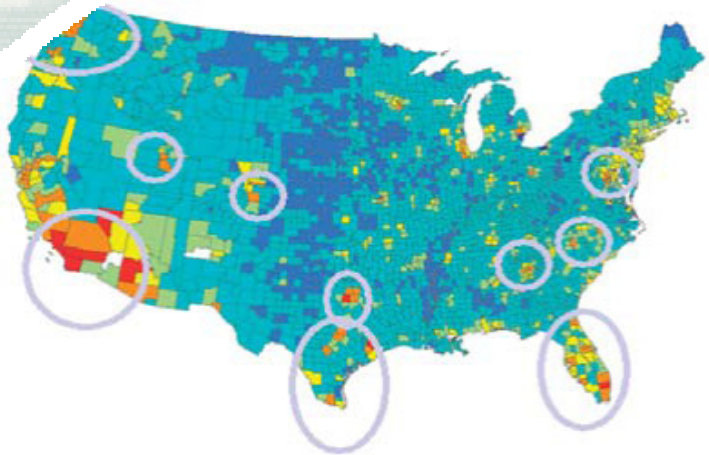
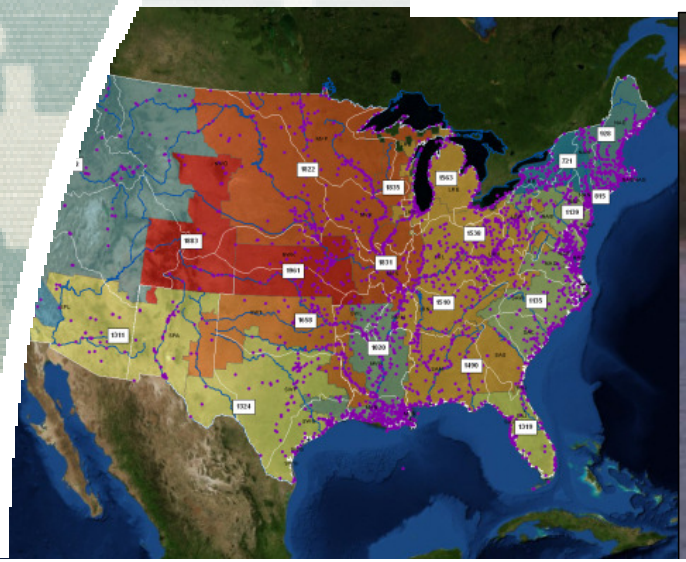
United States Army Corps of Engineers
Inland Hydrology Climate Change Adaptation
Engineering Construction Bulletin 2014

