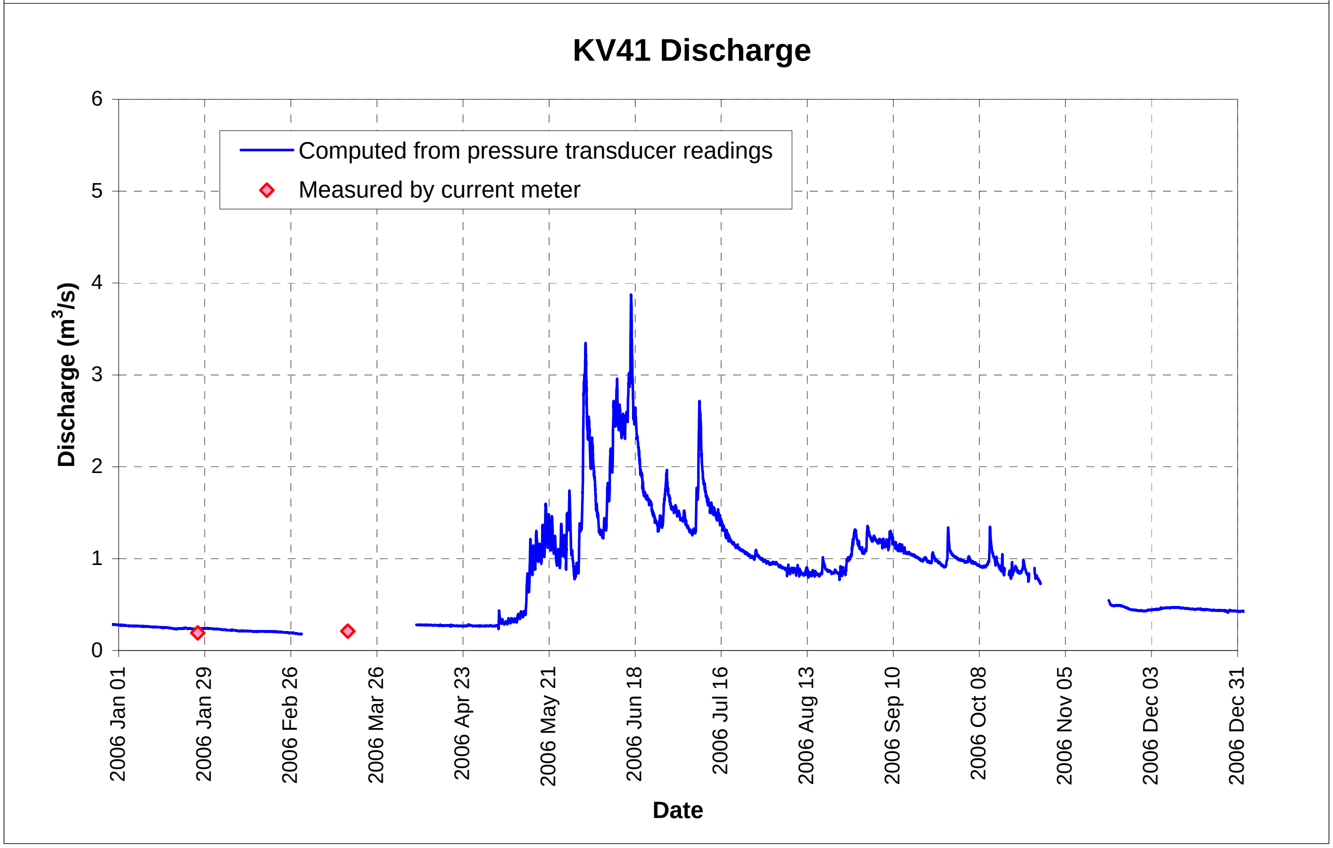
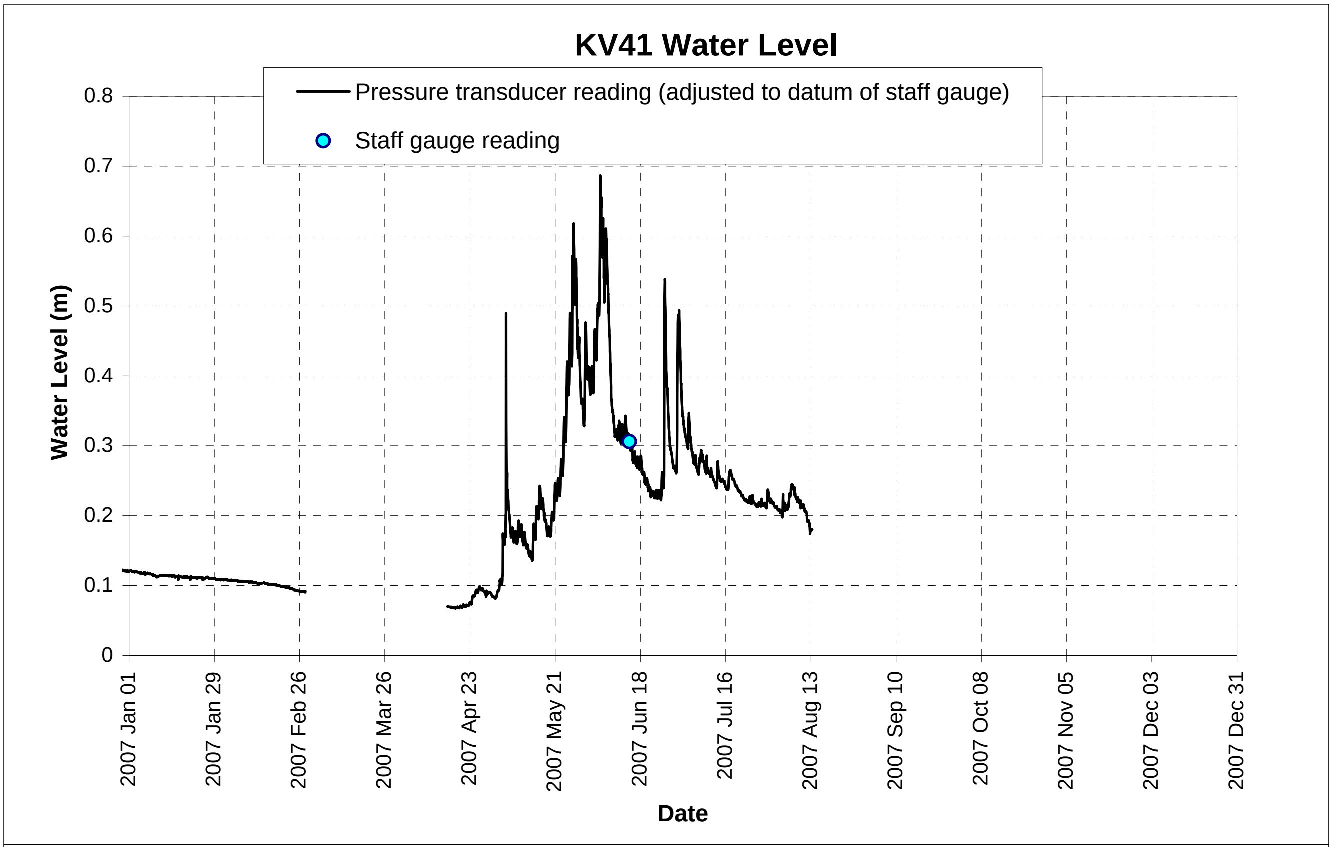


Figure 10 2006 Stage