Lecture 2.2

Bulletin 17C and Expected Moments Algorithm (EMA)

General Data Representation

Flood Frequency Analysis
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Goals

- Discuss a new (and possibly unfamiliar) **data requirement** for flood frequency analysis with Bulletin 17C
- Understand how the generalization of the data description allows more types of information to inform the frequency analysis

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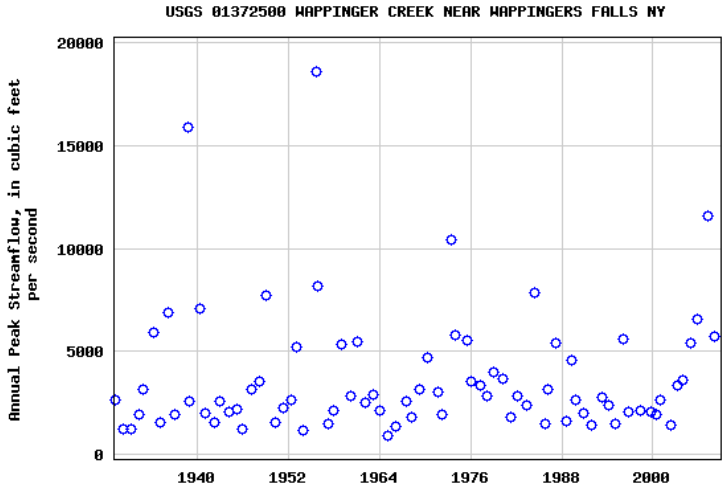
Annual Maximum Stream Flows

gaged flow measurements are POINT values



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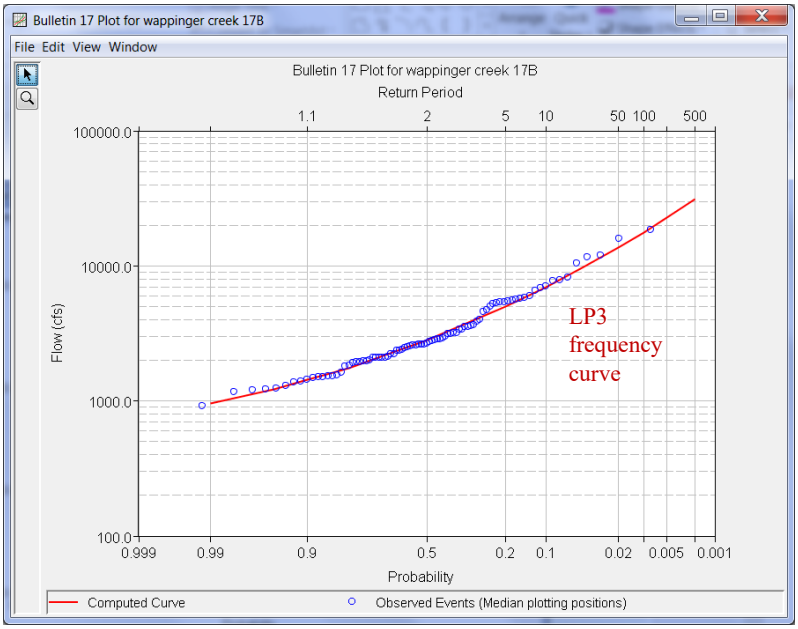
Traditionally, the annual maximum series has a single point value for each year of data.

previous methods estimated the LP3 frequency curve from the point values

(and some adjustments)



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The method of frequency analysis (frequency curve fitting) used in Bulletin 17B was able to use point values to estimate an annual peak flow frequency curve. Some non-point information could be used – the fact that a period of historical years did not exceed a threshold – but other information could not.

