

# INCORPORATION OF CLIMATE CHANGE IMPACTS INTO INLAND HYDROLOGIC ANALYSIS

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September 7, 2017

*“The views, opinions and findings contained in this report are those of the authors(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other official documentation.”*



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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



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



The primary and overarching policy document for USACE is the *USACE Climate Preparedness and Resilience Policy Statement*, signed by Assistant Secretary of the Army Jo-Ellen Darcy in June 2014.

As the Nation's largest and oldest manager of water resources, the US Army Corps of Engineers (USACE) has long been successfully adapting its policies, programs, projects, planning, and operations to impacts from important drivers of global change and variability.

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.

USACE shall continue understanding the climate change preparedness and resilience plans internal and external reports and and Contents, and shall implement using the best available – and acts and climate change information. U

its efforts with other agencies to di engineering research on climate of actionable basis for adapting to di Fulfillment, USACE shall continue climate change impacts when and planning, setting priorities, and ma resources, programs, policies, and These actions, which USACE is no has outlined for the future, are fully guiding principles and framework Preparedness and Resilience and Federal Interagency Climate Chen Force, with Executive Order 13652

19, 2013 instructions Preparing Federal Agency Climate Change Adaptation Plans in Accordance with Executive Order 13652 and with Executive Order 13514 and the Implementing Instructions for Federal Agency Climate Change Adaptation issued on March 4, 2011.

USACE understands and is acting to integrate climate adaptation (managing the unavoidable impacts) with mitigation (avoiding the unavoidable impacts). USACE recognizes the very significant differences between climate change adaptation and climate change mitigation in terms of physical complexity, fiscal and material resources, level of knowledge and technical readiness, and temporal and geographic scale. These differences mean that any different

0002 2014 Climate Change Adaptation Policy Statement

adaptation. Mainstreaming climate change adaptation means that it will be considered at every step in the project life cycle for all USACE projects, both existing and planned, through a logical, rational, legally justifiable process that develops practical, nationally consistent, and cost effective adaptation measures, both structural and nonstructural, to reduce vulnerabilities and enhance the resilience of our water resource infrastructure.

The magnitude and complexity of climate change impacts facing water resource managers in the US has spurred USACE to embark on close, more fruitful interagency cooperation for developing methods supporting climate change adaptation. Close collaboration, both nationally and internationally, is the most effective way to develop the measures to identify and reduce the USACE mission vulnerabilities to potential future climate changes. USACE has demonstrated its commitment to engage and lead such collaboration through efforts including the Building Strong Collaborative Relationships for a Sustainable Water Resources Future Initiative<sup>1</sup> and the federal interagency Climate Change and Water Working Group (CCAWWG).

Signed,

*Jo-Ellen Darcy*  
Jo-Ellen Darcy  
Assistant Secretary of the Army for Civil Works



*"Adaptation is not optional."*

Mr. James C. Dalton, PE, RES, Chair of the USACE Climate Change Adaptation Steering Committee, January 19, 2012

“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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## 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

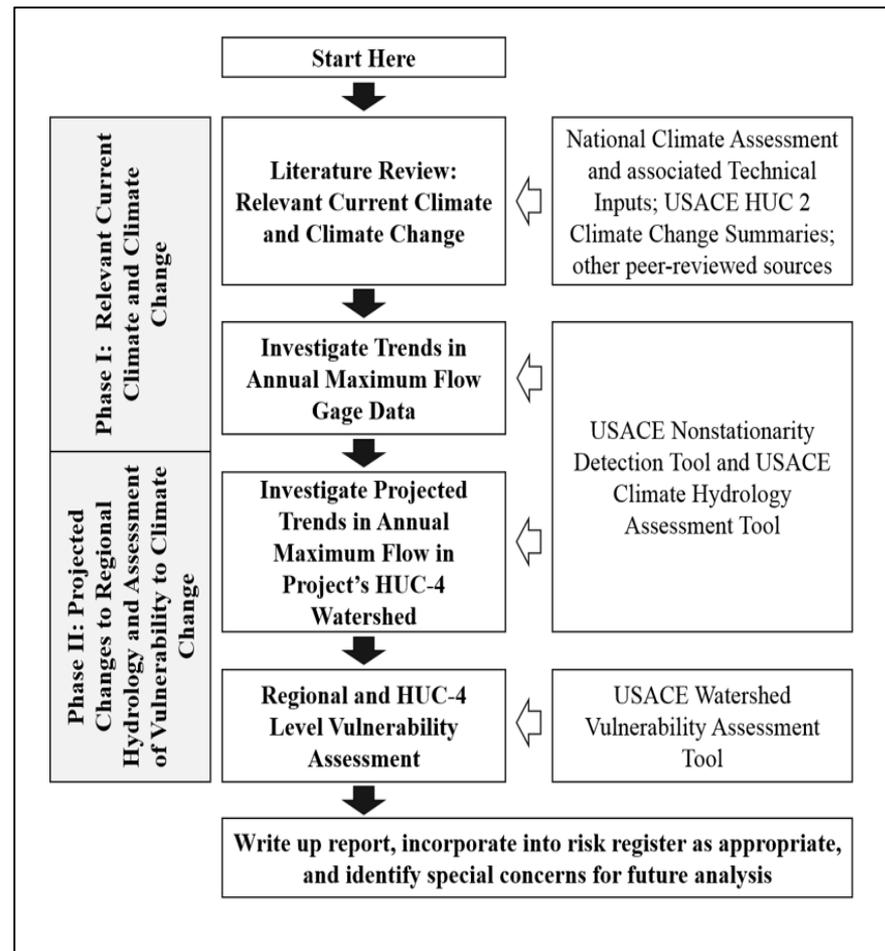


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# ECB 2016-25: GUIDANCE FOR INCORPORATING CLIMATE CHANGE IMPACTS TO INLAND HYDROLOGY IN CIVIL WORK STUDIES, DESIGNS, AND PROJECTS