and Flow Records for Station KV41



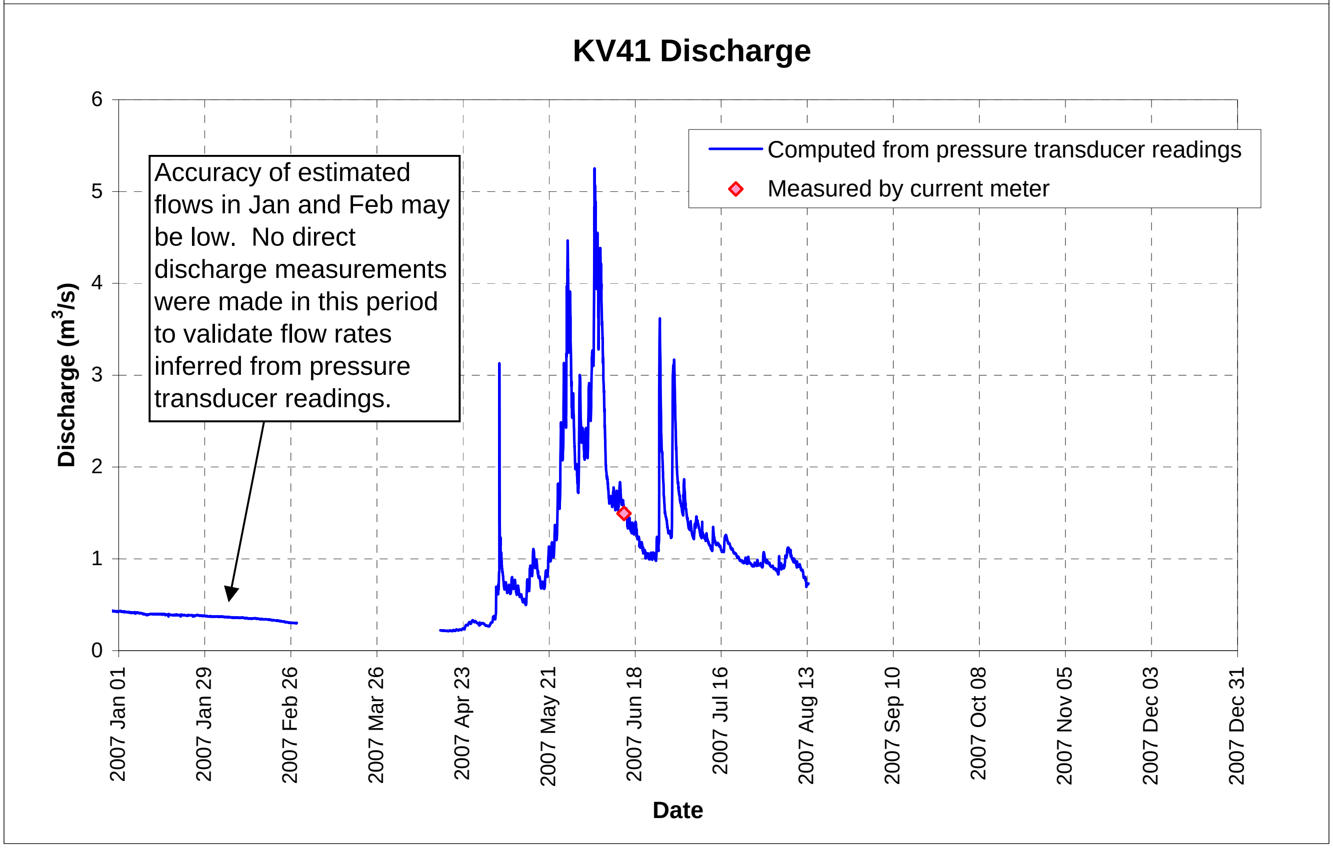


Figure 11 2007 Stage and Flow