Peak-Flow Frequency Analysis:

An overview of the new Bulletin 17C guidelines and their application to Montana peak-flow datasets

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U.S. Geological Survey

PRESENTATION OUTLINE

Flood-frequency analysis in Montana…it's complicated!

1. Background concepts and terminology
2. Montana flood hydrology--- Big picture complexities
3. Montana flood hydrology --- Smaller picture complexities
4. Compare and contrast --- Bulletin 17B and Bulletin 17C
5. WY-MT WSC peak-flow frequency procedures
6. PEAKFQv7.1 --- How to run it
7. Other topics

- No clue how long this will take…could get entertaining
- Probably will result in more questions than answers (sorry about that)
- Feel free to contact us:
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  - Kathy Chase (kchase@usgs.gov)
  - Steve Sando (sksando@usgs.gov)

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1a. Background concepts and terminology

“peak-flow” versus “flood”

- Annual peak flow
  - Maximum instantaneous discharge recorded for each water year
  - Defined on the basis of discharge
  - There can be one and only one annual peak flow per year
  - In dry years, peak flow can be very small (sometimes zero)
- Flood
  - Any high streamflow that overtops the natural or artificial banks
  - Defined on the basis of stage
  - There can be zero, one, or multiple independent floods per year

There’s a technical distinction between a peak-flow and a flood. In a typical frequency analysis, we analyze peak-flow data. But, “peak-flow frequency analysis” and “flood-frequency analysis” often are used synonymously.

In some cases, the distinction between “flood frequency analysis” and “peak-flow frequency analysis” can be important (eg., ice-jam issues).

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1b. Background concepts and terminology

Primary major objectives of peak-flow frequency analysis:

- Protection of human life
- Protection of human property
- Protection/maintenance of the stream environment

Typical peak-flow frequency applications:

- Infrastructure design (bridges, culverts, roads, etc.)
- Dam design and analysis
- Flood-plain mapping and insurance studies
- Instream-flow water rights requests

The primary objectives of frequency analysis are variable. Specific applications can have substantially different criteria and risk tolerance.

The peak-flow frequency arena involves interaction of hydrologic, climatologic, statistical, and engineering expertise….it's complicated!

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1c. Background concepts and terminology

Frequency analysis is a “moving target”

- Continual change in:
  1. Available data
  2. Understanding of hydroclimatic processes
  3. Analytical methods (and agency policy)
- Sometimes changes in landuse characteristics
- Differences in criteria and risk tolerance among applications

But, there’s continual need for frequency analyses based on best available data and methods

USGS WY-MT WSC approach:

- Investigation of hydrologic regimes, peak-flow datasets, and available frequency-analysis methods
- Selection of best available methods
- Thorough documentation of why and how the methods were applied

We are striving to report reliable, impartial, and timely frequency analyses that support informed decisions for frequency-analysis applications.

Consistency among streamgages is important.

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2a. Montana flood hydrology --- Big picture complexities

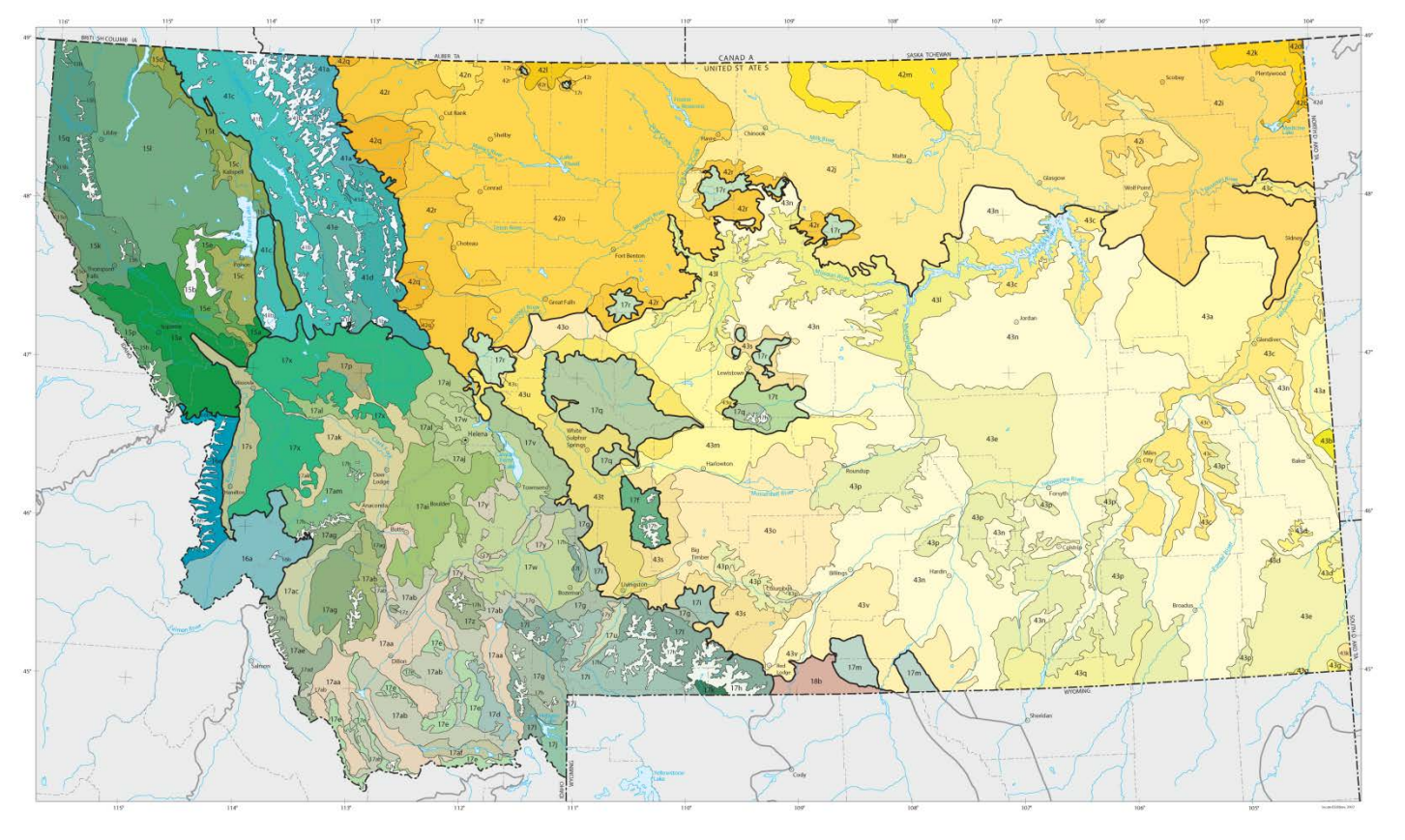
Montana ranks:

4th in size
46th in population

Ecoregions:

6 diverse ecoregions

EPA Level III Ecoregions of Montana



The hydrologic and socioeconomic setting of Montana poses large challenges in operating a statewide streamgage network that accurately captures the hydrologic variability.

Analysis and reporting of peak-flow frequencies are “soft” funding activities.

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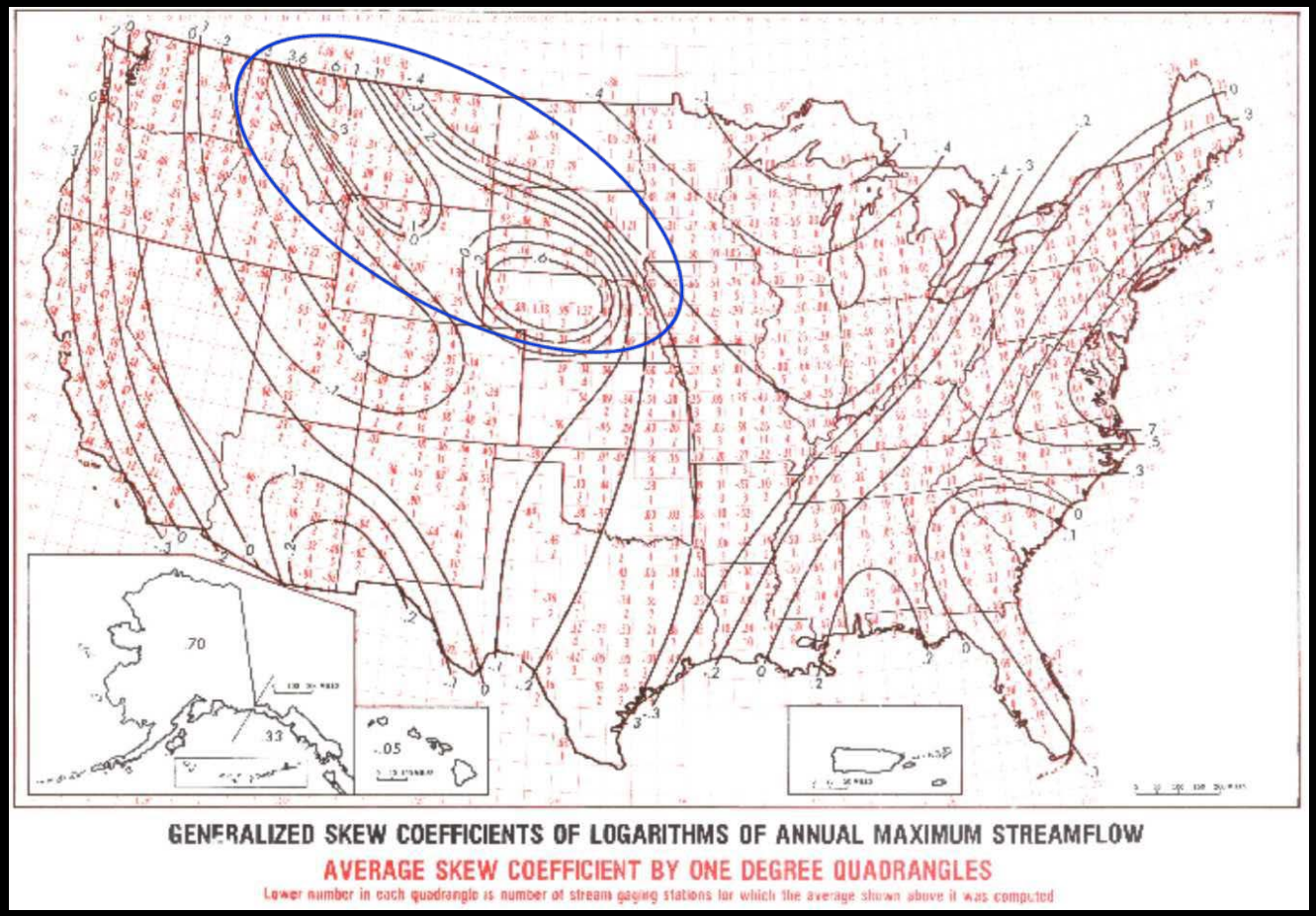
2b. Montana flood hydrology --- Big picture complexities

National scale flood-hydrology complexity

- North-central U.S. has the largest complexity
- Due to interaction of regional physiographic and continental hydroclimatic characteristics

Bulletin 17B regional skew map (antiquated)



Major points:

- MT has large complexity in flood hydrology
- National-scale methods don't always capture the variability

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2c. Montana flood hydrology --- Big picture complexities

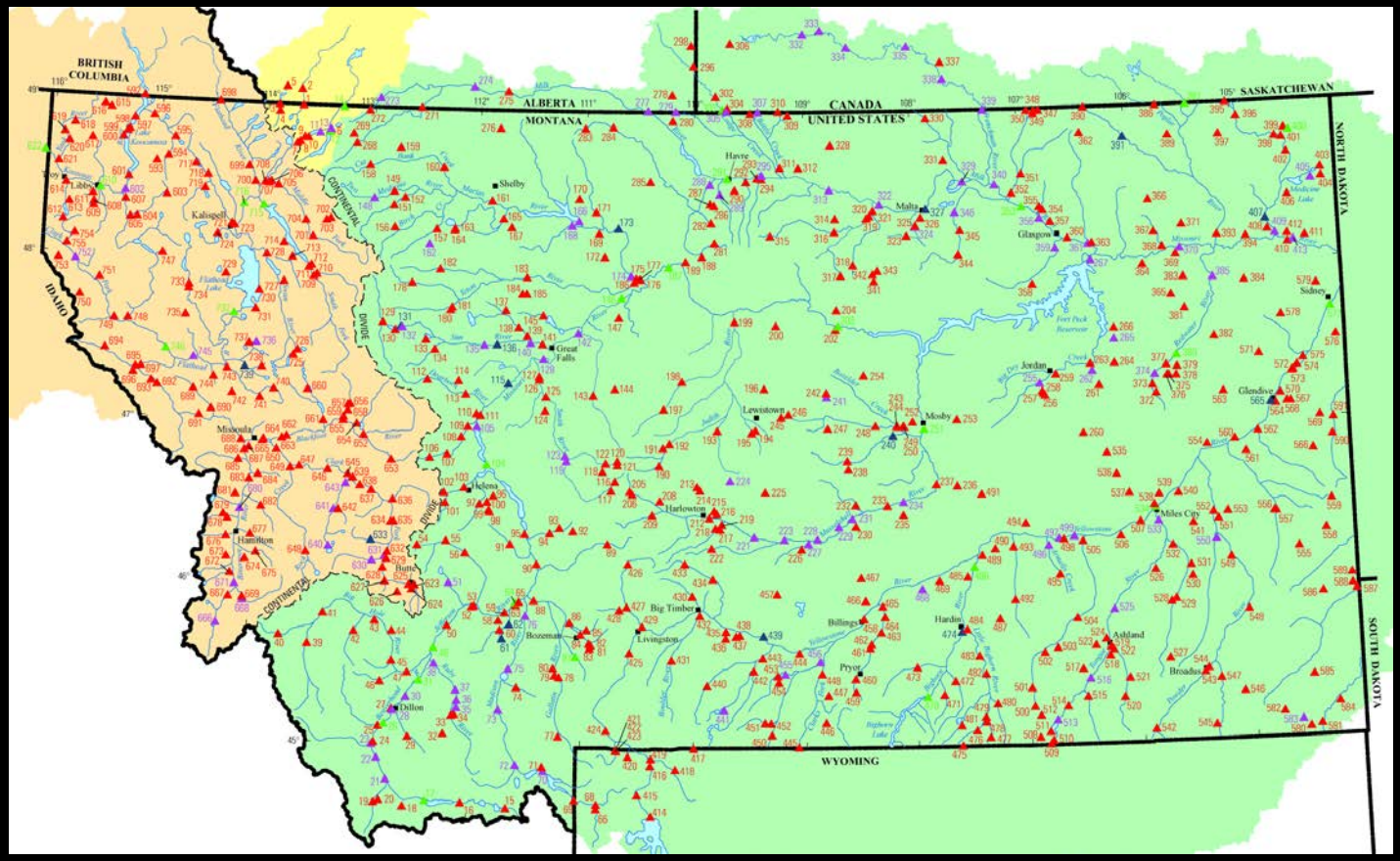
Montana streamgage network

- WY-MT WSC reports frequency analyses for 725 streamgages in or near MT (average record length about 30-35 years; range of 10-126 years)

This is a daunting task!

- Each streamgage dataset is different with respect to:
  1. Flood hydrology
  2. Length and timing of peak-flow records

Reported streamgages



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3. Montana flood hydrology --- Smaller picture complexities

a. Regulation issues

b. Mixed-population datasets

c. Hydroclimatic persistence

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3. Montana flood hydrology --- Smaller picture complexities

3a. Regulation (artificial alteration of natural hydrologic regime)

- Bulletin 17 series statistical procedures assume that a given peak-flow dataset is not affected by artificial regulation that might alter a natural flood regime
- However, peak-flow frequency analyses are needed on regulated streams
- USGS policy (in a nutshell) is that Bulletin 17 guidelines can be used for regulated streams with proper handling

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3. Montana flood hydrology --- Smaller picture complexities

3a. Regulation

- Consistent determination of regulation status within a large statewide streamgage network has various complexities:

  1. Cumulative effects of small impoundments
  2. Effects of canal and irrigation diversions
  3. Variable reservoir operating criteria
  4. Downstream extrapolation of the regulation effects
  5. Consideration of regulation effects with respect to the purpose of the frequency analysis

- Current (2017) WY-MT WSC regulation criteria:

  1. Unregulated if the conjoined drainage area of all upstream dams does not exceed 20% of the streamgage basin
  2. Regulated if the conjoined drainage area of all upstream dams is greater than or equal to 20% of the streamgage basin
  3. Major regulation if the drainage area of a single dam exceeds 20%
  4. Minor regulation if no single dam exceeds 20%, however the conjoined drainage area of all dams exceeds 20%
  5. Exceptions for known “run-of-the-river” dams that don’t clearly affect peaks

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3. Montana flood hydrology --- Smaller picture complexities

3a. Regulation

- Recognized deficiencies in WY-MT WSC approach:

  1. Based on drainage area and does not specifically include information on reservoir storage in relation to streamflow characteristics
  2. Little accounting for reservoir operations
  3. Poor quantification and understanding of small impoundments
  4. Little consideration of canal/irrigation diversions

- Regulation remark codes in NWIS:

  1. Code 5 --- discharge affected to *unknown* degree by regulation or diversion (typically assumed it should be an *unregulated* frequency analysis)
  2. Code 6 --- discharge affected by regulation or diversion (typically assumed it should be a regulated frequency analysis)
  3. For MT streamgages, the regulation remark codes are not consistent in NWIS….be careful

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Advancing the handling of regulation status is a primary priority in WY-MT WSC peak-flow frequency activities.