- 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



# APPROPRIATE EXECUTION AND APPLICATION WITHIN THE PLANNING PROCESS

- **When?**

- Upfront
- Fully Integrated

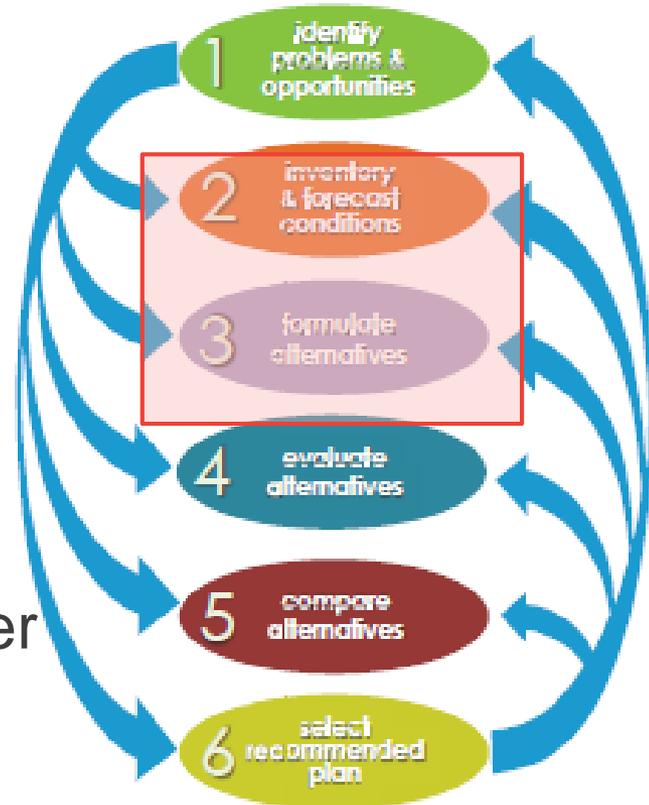
- **Who?**

- PDT Member
- Appropriate Expertise
- Collaboration
- Certified CPR ATR Reviewer

- **Expected Impact?**

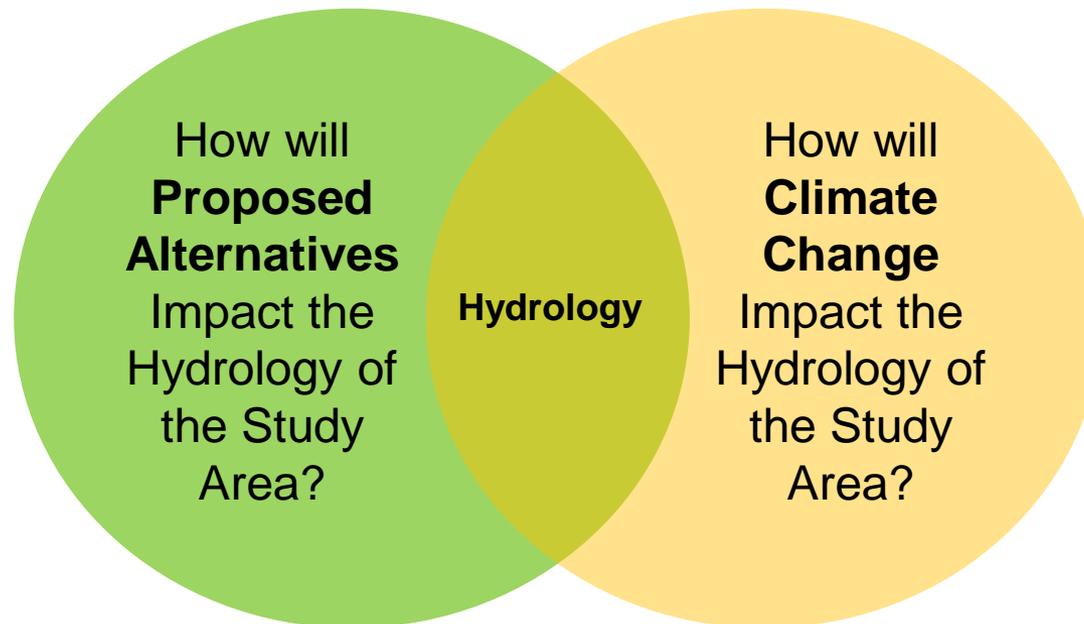
- Risk Informed Decision Making
- Build Resilience → Reduce Vulnerabilities

**FIGURE 1: THE CORPS' ITERATIVE SIX STEP PLANNING PROCESS**



# TIE BACK TO PROJECT PURPOSE

- What USACE business lines are impacted by the project?



