INCORPORATION OF CLIMATE CHANGE IMPACTS INTO INLAND HYDROLOGIC ANALYSIS

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PRESENTATION OUTLINE

I. Brief Overview of Guidance

II. Application

   i. Appropriate Role in Planning Process
   ii. Tailor to Project Purpose
   iii. Need for Exploratory Analysis
   iv. Requirements
   v. Addressing Uncertainty

III. Case Study

IV. Pathforward

USACE CLIMATE ADAPTATION POLICY: JUNE 2011 UPDATED JUNE 2014 TO REFLECT EO 13653

"It is the policy of USACE to integrate climate change preparedness and **resilience planning** and actions in all activities for the purpose of enhancing the resilience of our built and natural water-resource infrastructure and the effectiveness of our military support mission, and to **reduce the potential vulnerabilities** of that infrastructure and those missions to the effects of climate change and variability"

- ***Integrate best available and actionable climate science*** and climate change information at appropriate level of analysis into ***long-term planning, setting priorities, and making decisions***

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http://www.corpsclimate.us/adaptationpolicy.cfm

IN THE NEWS…

- Executive Order 13783 Issued in March 2017 – "**Presidential Executive Order on Promoting Energy Independence and Economic Growth"**
- Revocation of EO 13690, "**Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input"**

- ***Continue to implement climate preparedness and resilience activities until otherwise notified***
  - Comply with USACE policy and technical guidance until otherwise notified – all of which comply with other laws and authorities
  - Ensure the reliable performance and cost-effectiveness of our missions and operations both today and in the future

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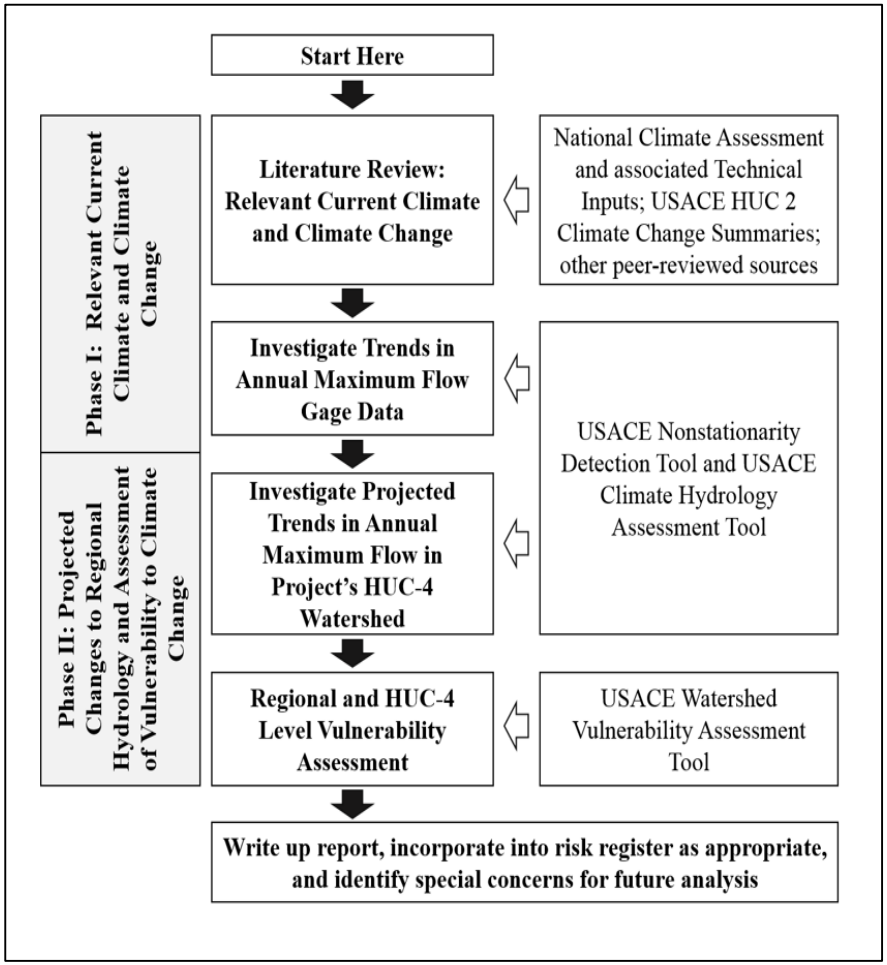
ECB 2016-25: GUIDANCE FOR INCORPORATING CLIMATE CHANGE IMPACTS TO INLAND HYDROLOGY IN CIVIL WORK STUDIES, DESIGNS, AND PROJECTS

- Requires **Qualitative** Analysis
- **Resilience** & **Adaptability** in Design & Decision making
- Key Components:
  - Literature Review
  - Considers Trends in both past (observed) & projected (future) changes to hydrologic inputs
  - Vulnerability Assessment
  - Nonstationarity Detection



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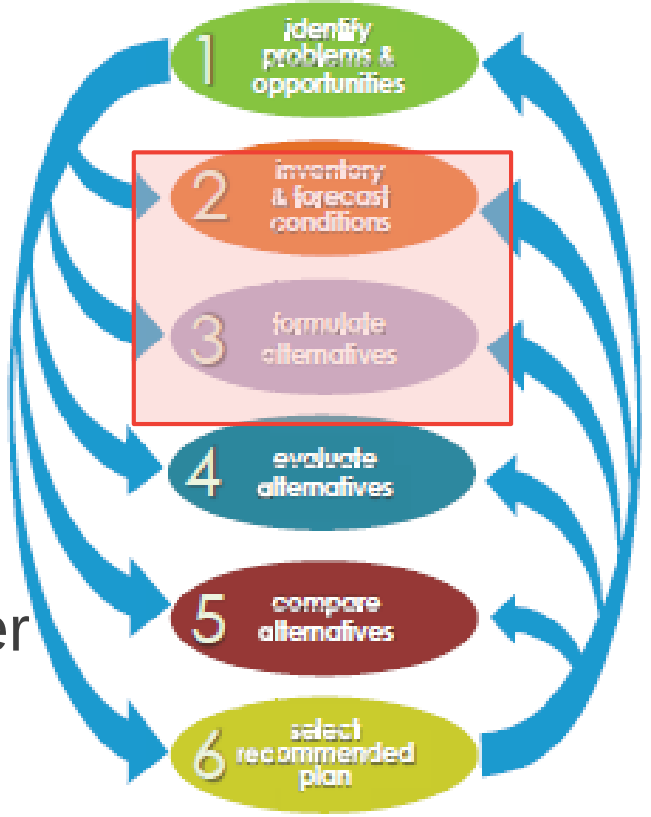
APPROPRIATE EXECUTION AND APPLICATION WITHIN THE PLANNING PROCESS