17C: Generalized Data Description

There is a **new requirement** for input to a frequency analysis

For **every year** in the *systematic* (gaged or equivalent) and *historical* period of record, must define two things:

1. Flow interval
   - Range that describes the annual peak flow of that year
2. Perception threshold range
   - Reflects the range of flow that would have been recorded (in some way) had it occurred in each year
   - *meaning, the flows that would have left some evidence*
   - implies implies a flow range for unobserved

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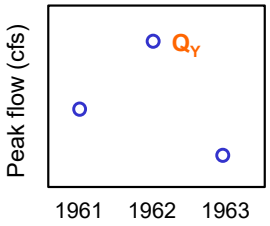
Every year of the record must have both a flow interval and a perception threshold range, but these can be very simple and are pre-defined for systematic gage data.

1. Annual Peaks as Flow Intervals

- Conventional ("Point"):

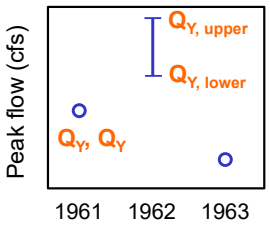
  Represent each observation, Q_Y, by a single value, Q_Y



- Generalized ("Interval"):

  Represent each *"observation,"* Q_Y, by an interval, $(Q_{Y,lower}, Q_{Y,upper})$

  - for a point, just (Q_Y, Q_Y)



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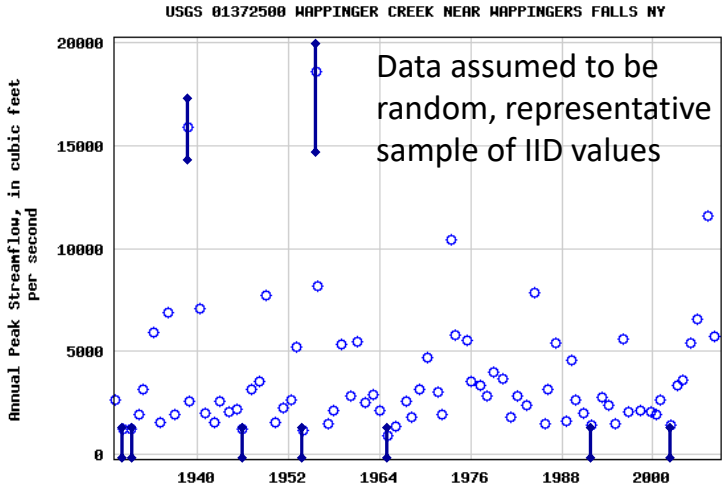
Above is the typical point data we are accustomed to. Below is an interval, that allows an annual peak flow value to be specified as a range.

Annual Maximum Stream Flows

Can represent some years as flow INTERVALS – uncertain or unobserved



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Here's how the annual maximum series of peak flow might look with some intervals specified. Here, they're sued for uncertainty in the large values, and for flows below the gage base in the low values.

Interval Data Can Represent…

- Uncertain flow estimates
- Limited range of measurable flow
  - *crest stage gages* …below a threshold
- Low outliers, or PILFs
  - *censored, and redefined as interval below*
- Historical and paleo flood information
- Years with information about threshold exceedance or non-exceedance
  - *Tree or slack water deposit provides minimum for an occurrence*
  - *Landmark never flooded provides maximum for unobserved years*

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Historical and paleo – knowledge that large event happened in the past, and some info on return period, or knowledge that gaged flow has longer return period, or that no large floods happened…

Historical = information from record keeping, often during the period of human habitation. This includes large flood before the gage, large flood during gage record that is known to be largest in longer period, years before gage known not to exceed some value

Paleo = geological and physical evidence, often before human record though can be during. Includes rare floods, or absence of floods

Estimate of flood magnitude, or defined threshold which has either been exceeded, or not been exceed. (slack water deposits, scars on trees, overturned trees with new sprouts

Potomac River at Great Falls Park, VA

(Source: John England, USBR)

Crooked River near Prineville, OR, 1861 flood

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These are other forms of historical information. The flood level sign along the Potomac River shows the levels of the large floods.

