USGS
science for a changing world

Preliminary Long-Term and Recent-Term Trend Analysis Results for Floods and High Flows in Iowa

Presented at the National Hydraulic Engineering Conference

Iowa City, IA

August 21, 2014

by David Eash

U.S. Geological Survey
Iowa Water Science Center
Iowa City, IA 52240
319-358-3615
daeash@usgs.gov

Iowa streamflow statistics study

- Compute streamflow statistics for all Iowa continuous-record streamgages for both the entire period of record and for the 1984-2013 record
- Statistical analyses include annual probabilities for instantaneous peak flow, high-flow for 1-, 3-, 7-, 15, and 30-day consecutive periods, low-flows for 1-, 3-, 7-, 14-, 30-, 60-, 90, 120-, and 183-day consecutive periods, and 23 flow-duration statistics that include 1 – 99% exceedance probabilities

Study cooperators

- Iowa DOT and Iowa Highway Research Board
- U.S. Army Corps of Engineers
- USGS Cooperative Water Program

USGS student help with statistical analyses:
Padraic O'shea
Adrian Simonson

Stationarity

- One of the key assumptions of streamflow probability analyses
- Stationarity, is the idea that the flood-, or high-flow-, or low-flow-generating mechanism fluctuates within an unchanging envelope of variability
- Stationarity assumes that future streamflow probabilities can be estimated on the basis of past streamflow probabilities
- Stationarity Is Dead: Whither Water Management? http://www.gfdl.noaa.gov/bibliography/related_files/pcm0801.pdf (Milly and others, 2008)

Trend analyses

- Kendall's tau hypothesis test was used to analyze for trends for both the entire period of record (long-term analyses) and for the 1984-2013 period of record (recent-term analyses) for all continuous-record streamgages in Iowa
- For this presentation, a subset of these streamgages with complete record for the period 1964-2013 were selected for evaluation
- Preliminary trend analysis results are presented for 55 USGS streamgages in Iowa

Kendall's Tau trend analyses

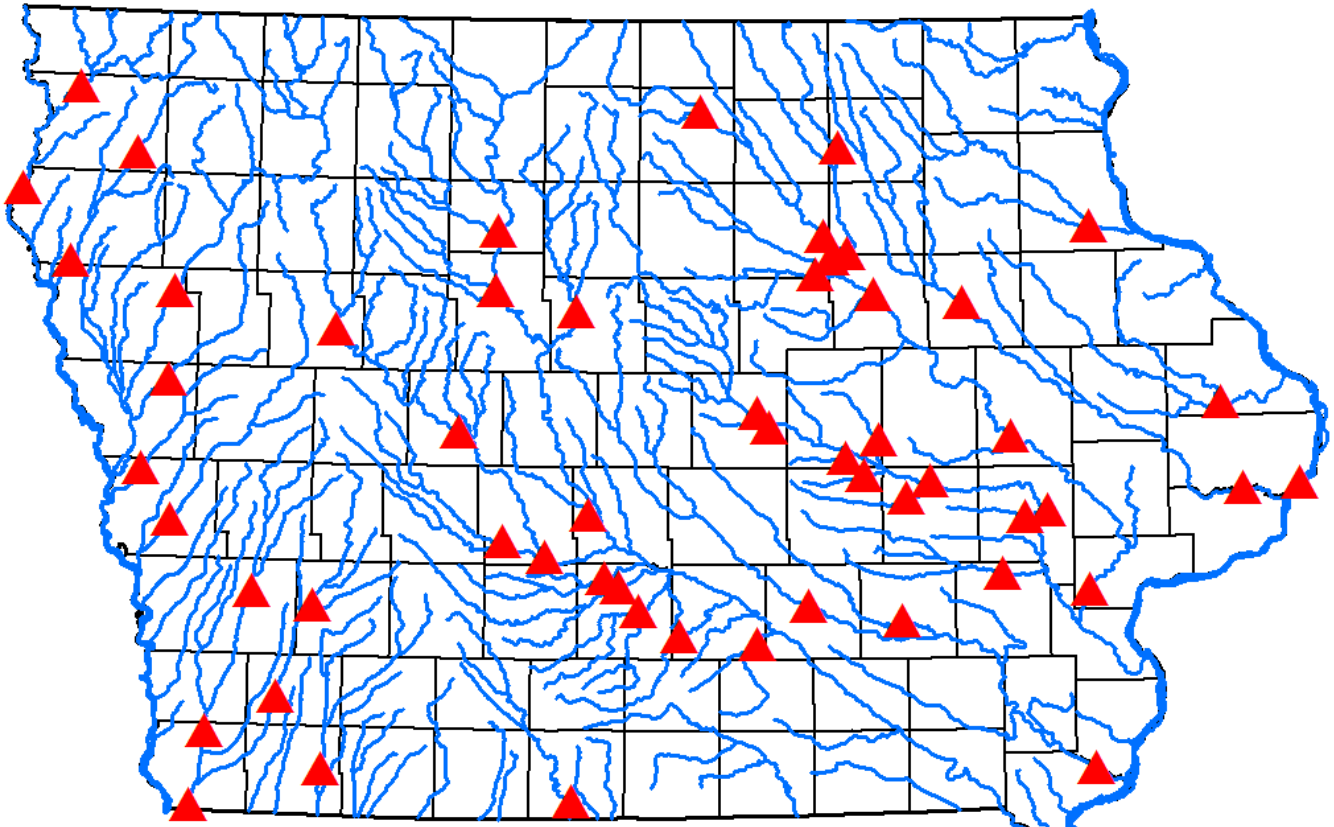
- Computes a monotonic relation between discharges and time (for water years or climatic years)
- A nonparametric test that indicates the likelihood of a positive or negative trend with time
- Kendall's tau test compares the rank of each annual discharge value with the rank of values following it in the series – if the second value is consistently greater than the first, the Kentau coefficient is positive, if the second value is consistently lower, the Kentau coefficient is negative