- **When?**
  - Upfront
  - Fully Integrated
- **Who?**
  - PDT Member
  - Appropriate Expertise
  - Collaboration
  - Certified CPR ATR Reviewer
- **Expected Impact?**
  - Risk Informed Decision Making
  - Build Resilience → Reduce Vulnerabilities

FIGURE 1: THE CORPS' ITERATIVE SIX STEP PLANNING PROCESS



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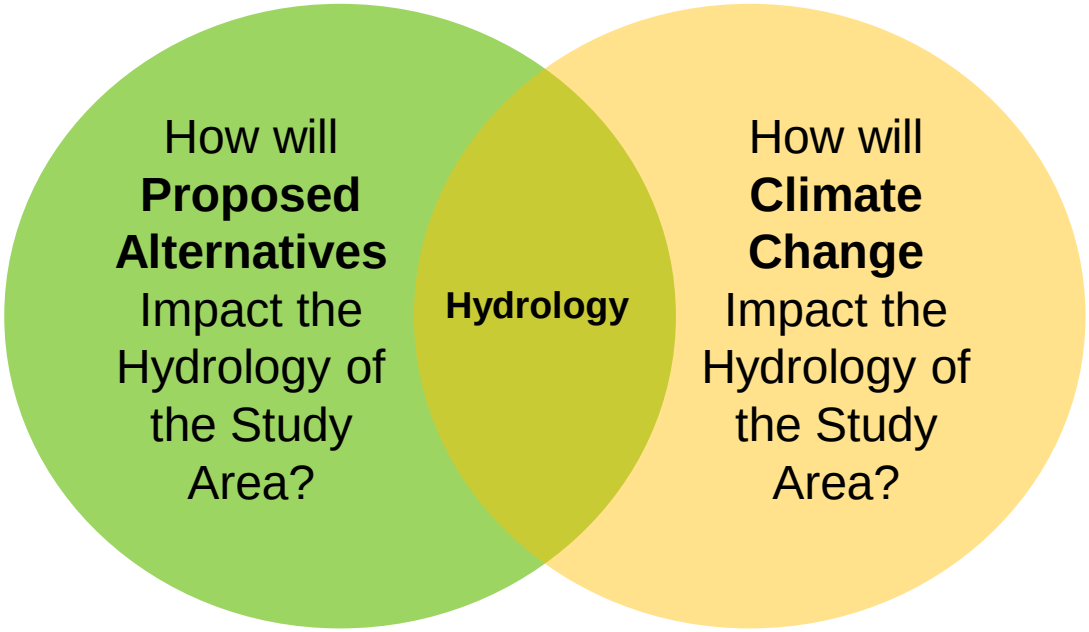
TIE BACK TO PROJECT PURPOSE

- What USACE business lines are impacted by the project?



- Look for Positive and Negative Feedback Loops

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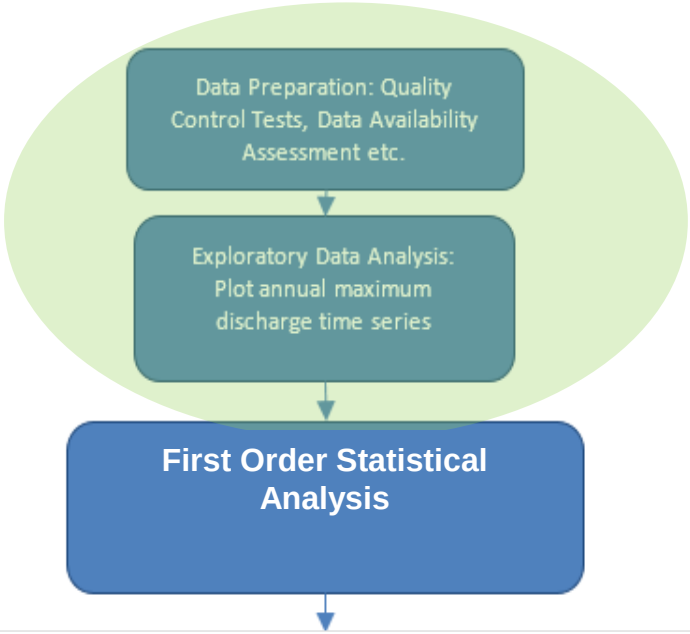
KNOW YOUR STUDY AREA & DATA/TOOL AVAILABILITY

- History of Regulation, Land Use Changes, Data Quality
- What variables are critical to assessing the impact of your project on the hydrology of the basin?
- What data is available in your basin?
- Many resources have been developed for studies primarily affecting high flows
- For other flow regimes:
  - Literature Review
  - Vulnerability Tool
  - Reach out to CPR POCS for guidance



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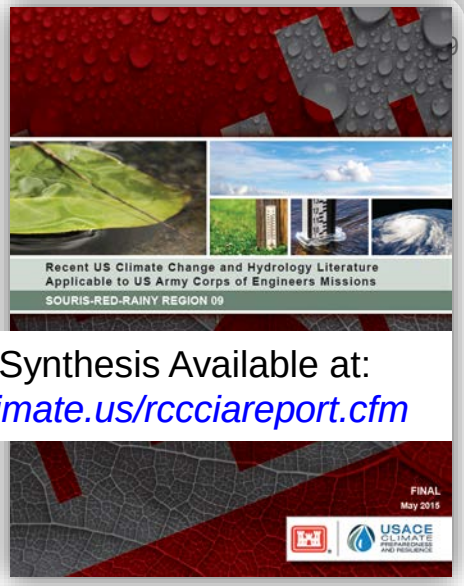
LITERATURE REVIEW

- Outline of broad trends in observed and projected changes to climate that might impact watershed hydrology

- Trends in Observed & Future Projections of:
  - Precipitation
  - Seasonality
  - Temperature
  - Streamflow