Paleo: The "schooner" trees in Oregon are physical evidence of a large flood. A flood large enough to knock over the trees happened, but the trees lived and sent up new trunks vertically. By coring and dating the new trunk, we can determine the date of the flood. This flood is a threshold exceedance, because we only know it was at least to the level of the tree, but not how much higher it was.

1. Flow Intervals

Continuous Gage – *Systematic Data*

Gaged estimate of annual peak flow:

$(Q_{Y,lower}, Q_{Y,upper}) = (Q_Y, Q_Y)$

Other types of data

Uncertain estimate (perhaps historical event):

$(Q_{Y,lower}, Q_{Y,upper}) = (Q_{Y,lower}, Q_{Y,upper})$

Censored exceedance:

$(Q_{Y,lower}, Q_{Y,upper}) = (Q_{Y,min}, \infty)$

Censored non-exceedance:

$(Q_{Y,lower}, Q_{Y,upper}) = (0, Q_{Y,max})$

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For systematic gage data, the interval has no width and is just the measured value.

For an uncertain estimate, can describe a range. For a year where it is only known that a flood exceeded a given value, the range is the value to infinity. For a year in which it is known that a flow did NOT exceed some value, the range is zero to that value.

2. Perception Thresholds

- Reflects what flow range we can/could perceive
- The range of flows that would have left some kind of ***evidence*** in the watershed, had they occurred
- $(T_{Y,lower}, T_{Y,upper})$, usually $(T_{Y,lower}, \infty)$

  $T_{Y,\,lower}$ = smallest peak that would result in a documented flow

  $T_{Y,\,upper}$ = largest peak that would result in a documented flow

  usually ∞

- Perception thresholds are, theoretically, ***independent*** of actual peak discharges that have occurred

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Perception thresholds describe our ability it perceive floods in the watershed, generally flood large enough that they would leave some physical evidence in the watershed or would have been noted by people nearby and recorded.

The low end of the range is the smallest value that would leave evidence. The high end of the range is nearly always infinity.

Theoretically, our ability to perceive flows in the watershed is independent of what has actually occurred. However, sometimes our only information about perception thresholds is the fact that some large events occurred and were noted in the historical period before the gage.

2. Perception Thresholds

- For periods of continuous, full-range streamgage, ***systematic***:
  - $(T_{Y,lower}, T_{Y,upper})$ = **(0, ∞)**
- For periods with **no information** about streamflow:
  - $(T_{Y,lower}, T_{Y,upper})$ = **(∞, ∞)**
- For periods prior to (or after) direct observation, but with historical or geologic evidence:
  - $(T_{Y,lower}, T_{Y,upper})$ = (threshold, ∞)
- *Perception thresholds imply a complementary flow range for unobserved years in analysis period (ie, was below the threshold)*

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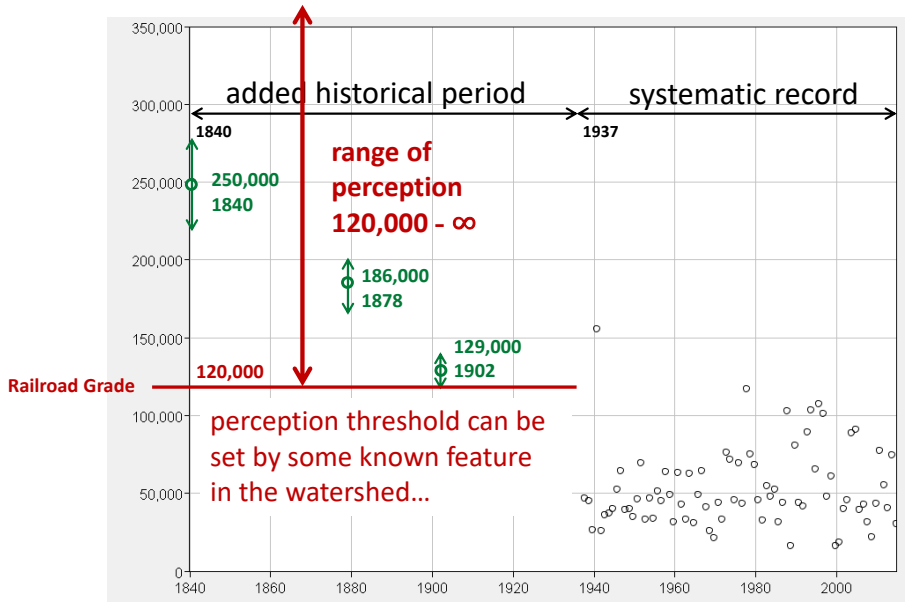
When a gage is present, it is assumed all flows would have been perceived, so the range is 0 to infinity

