

Streamflow variation in Poudre River

Robert T Milhous

Abstract

The Cache la Poudre (Poudre) River has a history high streamflow variation sometimes caused by natural factors but mostly caused by many diversions from the river and discharges to the river. Two topics are addressed in this presentation. The first topic is to develop an understanding of the causes of the high variation and the second is to quantify the high variation indexes that allow comparison of rivers, differences between locations on the same river, and changes from year to year. This presentation mostly deals with the second topic. The variation of streamflows at a gage at the mouth of Poudre Canyon has been used as somewhat representative of 'natural' flows. This presentation shows that this assumption is useful but not quite true because of storage and releases of water from reservoirs in the basin, at least one major diversions from the river, and transfer of water from adjacent basins to the Poudre Basin. The second topic, variation indexes, is presented by using two indexes to flashiness. One is the Richards-Baker Flashiness Index – measure of the average change in discharge between days to the average discharge. The second index is a Flashiness Index that is a measure of the average daily fractional change in discharge. As an example, the Flashiness Index variation along the river during water year 2010 was 0.13 at the canyon mouth, downstream at Fort Collins 0.23 and further downstream above Boxelder Creek 0.23. The index on a nearby river with no diversions and storage was 0.10. The limit of the index is 0.0 (no change) and 2.0 (total loss and gain between days).

References

- Baker, D.B., R.P. Richards, T.T. Loftus, and J.W. Kramer. 2004. A new flashiness index: characteristics and applications to mid western rivers and streams. *Journal of the American Water Resources Association* 40 (2): 503-522.
- Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Laron, and S.J. Burges. 2004. Reviving urban streams: land use, hydrology, biology, and human behavior. *Journal of American Water Resources Association*. 40(5): 1351 – 1364.

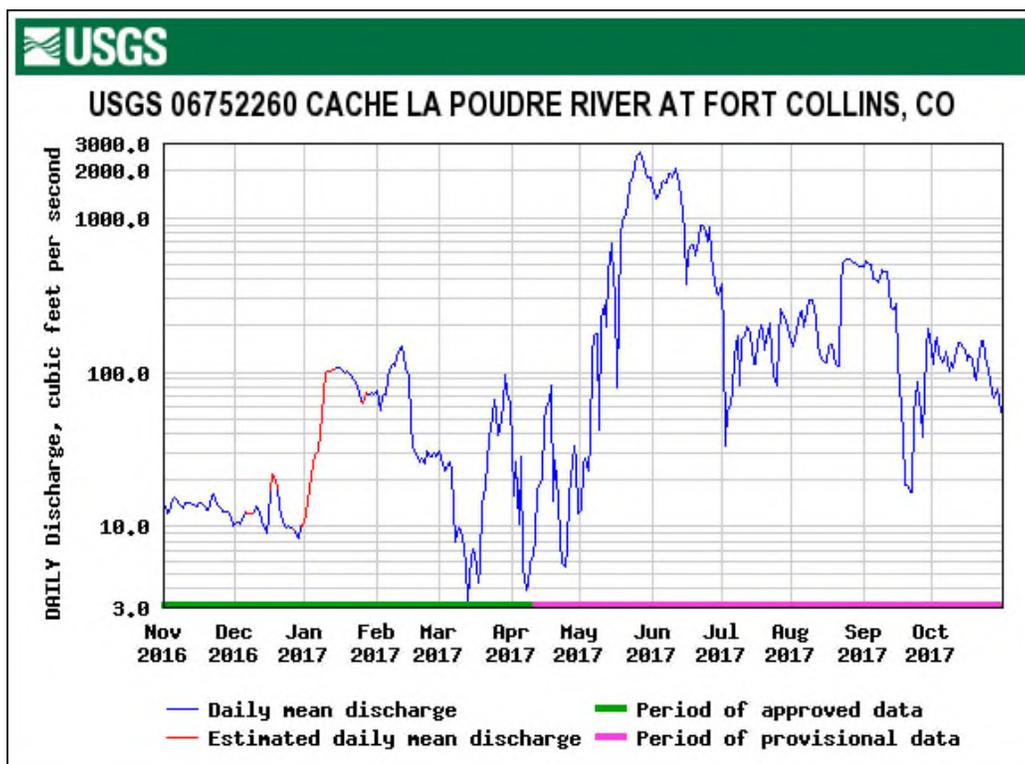
Slide 1. Title slide

There are two topics that could be address in a paper on high streamflow variation. One is to develop an understanding of the causes of the high variation and the second is to quantify the high variation that allows comparison of rivers and changes from years to year. This presentation deals mostly with the second topic.