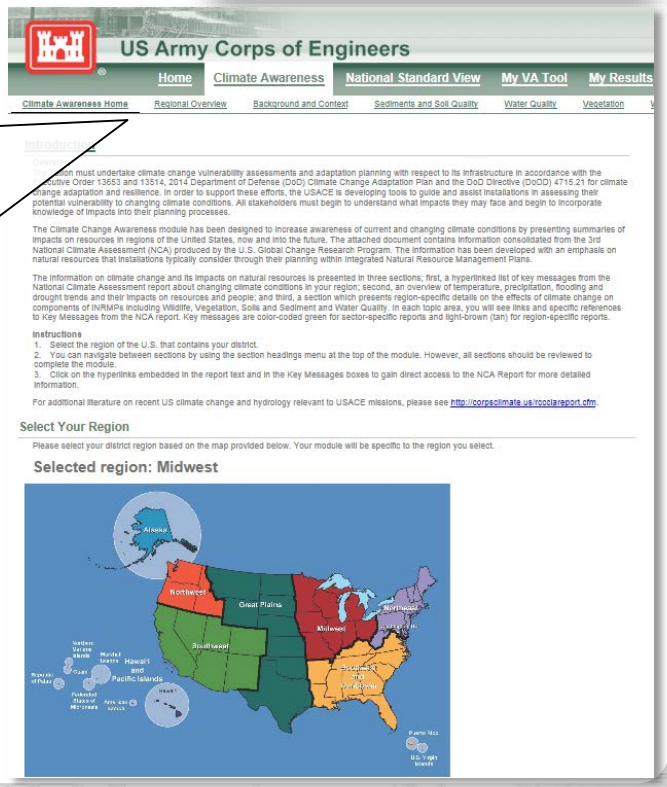
- Resources for Literature Review
  - USACE HUC02 Literature Synthesis
  - 3rd National Climate Assessment – Vulnerability Tool



USACE Literature Synthesis Available at:
http://www.corpsclimate.us/rccciareport.cfm

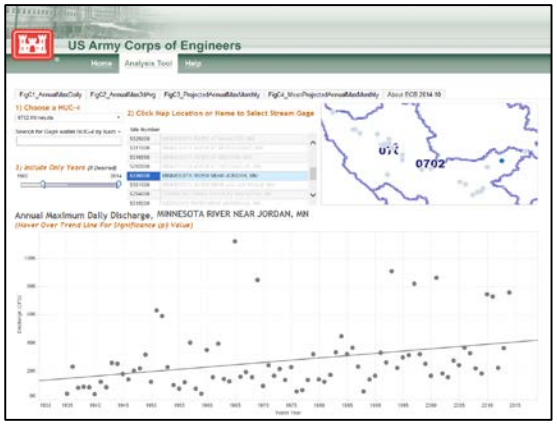
Vulnerability Tool Climate Awareness Tab

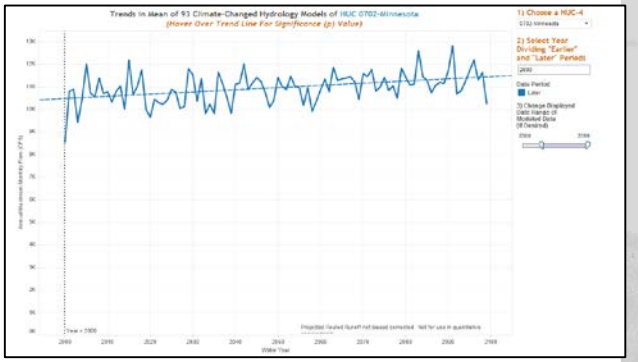
https://maps.crrel.usace.army.mil/apex/f?p=201:50:7230964129092::NO:::

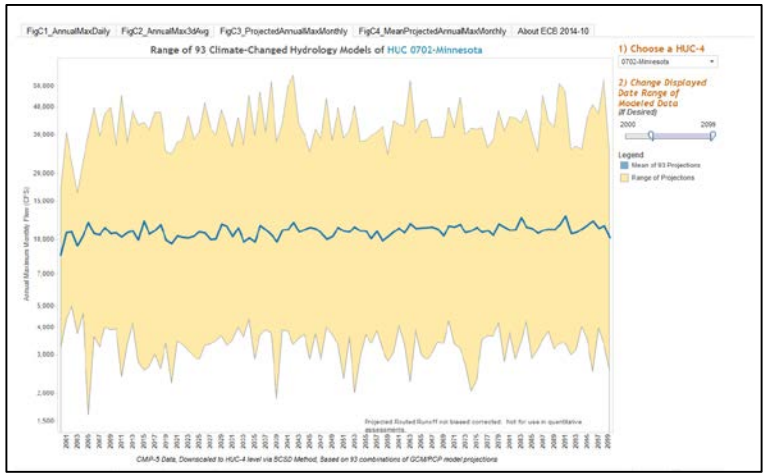


CLIMATE HYDROLOGY ASSESSMENT TOOL: TREND ANALYSIS

- Significant Linear Trends in Observed Annual Maximum Flows
- Significant Trends in Projected Annual Maximum Monthly Flow Data
  - Projected, Future Monthly Precipitation & Temperature Data
  - Based on 93 combinations of different global climate model outputs run for different greenhouse gas trajectories
  - Spatially Downscaled using a statistical method
  - Translated to an Unregulated Streamflow Response using a Hydrologic Model







Climate Hydrology Assessment Tool Available at:
http://corpsmapu.usace.army.mil/cm_apex/f?p=313:2:0::NO