Advisory Committee on Water Information
Subcommittee on Hydrology

February 7, 2014

David Raff
Chandra Pathak
Jeffrey Arnold





US Army Corps of Engineers
BUILDING STRONG®

Inland Hydrology Climate Change Adaptation

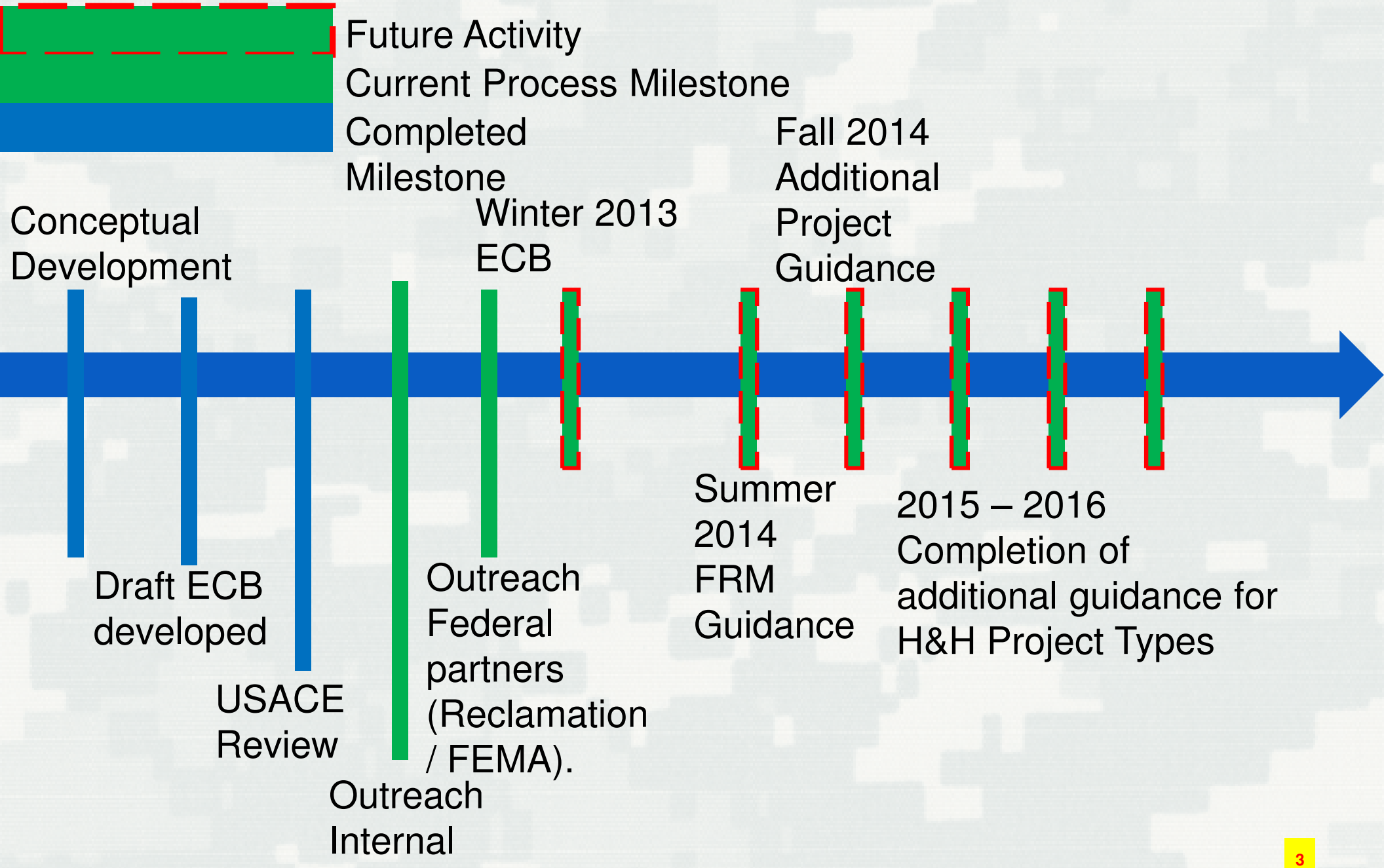
Bottom Line Up Front

Use the information that we know about observed and projected climate changes to reduce vulnerability and increase resilience.

1) ECB 2014 – Require Qualitative Analysis of climate change impacts to inform Planning and Engineering Design that is contingent on inland hydrology.

2) Layout framework for Quantitative Analysis that "hedges" known hydrology in direction that reduces vulnerability. Specific project type guidance to be issued as appendices in updated guidance beginning Summer 2014 for flood risk reduction.

ECB Development Process



US Army Corps of Engineers

ENGINEERING AND CONSTRUCTION BULLETIN

No. X **Issuing Office:** CECW-CE **Issued:** DD MMM 2013 **Expires:** DD MMM 2015

Subject: Guidance for Climate Change Adaptation Engineering Inputs to Inland Hydrology for Civil Works Planning Studies and Engineering Design

Applicability: This Engineering and Construction Bulletin (ECB) applies to all United States Army Corps of Engineers (USACE) elements having Civil Works responsibilities and is applicable to all USACE Civil Works activities, except Regulatory. This interim guidance is effective immediately, and supersedes all previous guidance on this subject and applies to all inland hydrology analyses in planning and engineering design of USACE projects and systems of projects. This guidance does not apply to hydrologic changes associated with coastal storms, which will be the subject of separate guidance.

References: Required and related references for climate change adaptation engineering inputs, described throughout this ECB, relevant for inland hydrology considerations are in Appendix A.

1. **Purpose**: This document provides USACE guidance for incorporating climate change information in hydrology studies for planning and engineering design of USACE projects, systems of projects, and programs. USACE policy (ASA/CW, June 2011) requires consideration of climate change in all current and future studies "to reduce vulnerabilities and enhance the resilience of our water-resource infrastructure." This ECB provides initial guidance on three aspects of climate change elements of inland hydrology studies in planning and engineering design:

   a. development of climate change adaptation inputs into USACE inland hydrology studies qualitatively, what the relevant questions to be addressed are;
   b. where to find information to address those relevant questions; and
   c. what future guidance will require with respect to quantitatively including climate change adaptation inputs to USACE inland hydrology studies.

This ECB is the first guidance for climate change adaptation within inland hydrology applications. The initial implementation of this guidance requires climate change information, that is readily available from literature, to be provided as engineering inputs to planning studies and engineering designs. The initial implementation is not intended to provide specific details on quantitative changes to the numeric of hydrology studies for projects with different project purpose(s): those details will be the subject of future Engineer Circulars (ECs) to be published as they are completed by USACE. The guidance in this ECB includes a short hierarchy of information gathering and analysis steps. This allows USACE staff to identify the appropriate level of analysis for incorporation of climate change information with respect to the planning study or engineering decision at hand in a manner consistent with SMART planning. This ECB also provides a series of information resources to support guidance implementation.