3. Montana flood hydrology --- Smaller picture complexities

3b. Mixed-population datasets

- Bulletin 17 series statistical procedures assume that a given peak-flow dataset can be effectively treated as a <u>single</u> homogeneous population

- All MT peak-flow datasets include or have the potential to include <u>mixed</u> populations of peak-flow events

- Primary MT peak-flow drivers:
  1. Snowmelt
  2. Rainfall
  3. Snowmelt with rainfall
  - Secondary issues (cool-season floods):
    1. Unusual rainfall events and atmospheric rivers
    2. Chinook events and unusually rapid melt
    3. Ice-jam releases

- <u>Most</u> MT datasets have reasonable appearance of homogeneity and are handled with standard analyses

- <u>Some</u> MT datasets have appearance of nonhomogeneity and require alternate approaches

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3. Montana flood hydrology --- Smaller picture complexities

3b. Mixed-population datasets

Bulletin 17 series guidelines for mixed-population datasets (U.S. Army Corps of Engineers, 1982; http://www.hec.usace.army.mil/publications/TrainingDocuments/TD-17.pdf)

- If the mixed-population peaks are nonhomogeneous and can be segregated based on flood-generating mechanisms:

  1. Segregate peaks into discrete subpopulations representing distinctly different flood generating mechanisms
  2. Perform frequency analyses on each subpopulation
  3. Combine the frequency analyses using joint-probability theory

- If the mixed-population peaks cannot be segregated based on flood-generating mechanisms:

  1. All peaks are considered as a single homogeneous population
  2. Frequency analysis performed using typical procedures

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3. Montana flood hydrology --- Smaller picture complexities

3b. Mixed-population datasets

- The Bulletin 17 series mixed-population guidelines are problematic for application to MT datasets that have the appearance of nonhomogeneity:

  1. Difficult to segregate *all* peaks into discrete flood-generating mechanisms
     - Snowmelt/rainfall continuum
     - Pacific moisture/Gulf of Mexico moisture
     - Cool-season flood issues
  2. Even if we could segregate by mechanism, generally insufficient data to perform valid separate frequency analyses
  3. Treating a mixed-population dataset as a single population using “standard” procedures can produce inappropriate frequency curves

- The Bulletin 17 series guidelines provide no guidance on distinguishing between homogeneous and nonhomogeneous datasets

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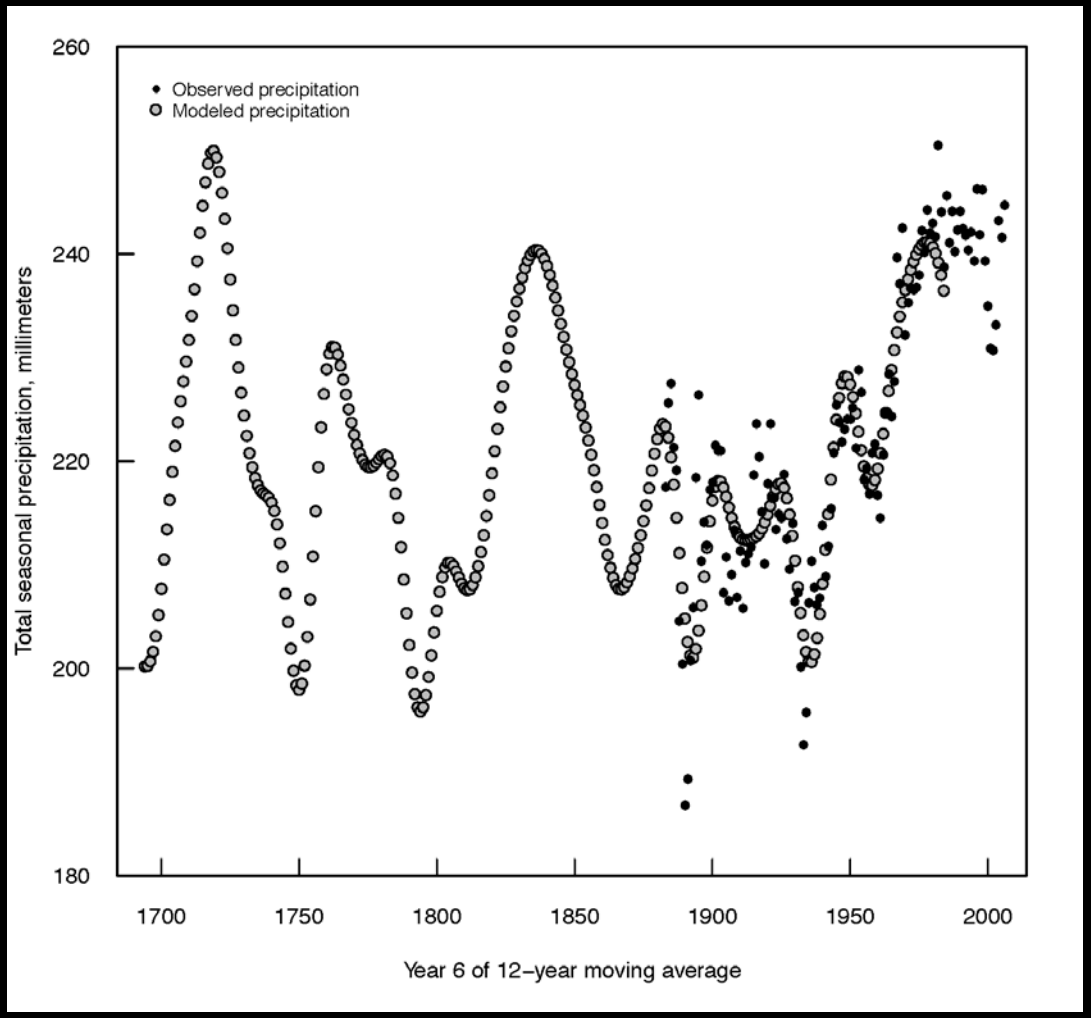
3. Montana flood hydrology --- Smaller picture complexities

3c. Hydroclimatic persistence



Summer/Fall (July-Oct) precipitation for eastern Souris/ Northern Red River Basin (ND)

[12-year moving average observed and tree-ring reconstructed precipitation]

Major points:

- Somewhat distinct hydroclimatic persistence (ND)
- Safe to assume that hydroclimatic persistence also occurs in MT (but different from ND)

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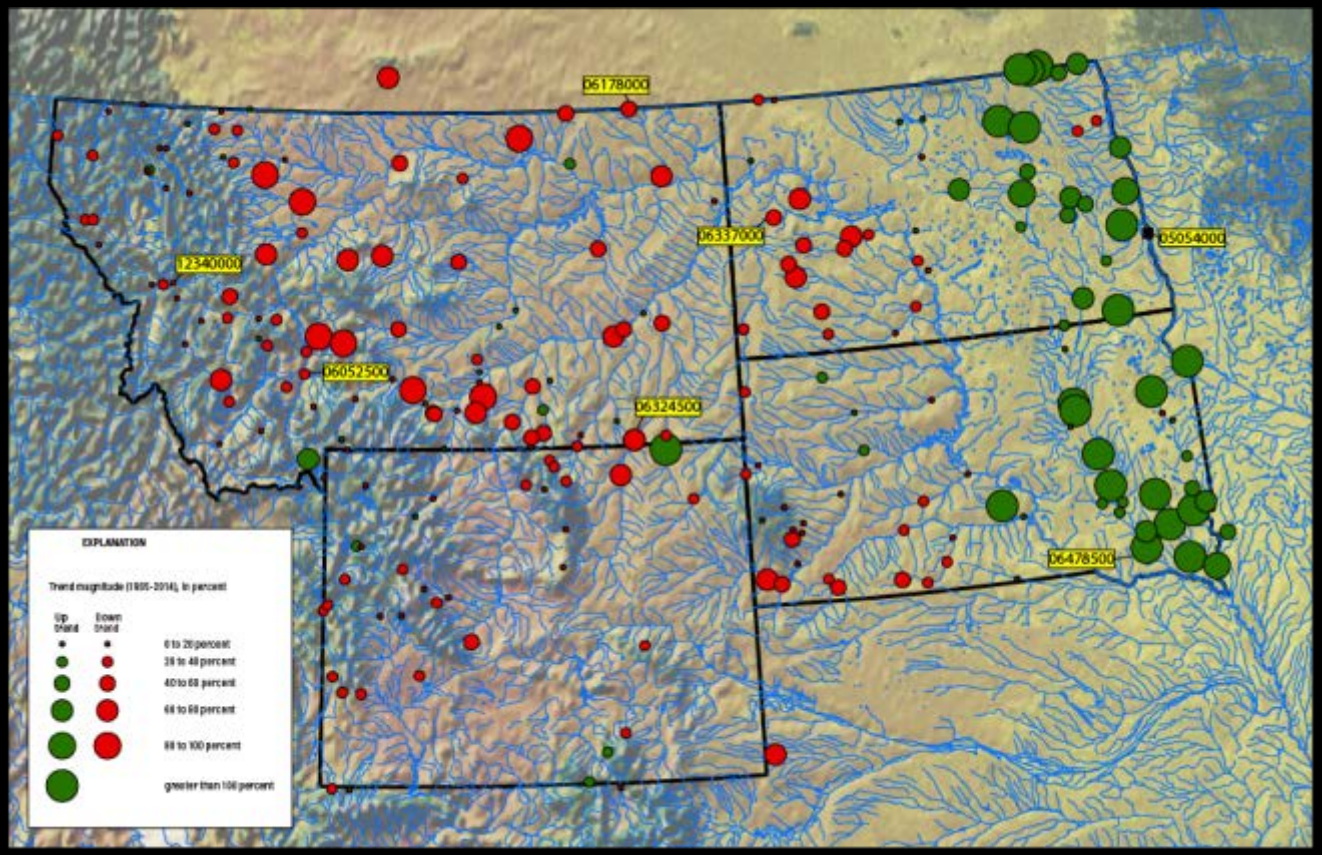
- Before the start of streamgage records (~1890), there were both wetter and drier periods than observed during the historical record

3. Montana flood hydrology --- Smaller picture complexities

3c. Hydroclimatic persistence



1965-2014 peak-flow trends

Streamgages with at least 75% data coverage (38 years)

Major points:

- Distinct spatial patterns in trends
  1. Strong upward in eastern Dakotas;
  2. Strong downward in MT/ND Great Plains;
  3. Small downward in western MT/WY interior mountains

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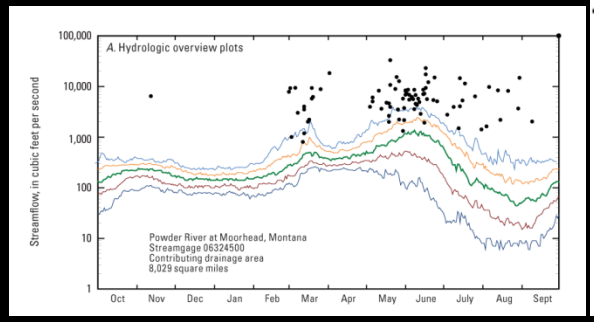
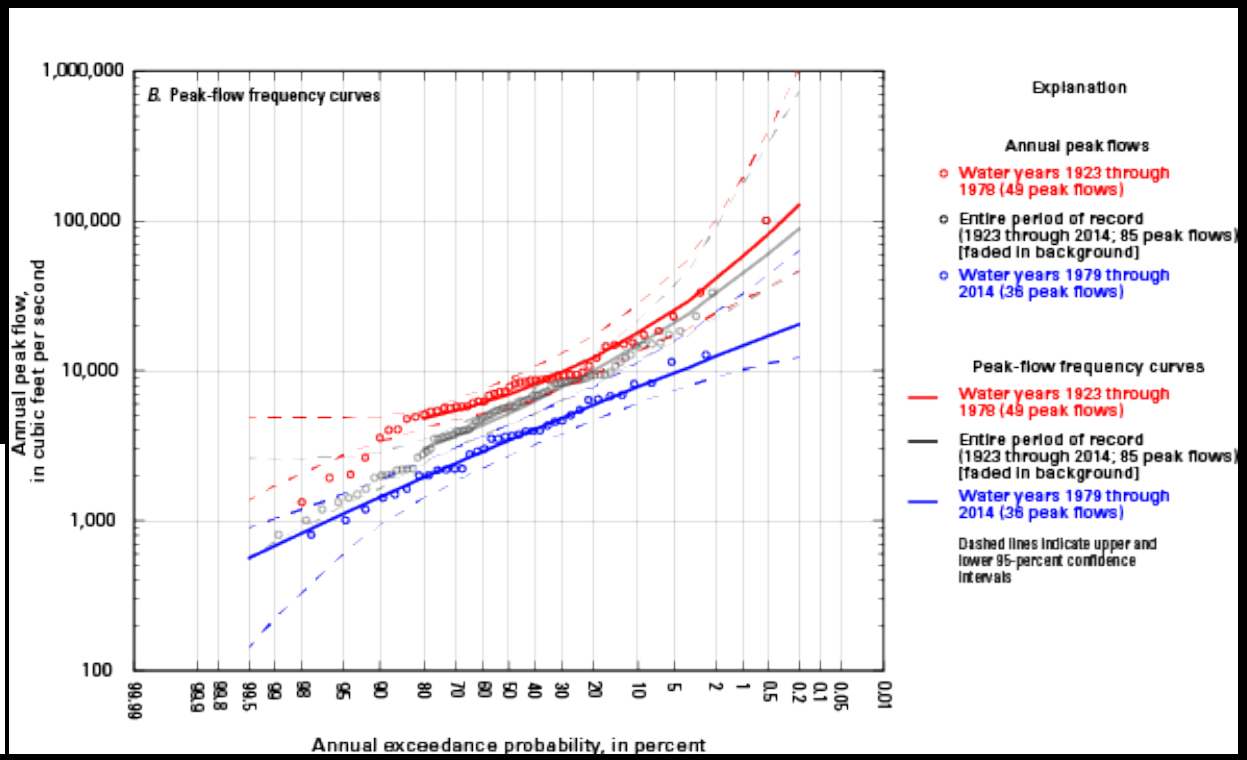
3. Montana flood hydrology --- Smaller picture complexities

3c. Hydroclimatic persistence (cont.)

- Potential effects of hydroclimatic persistence on peak-flow frequency analyses

Powder River @ Moorhead





Major points:

- We can get substantially different frequency analyses depending on when the data were collected
- Unlikely that current methods adequately account for this

3. Montana flood hydrology --- Smaller picture complexities

3c. Hydroclimatic persistence

- Much research (everybody's in on it) is being conducted on accommodating hydroclimatic persistence in peak-flow frequency analysis
- National USGS/FHWA study (in progress)
- USGS 5-state regional study (WY, MT, ND, SD, NE); advanced proposal stage

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4. Compare and contrast --- Bulletin 17B and Bulletin 17C

- Bulletin 17B (1982)
  - Method of moments for fitting log Pearson III distribution
  - Based on point-value peak-flow data
  - Specific problems with:
    - ✓ historical adjustments (accommodating periods lacking gaged records)
    - ✓ low outliers and zero flows
  - Nationwide generalized skew-coefficient map for determining weighted skews
  - Single Grubbs-Beck test (inefficient in identifying low outliers)
  - Matalas/Jacobs procedure for record extension

- Bulletin 17C (currently in draft form)
  - Expected Moments Algorithm (EMA) for fitting log Pearson III distribution
  - Interval and perception-threshold framework allows consistent treatment of periods with and without peak-flow records
  - Bayesian-regression generalized skew coefficients for weighted skews
  - Multiple Grubbs-Beck test more efficient in identifying potentially influential low flows (PILFs)
  - Maintenance of Variance Type III (MOVE.3) method for record extension

Major points:

- B17B and B17C provide identical frequency curves for datasets with no PILFs or historical adjustments
- B17C produces larger confidence intervals
- B17C substantially advances historical adjustment procedures (allows multiple historic peaks and accommodation of paleoflood data)
- MGBT performs well for identifying PILFs
- MOVE.3 is nice

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4. Compare and contrast --- Bulletin 17B and Bulletin 17C

Transitioning from Bulletin 17B to Bulletin 17C

- USGS policy to use EMA since 2013
- The full Bulletin 17C approach is handled within USGS PeakFQv7.1
- Bayesian-regression generalized skew coefficients for MT not yet available; study in progress; use Bulletin 17B nationwide map in interim
- In theory, B17C requires substantial documentation of perception thresholds used in historical adjustments; full documentation will take time

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5. WY-MT WSC peak-flow frequency procedures

Current (2017) WY-MT WSC “standard” procedures for peak-flow frequency analysis

- Use of EMA for fitting log-Pearson III distribution
- Use of weighted skew coefficients (using Bulletin 17B nationwide generalized skew coefficient map; non-ideal)
- Use of the MGBT for identifying PILFs
- When applicable, the use of historical adjustment procedures based on best-available definition and documentation of perception thresholds

Major points:

- Basically, we are doing our best to implement Bulletin 17C
- We are prioritizing activities to iron out the wrinkles

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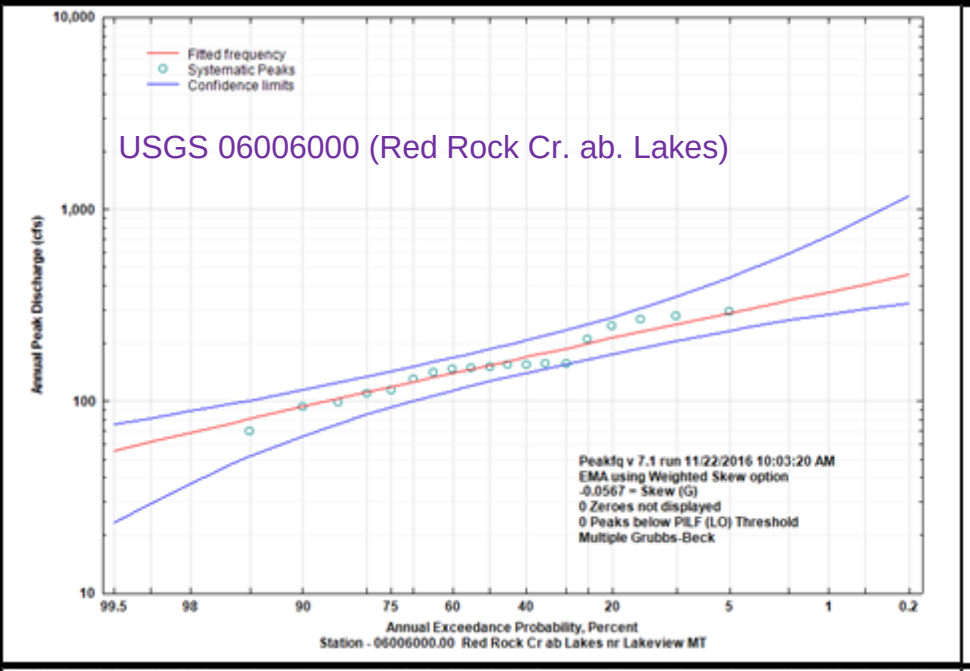
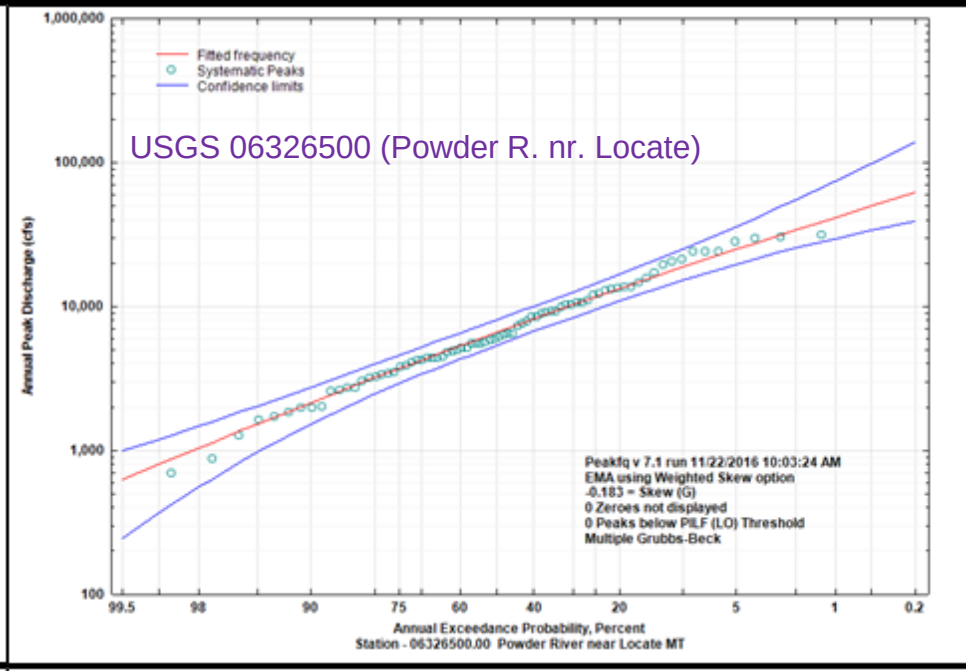
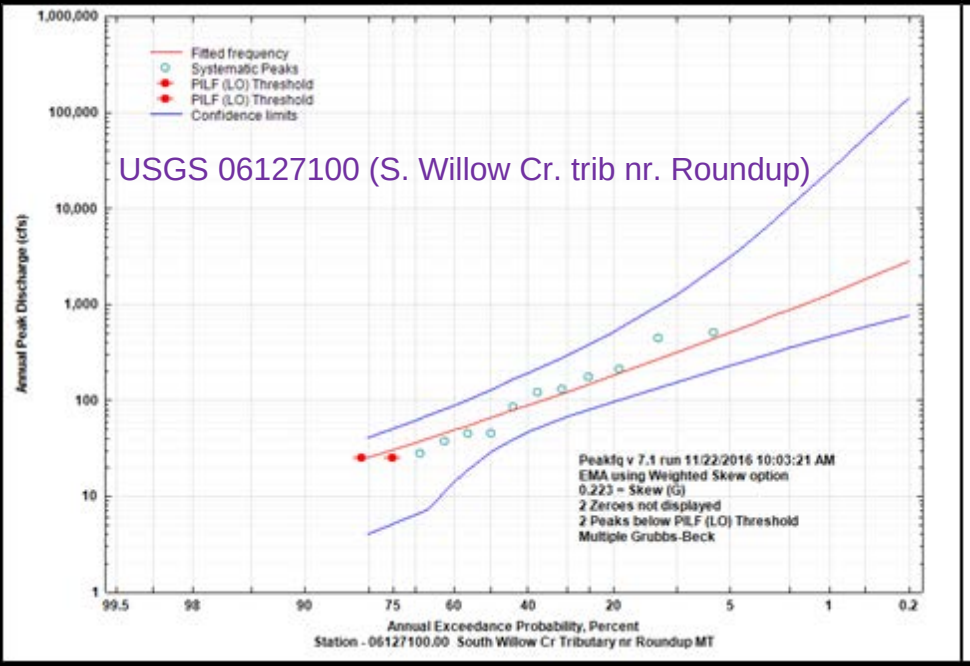
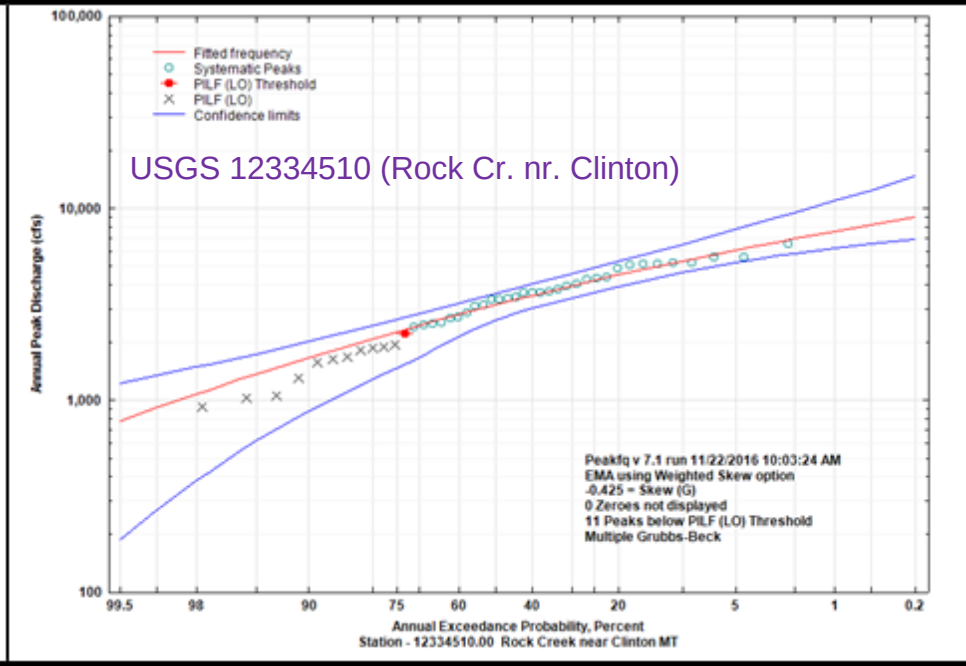
5. WY-MT WSC peak-flow frequency procedures