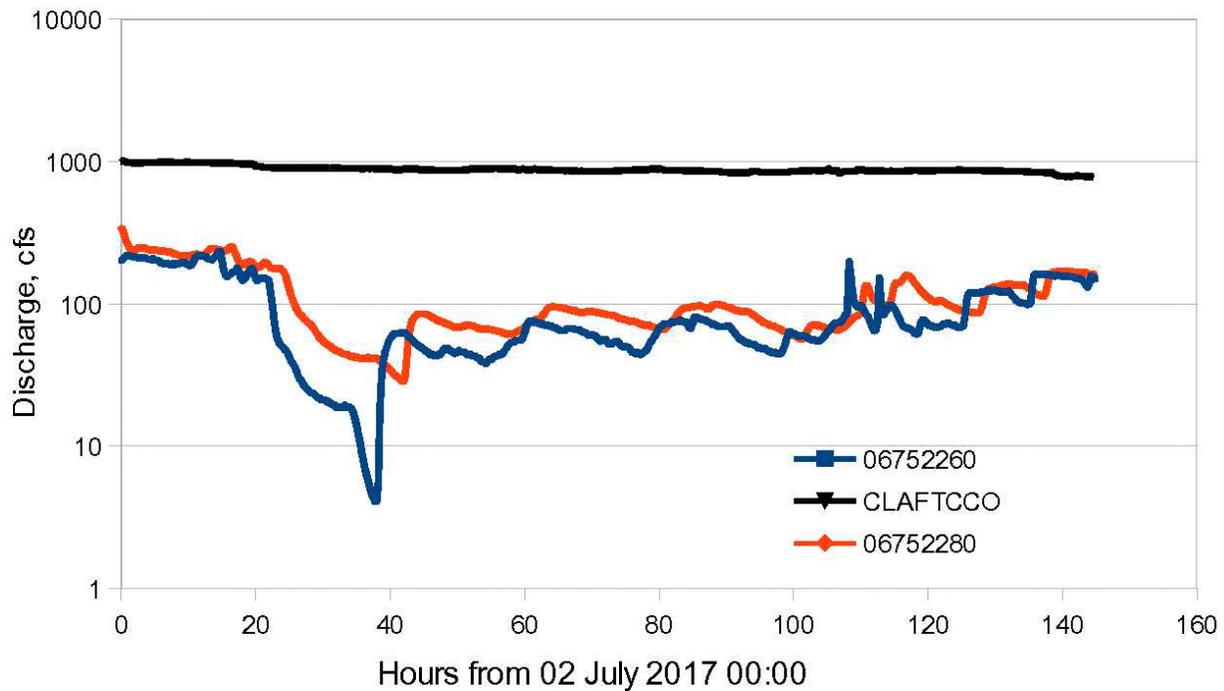
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Slide 2. Measured daily streamflows for the Cache la Poudre River at Fort Collins (Lincoln Street gage). The period is from 1 November 2016 to 31 October 2017. The streamflow variation is partly caused by the natural pattern of streamflows in the region but many of the sudden changes are caused by diversion to the river and diversions from the river. The Hansen Supply Canal transports water from Horsetooth Reservoir to the Poudre River. Releases from the reservoir started on 9 February 2017 and maybe the reason for the 'hump' in the graph in February. Between 19 August and 13 September discharges in the Hansen Supply Canal were large with 12 of the 24 days having daily discharge in excess of 1000 cfs. The maximum daily discharge at the Lincoln Street gage during the period was 540 cfs on 25 August. The Hansen Supply Canal diversion decreased from 828 cfs on the 10 September to 83 cfs on 16 September. The diversion decrease probably contributed to the change from 284 cfs on 15 September to 19.2 cfs on the 21st. There are many diversions above the Lincoln Street gage which makes it difficult to determine the causes of highly variable streamflows at the Lincoln Street gage.



Slide 3. The variation of the 15-minute discharge starting on 2 July (day 243 from 1 November 2017). It is probable that the short period decrease to below 10 cfs was caused by a single diversion. The minimum discharge at the Lincoln Street gage (06752260) was 4.09 cfs on 3 July at 12:45 and 13:00. At the gage above Boxelder Creek (06752280) the minimum discharge was 32.1 cfs at 16:45 and 17:00.



Slide 4. Topics of presentation.

Purpose of presentation

Present variations of streamflows in Cache la Poudre River

Address question: Is canyon mouth gage representative of natural variations?

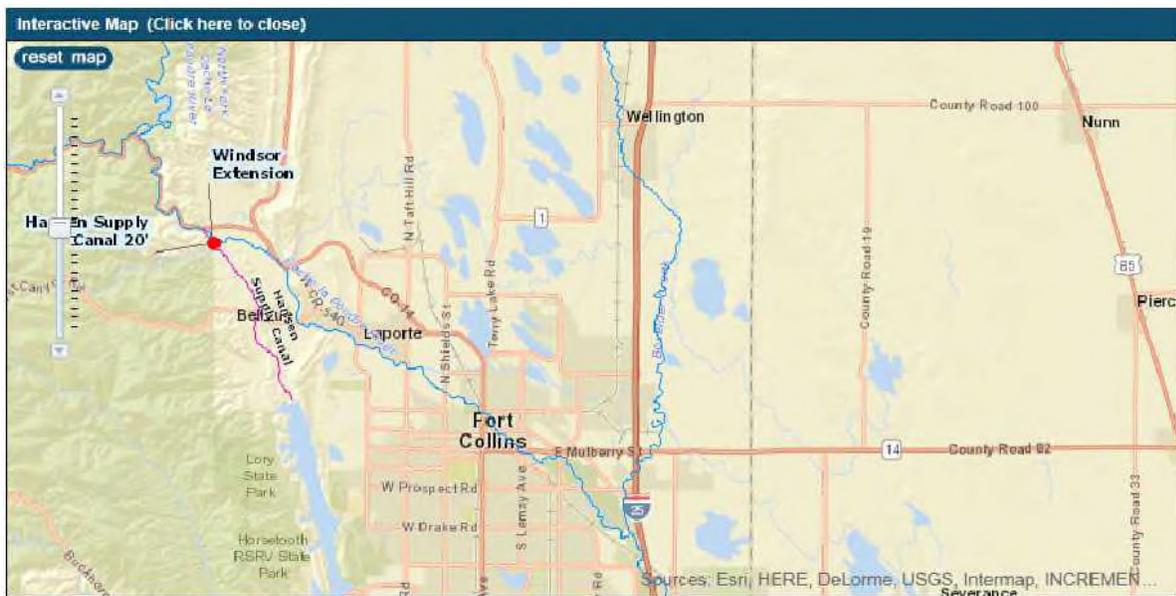
Present three indices to streamflow variations

Slide 5. Title of first section.