- ECB Currently in review / signing USACE HQ
- Anticipate Release Winter 2013

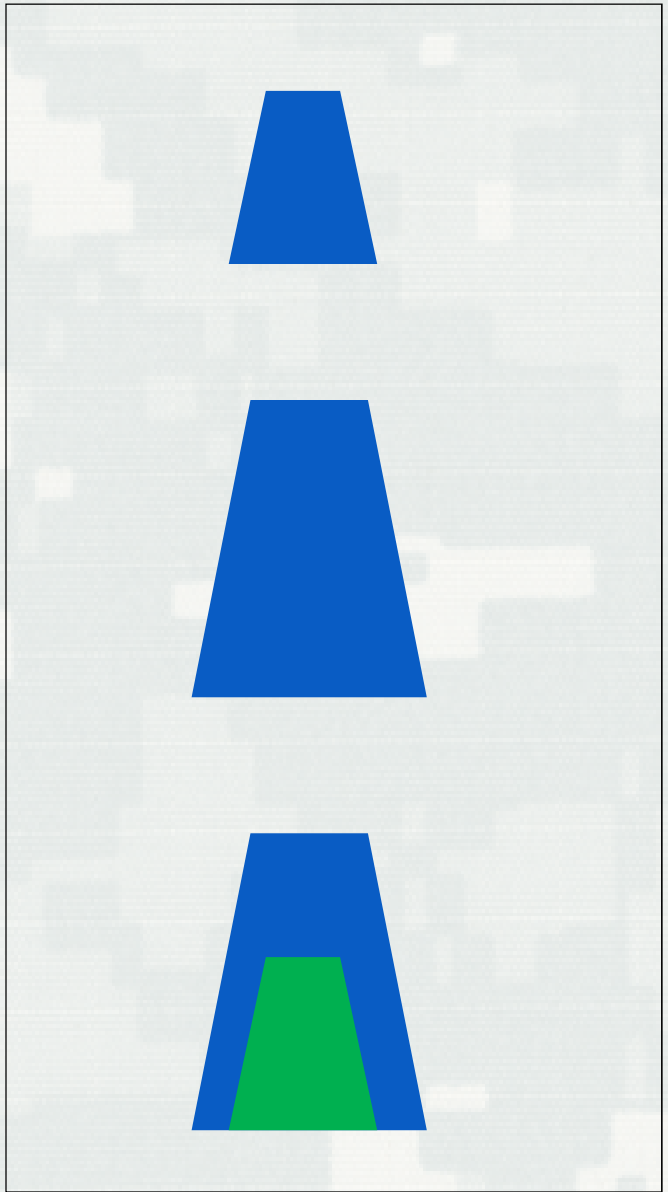
Qualitative Analysis

- No direct quantitative change to hydrology.
- Always required. Level of detail and use intended to be scaled to the decision.
- Collect readily available information from peer reviewed literature and data.
- Assess potential impacts and vulnerabilities to project goals and engineering designs.
- Information available during alternative selection and engineering design.

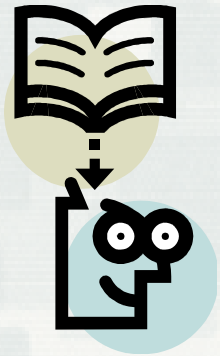
Qualitative Analysis Example

Flood Reduction Project - Levee

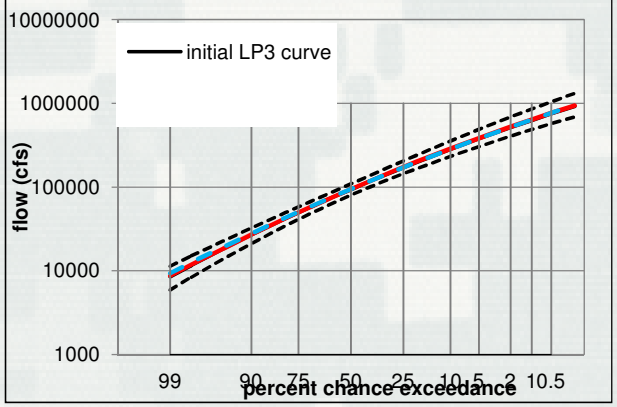
Potential Alternatives



Qualitative Climate Change Information



Hydrology - FDA



Selection

Qualitative Example
What Does It Mean to Your Project?
ECB 2013 – Provides Example In Appendix C

- Initial Assessment – Determine climate change relevancy.
- If Climate Relevant – More in-depth literature review to identify climate threats and potential impacts to **your** project goals and designs.
- When Quantitative Analysis Online – Identify available data, methods, and models that can support Quantitative Analysis Steps.

Quantitative Analysis

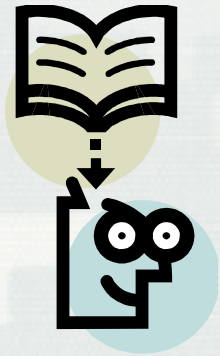
- Directly alters hydrology information informing planning and engineering design.
- Alteration of hydrology always done in direction of “hedge” to reduce vulnerability to climate change.
- Amount of alteration dependent on evidence of current and future climate change impacts.
- Amount of alteration always within current assessment of uncertainty of hydrologic inputs.