Example "standard" procedures frequency analyses (no historical adjustments)









5. WY-MT WSC peak-flow frequency procedures

WY-MT WSC approaches for historical adjustments and definition of perception thresholds

- Historical adjustments
  - Flood information outside of the systematic record is used to extend a frequency analysis to a historical period
  - Thus, there are some years without peak-flow data included in the analysis
  - Typical situations:
    - ✓ special acquisition of “historic” peak flow(s) (outside of systematic record)
    - ✓ unusually large systematic-record peak flow(s) statistically misrepresented in the period of record
- In EMA, perception thresholds (T_h) serve as the basis for performing historical adjustments with consistent treatment of gaged and ungaged periods
  - T_h describes the knowledge that the flood magnitudes in an ungaged period did or did not exceed a specified discharge
  - T_h required for each year (gaged or ungaged) included in a frequency analysis
  - Default T_h is: lower = infinity; upper = infinity; essentially “no knowledge”….used for data gaps when no historical adjustment
  - For ungaged periods in a historical adjustment analysis:
    - ✓ T_h is: lower = specified historic discharge; upper = infinity; “knowledge that a specific discharge was not equaled or exceeded”

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5. WY-MT WSC peak-flow frequency procedures

WY-MT WSC approaches for historical adjustments and definition of perception thresholds

- Apparently, there are various thoughts on the documentation required for setting T_h for historical adjustment analyses:
  1. documented monitoring of discrete stage markers (marks on bridges, buildings, monuments) to provide near certain determinations that are hard coded into NWIS
  2. hydrologic investigation of at-site information and areal flood history to provide reasonably confident determinations
- The long-term operations of the MT streamgage network are not consistent with approach 1
  - very few cases of defining (let alone monitoring) discrete stage markers
  - remote and sparsely populated areas
  - inconsistent coding in NWIS
- Current (2017) WY-MT WSC approaches for setting T_h:
  - follow approach 2 (“best available documentation”)
  - investigate previous handling of historical adjustments (Parrett and Johnson, 2004)
  - conduct additional hydrologic investigations of at-site and areal flood history

- Compiling documentation for T_h determinations and hardcoding into NWIS is a primary priority of WY-MT WSC

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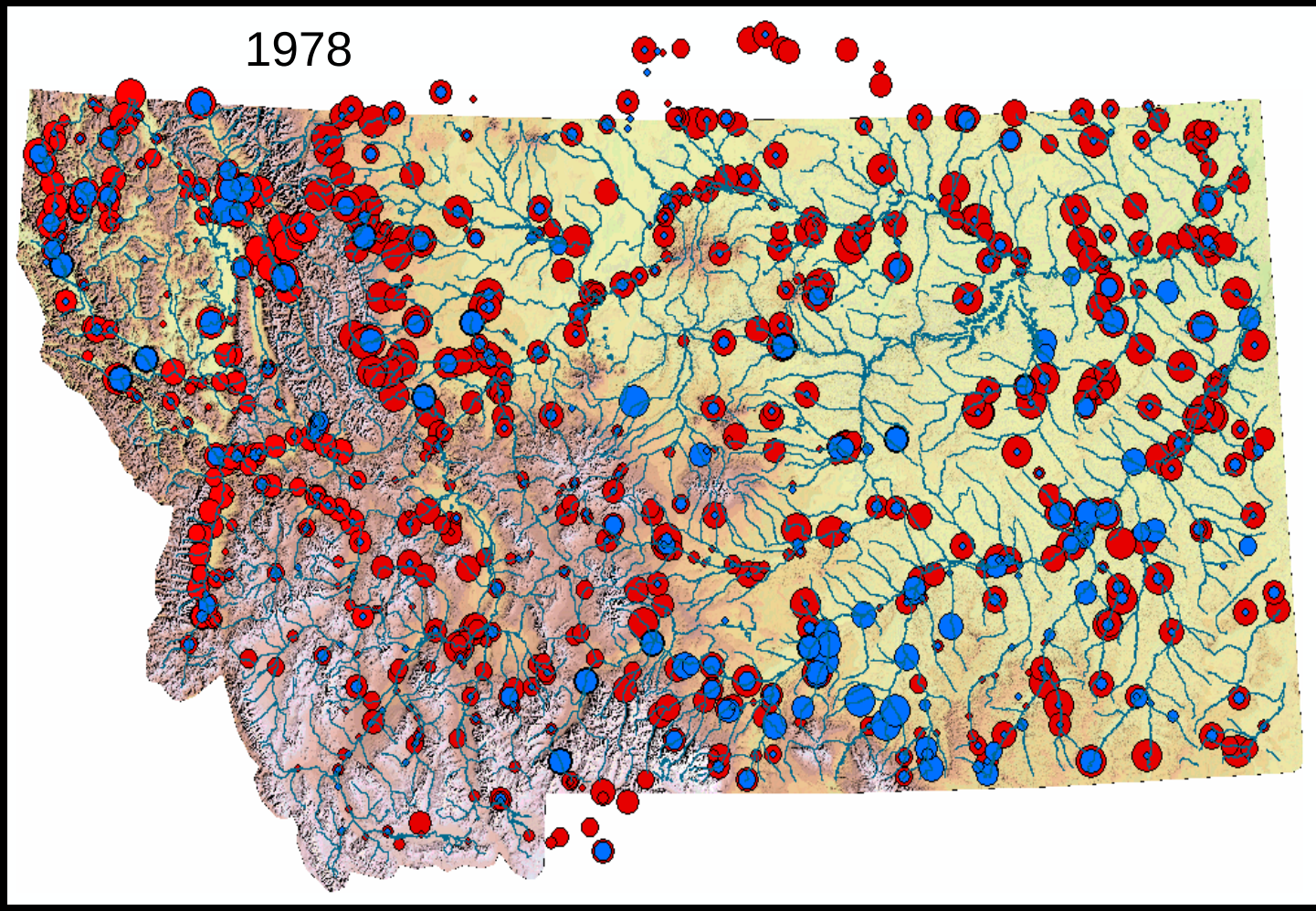
5. WY-MT WSC peak-flow frequency procedures

WY-MT WSC approaches for historical adjustments and definition of perception thresholds

- Statewide normalized maximum peaks map
- Plot each year to assess areal extent of flooding (example for 1978 is shown)

For a given historical adjustment analysis, we evaluate the likelihood that the specified historic discharge was exceeded in the individual ungaged years.



Maximum peak of record, normalized by drainage area

Peak for year (if gaged), normalized by drainage area

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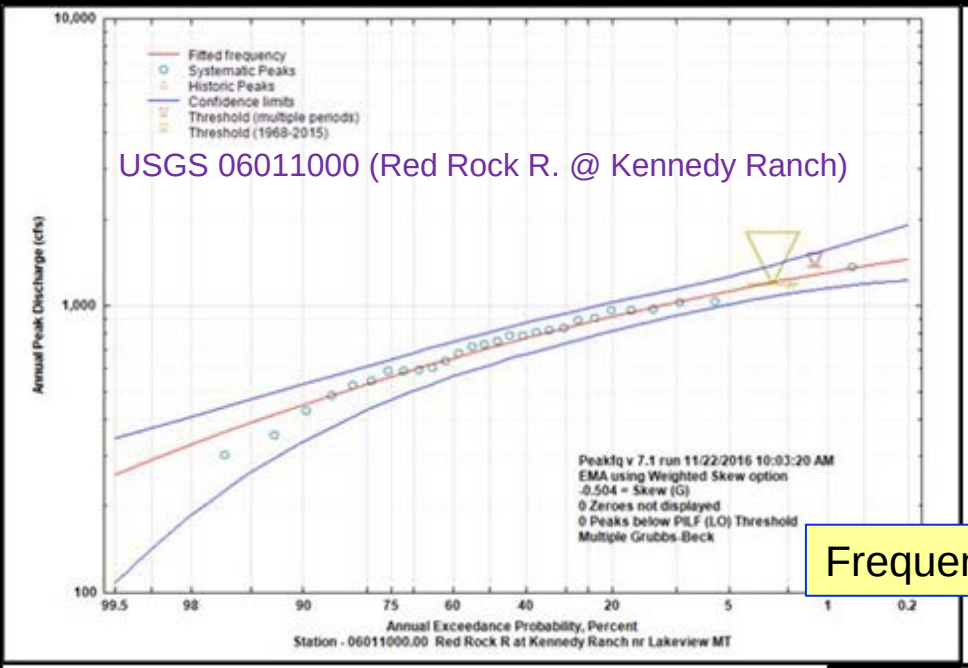
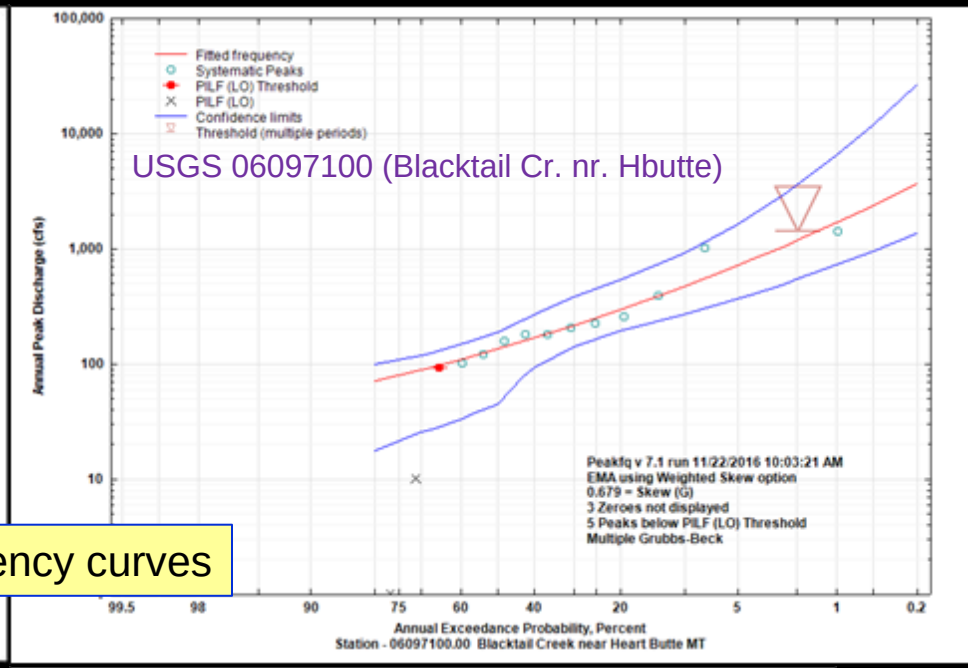
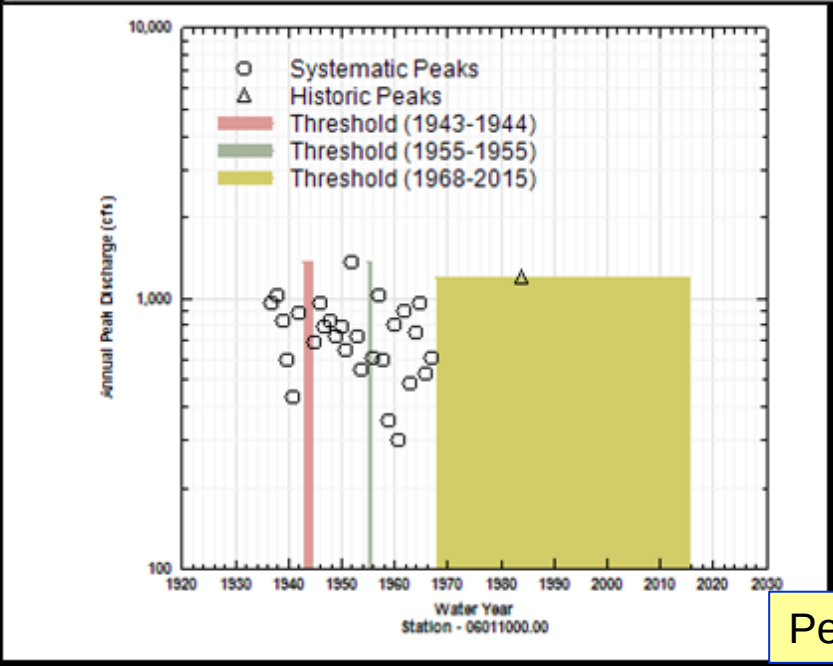
5. WY-MT WSC peak-flow frequency procedures

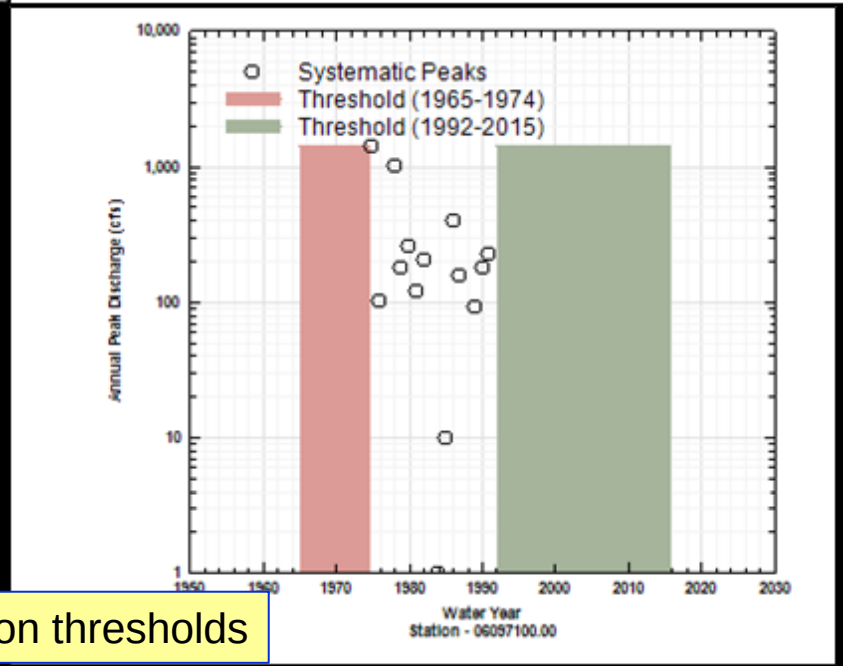
Example "standard" procedures frequency analyses (historical adjustments)





Frequency curves





Perception thresholds

5. WY-MT WSC peak-flow frequency procedures

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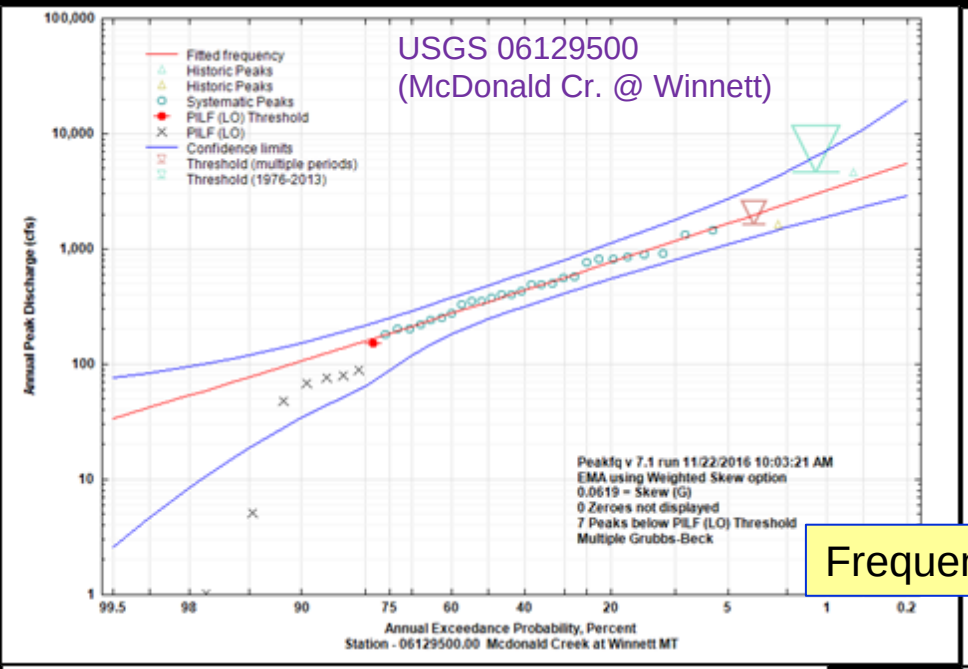