- Look for Positive and Negative Feedback Loops

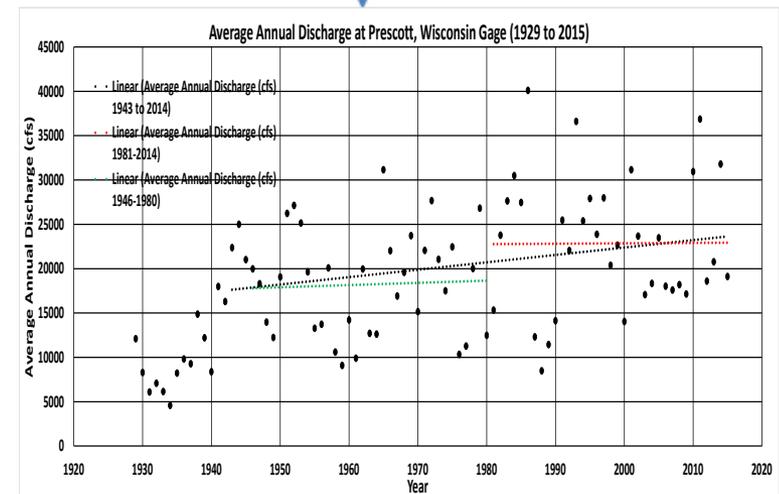
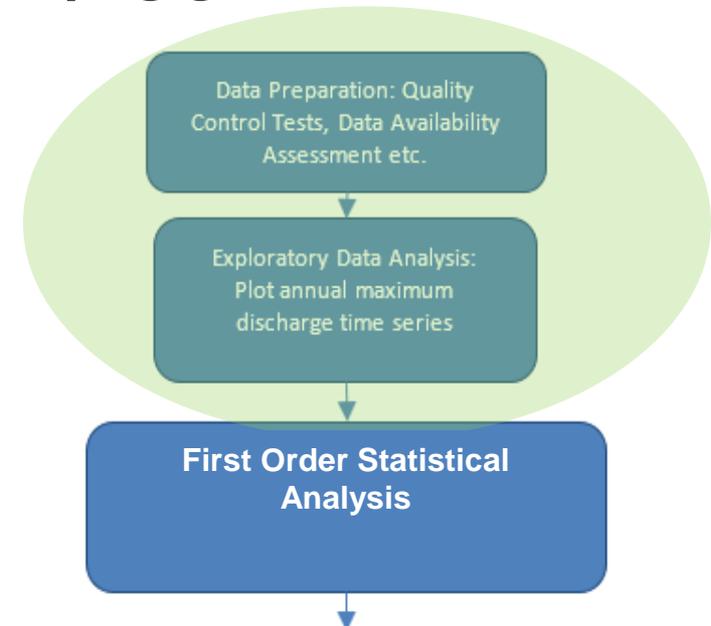


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# KNOW YOUR STUDY AREA & DATA/TOOL AVAILABILITY

- 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
  - 3<sup>rd</sup> 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>

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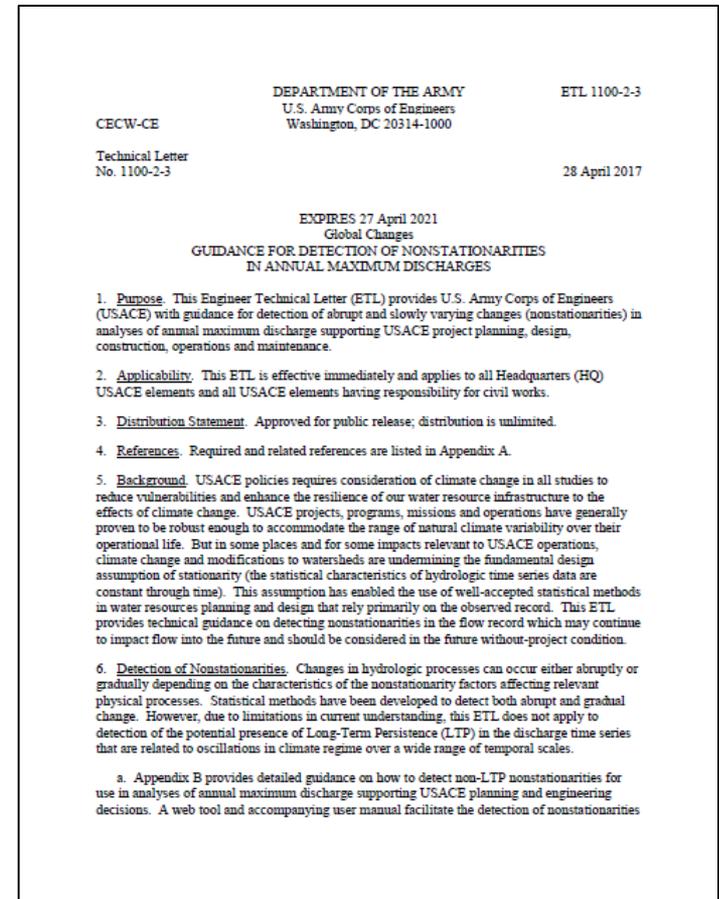
The image is a screenshot of the "US Army Corps of Engineers Climate Awareness" website. The header includes the USACE logo and navigation tabs: Home, Climate Awareness, National Standard View, My VA Tool, and My Results. Below the header, there is a section titled "Introduction" with text explaining the purpose of the module. It mentions that the module is designed to increase awareness of current and changing climate conditions by presenting summaries of impacts on resources in regions of the United States. The text also states that the information has been developed with an emphasis on natural resources that installations typically consider through their planning within Integrated Natural Resource Management Plans. Below the introduction, there are "Instructions" and a "Select Your Region" section. The "Selected region: Midwest" is shown, with a map of the United States highlighting the Midwest region in red. The map also shows other regions: Northwest, Great Plains, Southeast, and Northeast. There are also links to "Regional Overview", "Background and Context", "Sediments and Soil Quality", "Water Quality", and "Vegetation".