Kendall's Tau trend analyses (cont.)

- The Kentau coefficeint value is a measure of the correlation between the series and time
- A Ken p-value threshold of 5% (α=0.05) was used for the Kendall's tau test, and Ken p-values less than or equal to 5% indicate statistically significant trends (positive or negative)
- Results may be sensitive to multiyear sequences of larger or smaller values on either end of the record
- Kendall's tau trend tests were performed using USGS SWSTAT and PeakFQ programs

Location of 55 streamgages

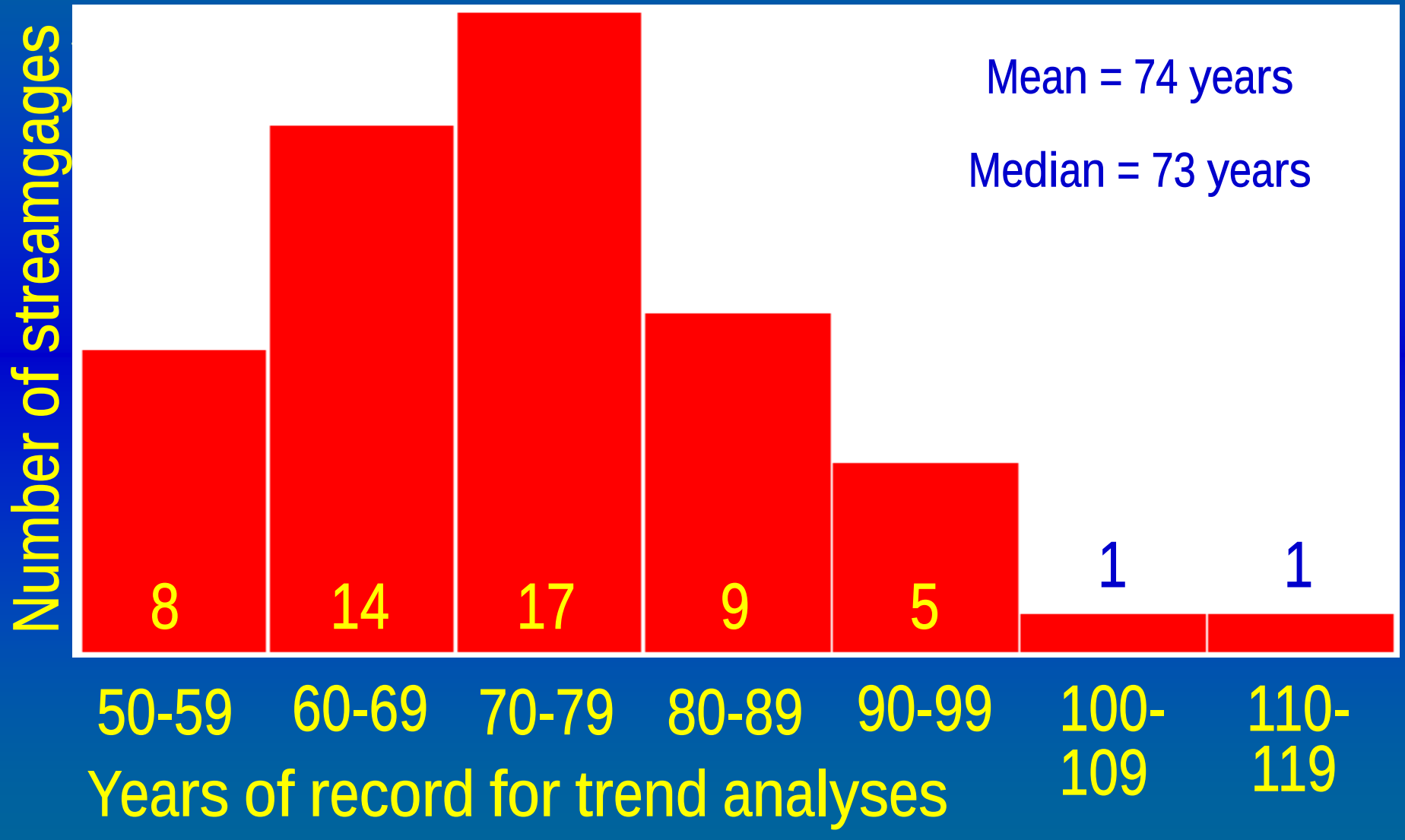
Complete streamflow records from 1964 to 2013



Drainage areas ranged from 25.3 to 85,600 mi^2

Mean drainage area size = 3,053 mi^2 and median = 846 mi^2

Record lengths of 55 streamgages



Magnitude of streamflow statistics for Cedar River at Cedar Rapids 05464500

High flows	Discharge (ft^3/s)			Low flows	Discharge (ft^3/s)	
Peak flow	(WIE, RI=50)	81,700		50% exceeds		2,270