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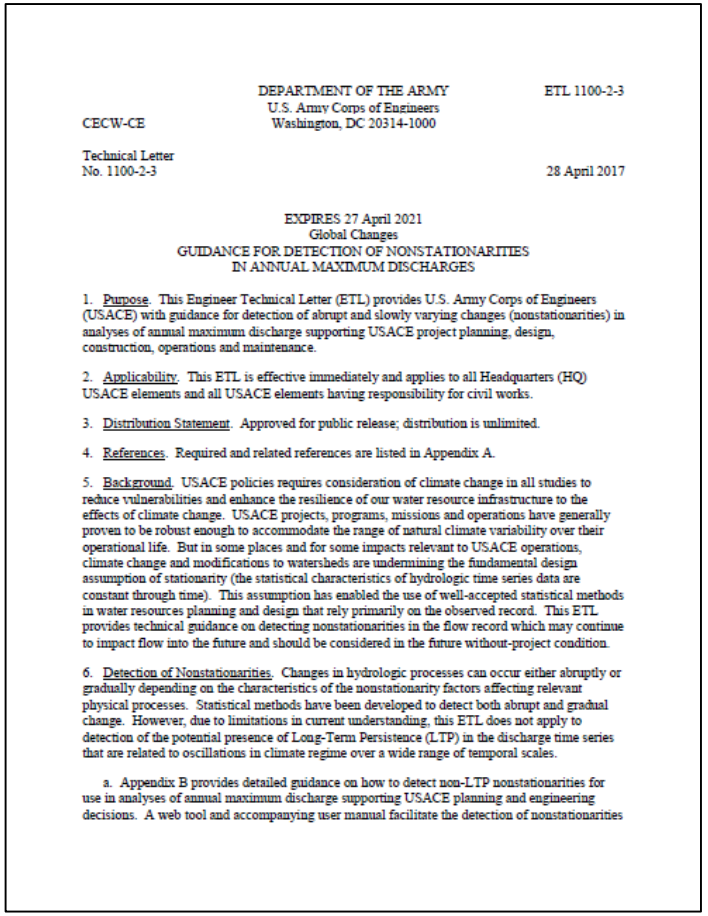
NONSTATIONARITY DETECTION GUIDANCE & WEB APPLICATION

- In April of 2017, USACE released technical guidance related to the detection of hydrologic non-stationarities in annual peak streamflow records
  - ETL 1100-2-3, Guidance for Detection of Non-stationarities in Annual Maximum Discharges

- Supported by a Web-based Tool



DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
CECW-CE Washington, DC 20314-1000

ETL 1100-2-3

Technical Letter
No. 1100-2-3

28 April 2017

EXPIRES 27 April 2021
Global Changes
GUIDANCE FOR DETECTION OF NONSTATIONARITIES
IN ANNUAL MAXIMUM DISCHARGES

1. Purpose. This Engineer Technical Letter (ETL) provides U.S. Army Corps of Engineers (USACE) with guidance for detection of abrupt and slowly varying changes (nonstationarities) in analyses of annual maximum discharge supporting USACE project planning, design, construction, operations and maintenance.

2. Applicability. This ETL is effective immediately and applies to all Headquarters (HQ) USACE elements and all USACE elements having responsibility for civil works.

3. Distribution Statement. Approved for public release; distribution is unlimited.

4. References. Required and related references are listed in Appendix A.

5. Background. USACE policies requires consideration of climate change in all studies to reduce vulnerabilities and enhance the resilience of our water resource infrastructure to the effects of climate change. USACE projects, programs, missions and operations have generally proven to be robust enough to accommodate the range of natural climate variability over their operational life. But in some places and for some impacts relevant to USACE operations, climate change and modifications to watersheds are undermining the fundamental design assumption of stationarity (the statistical characteristics of hydrologic time series data are constant through time). This assumption has enabled the use of well-accepted statistical methods in water resources planning and design that rely primarily on the observed record. This ETL provides technical guidance on detecting nonstationarities in the flow record which may continue to impact flow into the future and should be considered in the future without-project condition.

6. Detection of Nonstationarities. Changes in hydrologic processes can occur either abruptly or gradually depending on the characteristics of the nonstationarity factors affecting relevant physical processes. Statistical methods have been developed to detect both abrupt and gradual change. However, due to limitations in current understanding, this ETL does not apply to detection of the potential presence of Long-Term Persistence (LTP) in the discharge time series that are related to oscillations in climate regime over a wide range of temporal scales.

a. Appendix B provides detailed guidance on how to detect non-LTP nonstationarities for use in analyses of annual maximum discharge supporting USACE planning and engineering decisions. A web tool and accompanying user manual facilitate the detection of nonstationarities

Nonstationarity Detection Tool Available at:
http://corpsmapu.usace.army.mil/cm_apex/f?p=257:2:0::NO:::

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THE STATIONARITY ASSUMPTION

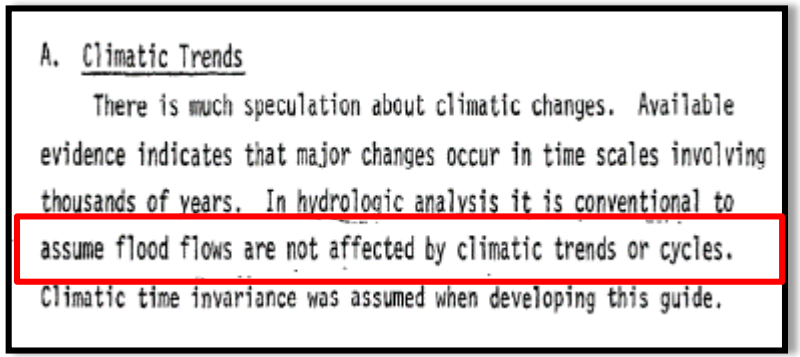
Stationarity: The assumption that the statistical characteristics of hydrologic time series data are constant through time. The concept of stationarity is a fundamental assumption underlying hydrologic analysis and design.

Application of the Stationarity Assumptions

- Enables the use of well-accepted statistical methods in water resources planning and design (example: Bulletin 17b/c)
- Relies primarily on the observed record
- What happens if the data collected in the past no longer resembles what lies ahead?

Potential Drivers of Non-Stationarity in hydro-metrological records:

- Climate Change
- Watershed Modification


Guidelines
For
Determining

Flood
Flow
Frequency

Bulletin #17B
of the
Hydrology Subcommittee

A. Climatic Trends

There is much speculation about climatic changes. Available evidence indicates that major changes occur in time scales involving thousands of years. In hydrologic analysis it is conventional to assume flood flows are not affected by climatic trends or cycles. Climatic time invariance was assumed when developing this guide.