Poudre River Streamflow Variation

Slide 6. Map showing location of river near Fort Collins. The station ID's used are

HSCCLPCO	Hansen Supply Canal 20' flume
CLAFTCCO	Cache la Poudre River at Canyon Mouth (also 06752000)
CLANSECO	North Fork Cache la Poudre River below Seaman Reservoir
MUNCANCO	Munroe Canal
LAPTUNCO	Laramie Poudre Tunnel @ 10 ft Parshall Flume
LAPLODCO	La Poudre Pass Creek below Long Draw Reservoir
MICDCPCO	Michigan Ditch at Cameron Pass
GRNDRDCP	Grand River Ditch at La Poudre Pass
06746110	Joe Wright Creek below Joe Wright Reservoirs
06752260	Cache la Poudre River at Fort Collins
06752280	Cache la Poudre River above Boxelder Creek
402114105350101	Big Thompson River below Moraine Park



Slide 7. Diversion structure in Laporte. Picture taken on 12 November 2017 @ 12:12 MST. The diversion is for Little Cache la Poudre Ditch. (The Taylor and Gill Ditch is at nearly the same location- the canals are right next to each other but Taylor and Gill Ditch is much the smaller.) The diversion from the river is a 'U' and both the Little Cache la Poudre Ditch and the Taylor and Gill Ditch divert water from the 'U'. The 'U' has flow in it even when there is no diversion by either ditch

The two pictures of low flows caused by the diversion in Laporte were taken on 9 November about 14:30 MST. On 9 November the streamflows measured at the Lincoln Street gage were 13.9 cfs at 14:30 and 13.5 cfs at 18:30. The picture taken after diversion ceased was taken about 13:30 on 14 November. On the 14th the stream flows were 72.9 cfs at 13:30 and 61.6 cfs at 17:30.

Even though there was almost now flow there were shallow pools. question relevant to the relative shot periods of low flows is how can time be included in the analysis of streamflow variations. The same low flow will have a different impact on the fluvial depending on how long the low flow persists.



Slide 8. Right channel downstream of trail bridge. Picture taken 09 November 2017 @14:30 MST



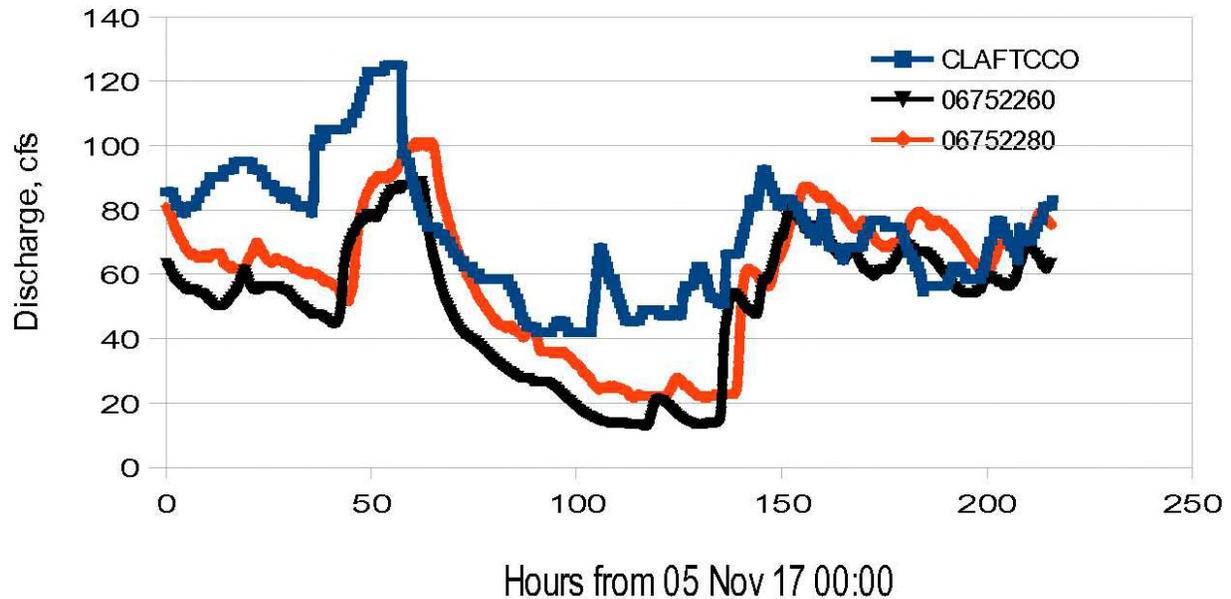
Slide 9. Left channel downstream of trail bridge. Picture taken 09 November 2017 @14:32 MST



Slide 10. Left channel downstream of trail bridge. Picture taken 14 November 2017 @13:24 MST



Slide 11. The pictures of the low flow channels was take about 14:30 MST on 9 November 2017 which is hour 110.5 on the slide.



Slide 12. In previous presentations the assumption has been made that the pattern of streamflow variation measured at the canyon mouth gage is representative of the 'natural' pattern. Is that a reasonable assumption?