Quantitative Analysis Example

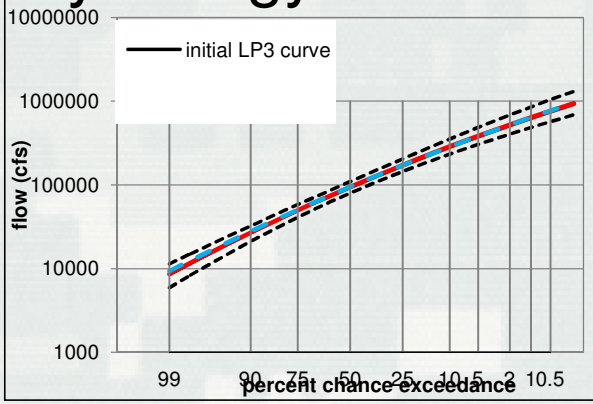
Flood Reduction Project - Levee

Potential Alternatives

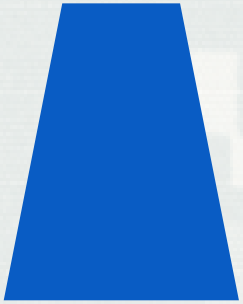
Qualitative Climate Change Information



Climate Hedged Hydrology - FDA



Selection



Discussion - Quantitative Evaluation Process Steps

1) Detect (Yes / No) and Attribute Hydrologic Changes (Yes / No)
   - This is the PAST
2) Will available projections of change alter hydrology (Yes / No)
   - This is the FUTURE

Detect and Attribute Change from Observed Hydrology	**Projected Change from Climate Change Simulated Hydrology**	**Hydrology Adjustment DRAFT NUMBERS BEING EVALUATED**
Yes	Yes	High
Yes	No	Medium
No	Yes	Low
No	No	0% (Business as Usual)

3) Adjust inputs to USACE methodologies within uncertainty estimates currently available. (HEDGE USACE Decision)
4) Conduct analysis per existing USACE guidance

Next Steps

- FY 2014 – Work with USACE Planning Community to develop joint EC

- Continue Development of Quantitative Adjustments for Project Specific Types.
  - Flood Risk
  - Water Supply
  - Dam Safety
  - Levee Safety
  - Ecosystem Restoration
  - Navigation
  - Hydropower
  - Recreation

Next Steps
Quantitative Analysis Development

- Determine Quantitative Adjustments
  - Locally Relevant
  - Reasonably reflect evidence of climate change within uncertainty of hydrologic analysis
  - First in development is for flood risk reduction projects. Input is analysis of flood frequencies and internal team evaluating adjustment factors between 5 and 45 %.

Summary
Technical Implementation

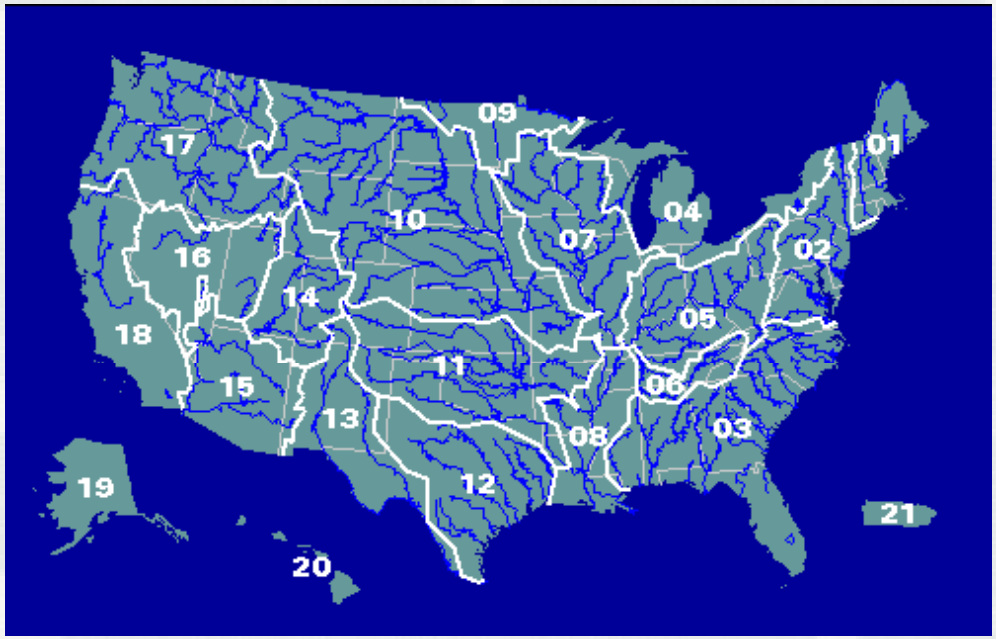
- Qualitative Analysis
  - Synthesis of **Available** Literature
  - Potentially **First Order** Statistical Analysis

- Quantitative Analysis
  - Statistical Analysis for **Detection of Change**
  - Statistical Analysis or literature synthesis for **Attribution of Change**
  - **Future Climate Projections**
  - **Hydrologic Simulation** Including Future Climate Projections
  - Translation into **Engineering Process**

Implementation Support

- USACE in process of developing and deploying the tools to support implementation of qualitative and quantitative analyses.
- Many of the tools being developed have been done so collaboratively with Reclamation and others.
- Both under auspices of CCAWWG and directly.