# 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

Nonstationarity Detection Tool Available at:  
[http://corpsmapu.usace.army.mil/cm\\_apex/f?p=257:2:0::NO::](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.



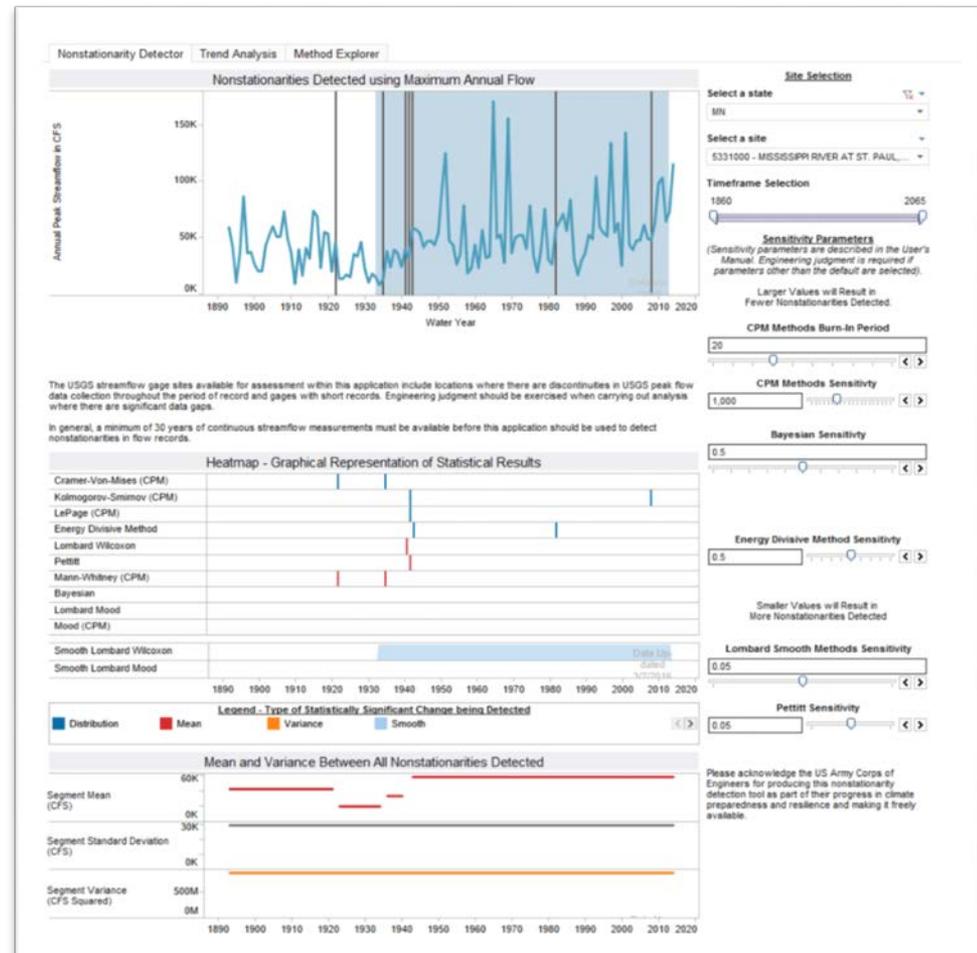
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# APPLICATION OF NONSTATIONARITY DETECTOR TESTS

- 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/rc/c/nsd/docs/Nonstationarity\\_Detector\\_Tool\\_User\\_Guide.pdf](http://corpsmapu.usace.army.mil/rc/c/nsd/docs/Nonstationarity_Detector_Tool_User_Guide.pdf).