Records for Station KV41

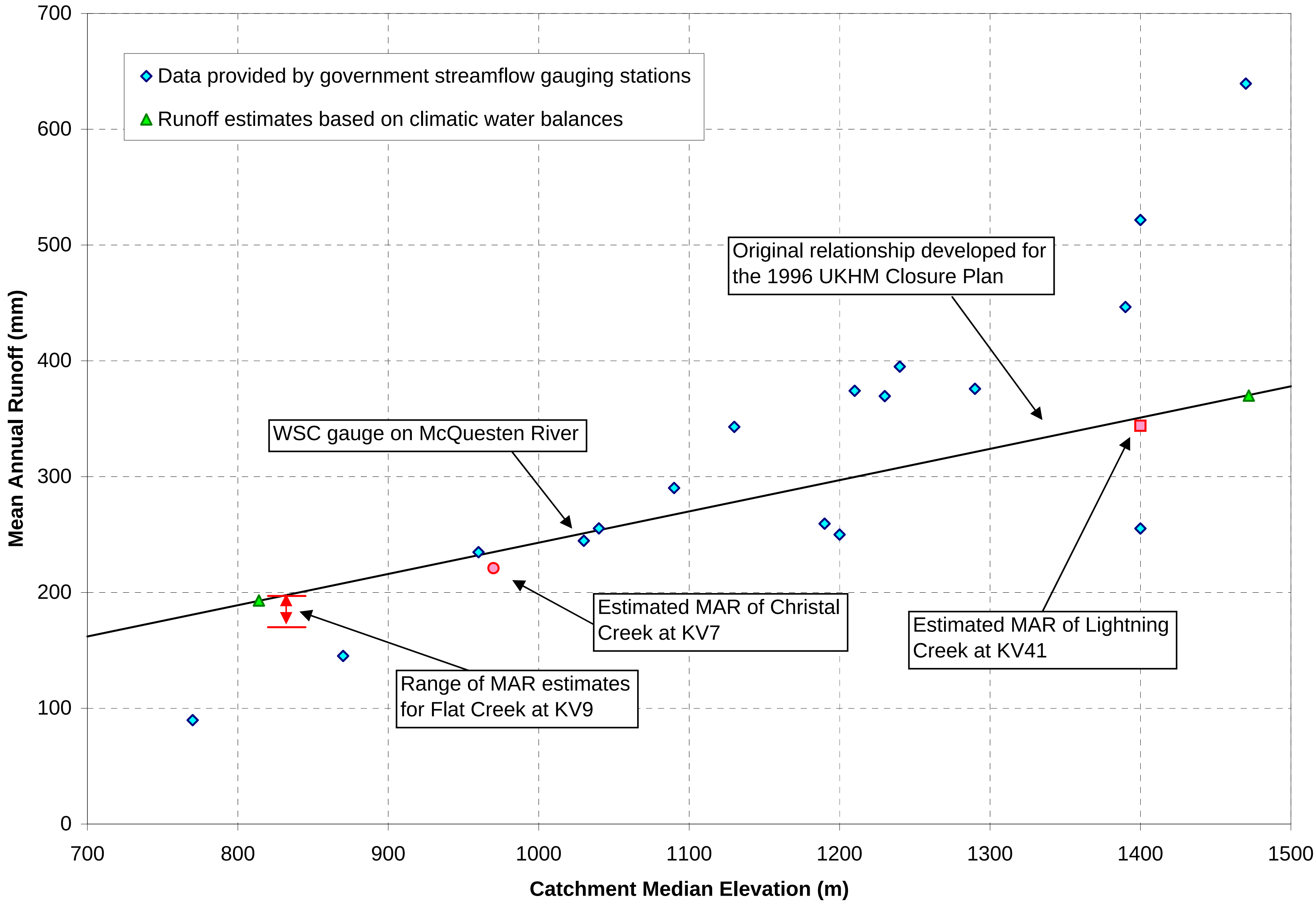


Figure 12 Validation of Regional