HUC 2 Literature Synthesis



Contents:

- Observed and Projected Changes
- Impacts by Business Line
- Consistent Graphics of Change Projections for each HUC2

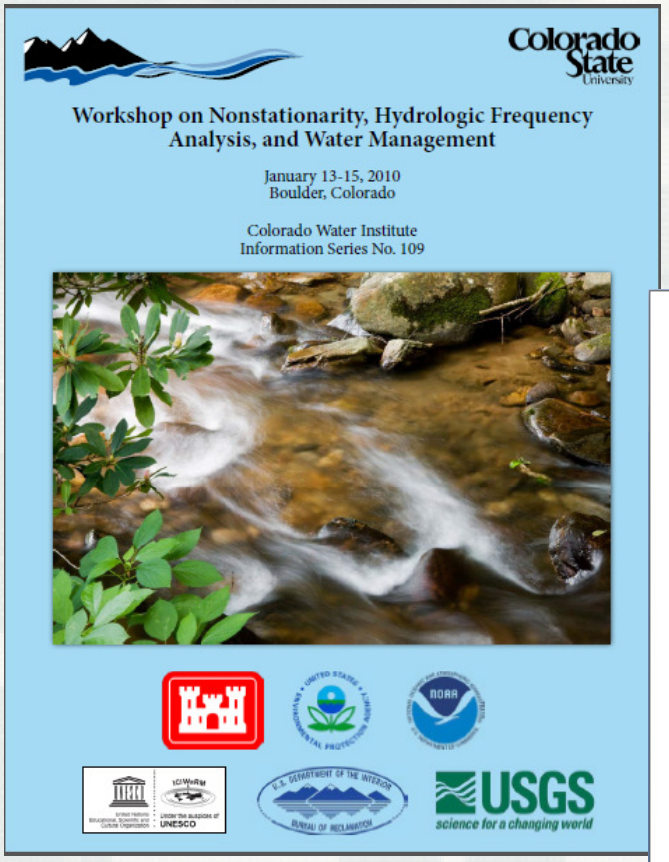
HUC 2 Literature Synthesis

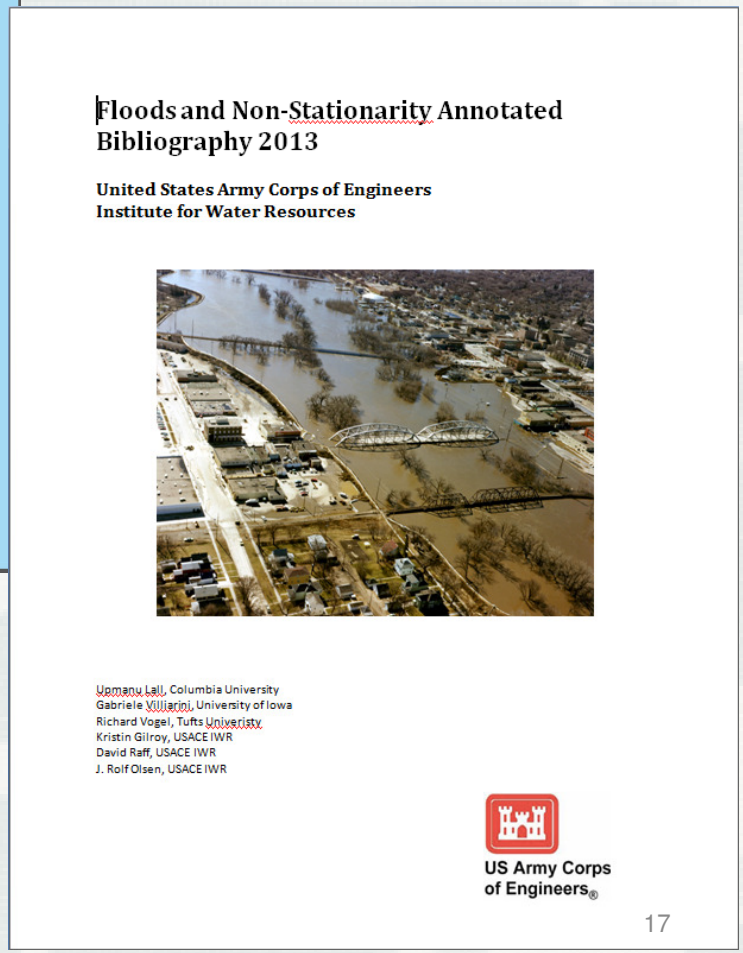
Leverage Existing Literature
Apply to USACE Geography
Peer Reviewed Literature with Impacts Identification Goal

1. USACE RCC Pilot Reports
2. National Climate Assessment Documents
   - Regional Synthesis
   - Technical Input Report
3. Federal Agency Synthesis Documents (CCAWWG)
   - Reclamation
   - EPA
   - NOAA Regional Climate Trends and Projections