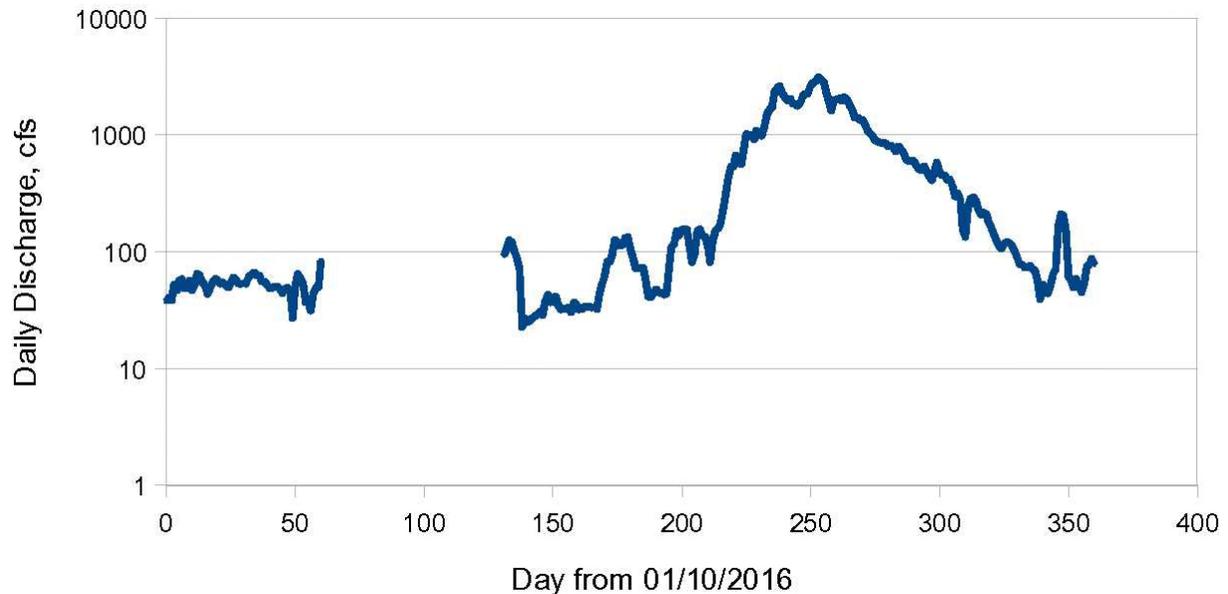
Is canyon mouth gage representative of natural variations?

Slide 13. Daily streamflows at the mouth of Poudre Canyon (gage CLAFTCCO/06752000). The streamflows in the spring and in the fall are probably modified relative to the 'base' streamflows more than in the summer and winter - this is not an adequately proven statement - just one based on reviewing the data (i.e. speculative). The 'hump' in September will be investigated in following two slides. The Poudre River has so many diversions from the river and to the river that it is difficult to know just what is happening. There seem to be phantom changes with no known cause based on the data available.

The reductions in streamflow between 15 February - 22 March (day 137-172) and between 31 March - 15 April (day 181-196) are probably caused by diversions upstream of the canyon mouth gage. There are at least two diversions upstream that could cause reductions in streamflow 1) Munroe Canal and 2) Poudre Valley Canal. Both of these diversions have considerable capacity. Another possibility is operations of the Fort Collins Utilities.

The period from 2 December 2016 - 7 February 2017 is missing - most probably because of ice on the river.

Poudre River at Canyon Mouth Water Year 2017



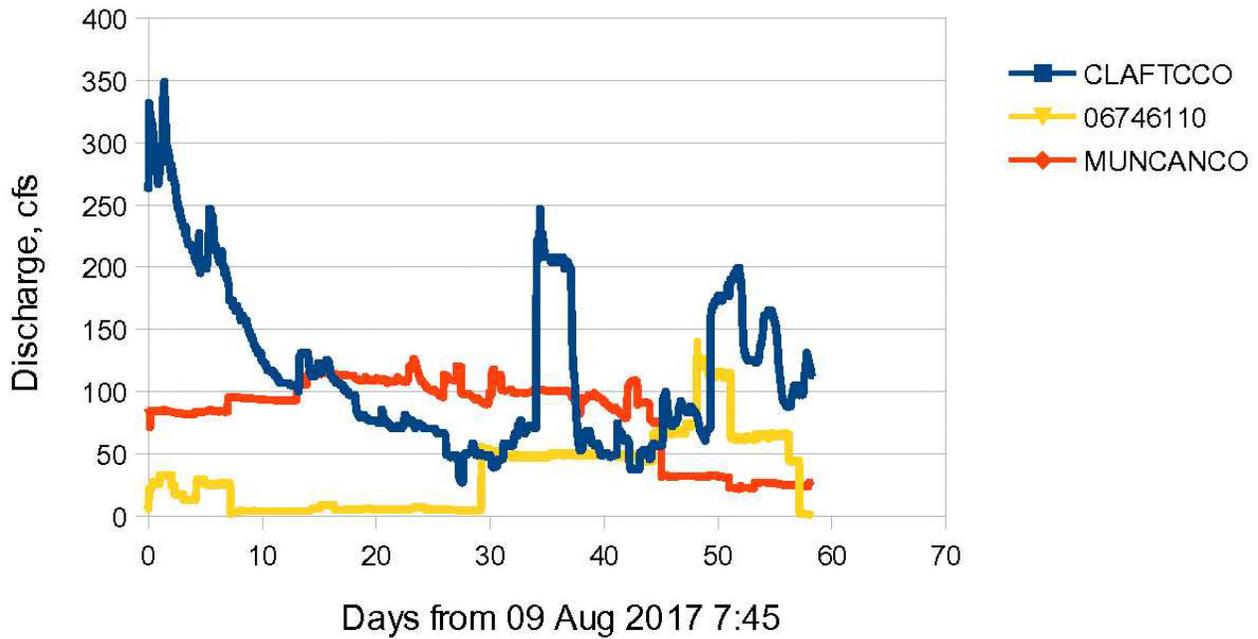
Slide 14. The river discharge in the Poudre River at the mouth of Poudre Canyon (CLAFTCCO) and at one diversion (MUNCANCO) and from one reservoir (06746110) upstream of the gage. MUNCANCO is the gage on Munroe Canal and 06746110 is the streamflow measured below Joe Wright Reservoir.