When nothing is known, such as the gage out of service, the range is infinity to infinity.

For periods when some threshold is known for flows that would have brought attention or left evidence if they were exceeded, the range is the threshold to infinity.

For unobserved years, saying that we would have observed the flow if it was above the threshold implies that if we didn't, it was below the threshold, which suggests a complementary flow range of 0 to the threshold.

Data, Ranges and Thresholds



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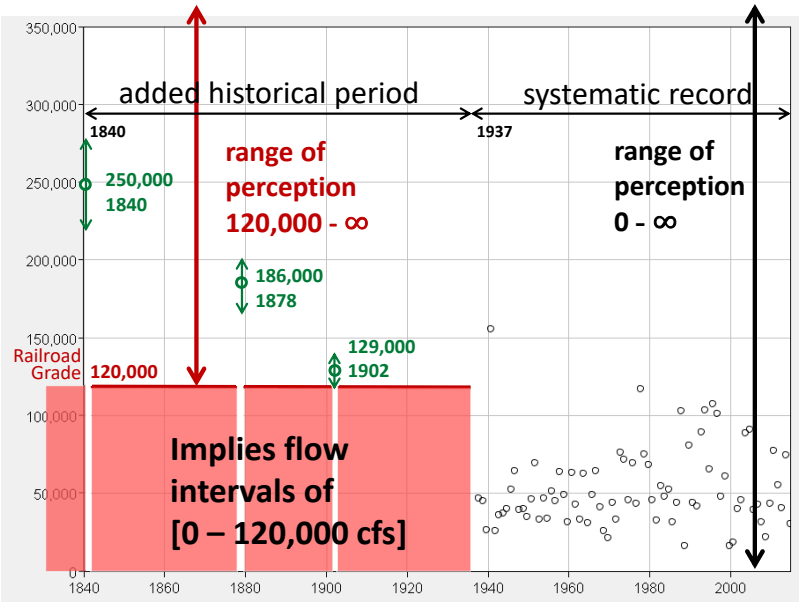
This data set has a systematic period, and a historical period with some observed large events. The large events can be specified as intervals to describe the uncertainty in their estimation.

The watershed might have a feature like a railroad grade that would have been damaged if flooded. Therefore, it can be used as a perception threshold for the period it existed. This one defines a perception range of 120,000 cfs to infinity.

Data, Ranges and Thresholds



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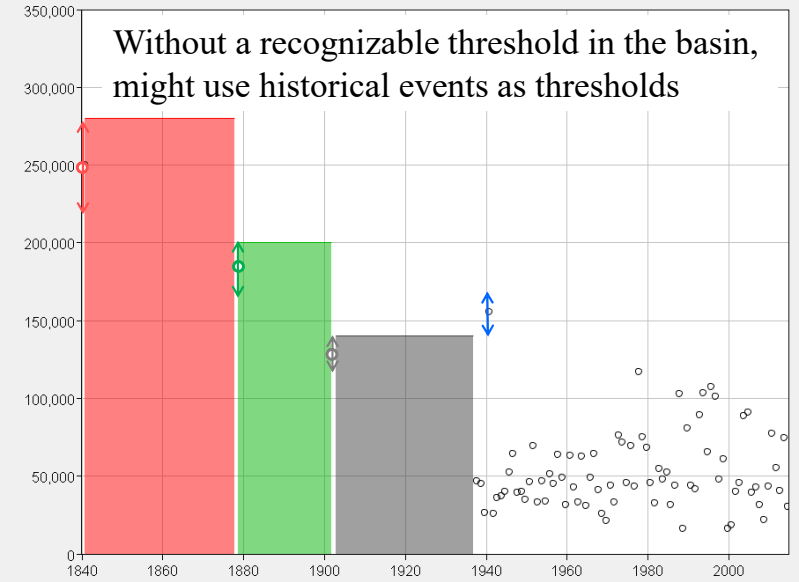
The perception threshold for the historical period implies a flow range for all the unobserved years in the historical period. If they were not noted, they must not have exceeded the threshold.