Detection and Attribution Literature Review

US Army Corps of Engineers





Floods and Non-Stationarity Annotated Bibliography 2013

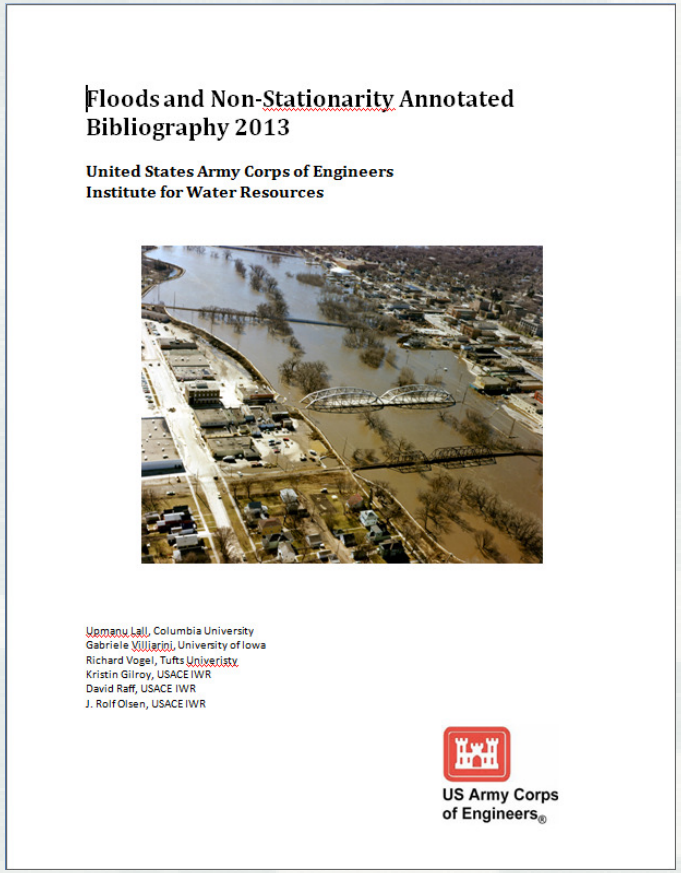
United States Army Corps of Engineers
Institute for Water Resources

Upmanu Lall, Columbia University
Gabriele Villarini, University of Iowa
Richard Vogel, Tufts Univeristy
Kristin Gilroy, USACE IWR
David Raff, USACE IWR
J. Rolf Olsen, USACE IWR

US Army Corps of Engineers®

Application Specific Change Detection and Attribution Guidance

US Army Corps of Engineers



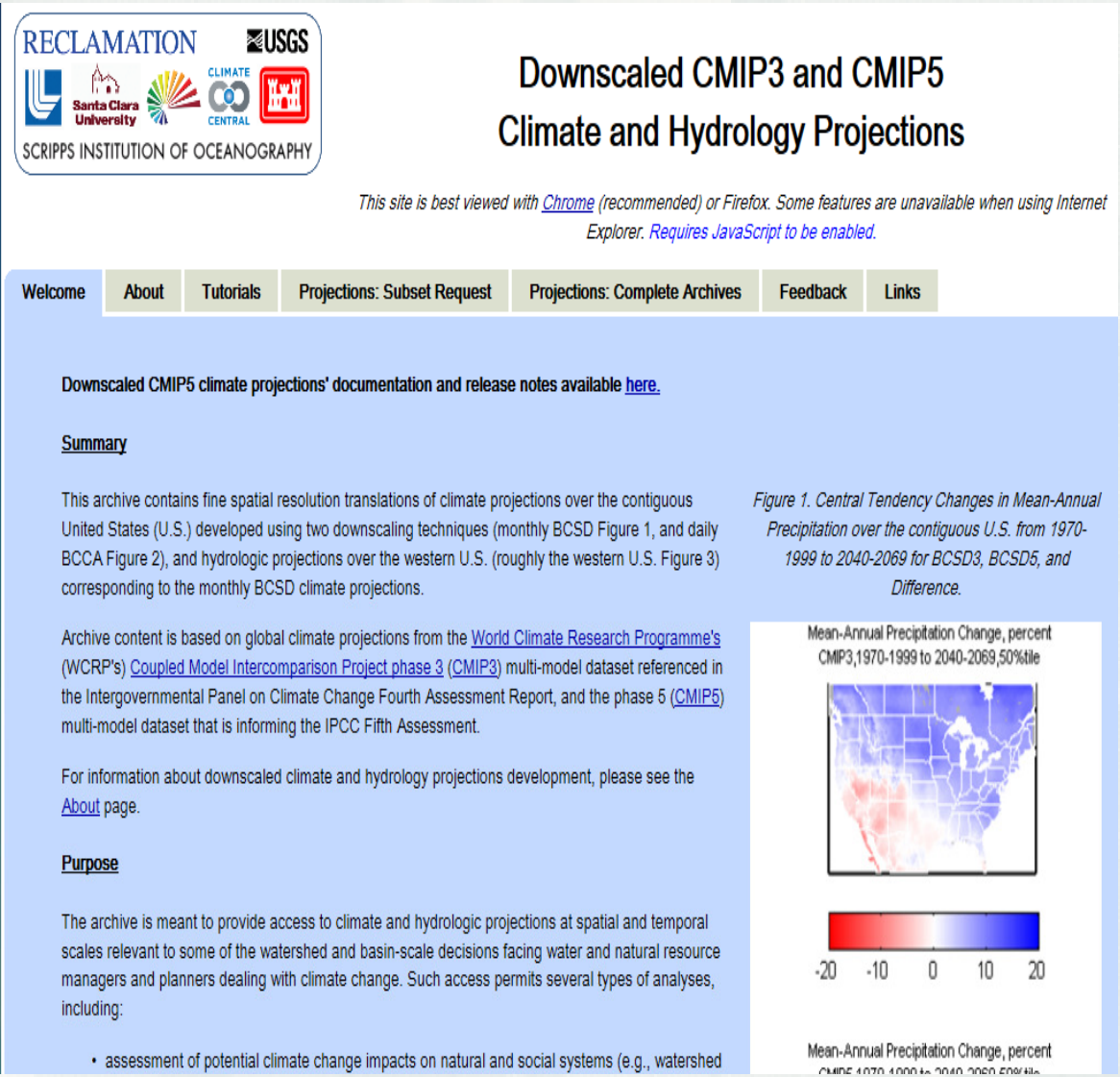
Floods and Non-Stationarity Annotated Bibliography 2013