Joe Wight Reservoir is some distance upstream and the releases from the reservoir flow through Chambers Lake before entering the Poudre River. 8 September in day 342 in the water year. There two sharp changes in streamflows - the first was a change from 70.3 cfs on 12 September at 8:45 to 222 cfs at 11:00 a change of 152 cfs in 2.25 hours; the second was a change from 72.4 cfs at 15:30 on 27 September to 169 cfs 3.5 hours later (at 19:00) - why? The data suggests it was not a change in diversion from Munroe Canal or a release from Joe Wright Reservoir (such a sharp change caused by releases from Joe Wright Reservoir are not expected because of the distance upstream). Another possibility is releases from Long Draw Reservoir (Slide 15) but the releases are too small (about 80 cfs change below Long Draw Reservoir versus 97 cfs at the gage). Also, the times do not seem to be right.

The conclusion is that there is significant impact on the variation of streamflows at the canyon mouth gage. This must be considered when comparing variation in locations along the river.

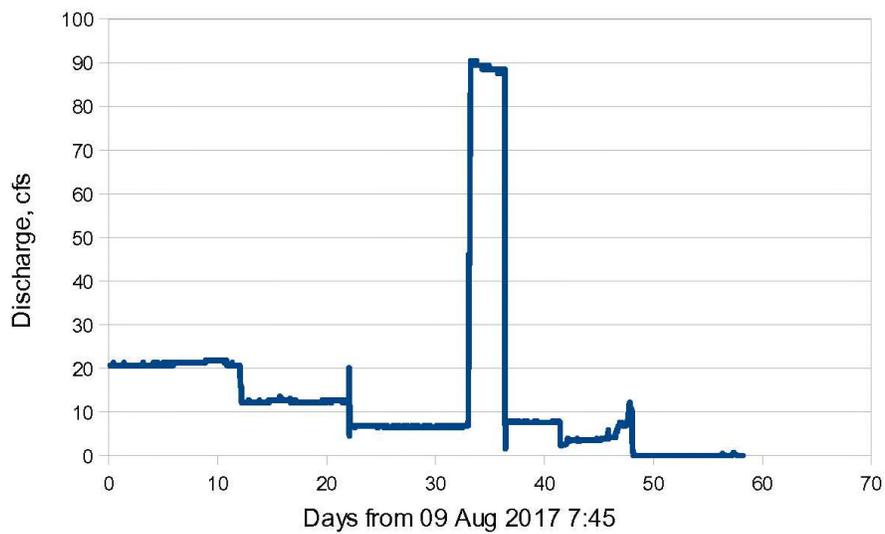
Information on gaging stations in the general vicinity of the canyon mouth gage. There is only one gage that might be useful to compare to the canyon mouth gage. That gage is Big Thompson River below Moraine Park (402114105350101). A comparison of the gage elevation and watershed area is made in the following table. Using the Big Thompson information which unregulated to compare to the regulated Poudre River is far from ideal but is the best available.

Location	Elevation of gage, feet	Watershed area, sq miles
Poudre River at Canyon Mouth	5220	1054
Big Thompson River below Moraine Park	8005	39.8



Slide 15. Discharge in La Poudre Pass Creek below Long Draw Reservoir (Station ID: LAPLODCO)

La Poudre Pass Creek below Long Draw Reservoir



Slide 16. Title of third section

Three indices to streamflow variations

Slide 17 The equations used to calculate an index to the flashiness of streamflows are the following. Presentations by researchers from the University of Washington have shown there is a relation between TQmean and the quality of the benthic environment.

The Richards-Baker Flashiness Index (RBI) and is the ratio of the average change in daily discharge to the average discharge. The Flashiness Index is the average daily relative change in discharge where the relative change is the ratio of the change in discharge to the average discharge for each day.

TQmean is the fraction of days in a period (a year in this presentation) that are the same or larger than the mean discharge of the period. The limits are 1/N where N is the number of days in the period (only one day equal to larger than the mean) and 1.0 where all days have the average annual daily discharge. TQmean was originally used to consider the change in runoff characteristics caused by urbanization where storm runoff is pushed into shorter but more intense runoff periods. As the number of days in a period is reduced the more intense the runoff an increase in flashiness.

FLASHINESS INDEX EQUATIONS

$$\text{RBI} = [\sum(\text{abs}(Q(i)-Q(i-1)))] / [\sum((Q(i)+Q(i-1))/2)]$$

$$\text{Flashiness Index} = \sum[(\text{abs}(Q(i)-Q(i-1)) / ((Q(i)+Q(i-1))/2)]/N\text{days}$$

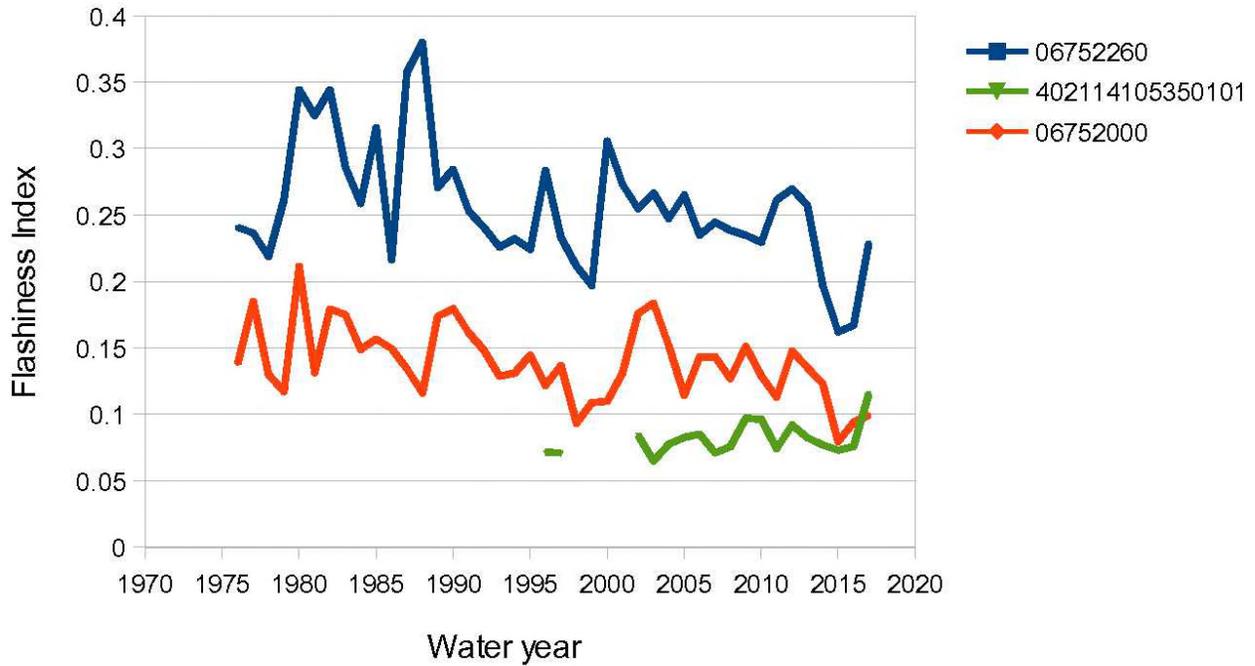
$$\text{TQmean} = \sum(N \text{ days } Q \geq Q_{\text{ave}})/N\text{days}$$