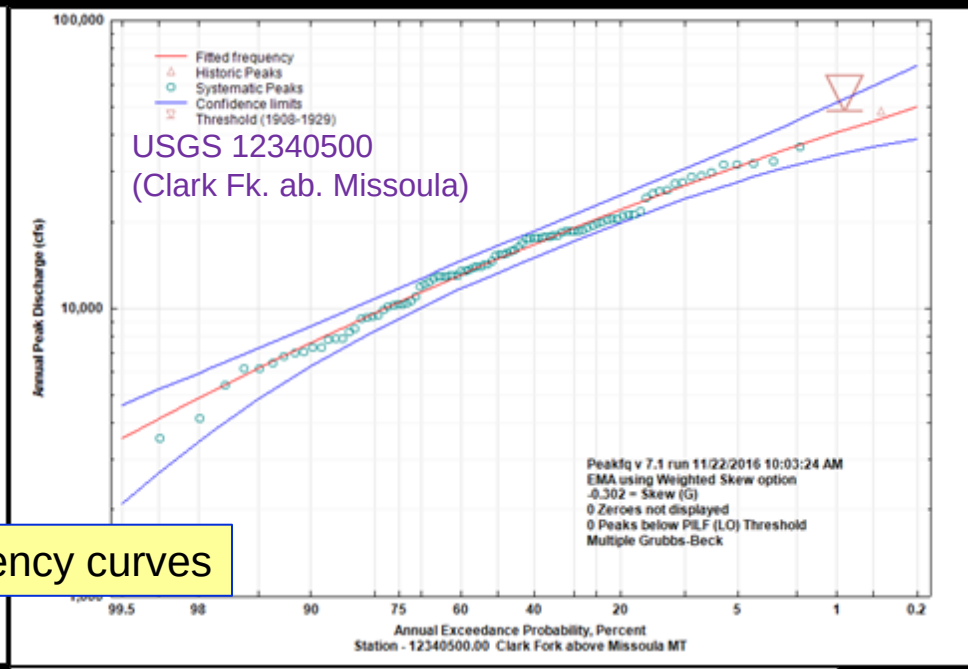

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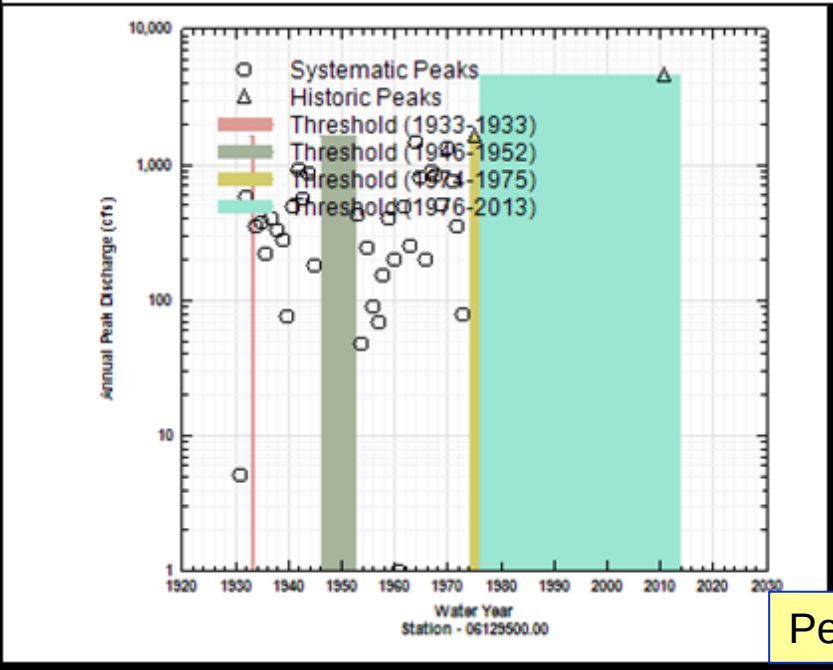

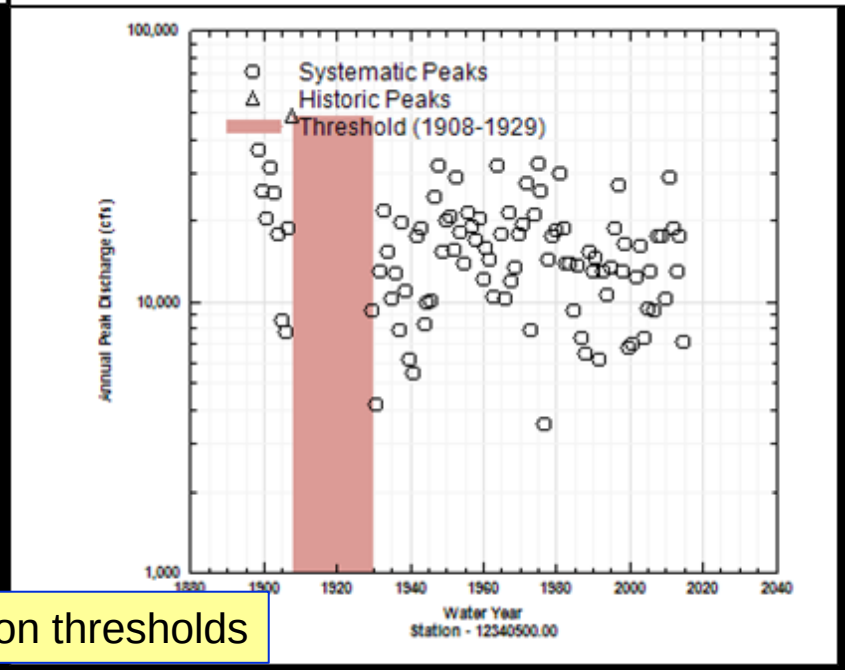

Perception thresholds

5. WY-MT WSC peak-flow frequency procedures

Typical WY-MT WSC “alternative” procedures for regulated streamgages

- Major regulation --- entire period of record (POR) is regulated

  1. Use station skew for percent regulation > 80%
  2. Use of station skew discretionary for percent regulation 20-80%
  3. Review MGBT for appropriate handling of PILFs
  4. If necessary, use manual PILF threshold

- Major regulation --- POR spans regulated and unregulated periods

  1. Regulated-period frequency analysis follows above procedures
  2. If percent regulation is less than 50%, report “total” POR analysis that combines the regulated and unregulated data; discretionary conservative analysis

- Minor regulation

  1. Treated as unregulated using standard unregulated procedures

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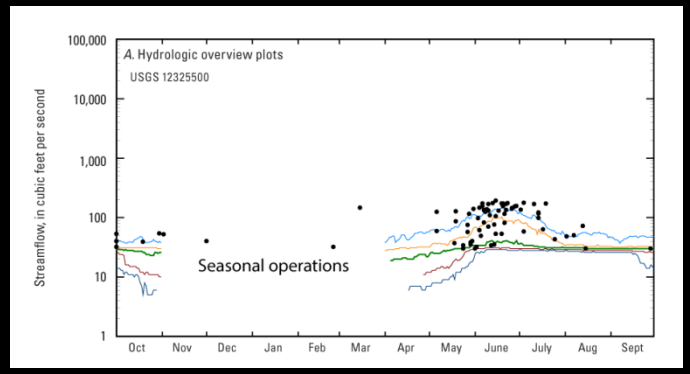
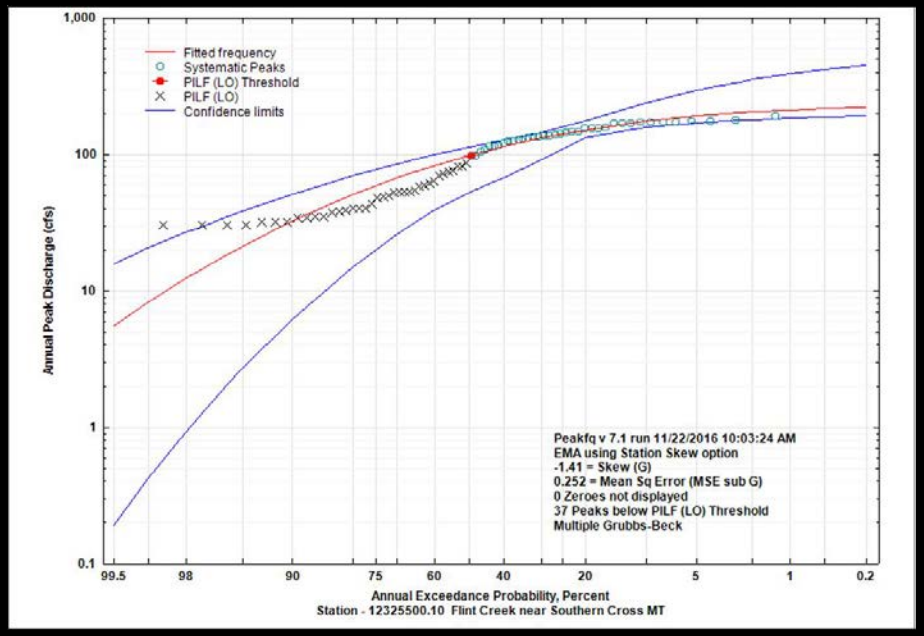
5. WY-MT WSC peak-flow frequency procedures

Example frequency analyses relating to major regulation

- USGS 12325500 (Flint Cr. @ Southern Cross)
  95.2% regulated
  S-shaped regulated frequency curve
  Station skew
  MGBT identifies 37 PILFs

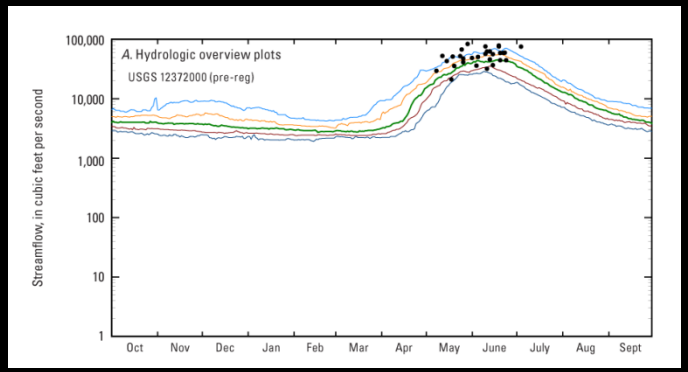


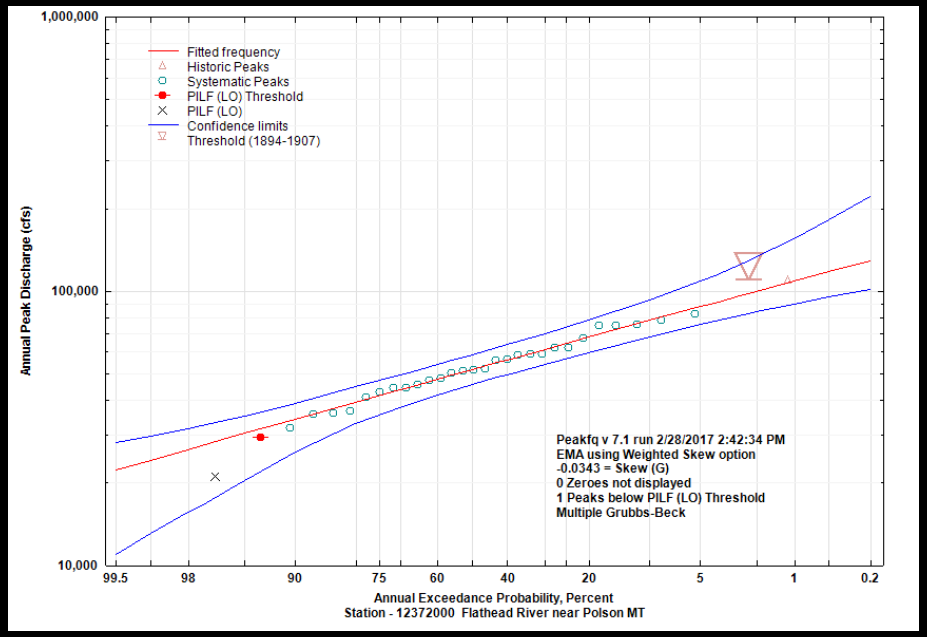


5. WY-MT WSC peak-flow frequency procedures

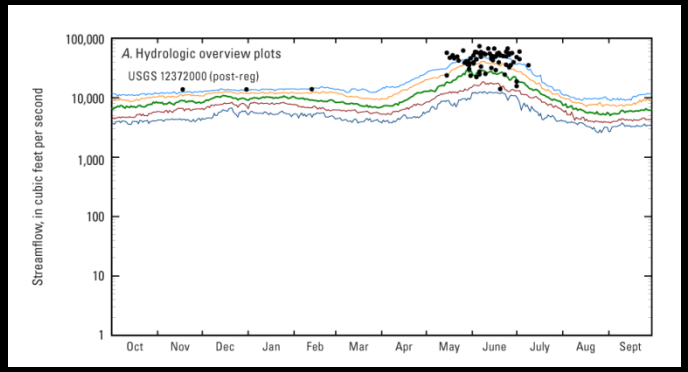
Example frequency analyses relating to major regulation

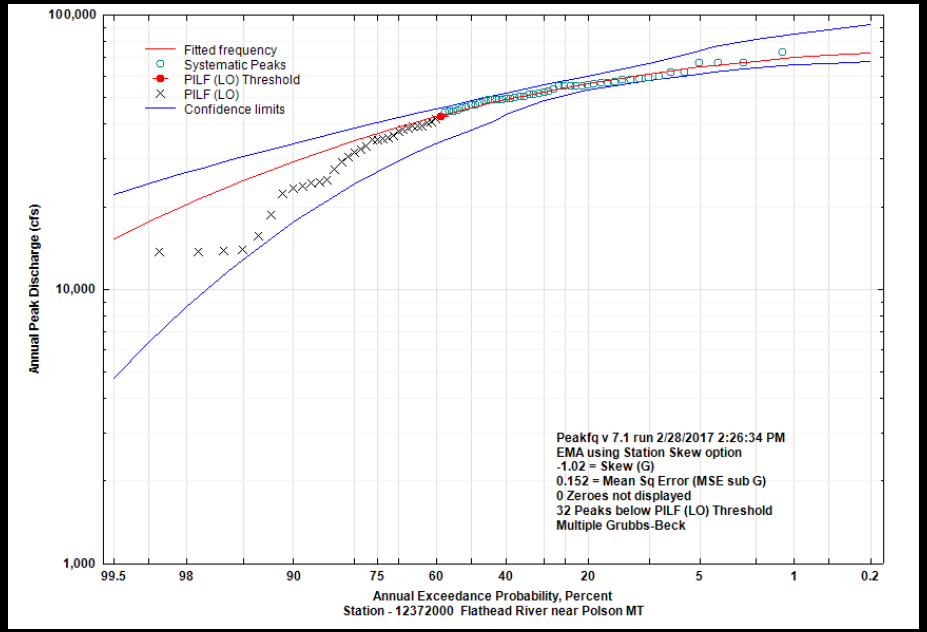
- **USGS 12372000 (Flathead R. nr. Polson)**
  Pre-regulation period (1894-1937)
  Unregulated frequency curve
  Weighted skew
  MGBT identifies 1 PILF





- **USGS 12372000 (Flathead R. nr. Polson)**
  Post-regulation period; 99.7% regulated
  Typical "S-shaped" regulated frequency curve
  Station skew
  MGBT identifies 37 PILFs

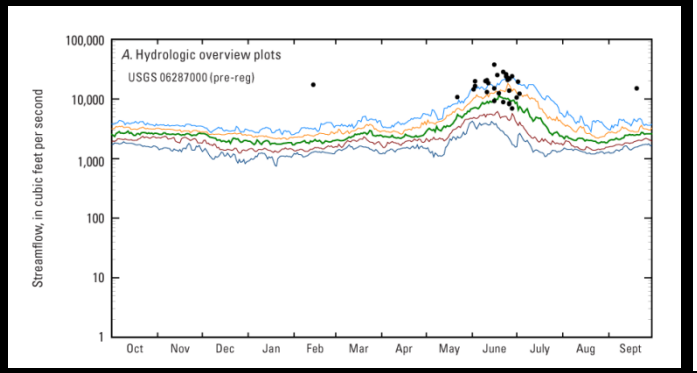


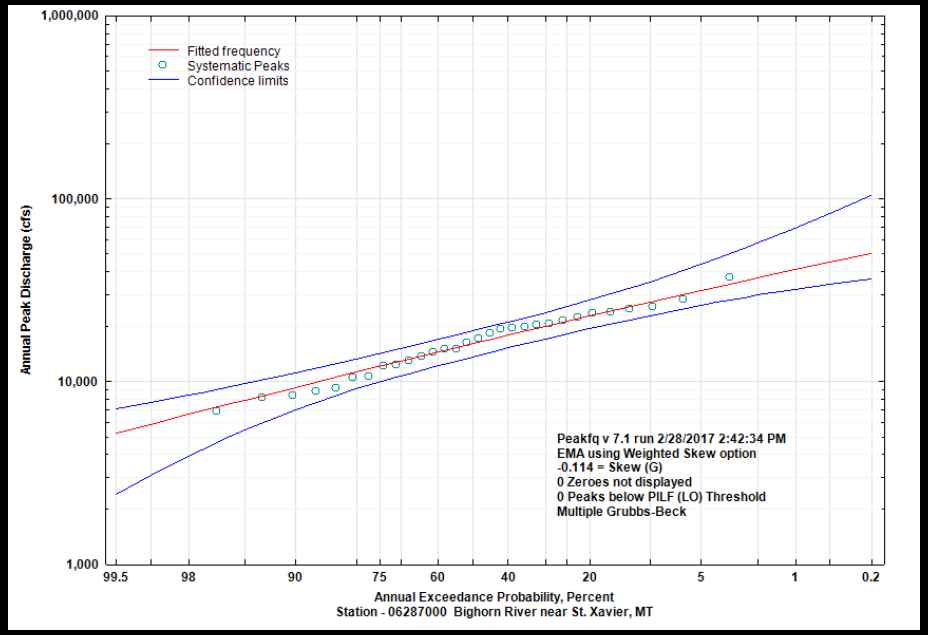


5. WY-MT WSC peak-flow frequency procedures

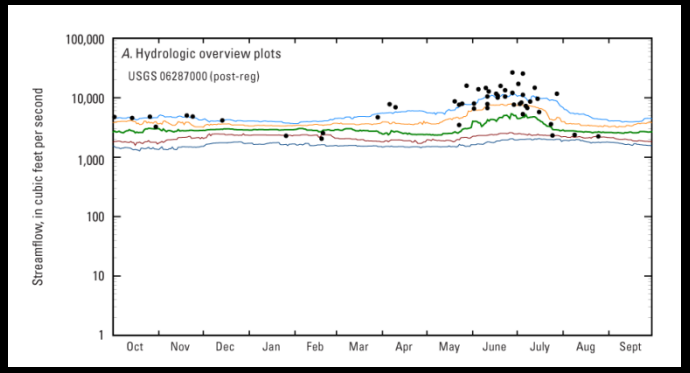
Example frequency analyses relating to major regulation