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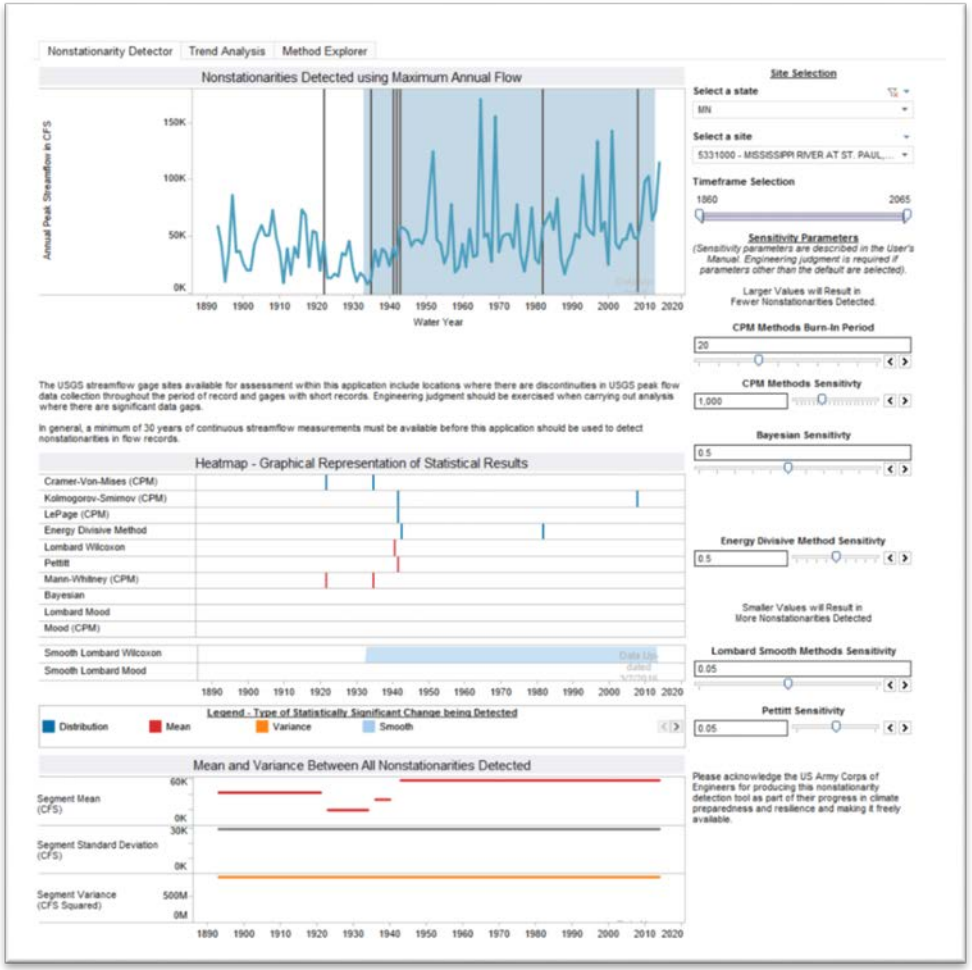
APPLICATION OF NONSTATIONARITY DETECTOR TESTS

- Apply a Variety of Statistical Tests
- Target Changepoints in Mean, Variance, and Overall Distribution
- Web-Accessible Tool – 12 Statistical Tests



- A detailed description of the statistical methods and their applications to hydrologic engineering can be found here - *http://corpsmapu.usace.army.mil/rcc/nsd/docs/Nonstationarity_Detection_Tool_User_Guide.pdf*.

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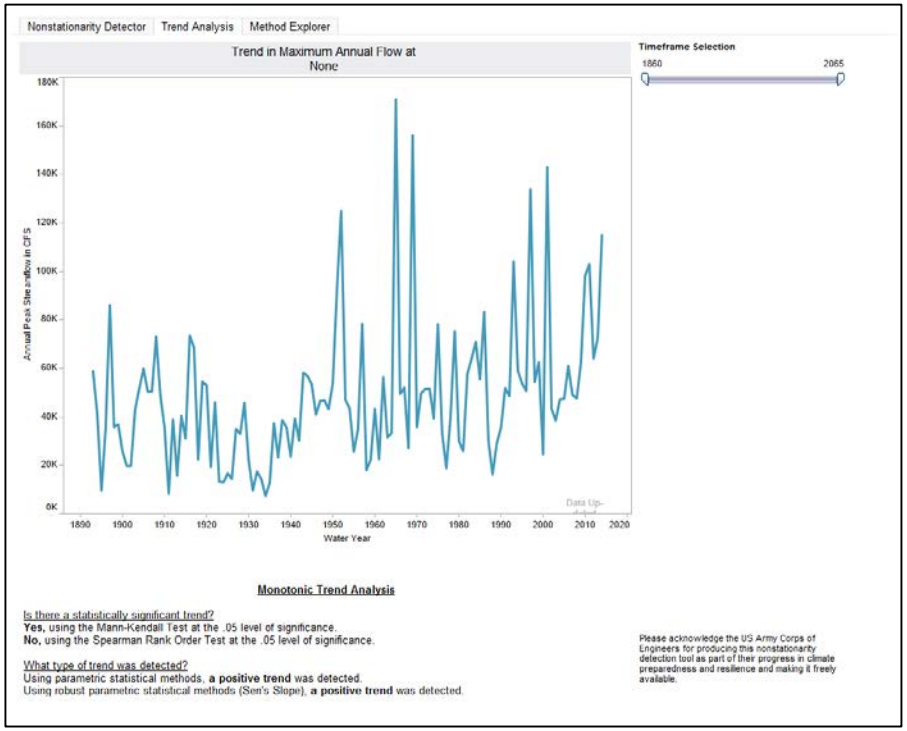
DETECTION OF MONOTONIC CHANGES

- Further evidence of Nonstationarity: Is there an increasing or decreasing trend in the data and/or subsets of the data?
- The detection of monotonic patterns is generally performed using either the Mann-Kendall test or the Spearman test
- Tests do not provide quantitative information related to magnitude of change observed