RBI is the Richards-Baker Flashiness Index

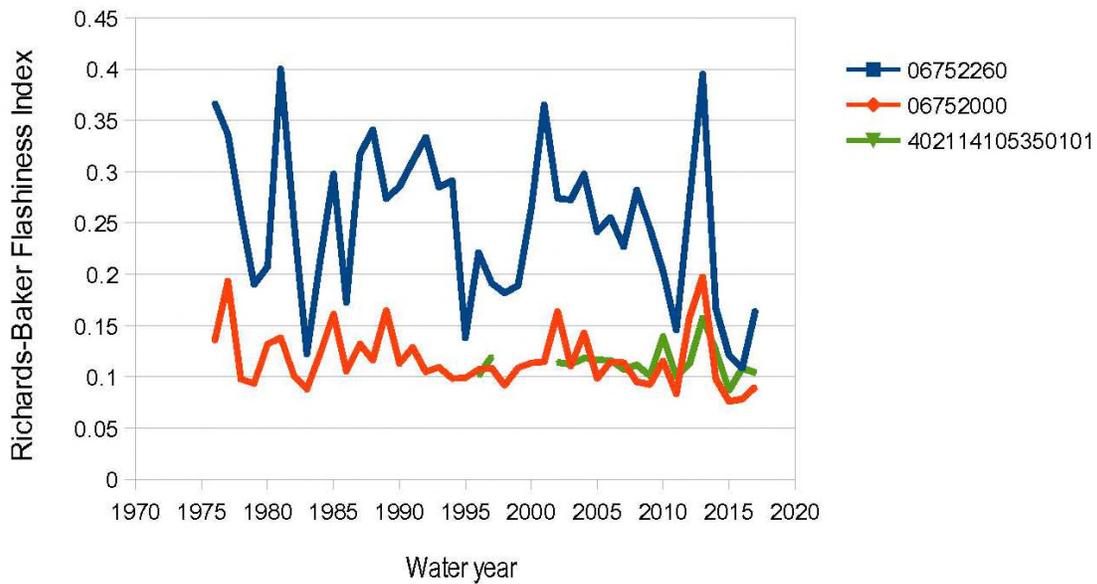
Slide 18. The variation of the annual Flashiness Index for the Poudre River at two locations (Fort Collins and Canyon Mouth) and the Big Thompson River below Moraine Park.

In WY2012 there were fires in both the Cache la Poudre River and the Big Thompson watersheds. The Big Thompson fire burned well into the fall and into the winter. In 2013 there was a significant flood in both watersheds. The impact of the flood on the watershed was probably most severe in the Big Thompson watershed.

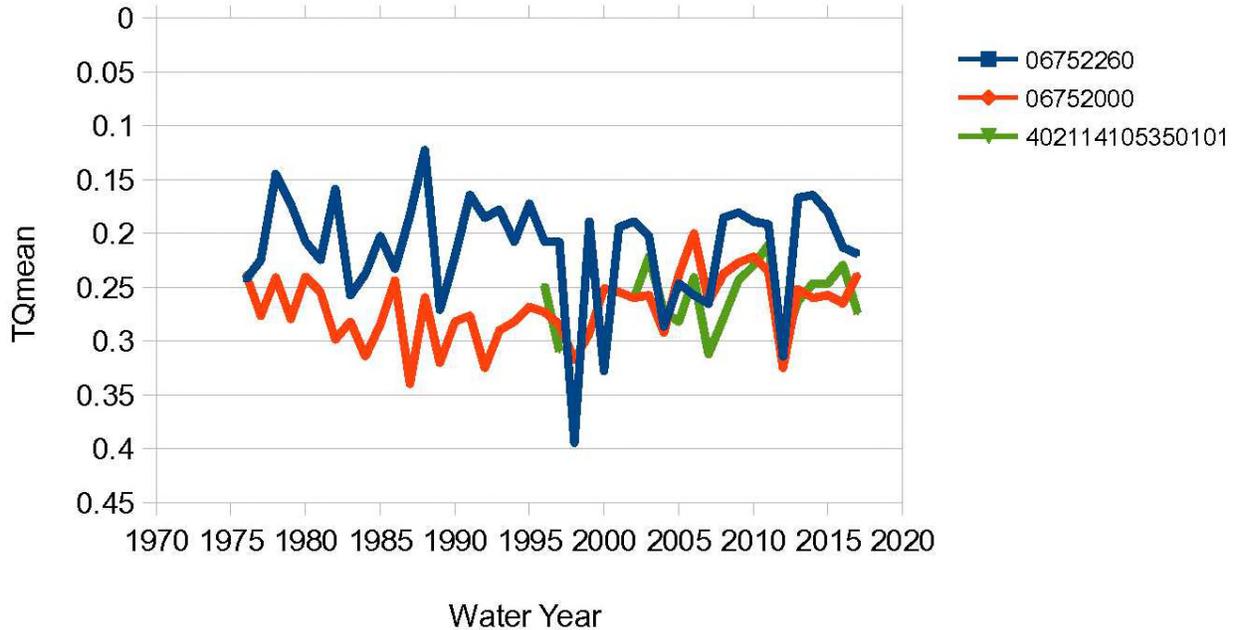
The Flashiness Index the average percent change during a year in contrast to the Richards-Baker Index which is a measure of the average fractional change