High 1-day	(LP3, RI=50)	80,400	NWS	75% exceeds		1,150
High 3-day	"	74,100	action	90% exceeds		694
High 7-day	"	57,600	stage	95% exceeds		544
High 15-day	"	42,200	for	99% exceeds		345
High 30-day	"	30,700	flooding=	Low 90-day	(LP3, RI=50)	331
1% exceeds		26,200	24,600 ft^3/s	Low 60-day	"	299
2% exceeds		20,400		Low 30-day	"	269
5% exceeds		13,100		Low 14-day	"	250
10% exceeds		8,960		Low 7-day	"	239
25% exceeds		4,550		Low 3-day	"	229
				Low 1-day	"	205

USGS

Trend analysis results for high flows for period of record for 55 streamgages

Streamflow	No. of significant trends ($p \leq 0.05$)	Percent with significant trends	Number with positive trends	Number with negative trends
Peak flow	10	18	8	2
High 1-day	9	16	9	0
High 3-day	9	16	9	0
High 7-day	12	22	12	0
High 15-day	20	36	20	0
High 30-day	25	45	25	0
1% exceeds	10	18	9	1
2% exceeds	16	29	16	0
5% exceeds	30	55	30	0
10% exceeds	44	80	44	0
25% exceeds	46	84	46	0