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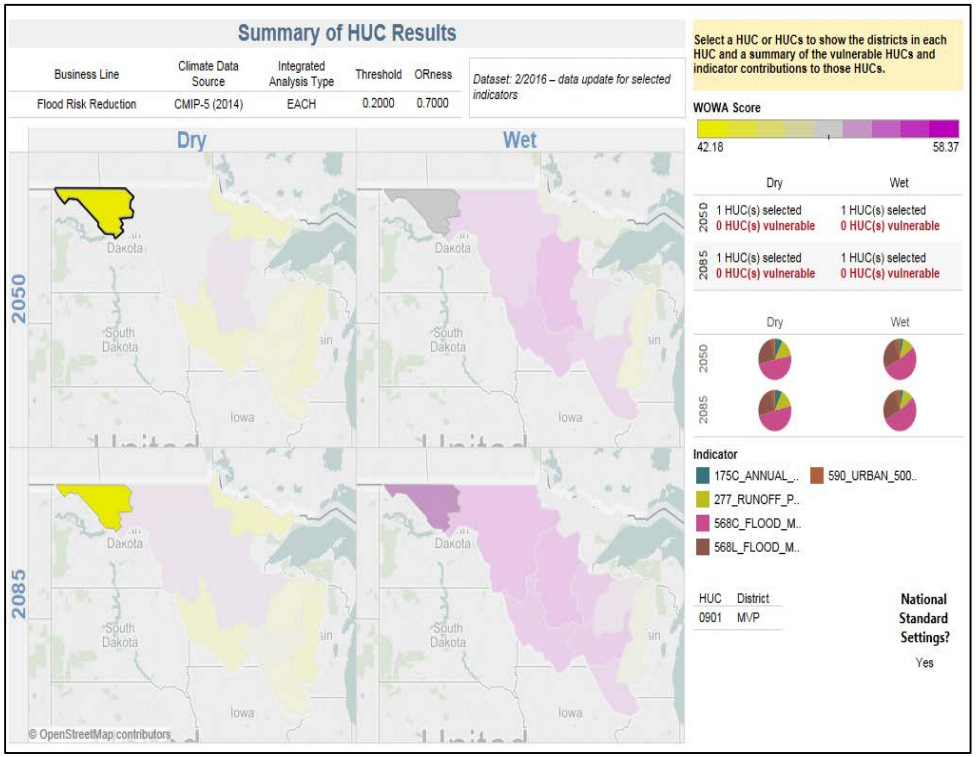
USACE WATERSHED VULNERABILITY ASSESSMENT TOOL

- Screening Level Tool
- Relative Vulnerability to Climate Change
- Comparative Analysis: 202 HUC4 watersheds
- Business Line Specific
- Global Climate Model + Different Greenhouse Gas Emission Scenarios + Hydrologic Model = 100 realizations of future flows/ precipitation/ temperature
  - Top 50% of traces “wet” bottom 50% “dry” by annual cumulative flow
  - Vulnerability Score Overtime (2050 & 2085)
- Weighted Order Weighted Average (WOWA) Vulnerability Score
- 27 predefined indicator Variables
- Top 20% are deemed Vulnerable
- Ex: Flood Risk
  - Acreage in the Floodplain
  - Variation in Annual Runoff
  - Runoff Elasticity
  - Indicators of Flood Magnification



Watershed Vulnerability Assessment Tool Available at (CAC Card Accessible):
https://maps.crrel.usace.army.mil/projects/rcc/portal.html

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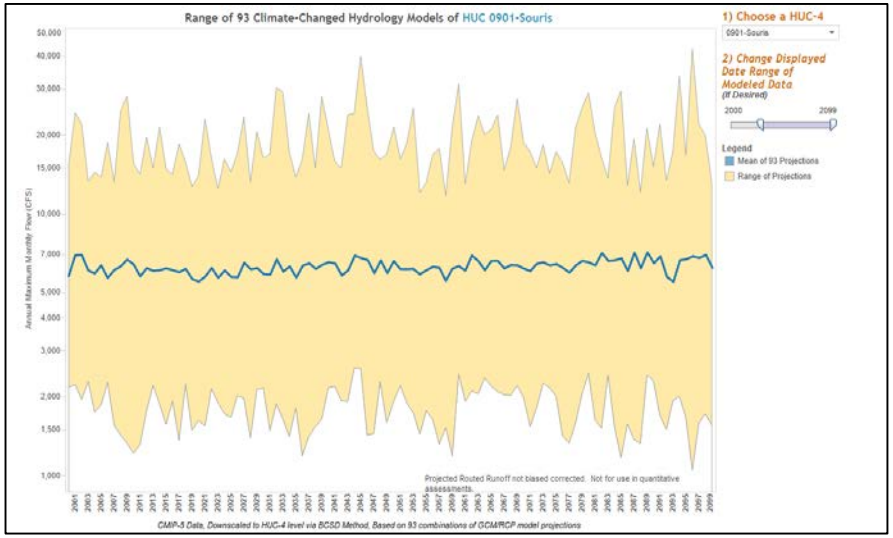
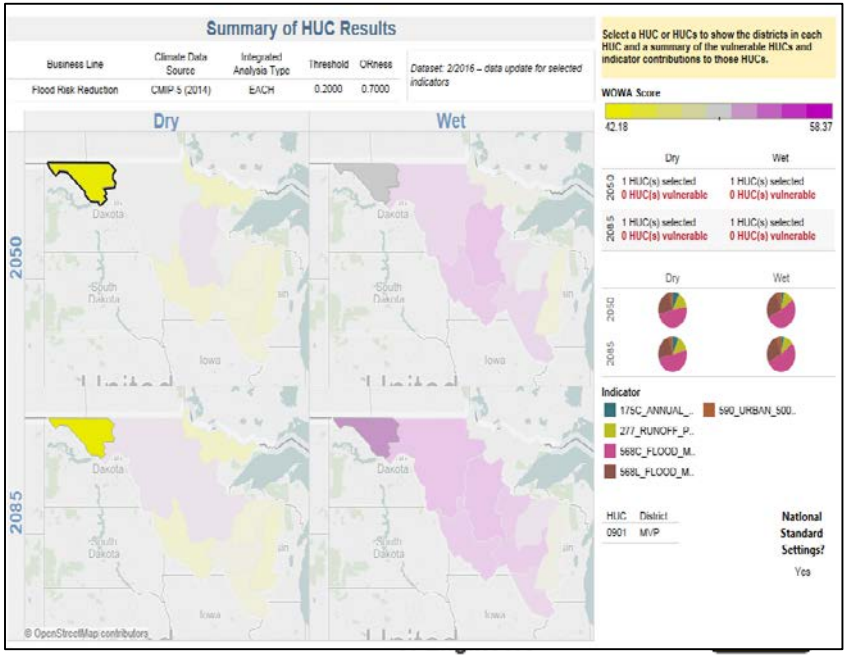
ADDRESSING UNCERTAINTY

- Acknowledge Uncertainty Associated with Climate Model Output for Future
- Interpreting Global Climate Model Output
- Hydrologic Model Uncertainty