Relationship Between MAR and Elevation

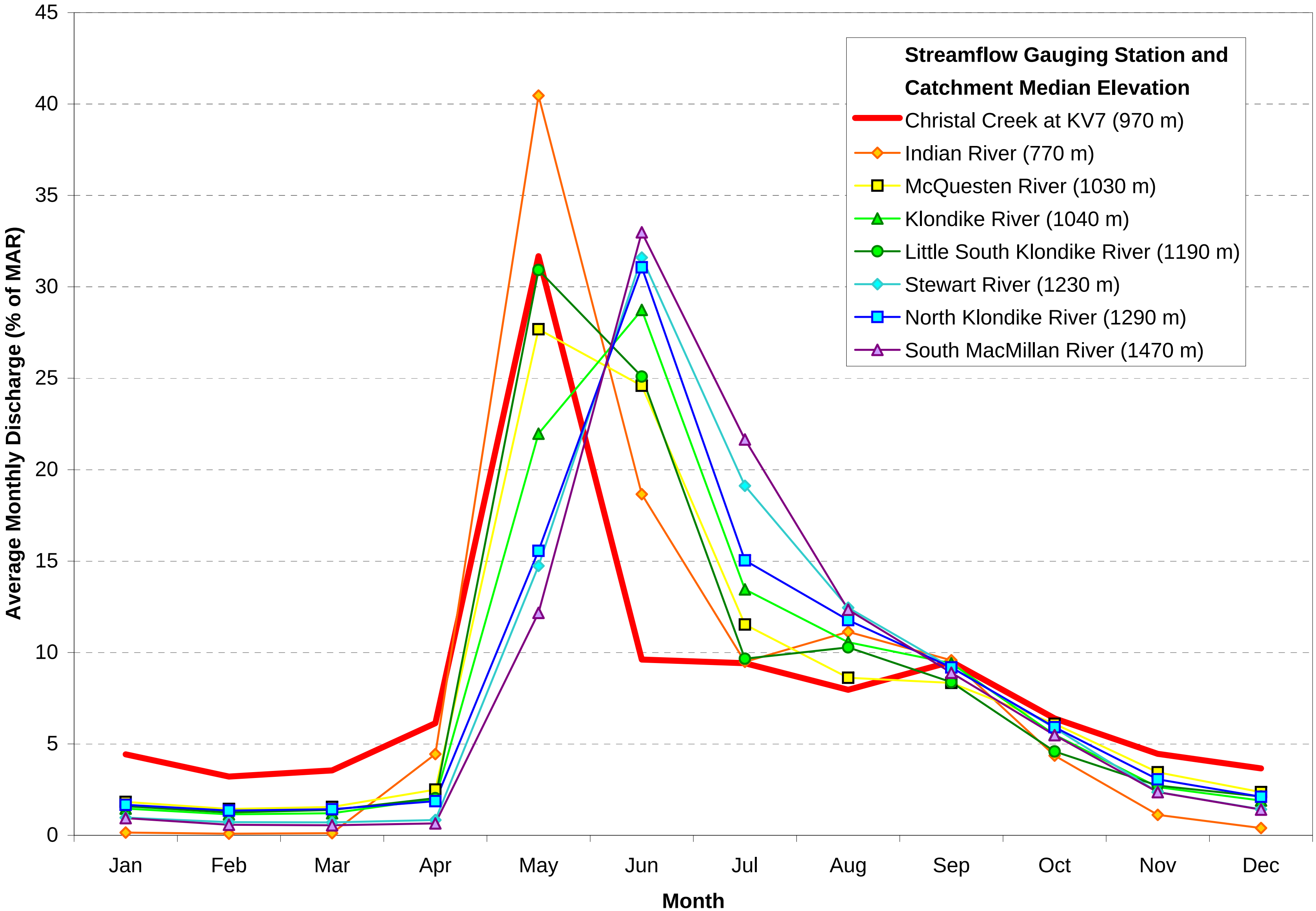


Figure 13 Comparison of