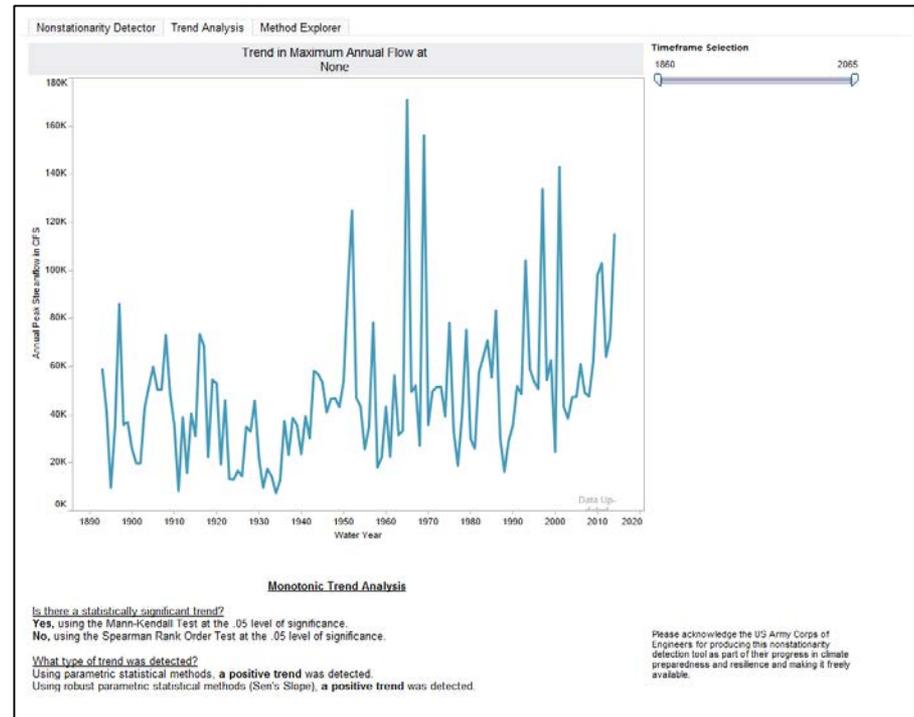


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# DETECTION OF MONOTONIC CHANGES

- 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

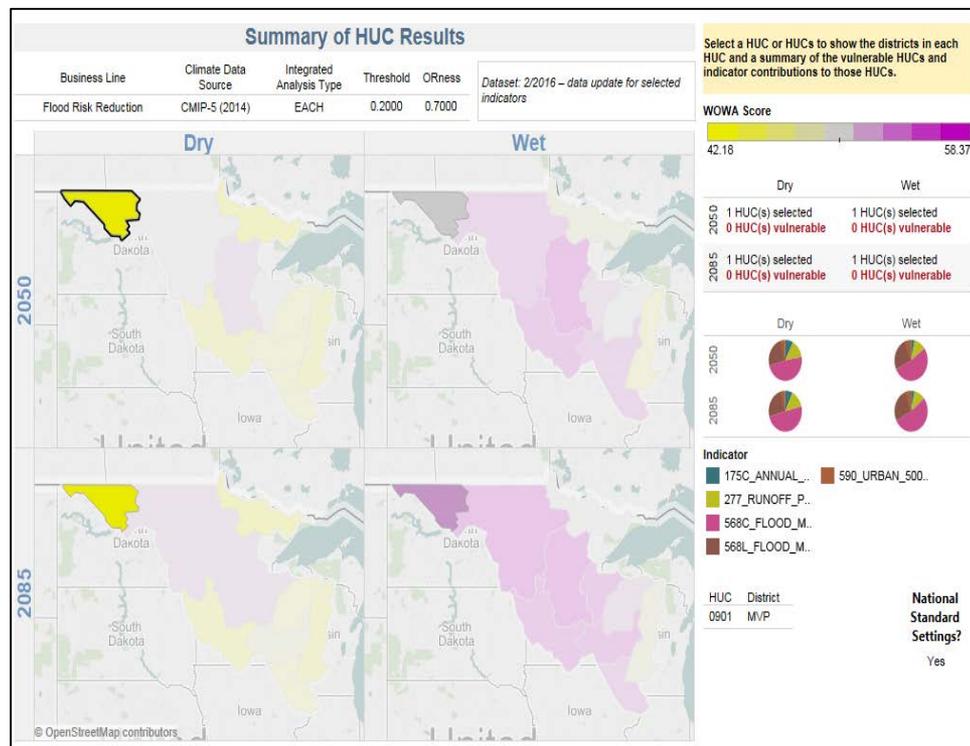


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# USACE WATERSHED VULNERABILITY ASSESSMENT TOOL

- 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



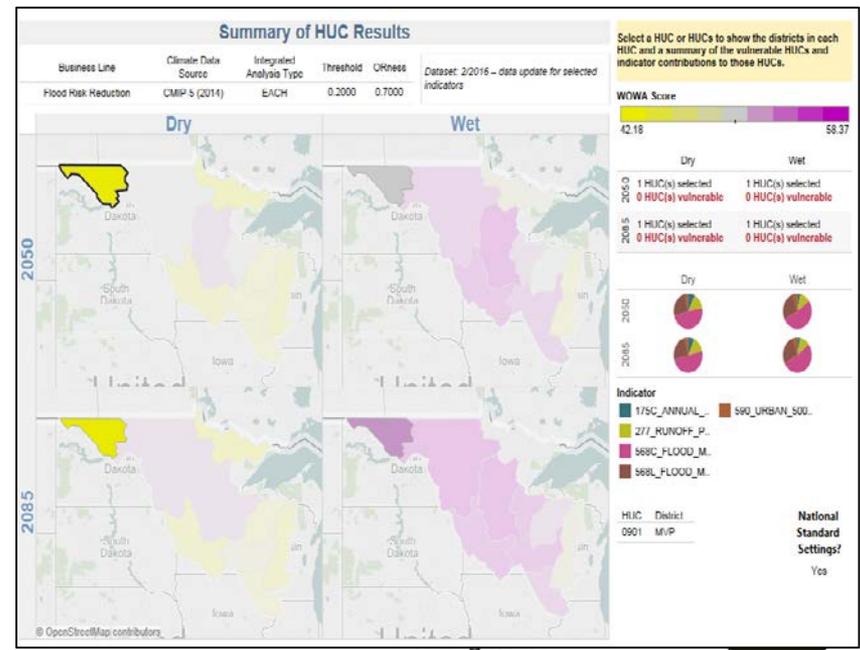
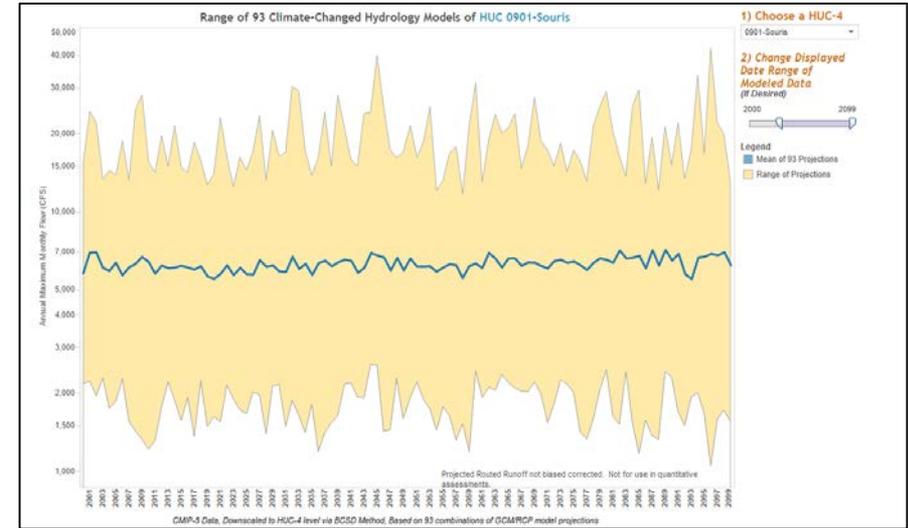
Watershed Vulnerability Assessment Tool Available at (CAC Card Accessible):