United States Army Corps of Engineers
Institute for Water Resources

Upmanu Lall, Columbia University
Gabriele Villarini, University of Iowa
Richard Vogel, Tufts Univeristy
Kristin Gilroy, USACE IWR
David Raff, USACE IWR
J. Rolf Olsen, USACE IWR

US Army Corps of Engineers

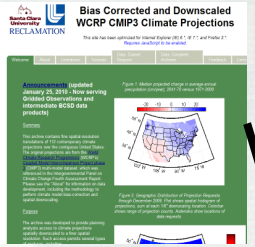
Future Climate Projections

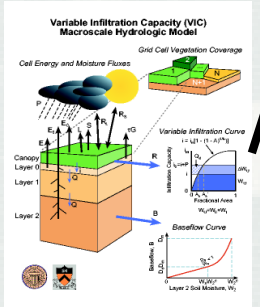


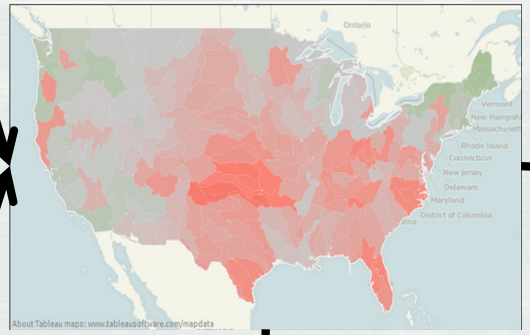
- Multiple Generation of Climate Models
  - CMIP3
  - CMIP5
- Multiple Statistical Downscaling Methodologies
  - Bias Corrected Spatially Downscaled (BCSD)
  - Bias Corrected Constructed Analogs (BCCA)

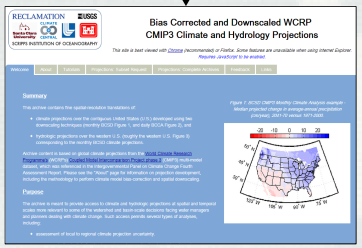
http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html