Trend analysis results for low flows for period of record for 55 streamgages

Streamflow	No. of significant trends ($p \leq 0.05$)	Percent with significant trends	Number with positive trends	Number with negative trends
50% exceeds	44	80	44	0
75% exceeds	49	89	49	0
90% exceeds	50	91	50	0
95% exceeds	50	91	50	0
99% exceeds	50	91	50	0
Low 90-day	44	80	44	0
Low 60-day	46	84	46	0
Low 30-day	53	96	53	0
Low 14-day	55	100	55	0
Low 7-day	55	100	55	0
Low 3-day	52	95	52	0
Low 1-day	51	93	51	0

Trend analysis results for high flows for 1984-2013 record for 55 streamgages

Streamflow	No. of significant trends ($p \leq 0.05$)	Percent with significant trends	Number with positive trends	Number with negative trends
Peak flow	1	2	1	0
High 1-day	0	0	0	0
High 3-day	0	0	0	0
High 7-day	0	0	0	0
High 15-day	0	0	0	0
High 30-day	0	0	0	0
1% exceeds	0	0	0	0
2% exceeds	0	0	0	0
5% exceeds	0	0	0	0
10% exceeds	0	0	0	0
25% exceeds	0	0	0	0

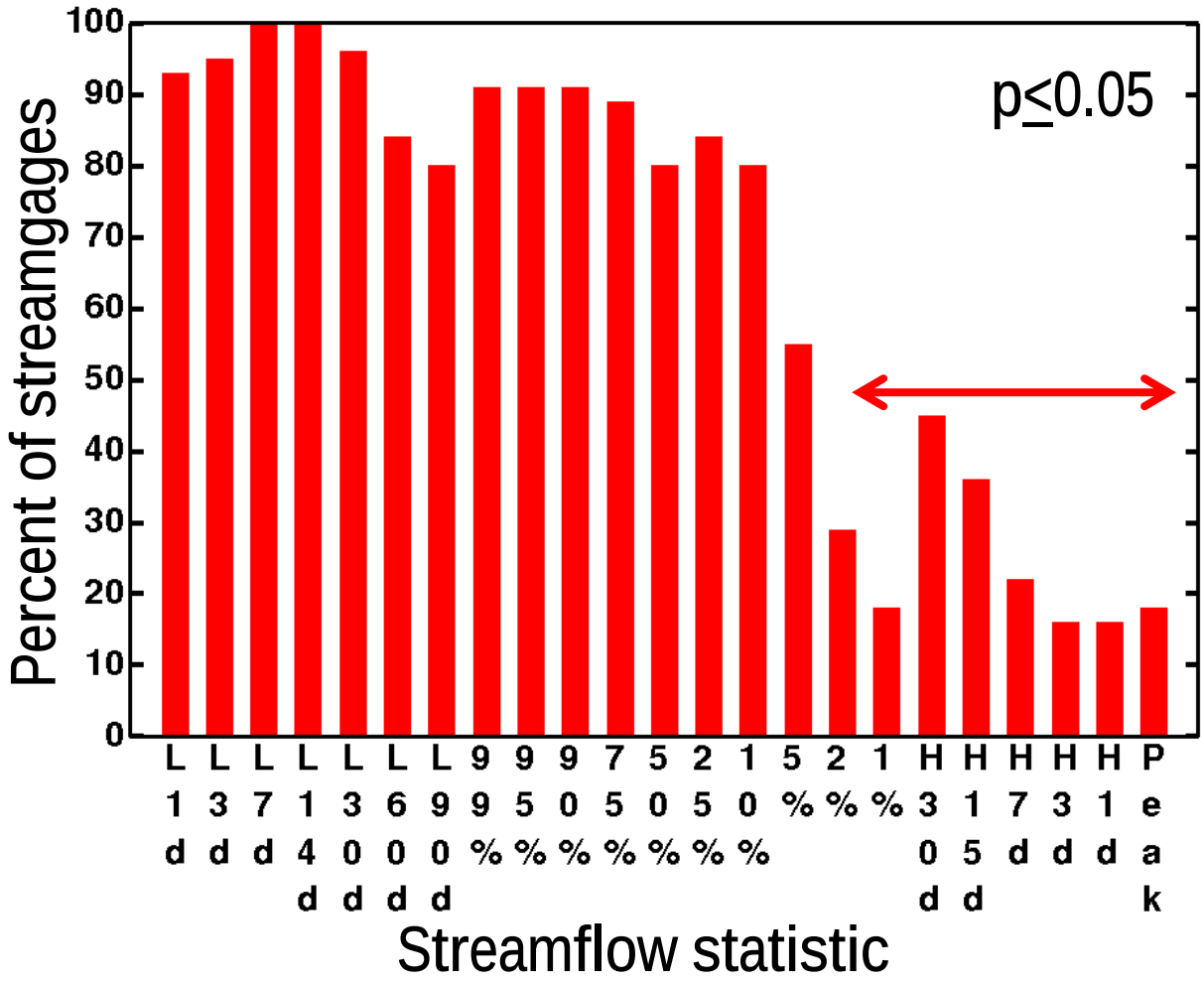
Trend analysis results for low flows for 1984-2013 record for 55 streamgages