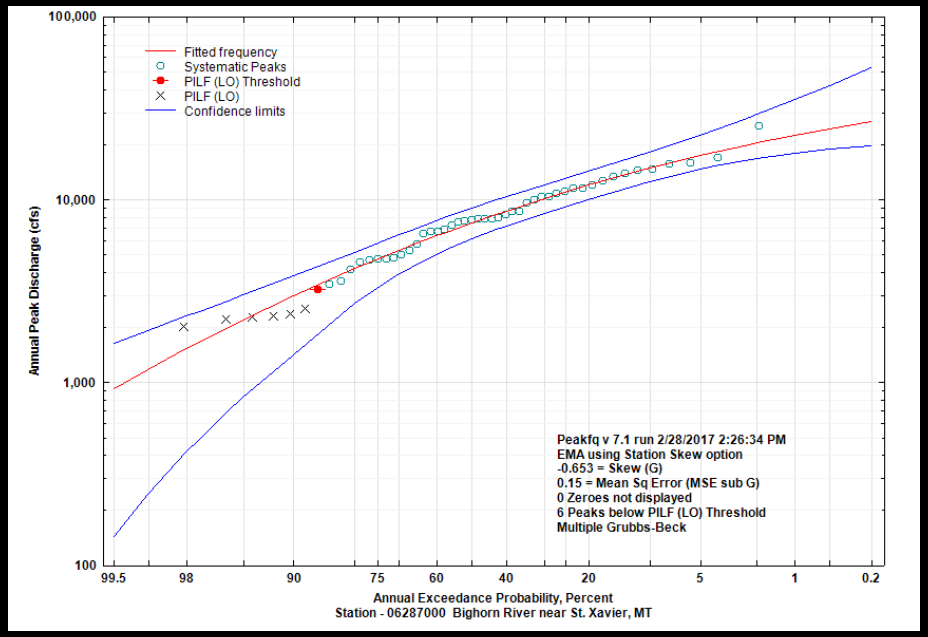
- **USGS 06287000 (Bighorn R. nr. St. X.)**
  Pre-regulation period (1935-64)
  Unregulated frequency curve
  Weighted skew
  MGBT identifies 0 PILFs





- **USGS 06287000 (Bighorn R. nr. St. X.)**
  99.8% regulated (1965-2015)
  S-shaped regulated frequency curve
  Station skew
  MGBT identifies 6 PILFs

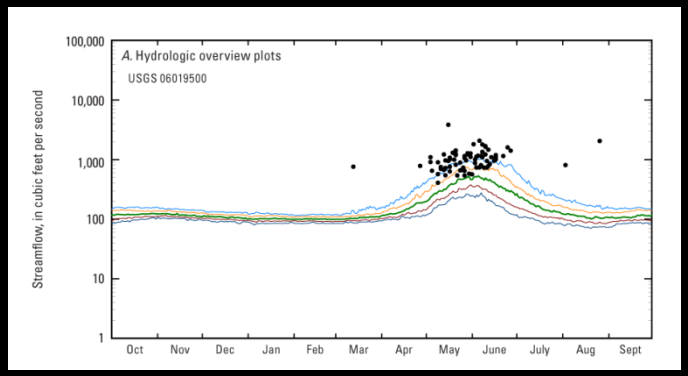


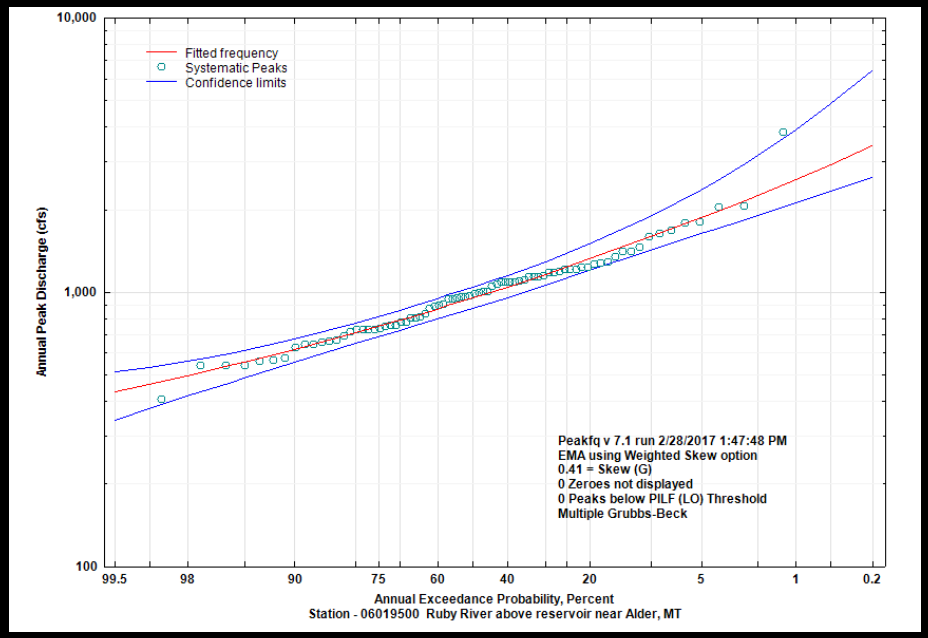


5. WY-MT WSC peak-flow frequency procedures

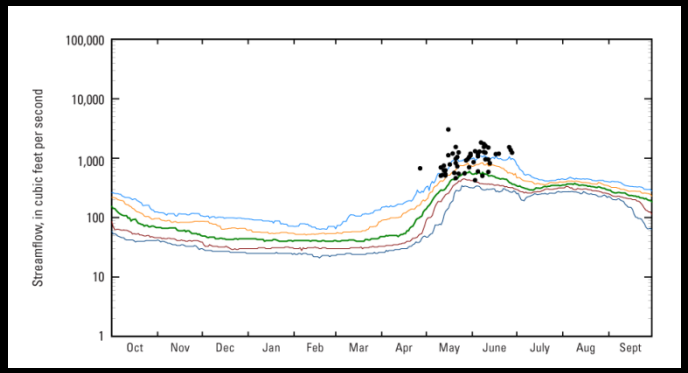
Example frequency analyses relating to major regulation

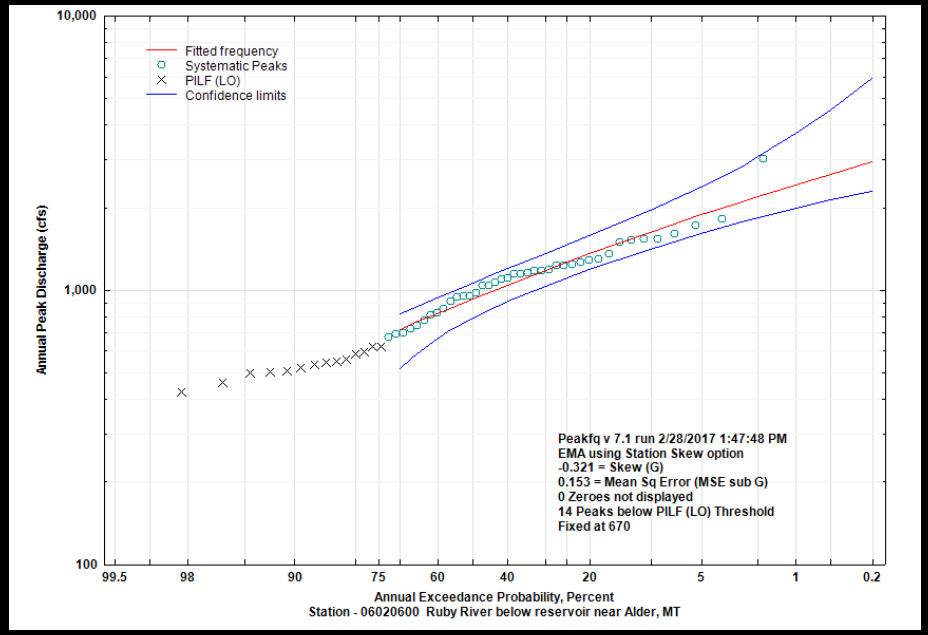
- USGS 06019500 (Ruby R. ab. reservoir)
  0% regulated
  Unregulated frequency curve
  Weighted skew
  MGBT identifies 0 PILFs





- USGS 06206000 (Ruby R. bel. reservoir)
  99.8% regulated
  S-shaped regulated frequency curve
  Station skew
  Manual PILF threshold --- 14 PILFs





5. WY-MT WSC peak-flow frequency procedures

Typical WY-MT WSC “alternative” procedures for mixed-population datasets

- Determination to treat as mixed-population dataset (“appearance” of nonhomogeneity) --- 5 criteria for determination (Sando and others, 2016; http://pubs.usgs.gov/sir/2015/5019C/sir20155019C.pdf)

- For mixed-population datasets:
  1. Use station skew
  2. Discretionary use of manual PILF

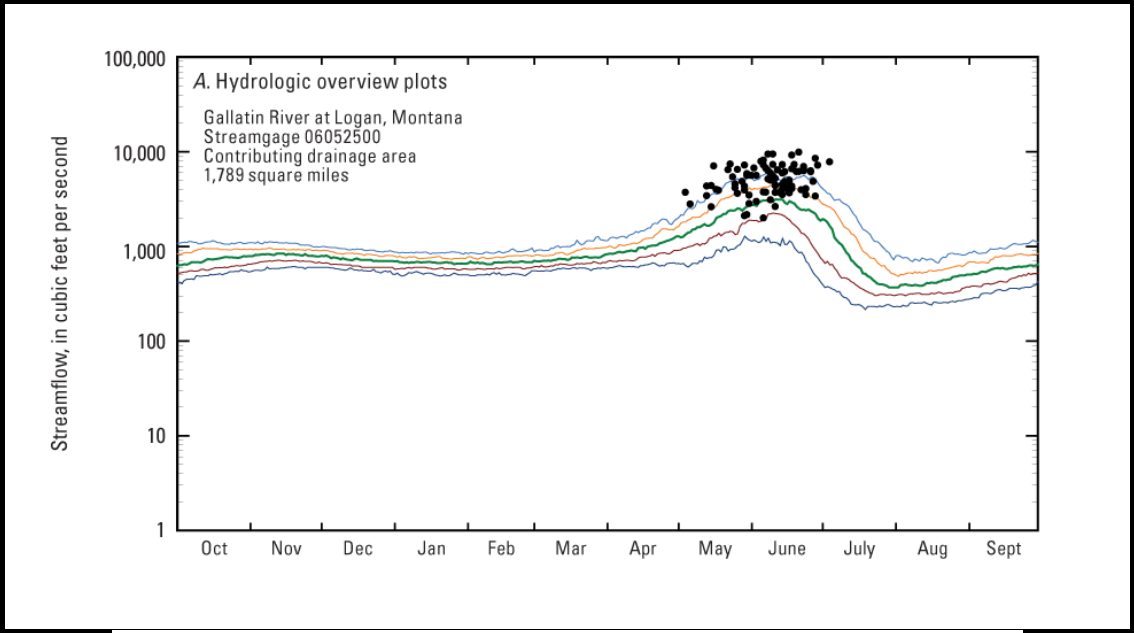
USGS

5. WY-MT WSC peak-flow frequency procedures

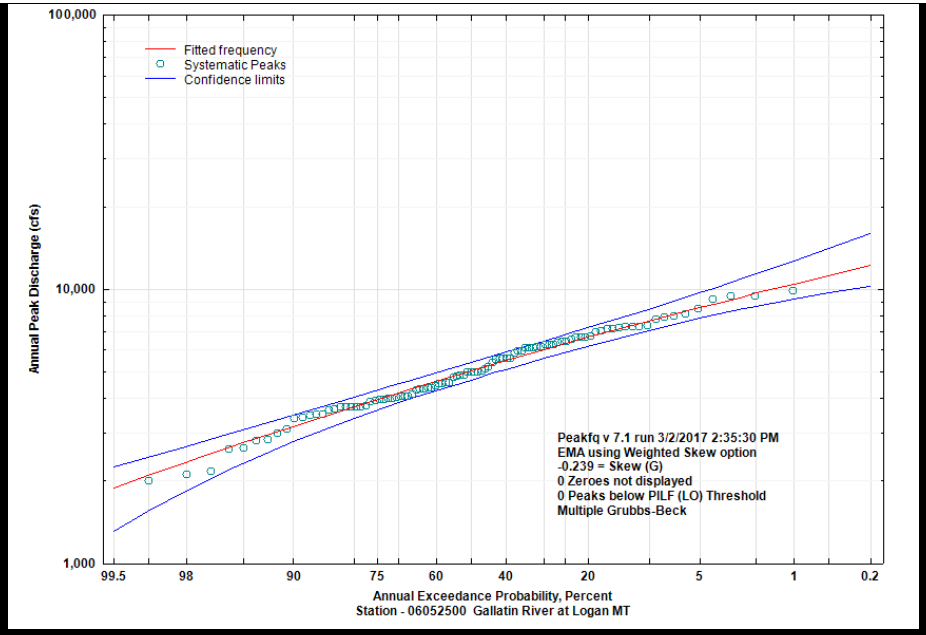
Examples relating to mixed-population issues

- Determination of mixed-population dataset….well-behaved station; little mixed-population characteristics

- USGS 06019500
- Gallatin River @ Logan
  UYCM hydrologic region
  Mean basin elevation 6,635 ft
  Well-behaved interior mountains



- Little indication of mixed-population effects
- Well-behaved frequency analysis



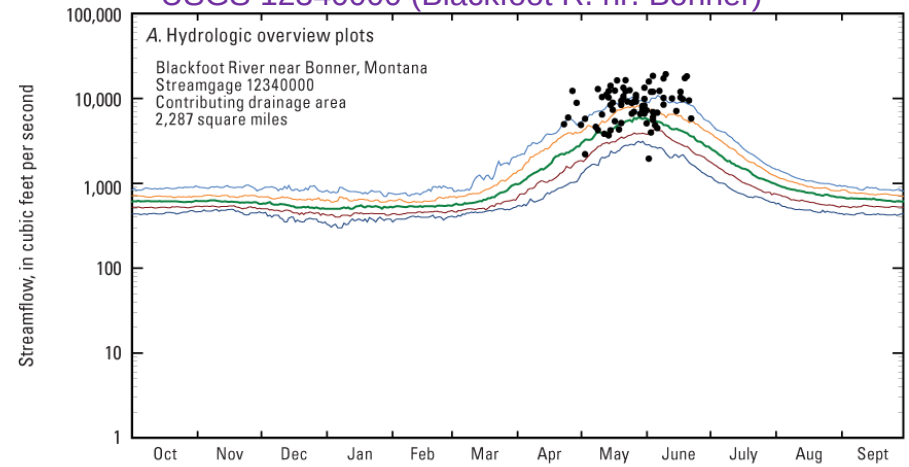
USGS

5. WY-MT WSC peak-flow frequency procedures

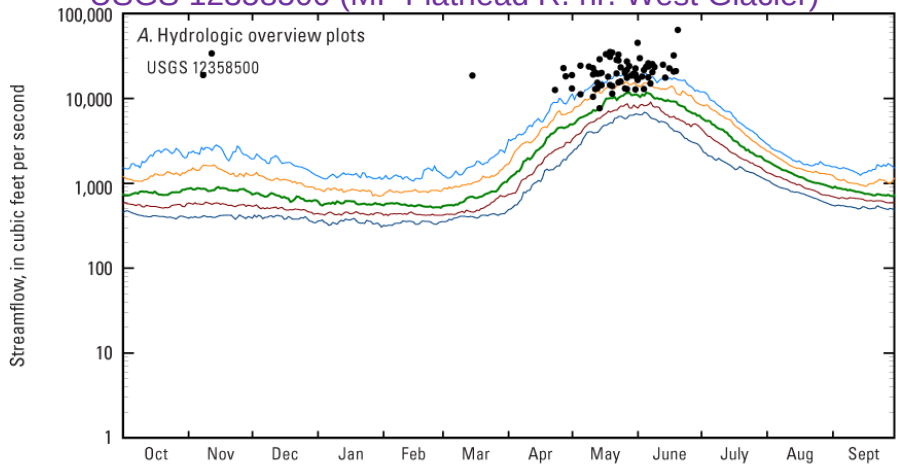
Examples relating to mixed-population issues

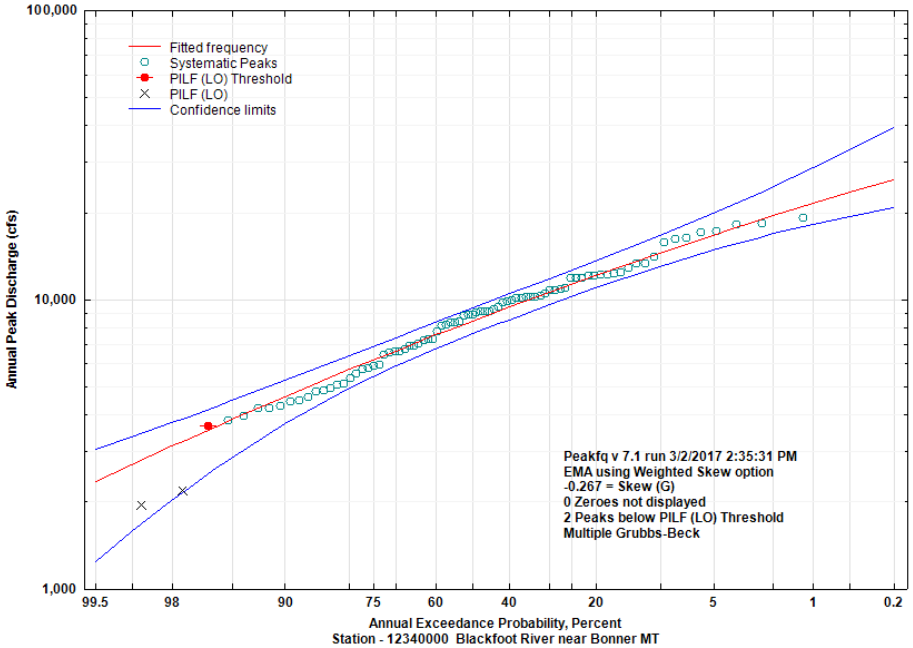
- Difficulties in defining a mixed-population dataset based on flood mechanism