EXAMPLE: CONWAY LAKE HABITAT REHABILITATION & ENHANCEMENT PROJECT FEASIBILITY REPORT & INTEGRATED ENVIRONMENTAL ASSESSMENT

- Part of the Upper Mississippi River Restoration Program
- HUC-04: 0706 Upper Mississippi-Maquoketa-Plum
- Located in Pool 9 (upstream of Lock & Dam 9) -Lansing, Iowa
- Includes Protecting or restoring 321 acres of aquatic and floodplain forest habitat
- Key Objectives
  - Overwintering habitat for fish
  - Establishment of floodplain forest
- 1,170 acre project area including Shore Slough and Phillipi Lake
- Long-term stream gage: USGS gage 05389500, Mississippi river at McGregor, Iowa

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EXAMPLE: CONWAY LAKE HABITAT REHABILITATION & ENHANCEMENT PROJECT FEASIBILITY REPORT & INTEGRATED ENVIRONMENTAL ASSESSMENT

- Literature Review written with an ecosystem restoration focus
  - "In Water Resources Region HUC 07, the Upper Mississippi Region, the report concludes that "increased air temperatures and increased frequencies of drought, particularly in the summer months, will result in **increased water temperatures**. This may lead to **water quality concerns**, particularly for the dissolved oxygen levels, which are an important water quality parameter **for aquatic life**.
  - **Increased air temperatures** are associated with the growth of nuisance **algal blooms** and influence wildlife and supporting food supplies.
  - **Increased mean annual precipitation** in the region may **pose complication to planning for ecosystem needs due to more variation in flows** (Civil Works Technical Report CWTS-2015-13, USACE (2015))."

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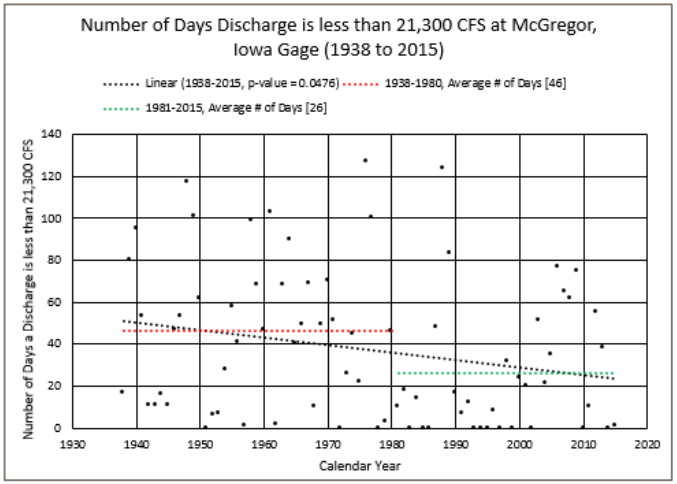
EXAMPLE: CONWAY LAKE HABITAT REHABILITATION & ENHANCEMENT PROJECT FEASIBILITY REPORT & INTEGRATED ENVIRONMENTAL ASSESSMENT

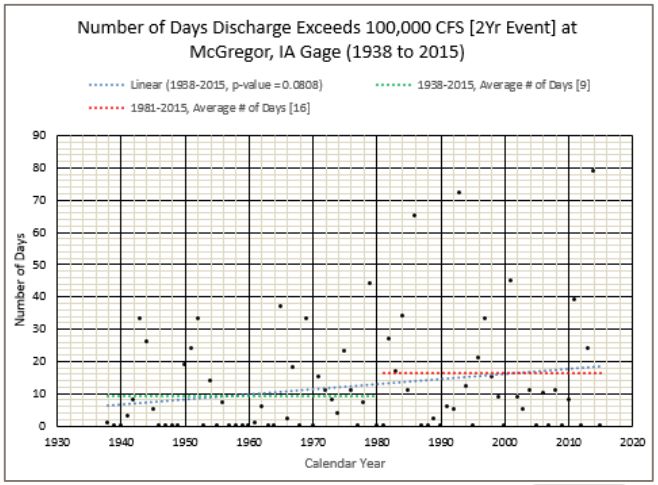
First Order Statistical Analysis

- Looked at trends in annual peak data (readily available in climate assessment tool)
- Looked at trends in datasets particularly relevant to the project purpose – ecosystem restoration

Not Done, but Recommended in future..

- Apply nonstationarity detection tool to variable specific to study purpose





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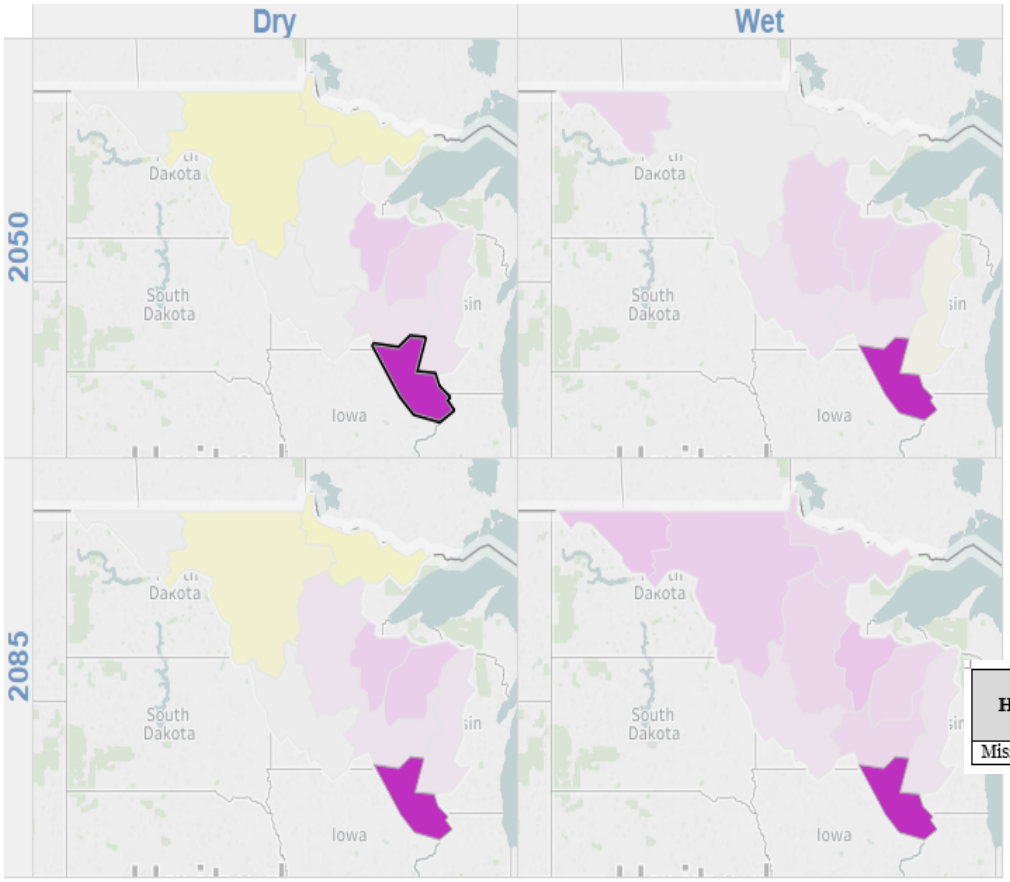
EXAMPLE: CONWAY LAKE HABITAT REHABILITATION & ENHANCEMENT PROJECT FEASIBILITY REPORT & INTEGRATED ENVIRONMENTAL ASSESSMENT: VULNERABILITY ASSESSMENT