Streamflow	No. of significant trends ($p \leq 0.05$)	Percent with significant trends	Number with positive trends	Number with negative trends
50% exceeds	0	0	0	0
75% exceeds	0	0	0	0
90% exceeds	0	0	0	0
95% exceeds	0	0	0	0
99% exceeds	2	4	2	0
Low 90-day	0	0	0	0
Low 60-day	1	2	0	1
Low 30-day	0	0	0	0
Low 14-day	0	0	0	0
Low 7-day	0	0	0	0
Low 3-day	0	0	0	0
Low 1-day	0	0	0	0

Trend analysis results for high flows for years of record for 53 streamgages

	Percent of significant positive trends for				
Streamflow	50-59 yrs, n = 8 (1955-63)	60-69 yrs, n = 14 (1946-54)	70-79 yrs, n = 17 (1935-42)	80-89 yrs, n =9 (1915-34)	90-99 yrs, n = 5 (1903-15)
Peak flow	12.5	0	12	44	20
High 1-day	12.5	0	6	0	20
High 3-day	12.5	0	12	0	20
High 7-day	25	0	18	0	40
High 15-day	37.5	36	47	11	40
High 30-day	50	36	59	11	60
1% exceeds	25	7	24	0	40
2% exceeds	25	36	59	0	40
5% exceeds	87.5	50	76	22	80
10% exceeds	100	86	88	78	100

Percent of streamgages, out of total of 55, with statistically significant positive trends for the POR