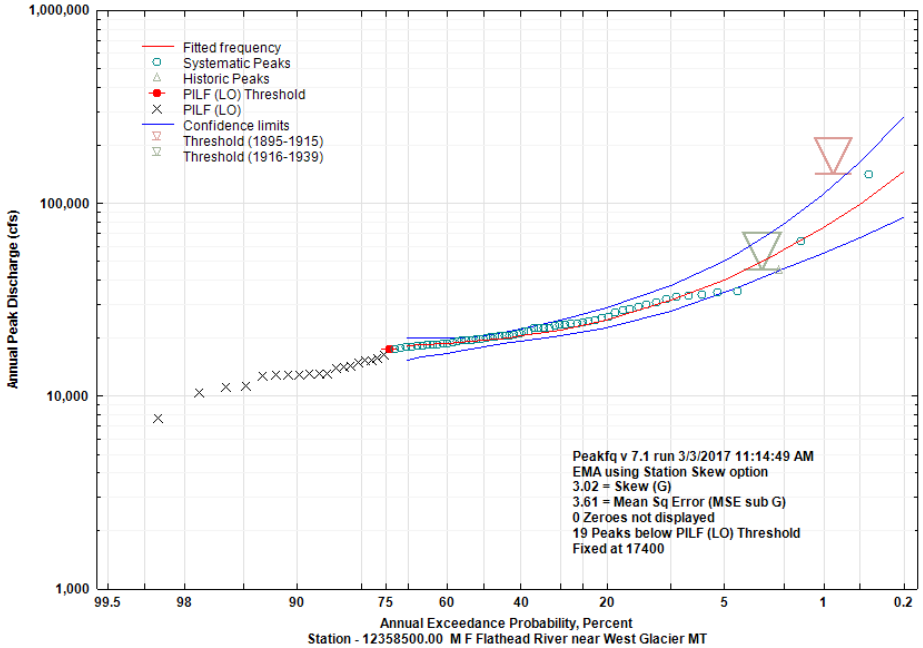
USGS 12340000 (Blackfoot R. nr. Bonner)



USGS 12358500 (MF Flathead R. nr. West Glacier)



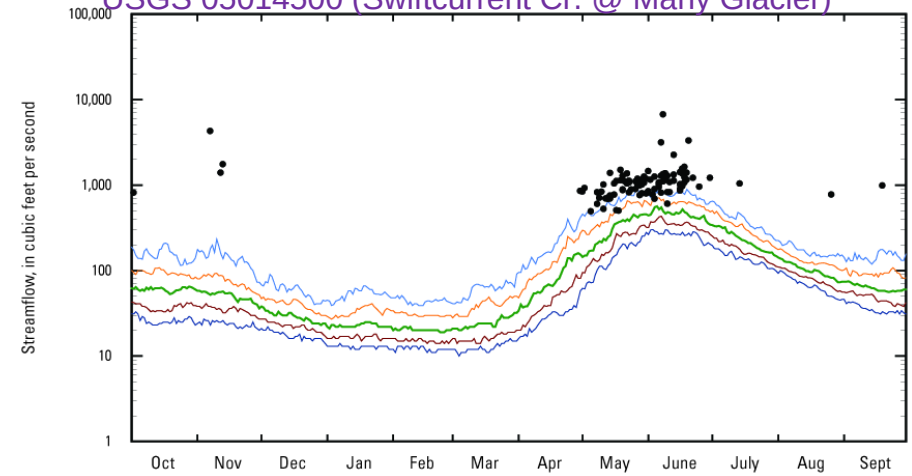




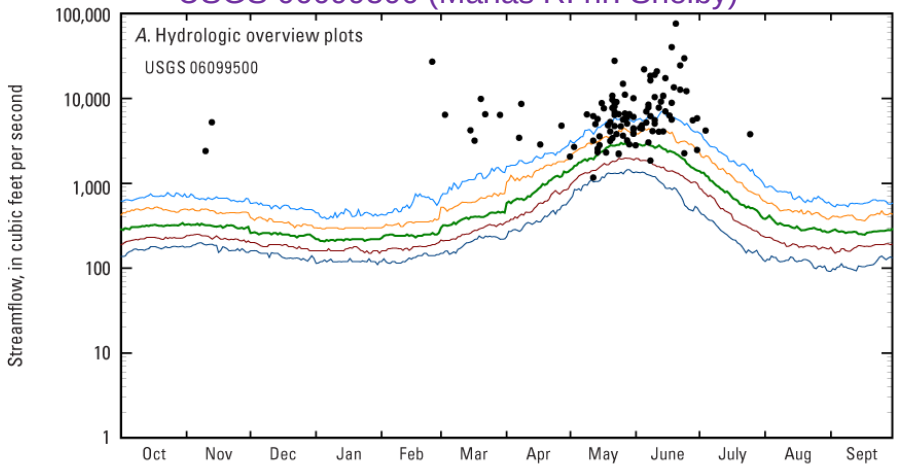
5. WY-MT WSC peak-flow frequency procedures

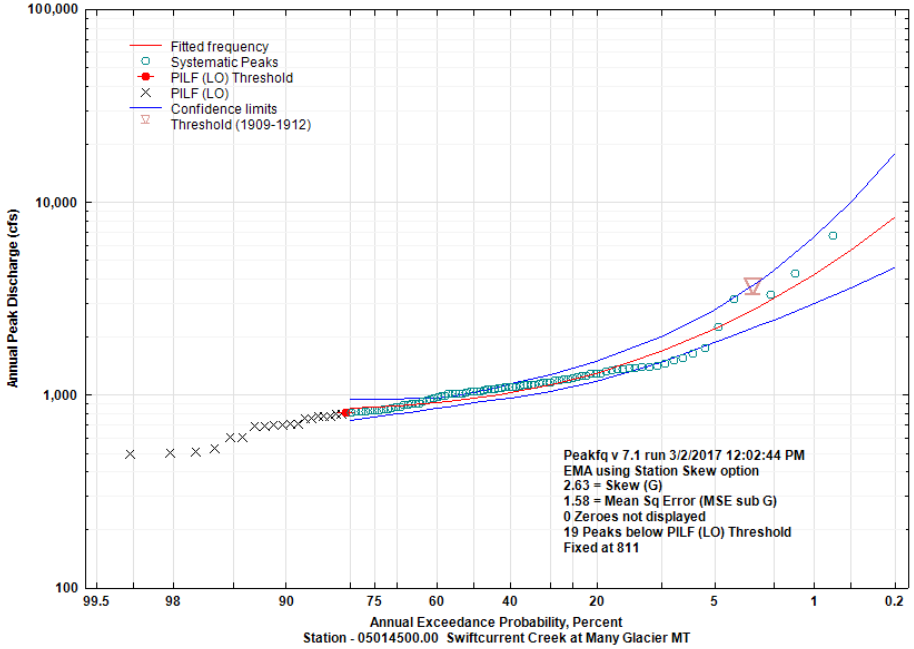
Examples relating to mixed-population issues

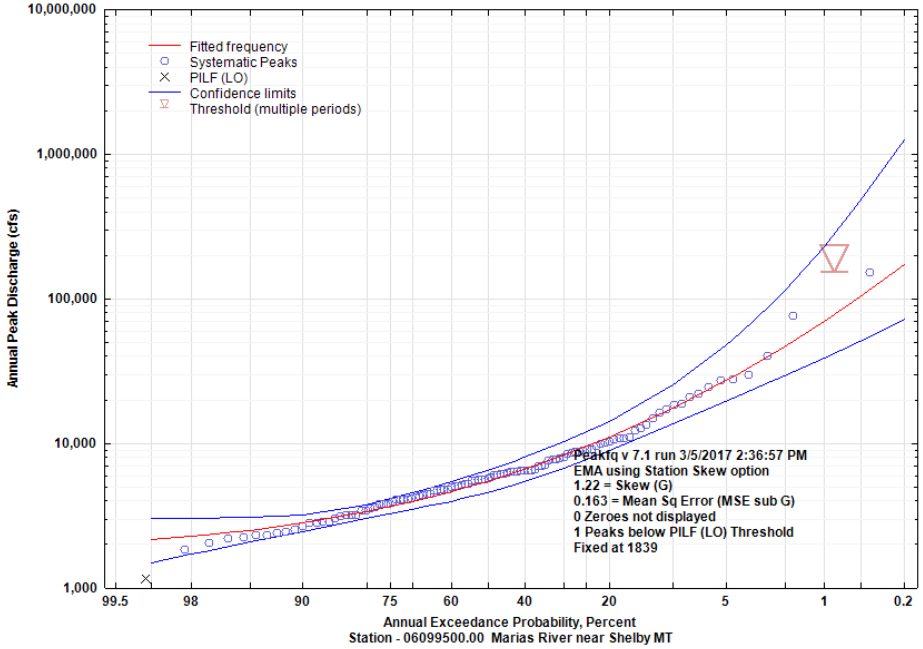
USGS 05014500 (Swiftcurrent Cr. @ Many Glacier)



USGS 06099500 (Marias R. nr. Shelby)



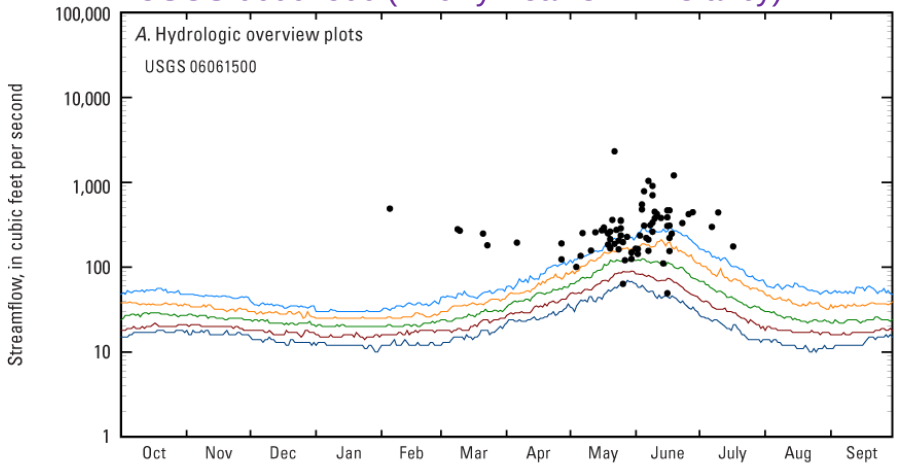


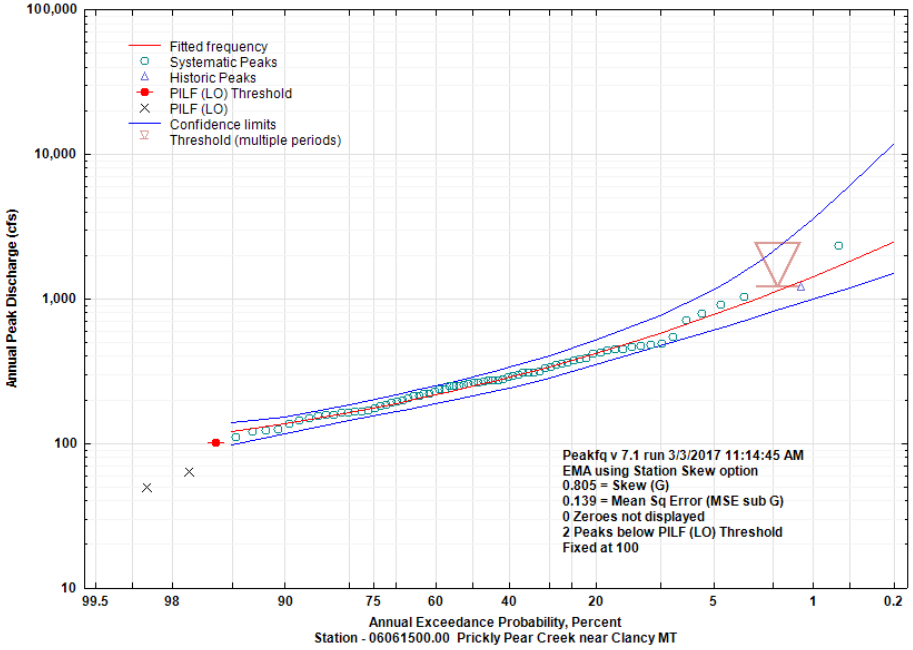


5. WY-MT WSC peak-flow frequency procedures

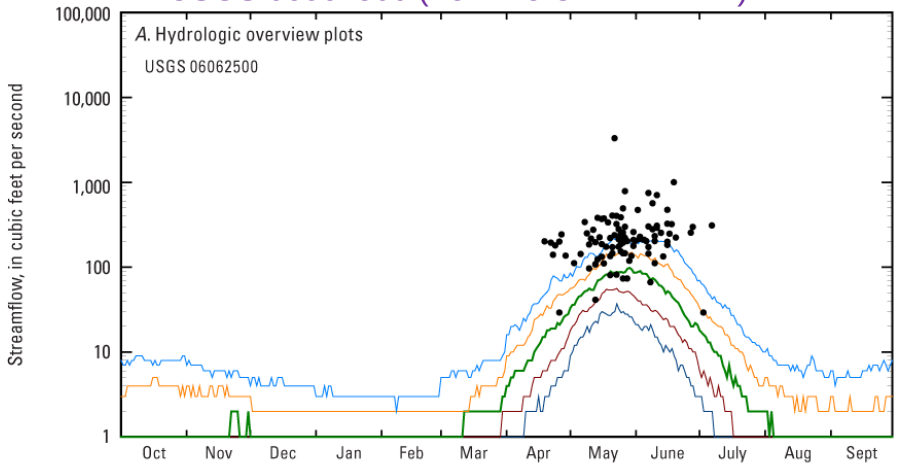
Examples relating to mixed-population issues

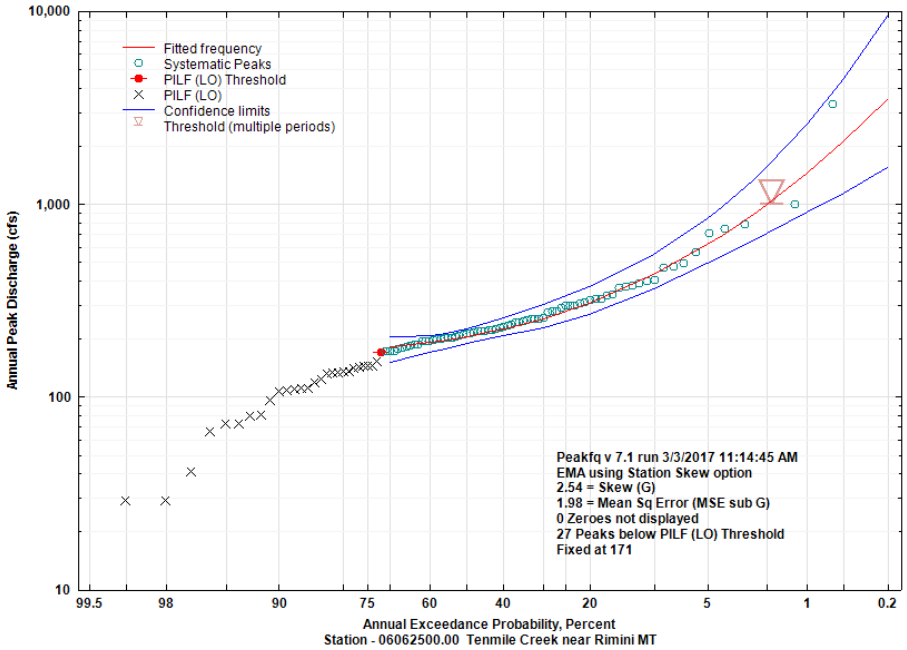
USGS 06061500 (Prickly Pear Cr. nr. Clancy)





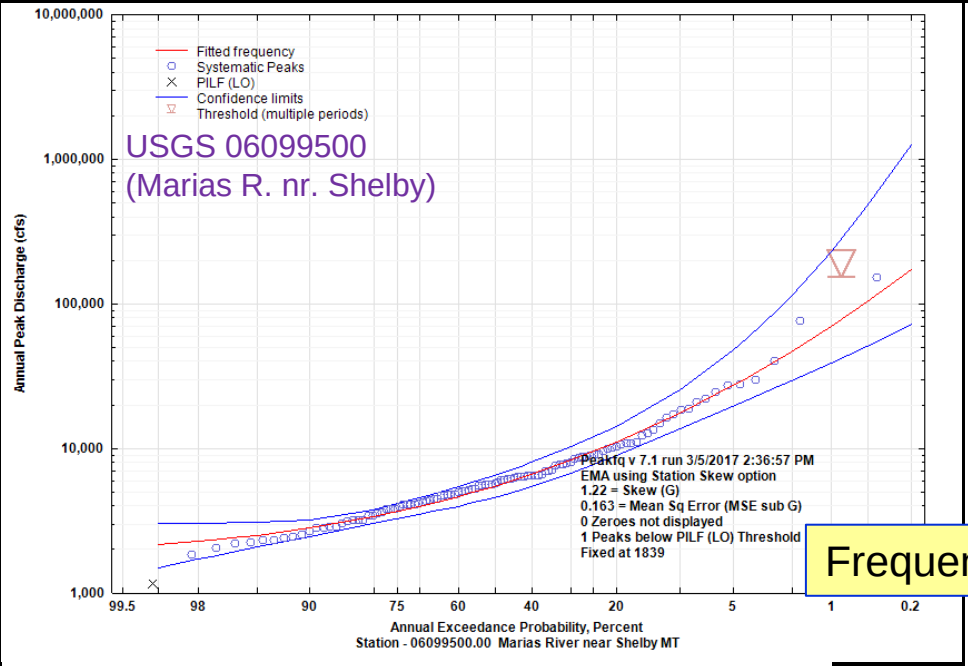
USGS 06062500 (Tenmile Cr. nr. Rimini)