Seasonal Runoff Distributions at Christal Creek and Regional WSC Stations

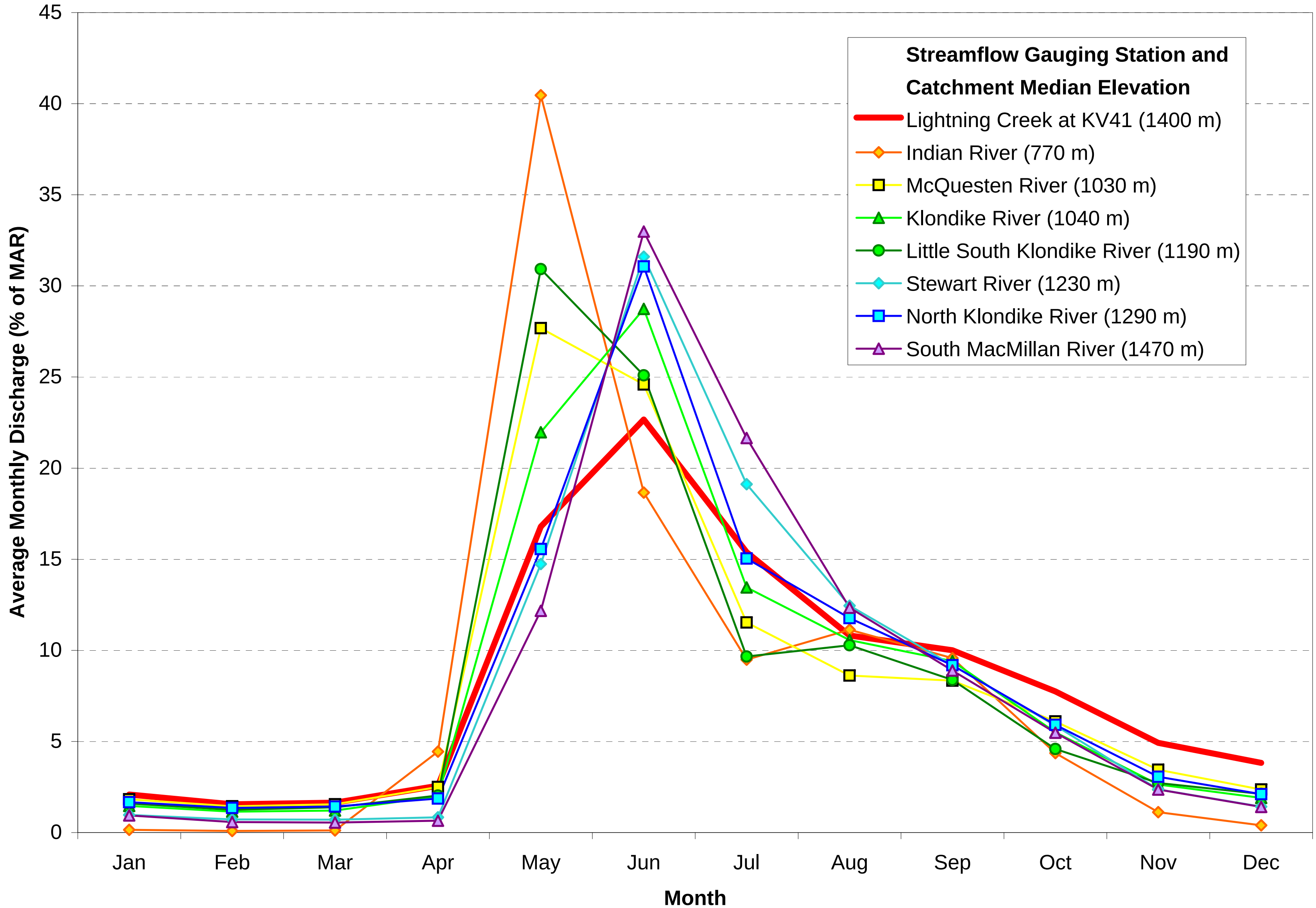


Figure 14 Comparison of Seasonal Runoff Distributions at Lightning Creek and Regional WSC Stations