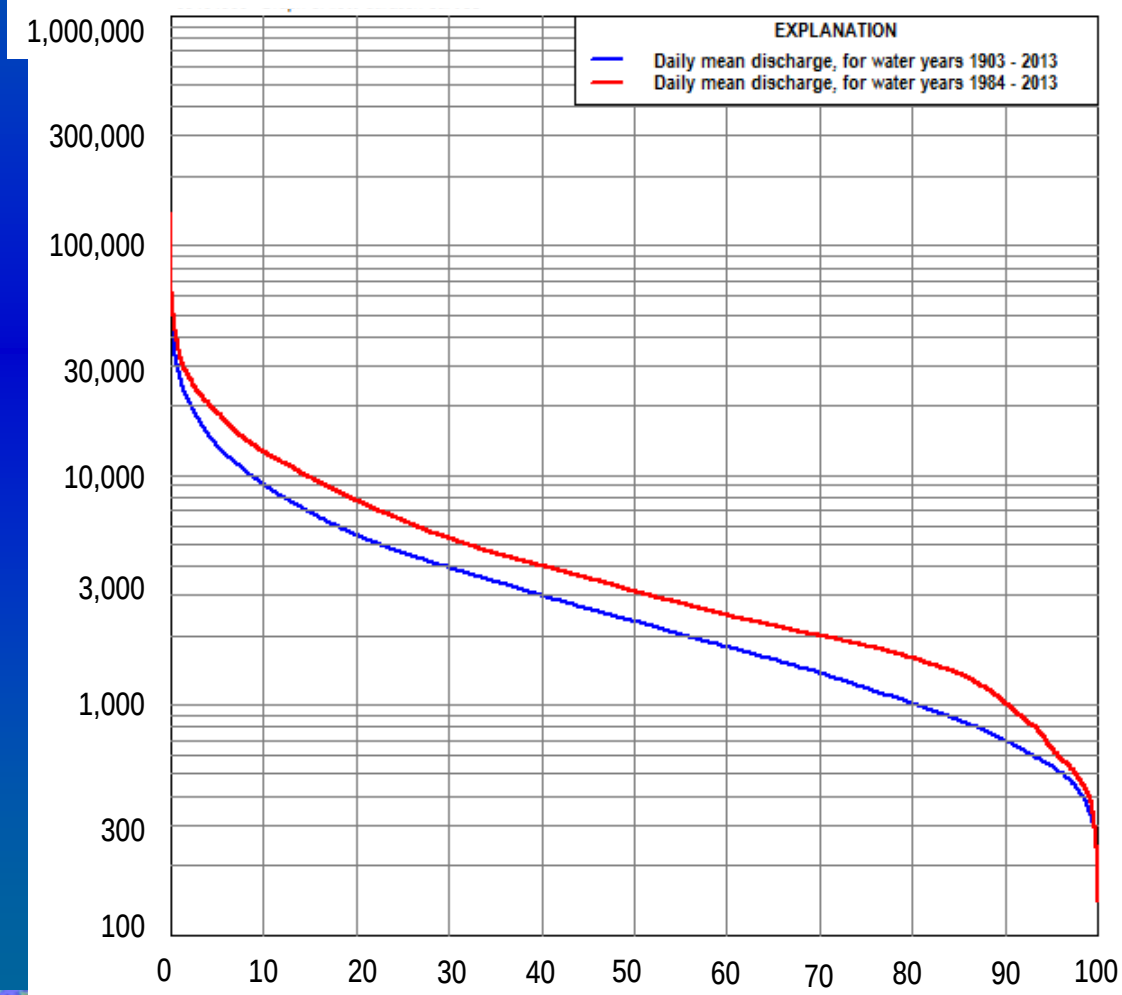
Summary of trend analysis results

- Sig trends are positive, few negative trends
- Long-term (period of record) analyses: high flows indicate sig trends for 16-45% of streamgages and low flows indicate sig trends for 80-100% of streamgages, strong pattern of increasing number of trends from high-flow to low-flow statistics – notable increase around 5-10% exceedance flows, maybe some trend differences in high flows due to record lengths
- Recent-term (1984-2013) analyses: no trends (2-4%) for entire range of streamflow statistics