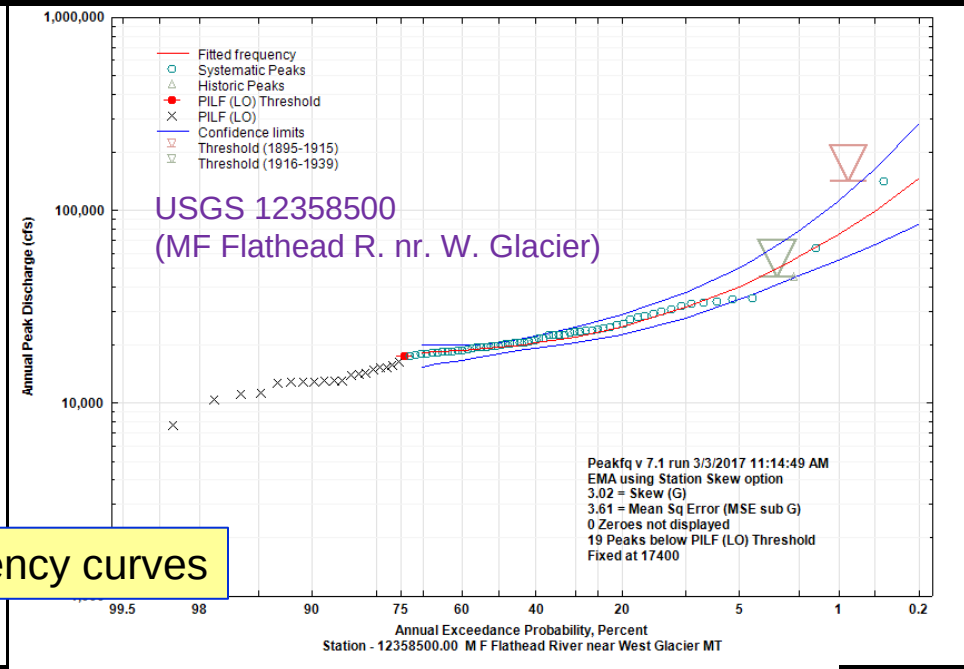




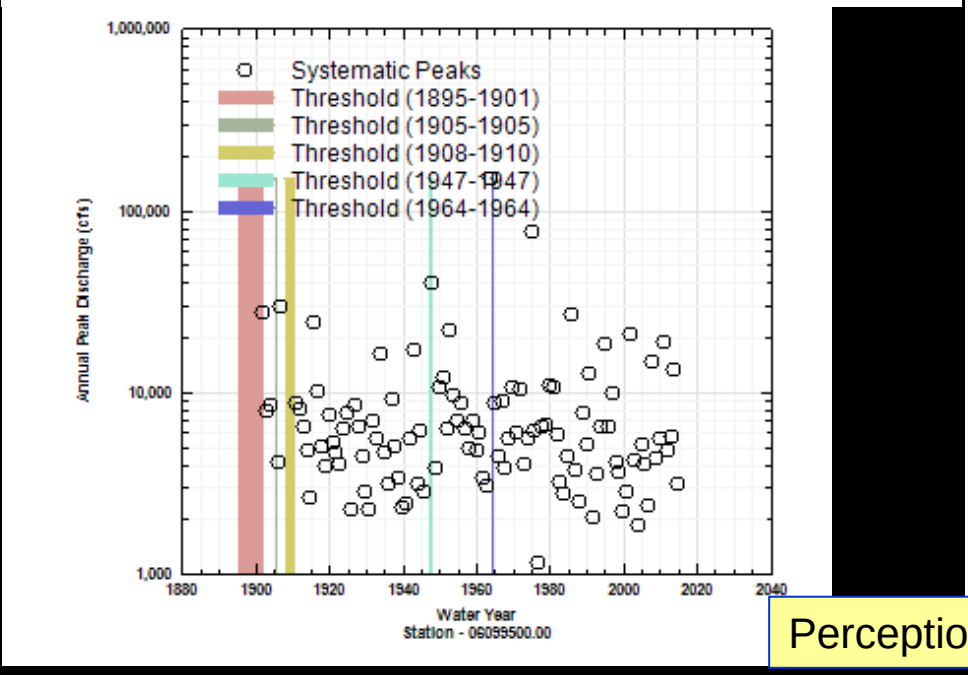
5. WY-MT WSC peak-flow frequency procedures

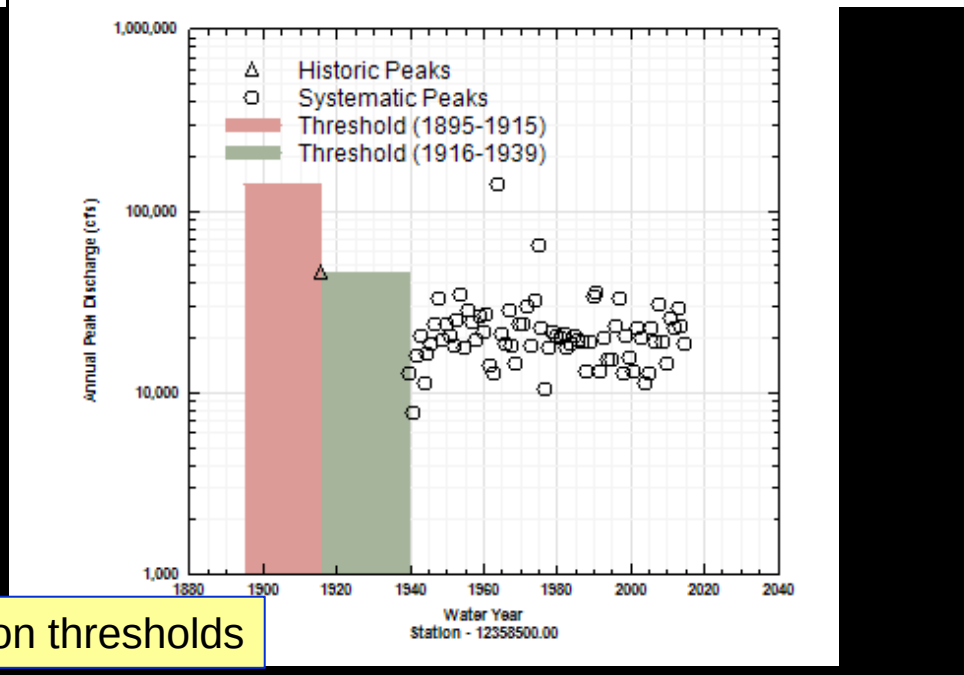
Examples relating to mixed-population issues: many mixed-population datasets have historical adjustments





Frequency curves

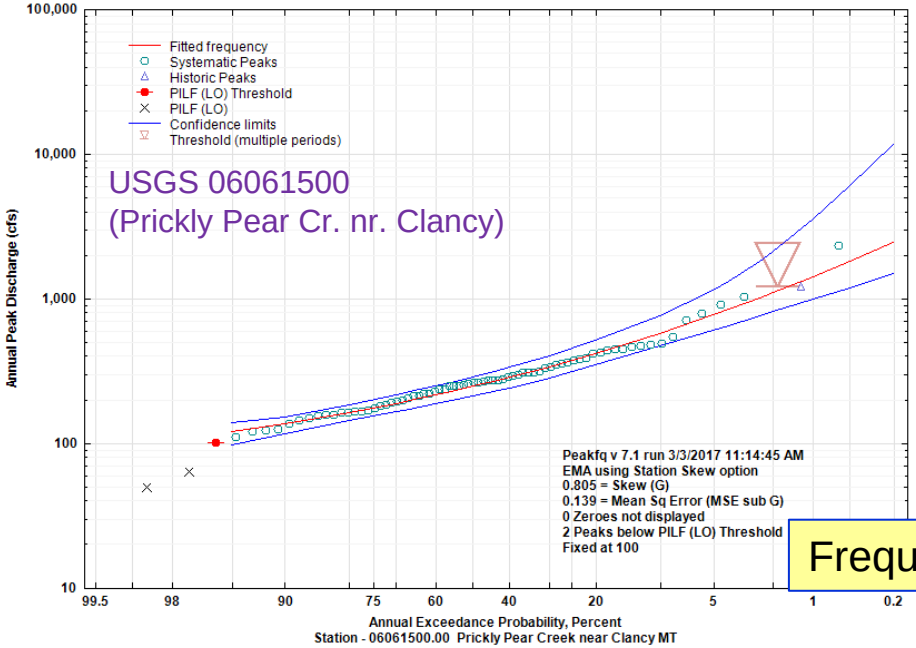


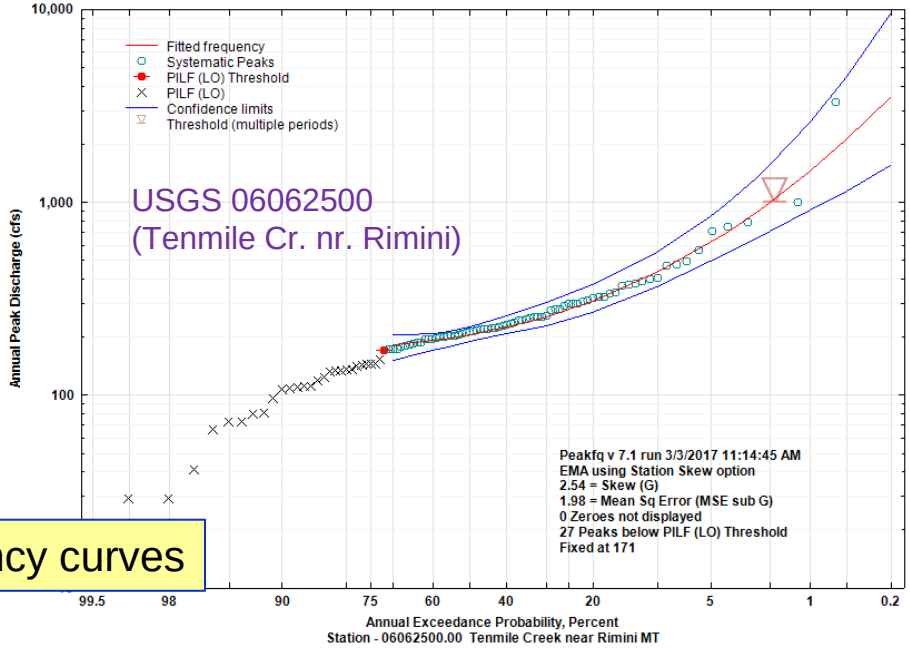


Perception thresholds

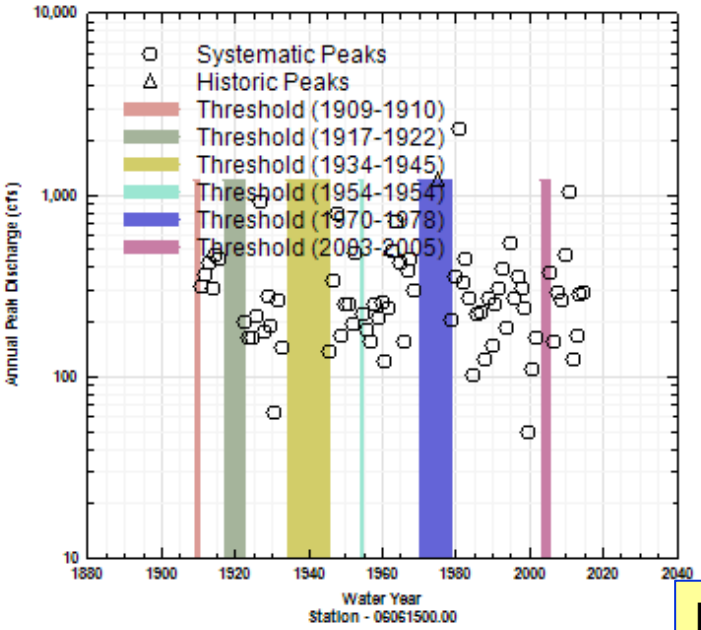
5. WY-MT WSC peak-flow frequency procedures

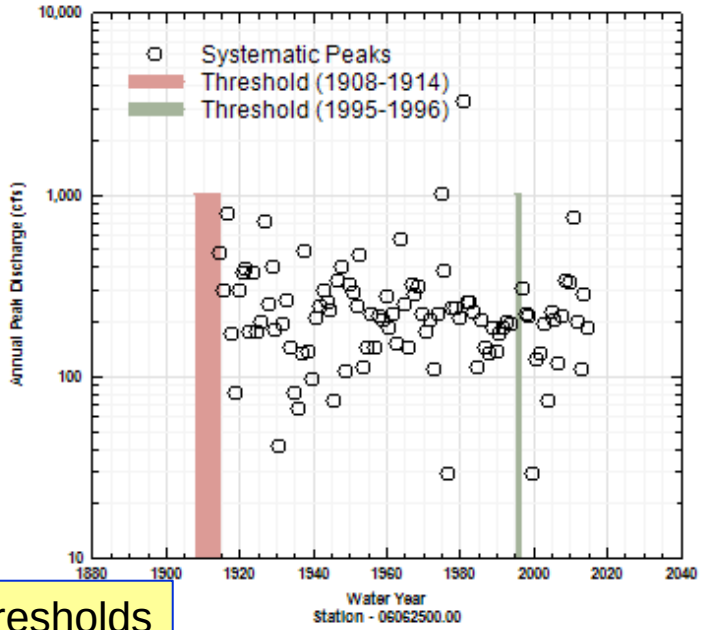
Examples relating to mixed-population issues: WY-MT WSC has extended use of mixed-population analyses





Frequency curves

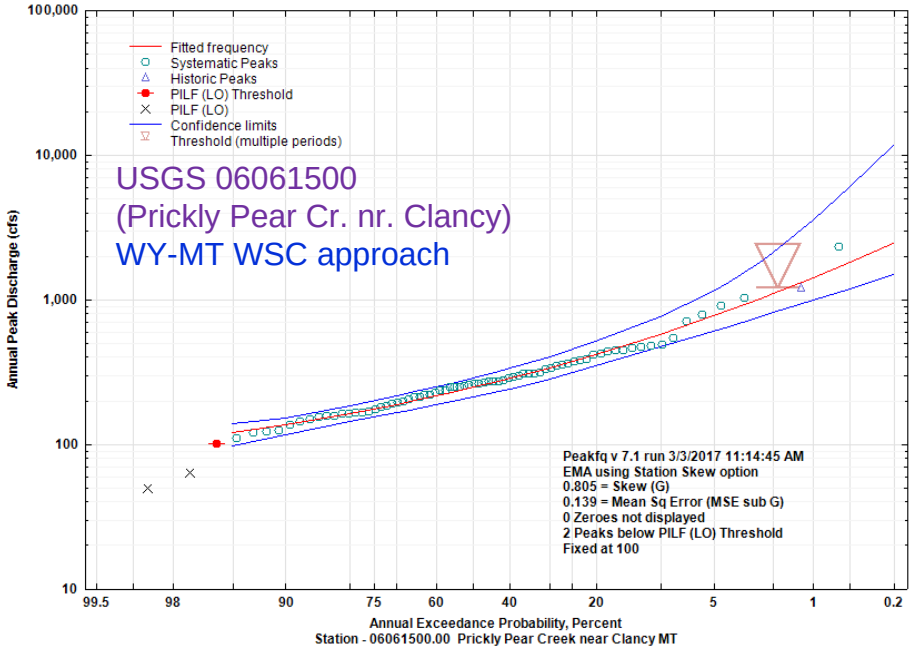


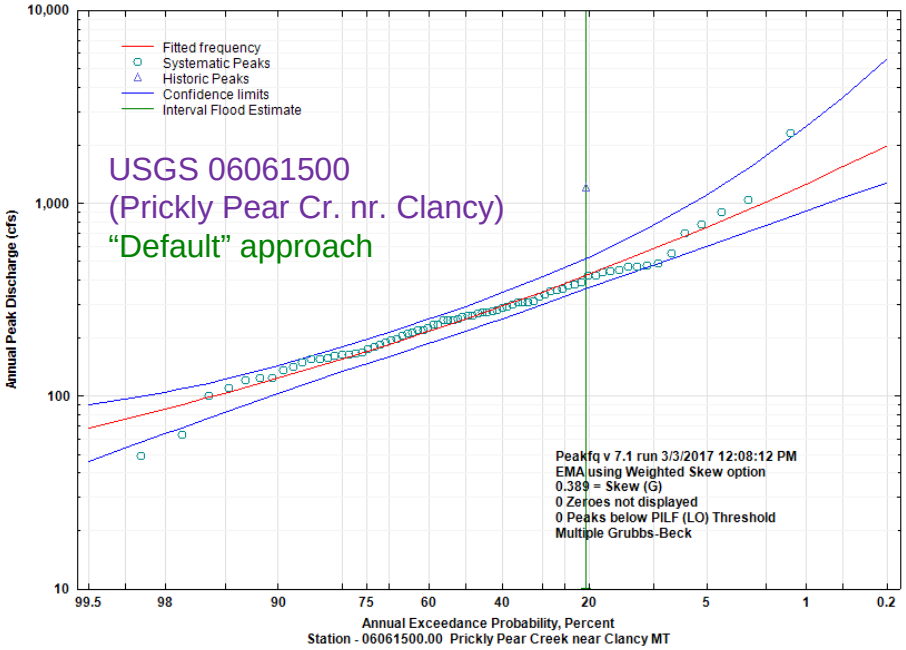


Perception thresholds

5. WY-MT WSC peak-flow frequency procedures

Examples relating to mixed-population issues





USGS

PRESENTATION OUTLINE

Flood-frequency analysis in Montana…it's complicated!

1. Background concepts and terminology
2. Montana flood hydrology--- Big picture complexities
3. Montana flood hydrology --- Smaller picture complexities
4. Compare and contrast --- Bulletin 17B and Bulletin 17C
5. WY-MT WSC peak-flow frequency procedures
6. **PEAKFQv7.1 --- How to run it**
7. Other topics

USGS

6. PeakFqv7.1 --- How to run it

- Download PeakFqv7.1 from: https://water.usgs.gov/software/PeakFQ/
- Download peak-flow data from: https://nwis.waterdata.usgs.gov/mt/nwis/peak
- Open peak-flow data file (or script file) in PeakFqv7.1

Example input file

ppt.peaks.txt - Notepad

File Edit Format View Help

```
Z05014500.00                    USGS
H05014500.00    484755113924003030035SW0904000131.2          4876.78
N05014500.00    Swiftcurrent Creek at Many Glacier MT
Y05014500.00
305014500.00    19130528   1150                4.25
305014500.00    19140604    690                3.40
305014500.00    19150508    600                3.10
305014500.00    19160617   1550                4.75
305014500.00    19170609   1220                4.20
305014500.00    19180610   1280                4.30
305014500.00    19190528   1100                4.00
305014500.00    19200616   1020                3.86
305014500.00    19210526   1100                3.97
305014500.00    19220520    868                3.54
305014500.00    19230601    815                4.38
305014500.00    19240516    771                4.001
305014500.00    19250522   1040                4.76
305014500.00    19260505    491                3.41
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305014500.00    19280523   1120                4.92
305014500.00    19290524    884                4.24
305014500.00    19300520    885                4.44
305014500.00    19310517   1110                4.61
305014500.00    19320522   1360                5.05
305014500.00    19330617   1360                5.00
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305014500.00    19380527   1130                4.61
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305014500.00    19400512    695                3.88
305014500.00    19410518    500                3.37
305014500.00    19420606   1040                4.65
305014500.00    19430618   1630                5.46
305014500.00    19440517    506                3.38
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305014500.00    19460529    798                4.20
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305014500.00    19530613   1320                5.29
305014500.00    19540520   1280                5.25
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305014500.00    19570508    821                4.11
305014500.00    19580510    834                4.25
305014500.00    19590606   1010                4.62
305014500.00    19600617    968                4.53
305014500.00    19610527   1010                4.62
305014500.00    19620610    603                3.62
305014500.00    19630610    825                4.19
305014500.00    19640608   6700               10.00
305014500.00    19650619   1390                5.52
305014500.00    19660611    825                4.19
305014500.00    19670523   1080                4.78
305014500.00    19680919    985                4.57
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Example script file

ppt.peaks.psf - Notepad

File Edit Format View Help

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I ASCI PPT.PEAKS.TXT
O File PPT.PEAKS.PRT
O Plot Style Graphics
O Plot Format PNG
O Additional Watstore PPT.PEAKS.BCD
O Export PPT.PEAKS.EXP
O Empirical PPT.PEAKS.EMP
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     PCPT_Thresh 1909 2015 0 1E+20  DEFAULT
     PCPT_Thresh 1909 1912 3310 1E+20  1975 SYSTEMATIC HISTORICAL PERIOD 1
     BegYear 1909
     EndYear 2015
     HistPeriod 107
     SkewOpt Station
     SkewSE 0.64
     LoThresh 811
     LOType FIXED
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     Analyze EMA
     PCPT_Thresh 1997 2015 0 1E+20  DEFAULT
     BegYear 1997
     EndYear 2015
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     LOType MGBT
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     PCPT_Thresh 1909 1910 1200 1E+20  1975 HISTORICAL PERIOD 1
     PCPT_Thresh 1917 1922 1200 1E+20  1975 HISTORICAL PERIOD 2
     PCPT_Thresh 1934 1945 1200 1E+20  1975 HISTORICAL PERIOD 3
     PCPT_Thresh 1954 1954 1200 1E+20  1975 HISTORICAL PERIOD 4
     PCPT_Thresh 1970 1978 1200 1E+20  1975 HISTORICAL PERIOD 5
     PCPT_Thresh 2003 2005 1200 1E+20  1975 HISTORICAL PERIOD 6
     Peak 1975 1200  H
     BegYear 1909
     EndYear 2015
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     BegYear 1908
     EndYear 2015
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     PCPT_Thresh 1905 1905 150000 1E+20  1964 SYSTEMATIC HISTORICAL PERIOD 2
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     PCPT_Thresh 1947 1947 150000 1E+20  1964 SYSTEMATIC HISTORICAL PERIOD 4
```

USGS

6. PeakFqv7.1 --- How to run it

- "Station Specifications" screen

PeakFQ Version 7.1

File Help

Use File menu to Open PeakFQ data or PKFQWin spec file.
Update Station, Threshold and Output specifications as desired.
Click Run PeakFQ button to generate results.