<https://maps.crrel.usace.army.mil/projects/rcc/portal.html>



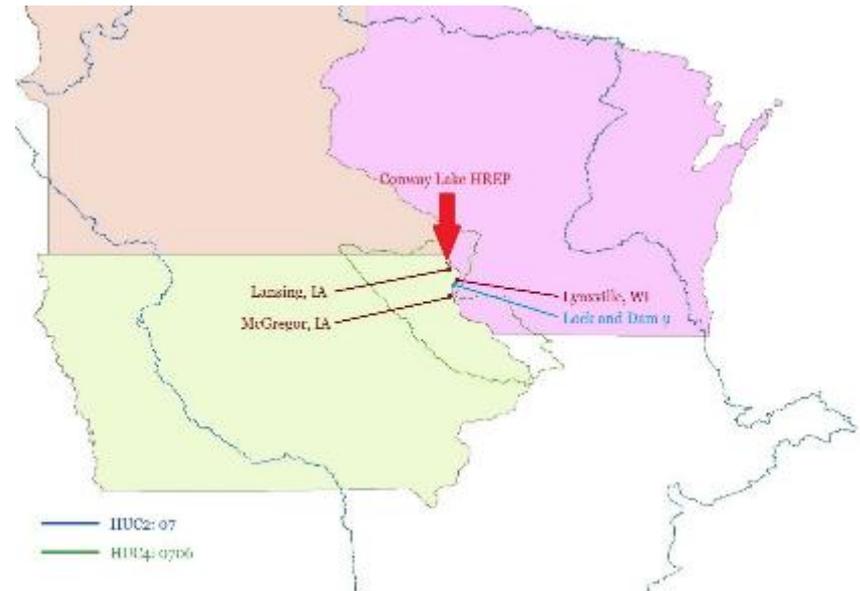
# ADDRESSING UNCERTAINTY

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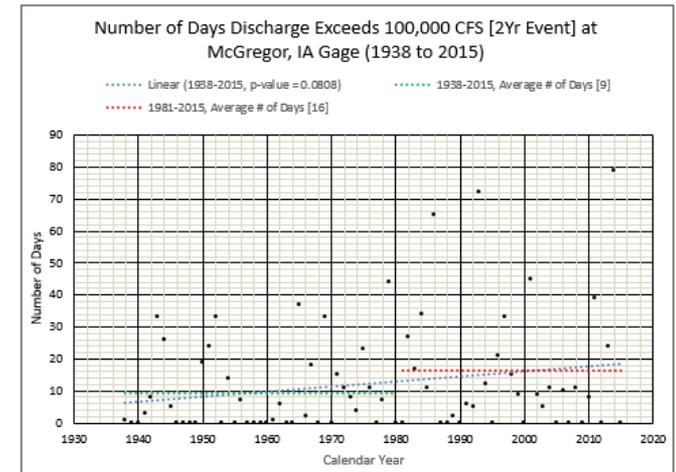
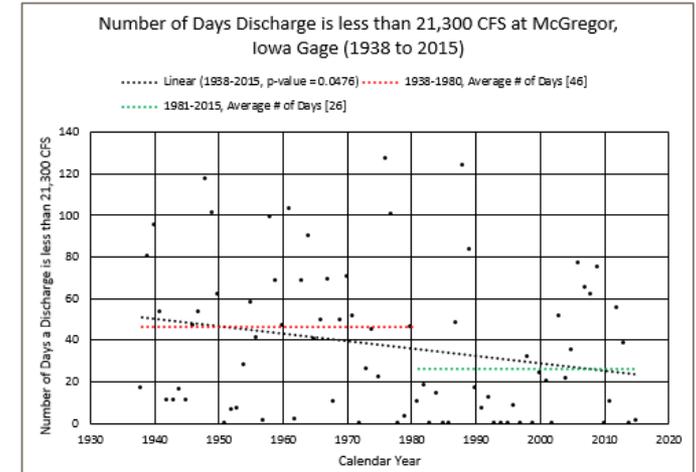
# EXAMPLE: CONWAY LAKE HABITAT REHABILITATION & ENHANCEMENT PROJECT FEASIBILITY REPORT & INTEGRATED ENVIRONMENTAL ASSESSMENT