Possible causes for period of record streamflow trends in Iowa

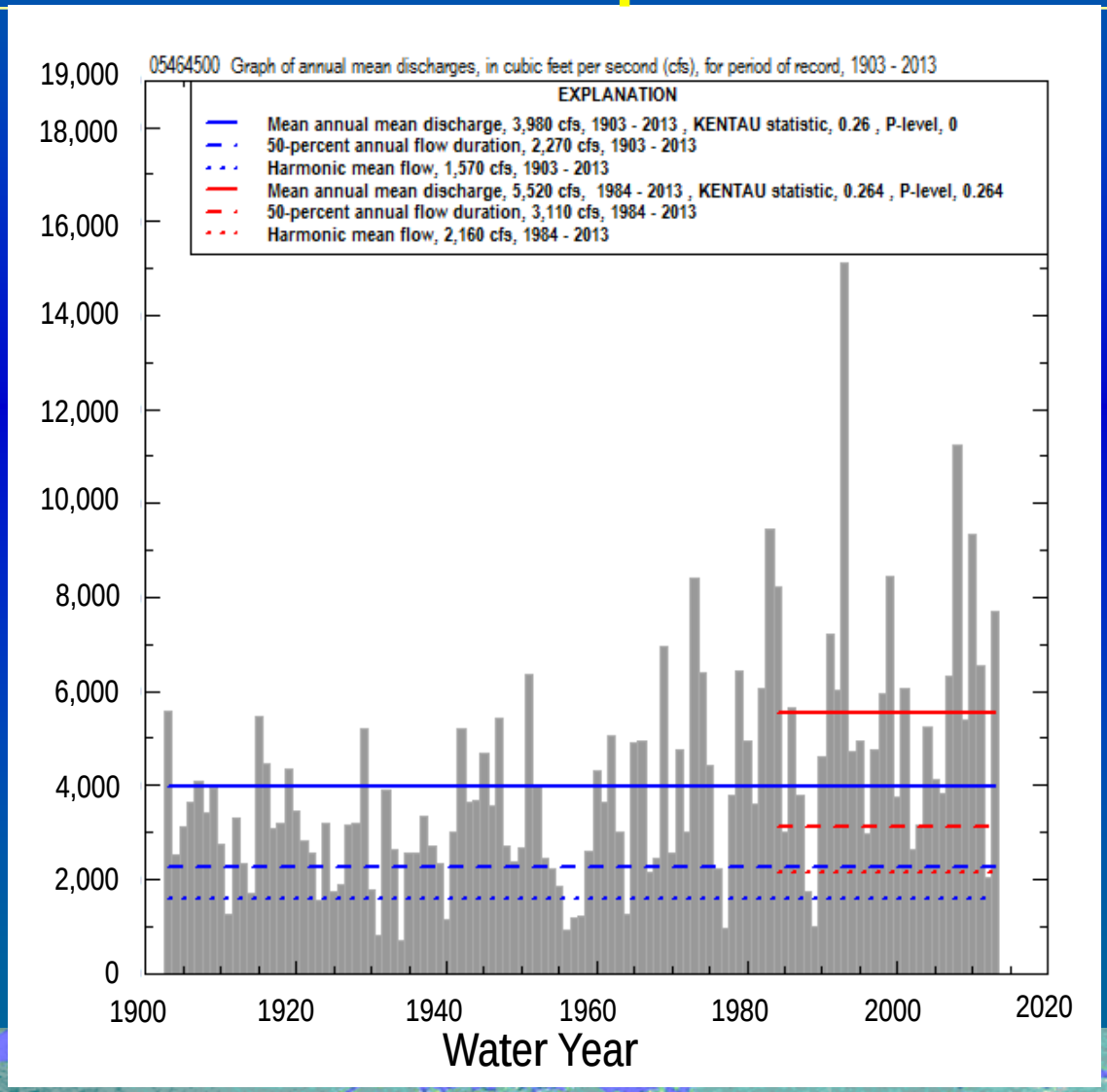
- High flows: Proportion of total precipitation contributed by extreme, one-day events has increased significantly during the last century; although increases in precipitation are modest, they are concentrated in the high-flow statistics
- Low flows: Increases in row-crop production are related to increases in base flows; increased base flows could also be caused by improved conservation practices, added artificial drainage, and channel incision

Flow-duration curves for Cedar River at Cedar Rapids 05464500



USGS

Annual mean discharges for Cedar River at Cedar Rapids 05464500



USGS

Mean daily mean discharges for Cedar River at Cedar Rapids 05464500

USGS

Conclusions

- Sig trends in Iowa are positive, few negative trends
- Long-term (period of record) analyses: Few streamgages (16-45%) with trends for high flows, many streamgages (80-100%) with trends for low flows
- Recent-term (1984-2013) analyses: No trends (2-4%) for entire range of streamflow statistics
- Assumption of stationarity is a concern, to minimize the bias of significant trends, streamflow statistics, other than peak flow, can be computed using a common or a variable record length without a significant trend

QUESTIONS

USGS