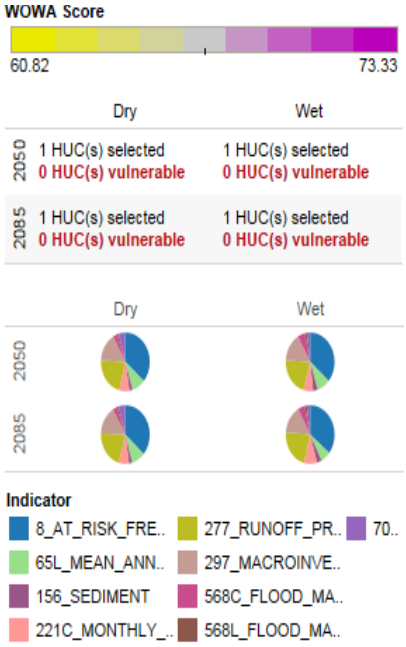
2050 Epoch	Mississippi River (0706)	
	Dry	Wet
Indicator	Contribution to WOWA Ecosystem Restoration Vulnerability Score	
Sediment (Change in Sediment Load / Current Load)	1.49	2.23
Short-term Variability in Hydrology (75th Percentile of Annual Ratios of StDev of Monthly Runoff)	4.78	4.57
Runoff Elasticity (% Change in Runoff / % Change in Precipitation)	15.69	15.24
Macroinvertebrate (Score of Six Metrics)	11.33	11.24
Flood Magnification - Cumulative	2.03	3.37
Flood Magnification - Local	0.81	1.00
Mean Annual Runoff	6.39	6.18
Change in Low Runoff	3.16	1.57
At Risk Freshwater Plants	26.11	25.89

Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Threshold	ORness
Ecosystem Restoration	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selec indicators





HUC 4 Watershed	Projected Vulnerability with Respect to Ecosystem Restoration Ecosystem Reduction Vulnerability Score			
	2050 Dry	2050 Wet	2085 Dry	2085 Wet
Mississippi River (0706)	71.78	71.28	71.38	71.82

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EXAMPLE: CONWAY LAKE HABITAT REHABILITATION & ENHANCEMENT PROJECT FEASIBILITY REPORT & INTEGRATED ENVIRONMENTAL ASSESSMENT

CONCLUSIONS

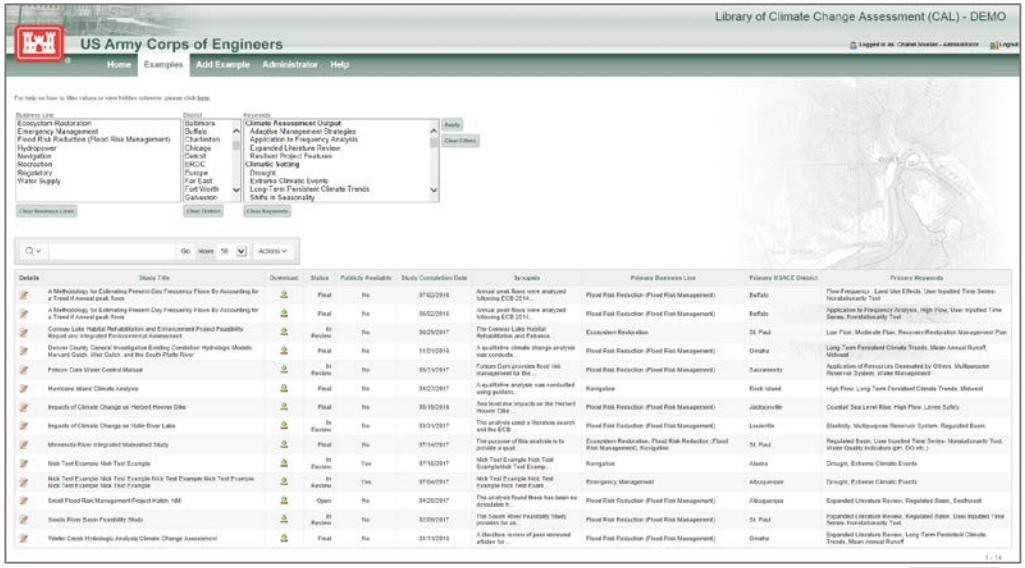
- Increased cold water inflow events
- Increased inter-annual variability in flow & precipitation
- Overall Flow increases
- Decreasing number of growing season low flow days

RESULTING RESILIENT FEATURES BUILT INTO PROJECT

- The elevation of floodplain forest project features was increased to account for the possibility of future increases in flows.
- Adaptive management options will be available for some project features:
    - Notching the rock closure built to form overwintering habitat to accommodate increased summer flows if the overwintering habitat performs well
    - Monitoring and maintaining riprap groins if they are damaged by high flow conditions.

UPCOMING SUPPORT

- Timeseries Toolbox: User Input Timeseries – Nonstationarity Detection Tool
- Example Library for ECB 2016-25
- Web Based & In-Person Training



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QUESTIONS/COMMENTS?

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