## 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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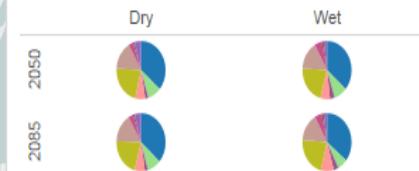
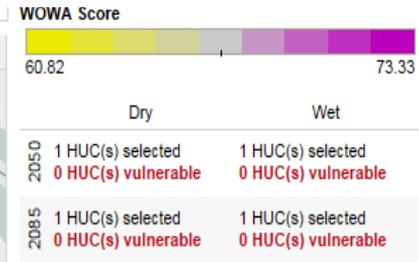
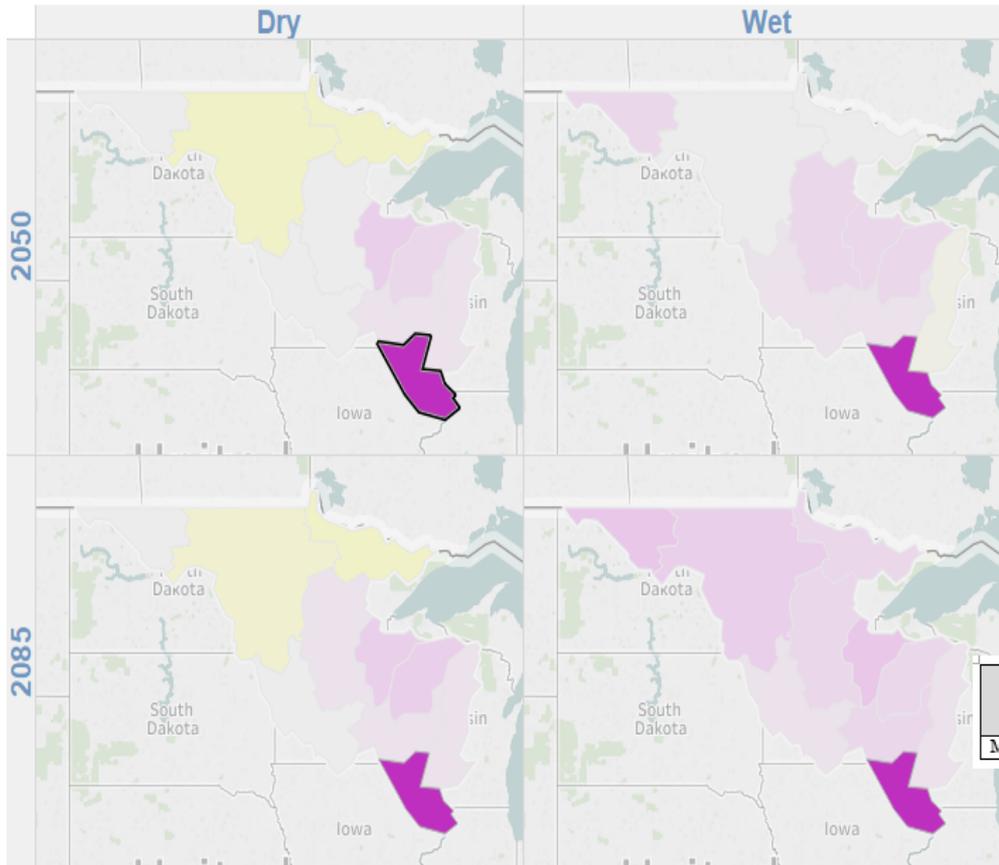


# EXAMPLE: CONWAY LAKE HABITAT REHABILITATION & ENHANCEMENT PROJECT FEASIBILITY REPORT & INTEGRATED ENVIRONMENTAL ASSESSMENT: VULNERABILITY ASSESSMENT

## Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Threshold	ORness	Dataset: 2/2016 – data update for select indicators
Ecosystem Restoration	CMIP-5 (2014)	EACH	20%	0.70	

Indicator	2050 Epoch	
	Dry	Wet
	Contribution to WOVA 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



- Indicator**
- 8\_AT\_RISK\_FRE..
  - 65L\_MEAN\_ANN..
  - 156\_SEDIMENT
  - 221C\_MONTHLY\_..
  - 277\_RUNOFF\_PR..
  - 297\_MACROINVE..
  - 568C\_FLOOD\_MA..
  - 568L\_FLOOD\_MA..
  - 70..