Slide 19. The variation of the annual Richards-Baker flashiness index (R-BI) for the Poudre River at two locations (Fort Collins and Canyon Mouth) and the Big Thompson River below Moraine Park. Analysis not given in this presentation suggests the RBI contains more information on fall/winter variations in flashiness than the Flashiness. This may be the reason the Big Thompson is similar to the canyon mouth gage because the winter flow variation are closer to 'natural' in the winter



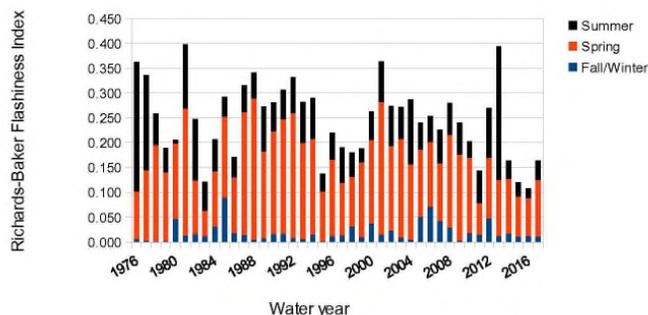
Slide 20. The variation of the TQmean for the Poudre River at two locations (Fort Collins and Canyon Mouth) and the Big Thompson River below. The logic of TQmean is not really applicable to Poudre River flow variations because the variations are not caused by changes in runoff characteristics.



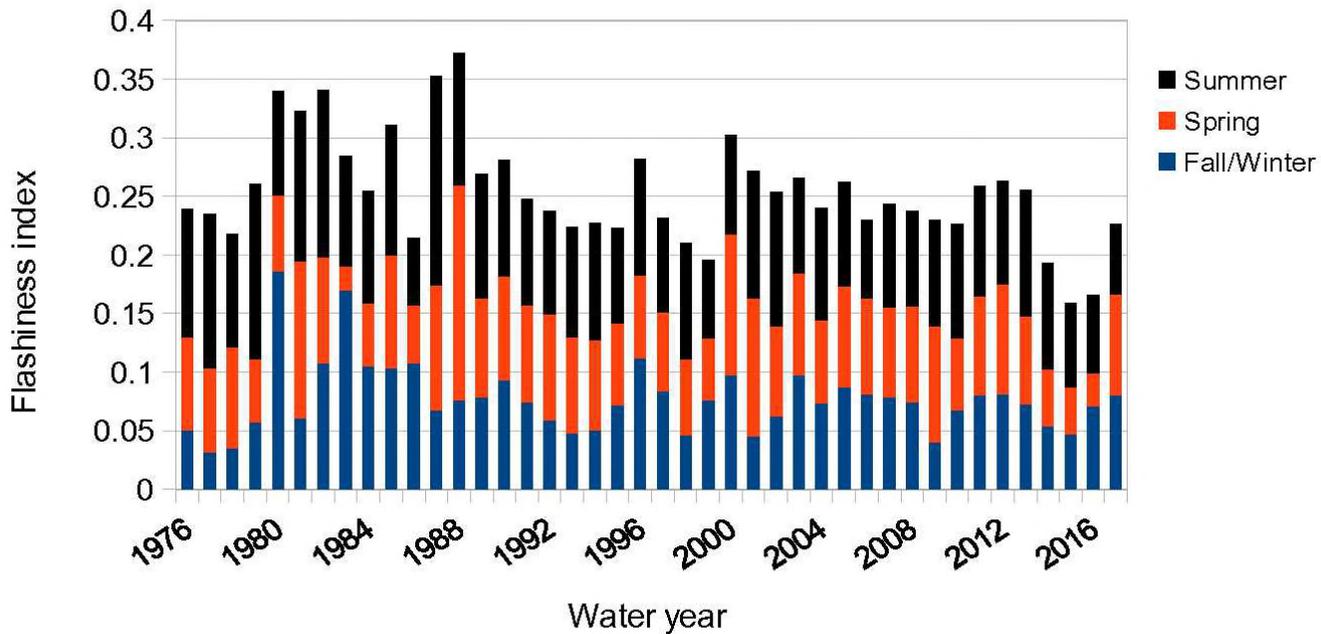
Slide 21. The distribution of the elements of the Flashiness Index by season. The seasons used in the analysis are:

- Fall/Winter 1 October - 31 March
- Spring 1 April - 30 June
- Summer 1 July - 30 September

The Flashiness Index has a distribution between seasons that I expected. But the Richards-Baker Flashiness Index did not. The reason for the concentration of so much of the flashiness of the RBI index in the spring is a result of the large changes that can occur during the runoff period.. This spring impact may be why the RBI at the canyon mouth gage is similar to the RBI of the Big Thompson River below Moraine Park.