Perception Thresholds



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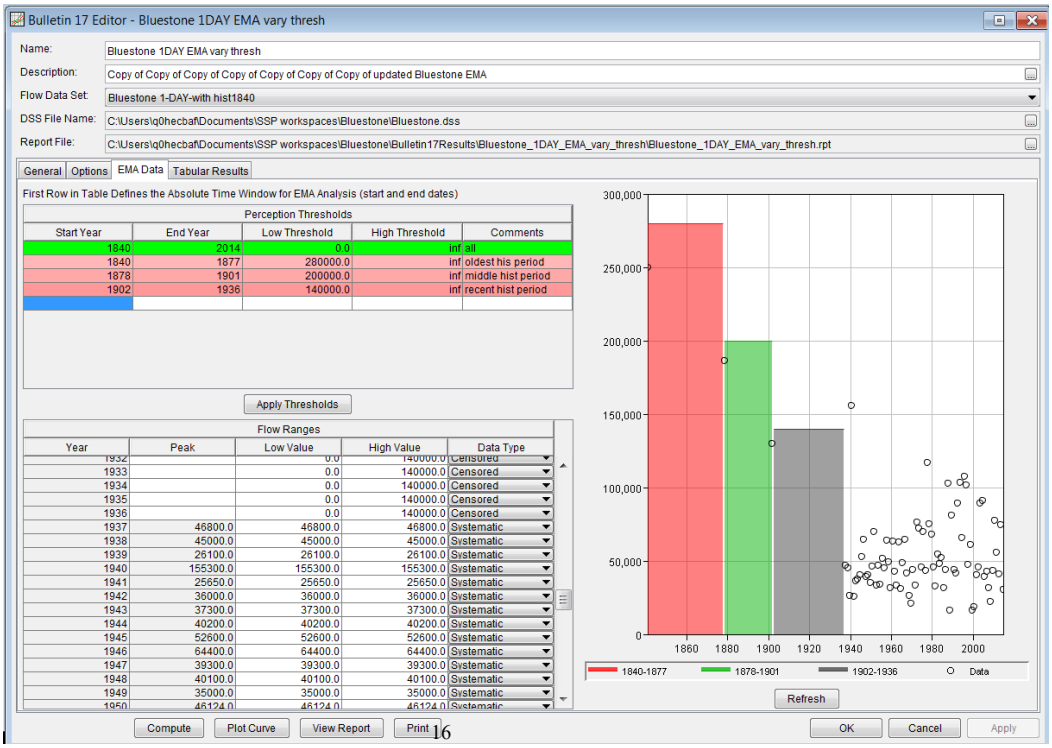
When there is no recognizable threshold in the basin, we might use the historical events, which were observed in some way and recorded, as thresholds for the period since the event occurred. In this case, we case say we'd have seen 140,000 since 1902, but we can't say for sure we'd have seen it before 1902, so we use 200,000 cfs after that flow was observed and until 1902. Same for 280,000 cfs between 1840 and 1878.



This is the HEC-SSP interface for Bulletin 17C. This is the EMA data tab. The table on top lists the perception threshold ranges, and the table on the bottom lists the known peak flows and flow ranges. Systematic data has the peak value as the range, and the unobserved historical years have the complement of the perception threshold range as the flow range.