PeakFQ Data File: C:\Users\sksando\Documents\DNRC_EMA\conf1\PPT.PEAKS.TXT

PKFQWin Spec File: C:\Users\sksando\Documents\DNRC_EMA\conf1\pptpeaks.psf

Station Specifications | Input/View | Output Options | Results

Global Analysis Option: EMA

Global PILF (LO) Test Option: Multiple Grubbs-Beck

Station ID	Analysis Option	Beginning Year	Ending Year	Record Length	Inc Hist Peaks	Skew Option	Generalized Skew	Gen Skew Std Error	Mean Sqr Err	Low Hist Peak	PILF (LO) Threshold	PILF (LO) Test	High Sys Peak	Hi-Outlier Threshold	Gage Base Discharge	Urban/Reg Peaks	Latitude	Longitude	Plot Name
05014500.00	EMA	1909	2015	107	Yes	Station	0.5603261	0.64	0.4096	0	811	Multiple +	6700	0	0	No	48.79861	113.6567	05014500
06006000.00	EMA	1997	2015	19	Yes	Weighted	-0.2267897	0.64	0.4096	0	0	Multiple +	293	0	0	No	44.61694	111.6567	06006000
06061500.00	EMA	1909	2015	107	Yes	Station	0.1718299	0.64	0.4096	1200	100	Multiple +	2300	0	0	No	46.51889	111.9467	06061500
06062500.00	EMA	1908	2015	108	Yes	Station	0.1265453	0.64	0.4096	0	171	Multiple +	3290	0	0	No	46.52389	112.2564	06062500
06099500.00	EMA	1895	2015	121	Yes	Station	0.3127461	0.64	0.4096	0	1839	Multiple +	150000	0	0	No	48.42694	111.8897	06099500
06127100.00	EMA	1962	1976	15	Yes	Weighted	0.0831885	0.64	0.4096	0	0	Multiple +	510	0	0	No	46.51445	108.5781	06127100
06324500.00	EMA	1919	2015	97	Yes	Station	-0.005341155	0.64	0.4096	100000	0	Multiple +	33000	0	0	No	45.05694	105.8783	06324500
06326500.00	EMA	1938	2015	78	Yes	Weighted	-0.2002058	0.64	0.4096	0	0	Multiple +	31000	0	0	No	46.42917	105.3103	06326500.00
12358500.00	EMA	1895	2015	121	Yes	Station	0.4445729	0.64	0.4096	45000	17400	Multiple +	140000	0	0	No	48.49528	114.01	12358500.00

Run PEAKFQ | Save Specs | Exit

Pay close attention to these items:

1. Global Analysis Option (EMA)
2. Beginning Year/Ending Year (historical adjustments)
3. Inc Hist Peaks (Yes)
4. Skew Option
5. Gen Skew Std Error
6. Global PILF (LO) Test Option (Multiple Grubbs-Beck)
7. PILF (LO) Threshold

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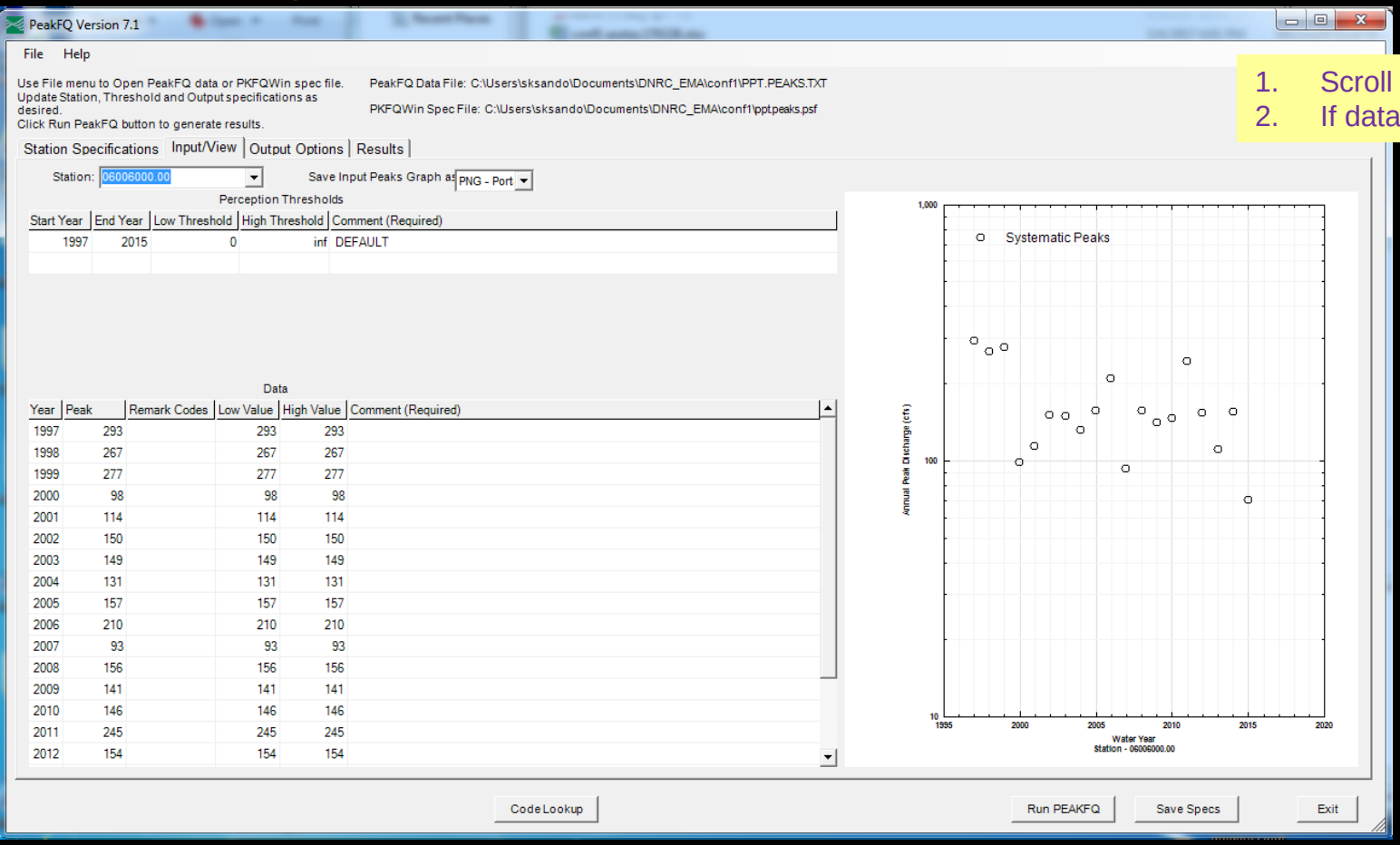
6. PeakFqv7.1 --- How to run it

- "Input/View" screen



1. Scroll through stations
2. If data gaps, assign T_h

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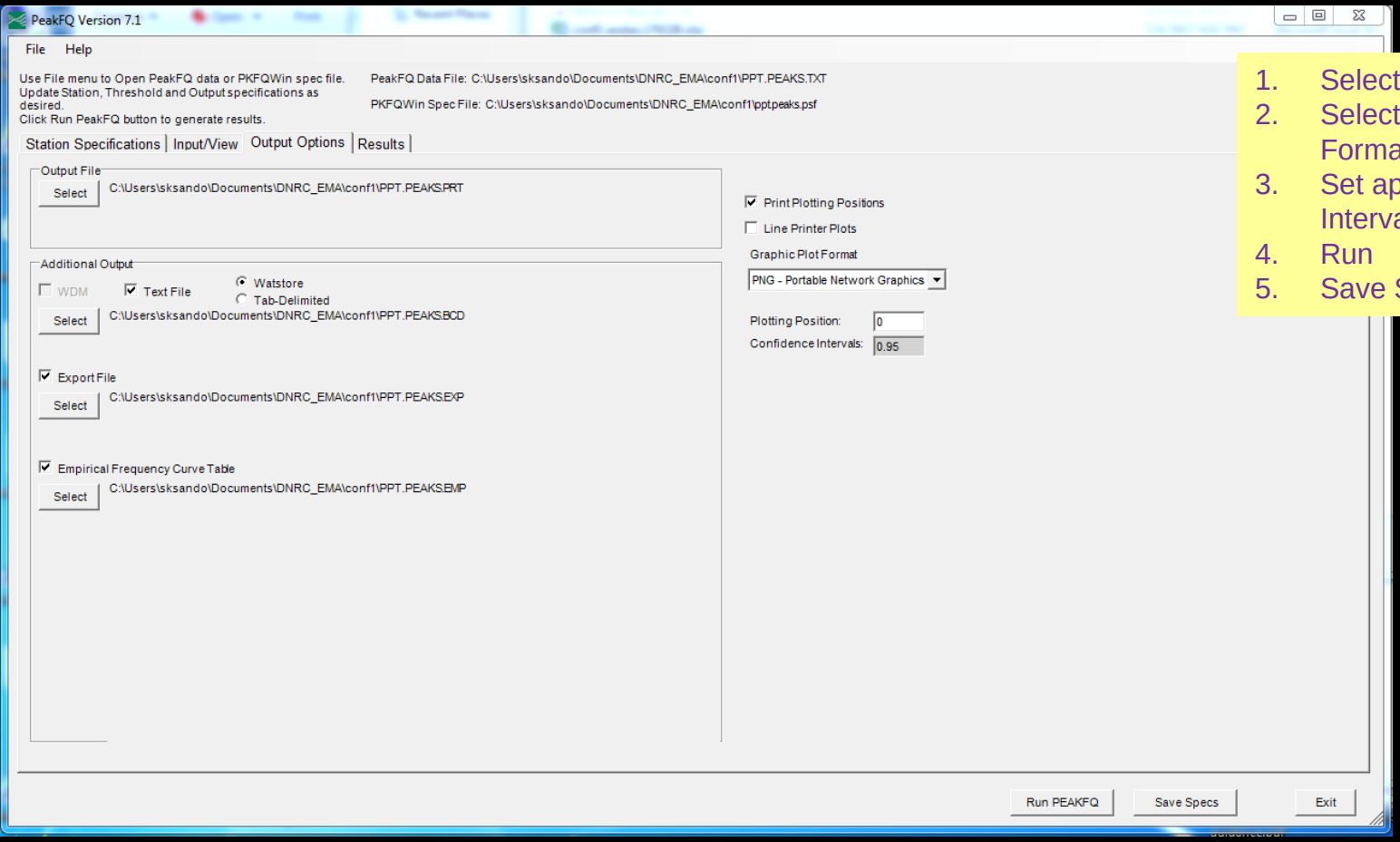
6. PeakFqv7.1 --- How to run it

- "Output Options" screen



1. Select all additional output
2. Select PNG for Graphic Plot Format
3. Set appropriate Confidence Intervals
4. Run
5. Save Specs

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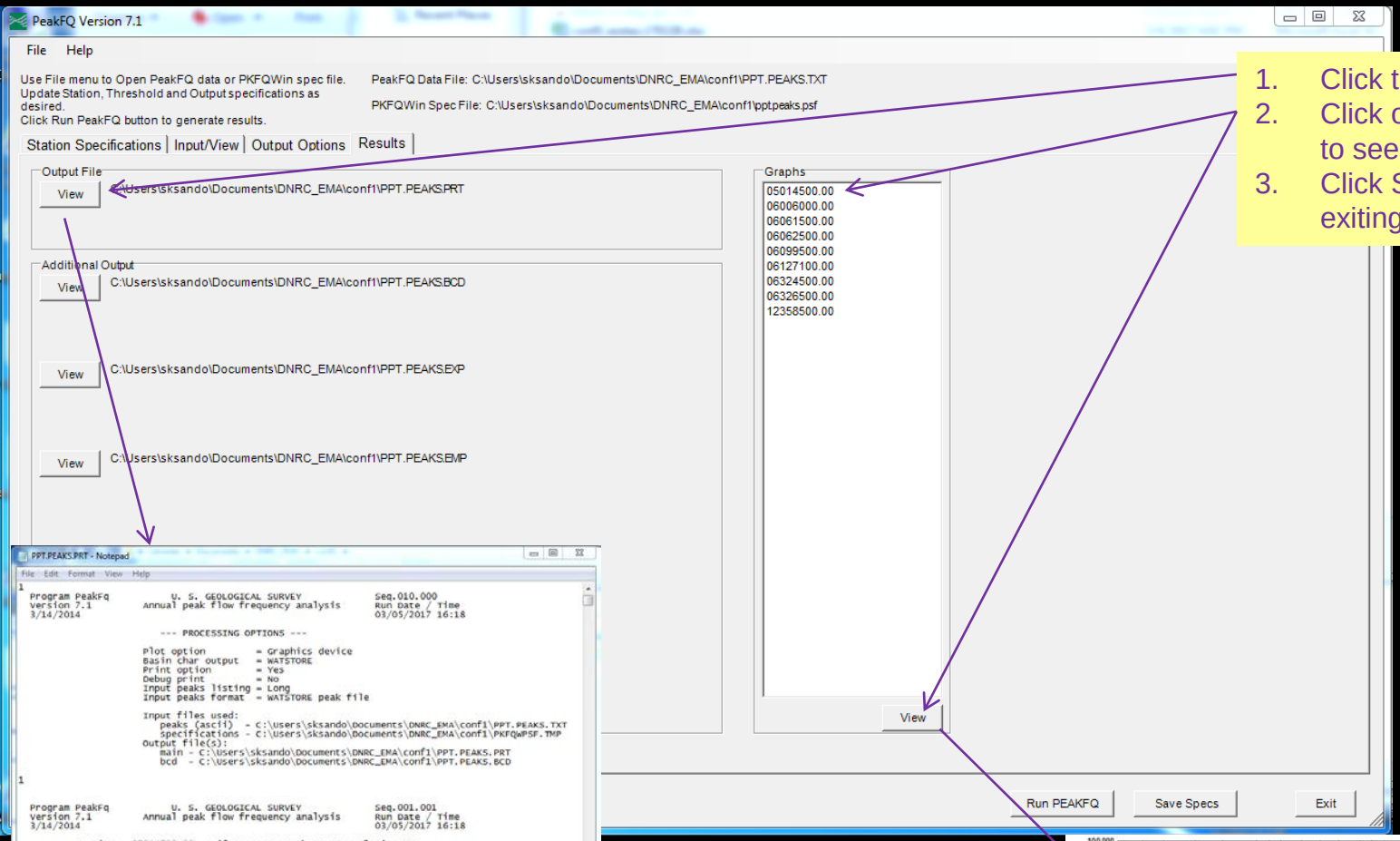
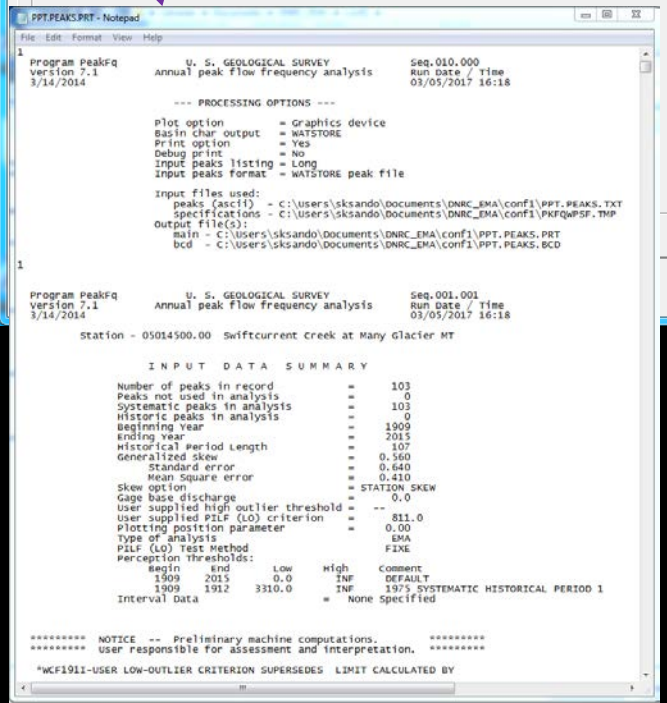
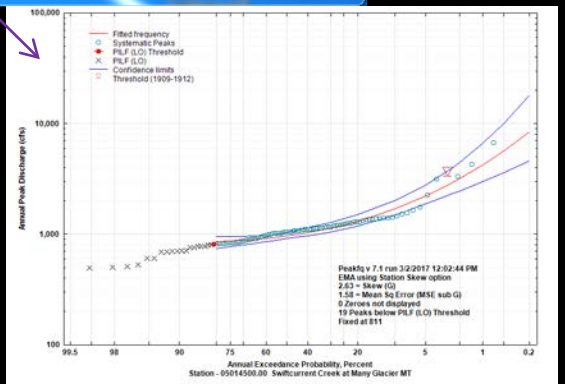
6. PeakFqv7.1 --- How to run it

- "Results" screen



1. Click to open results file (text)
2. Click on a site then click View to see frequency curve
3. Click Save Specs before exiting; important





PRESENTATION OUTLINE

Flood-frequency analysis in Montana…it's complicated!

1. Background concepts and terminology
2. Montana flood hydrology--- Big picture complexities
3. Montana flood hydrology --- Smaller picture complexities
4. Compare and contrast --- Bulletin 17B and Bulletin 17C
5. WY-MT WSC peak-flow frequency procedures
6. PEAKFQv7.1 --- How to run it
7. Other topics

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7. Other topics

Regional Regression Equations (RREs) and weighting at-site frequency analyses

- Each of the 8 hydrologic regions in Montana are large and complex
- The RREs do not capture all of the hydrologic variability and individual streamgages can be poorly represented
- WY-MT WSC reports both at-site frequency analyses and also weighted frequency analyses
- Both the at-site and weighted frequency analyses should be considered with respect to the characteristics of the streamgage and the specific purposes of the application

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7. Other topics

Record extension using MOVE.3

- In cases of multiple streamgages on a single stream channel
- Especially useful in synchronizing frequency analyses for different streamgages with different periods of record
- Synthesize missing peak-flow records for a specified base period
- Closely examine synthesized peaks
- Analyze the combined recorded and synthesized peak-flow datasets using the same methods as at-site frequency analyses
- Account for increased error due to synthesized data in calculating confidence intervals
- MOVE.3 might be a useful tool for special investigation of difficult datasets

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THE END

Flood-frequency analysis in Montana…it's complicated!

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