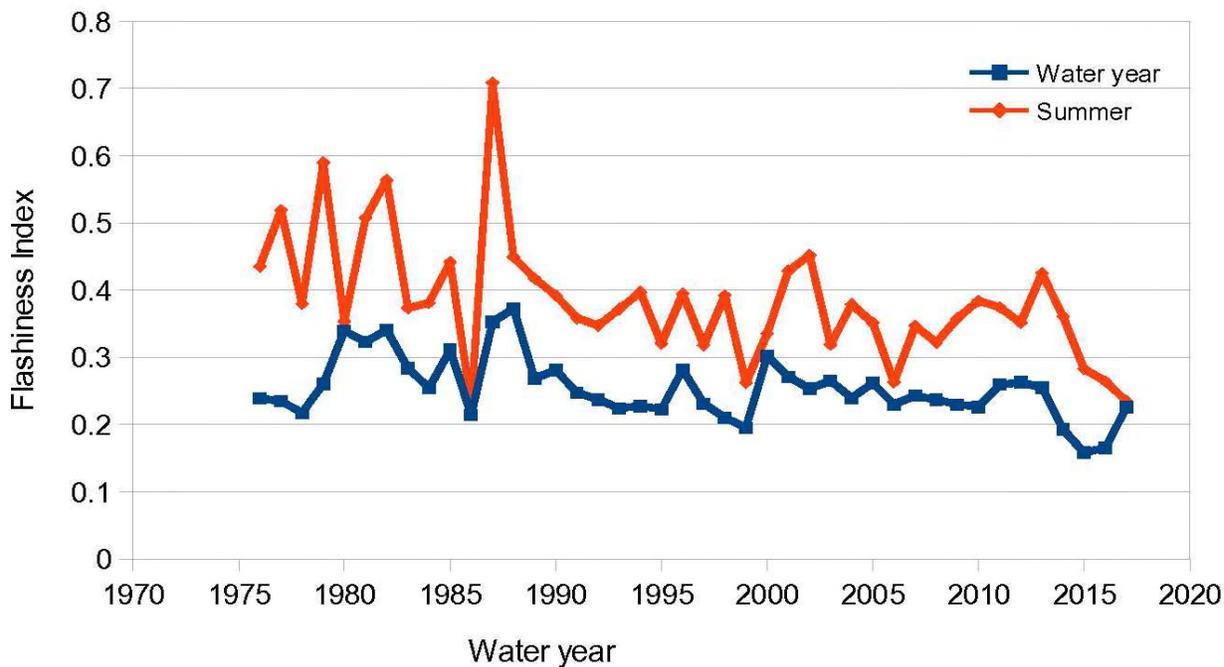


Cache la Poudre at Fort Collins



Slide 22. The summer Flashiness Index compared to the annual index. The summer index is calculated using the number of days in the summer period (92).

Cache la Poudre at Fort Collins

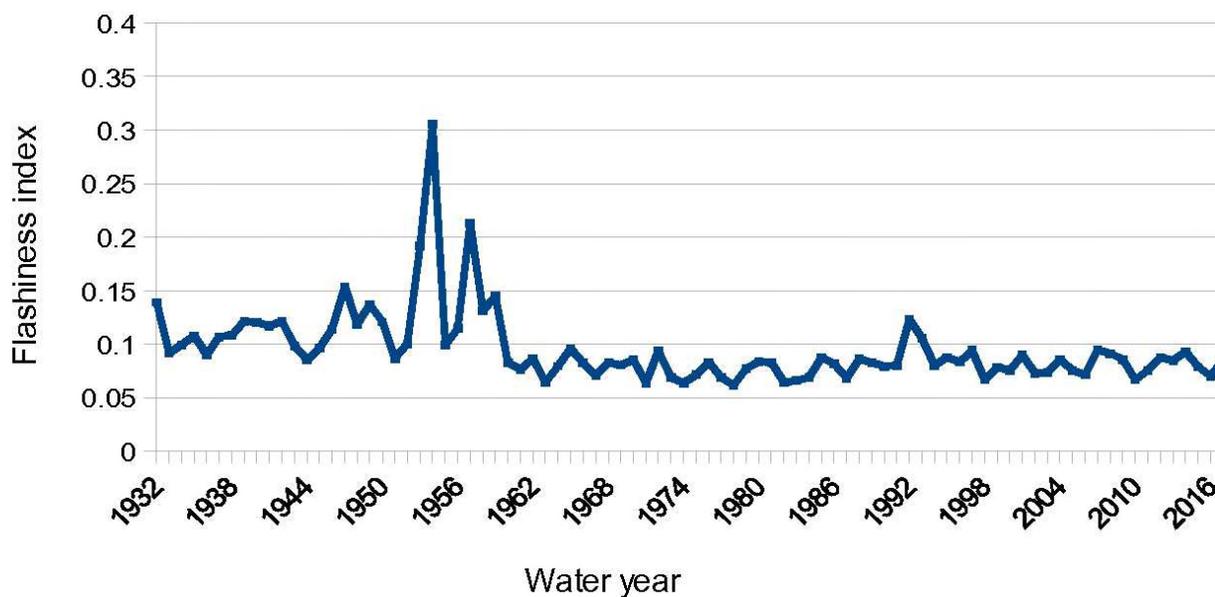


Slide 23. The original objective of the analysis of the Elkhart River was to determine the flashiness of a mid-western river and to compare this flashiness to the flashiness of the Poudre. And to see how this compared to the Big Thompson River below Moraine Park. The river selected was the Elkhart River at Goshen, Indiana.

Elkhart County, Indiana,
Drainage area: 594 square miles
Datum of gage: 769.15 feet
median annual discharge: 522 cfs
mean annual discharge: 542 cfs
median annual peak discharge: 2910 cfs
1 in 10 year annual peak discharge: 4860 cfs

The 1965 water data book for Indiana the streamflows were regulated by three power plants above the station. There was a hydroelectric plant at Goshen Pond Dam just upstream of the gage on Elkhart River at Goshen.

Elkhart River at Goshen, Indiana



Slide 24 End picture. This presentation is kind-of squirrely.