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



# 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.

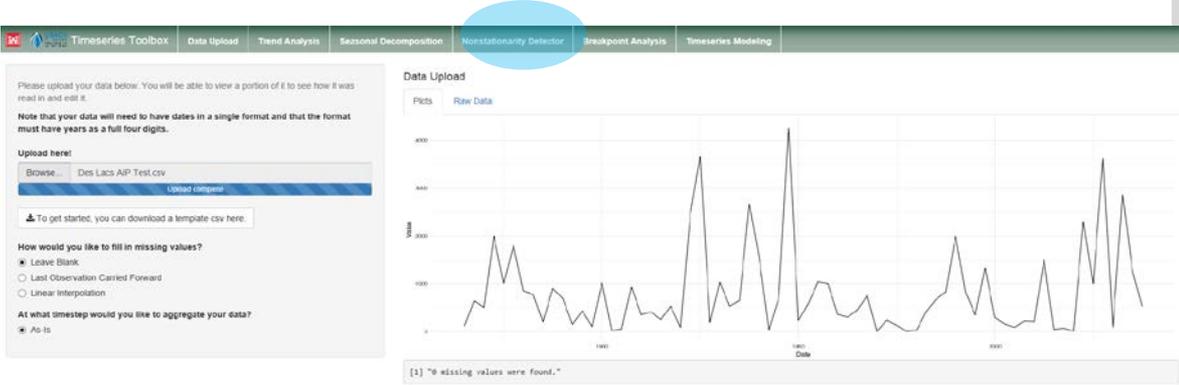


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# UPCOMING SUPPORT

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



Library of Climate Change Assessment (CAL) - DEMO

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Home Examples Add Example Administrator Help

For help on how to filter values or view hidden columns, please click here.

Details	State Title	Overview	Status	Publicly Available	Study Completion Date	Synopsis	Primary Business Line	Primary WACC Detail	Primary Keywords
	A Methodology for Estimating Present-Day Frequency Flows by Accounting for a Trend of Annual Peak Flows		Final	Yes	3/16/2018	Annual peak flows were analyzed using ECB 2014.	Flood Risk Reduction (Flood Risk Management)	Exhibit	Flood Frequency, Load Use Effects, User Input, Time Series, Nonstationarity, Test
	A Methodology for Estimating Present Day Frequency Flows by Accounting for a Trend of Annual Peak Flows		Final	Yes	3/16/2018	Annual peak flows were analyzed using ECB 2014.	Flood Risk Reduction (Flood Risk Management)	Exhibit	Application to Frequency Analysis, High Flow, User Input, Time Series, Nonstationarity, Test
	Comox Lake Habitat Rehabilitation and Enhancement Feasibility Report as Integrated Environmental Assessment		In Progress	No	3/29/2017	The Comox Lake Habitat Rehabilitation and Enhancement	Ecosystem Restoration	St. Paul	Low Flow, Moderate Flow, Reservoir/Restoration Management Plan
	Denver South-Central General Investigation Existing Condition Hydrology Models: Manual Study, 1960 Data, and the South Platte River		Final	Yes	11/19/2016	A qualitative climate change analysis was conducted.	Flood Risk Reduction (Flood Risk Management)	Omaha	Long Term Forecasted Climate Trends, Mean Annual Runoff Volume
	Federal City Water Control Manual		In Progress	No	05/19/2017	Federal City provides flood risk management for the	Flood Risk Reduction (Flood Risk Management)	Sacramento	Application of Resources Generated by Other, Multibasin Reservoir System, Water Management
	Minnesota Water Climate Analysis		Final	Yes	3/27/2017	A qualitative analysis was conducted using gage data.	Navigation	Risk Based	High Flow, Long Term Forecasted Climate Trends, Missouri
	Impacts of Climate Change on Westport Reservoir		Final	Yes	03/18/2018	Non-stationary analysis on the Westport Reservoir Case	Flood Risk Reduction (Flood Risk Management)	Jacksonville	Coastal Sea Level Rise, High Flow, Lower Safety
	Impacts of Climate Change on Lake Erie Lake		In Progress	No	03/19/2017	The analysis used a literature search and the ECB	Flood Risk Reduction (Flood Risk Management)	Louisville	Steadily, Multibasin Reservoir System, Regulated Basin
	Mississippi River Integrated Watershed Study		Final	Yes	07/14/2017	The purpose of this analysis is to provide a study	Ecosystem Restoration, Flood Risk Reduction (Flood Risk Management), Navigation	St. Paul	Regulated Basin, User Input, Time Series, Nonstationarity, Test, Short Climate Intervals (50, 100, etc.)
	Nick Test Example Nick Test Example		In Progress	Yes	07/18/2017	Nick Test Example Nick Test Example Nick Test Example	Navigation	Alaska	Drought, Extreme Climate Events
	Nick Test Example		In Progress	Yes	07/14/2017	Nick Test Example Nick Test Example Nick Test Example	Emergency Management	Albuquerque	Drought, Extreme Climate Events
	Small Flood Risk Management Project Public, NM		Open	No	3/20/2017	The original flood risk has been re-assessed.	Flood Risk Reduction (Flood Risk Management)	Albuquerque	Expanded Literature Review, Regulated Basin, Endflow
	South River Basin Feasibility Study		In Progress	Yes	02/09/2017	The South River Feasibility Study provides for us	Flood Risk Reduction (Flood Risk Management)	St. Paul	Regulated Basin, Regulated Basin, User Input, Test Series, Nonstationarity, Test
	Water Creek Hydrology Analysis Climate Change Assessment		Final	No	01/19/2018	A literature review of peer reviewed articles	Flood Risk Reduction (Flood Risk Management)	Omaha	Expanded Literature Review, Long Term Forecasted Climate Trends, Mean Annual Runoff

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# QUESTIONS/COMMENTS?



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