Hydrologic Projections









USACE Activities

Inland Hydrology
Guidance
Implementation

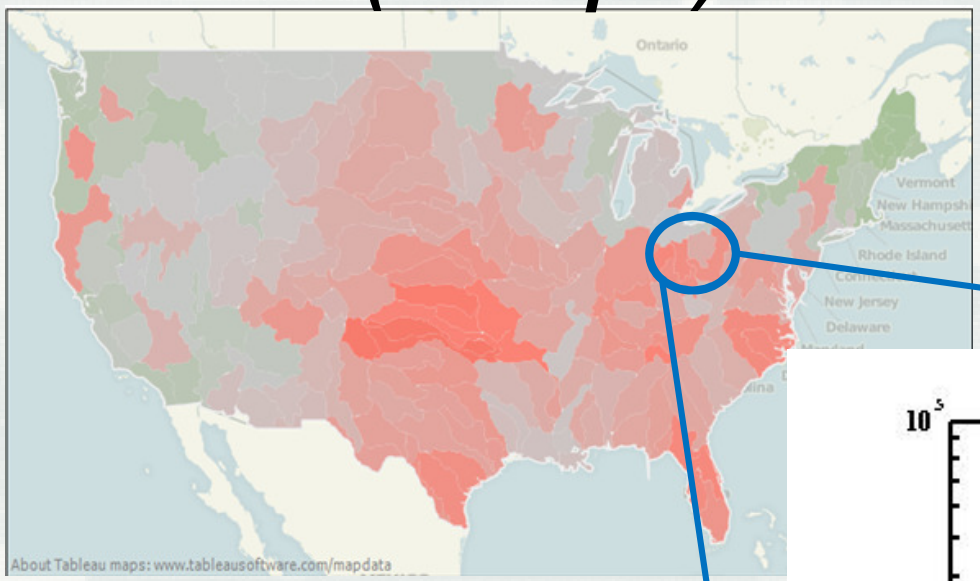
Sedimentation
Analyses

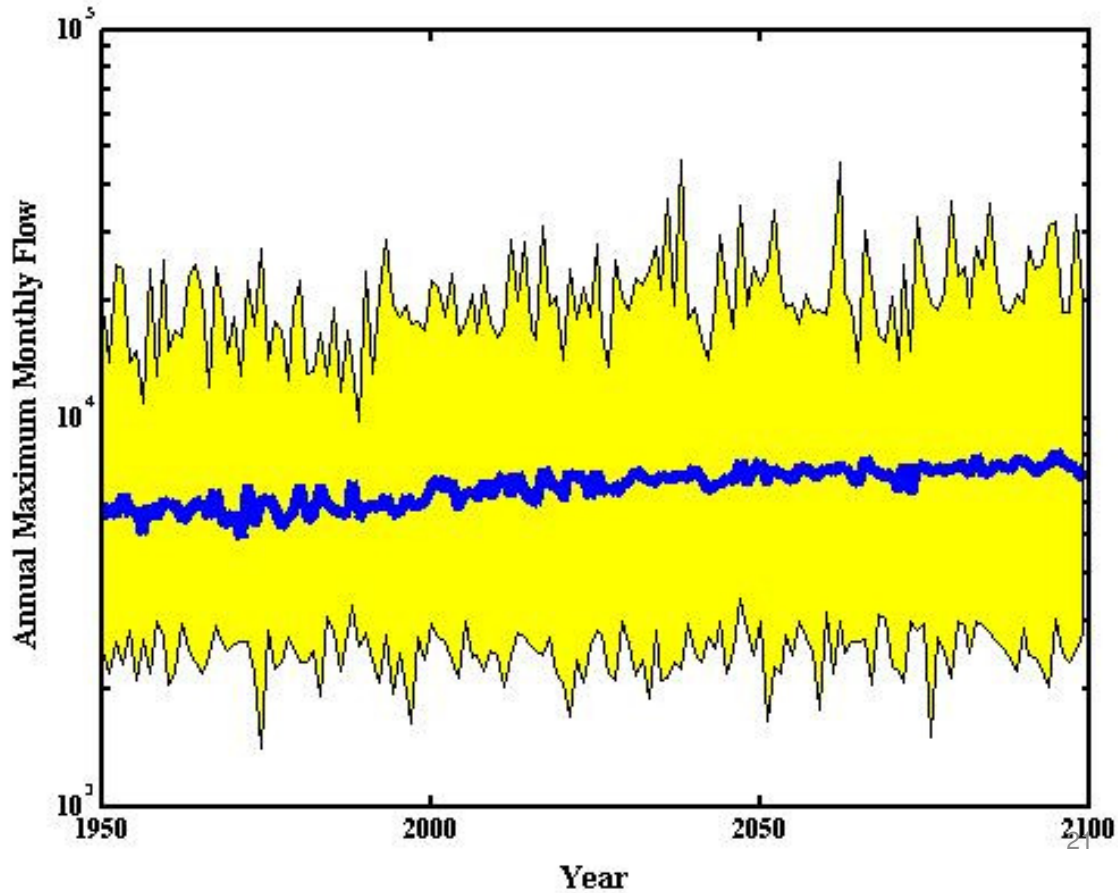
Vulnerability
Analyses

Drought
Contingency Plans

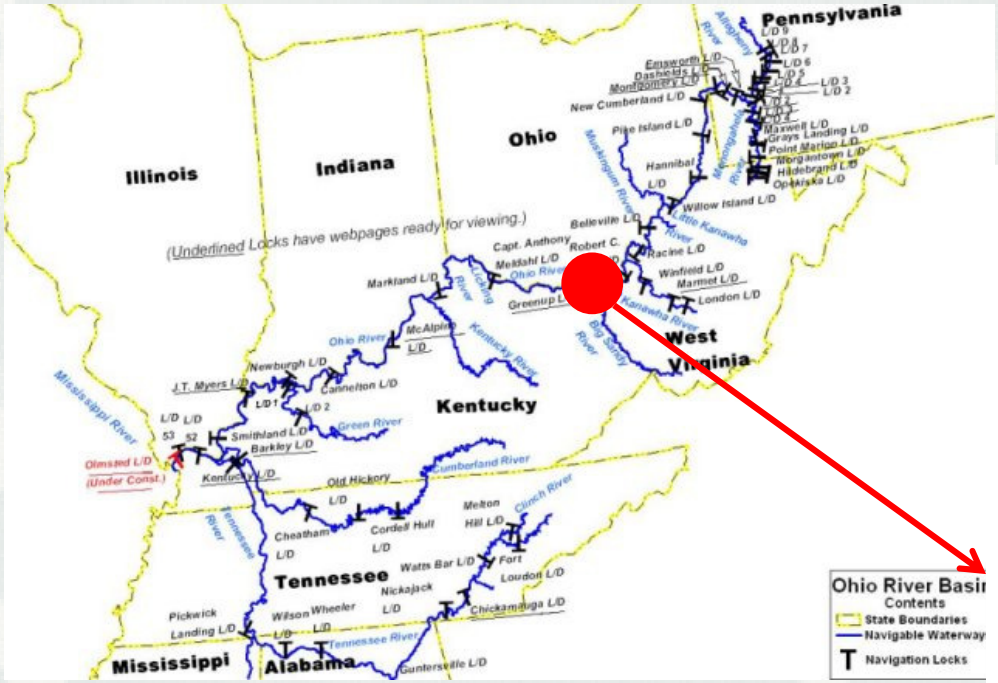
http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html

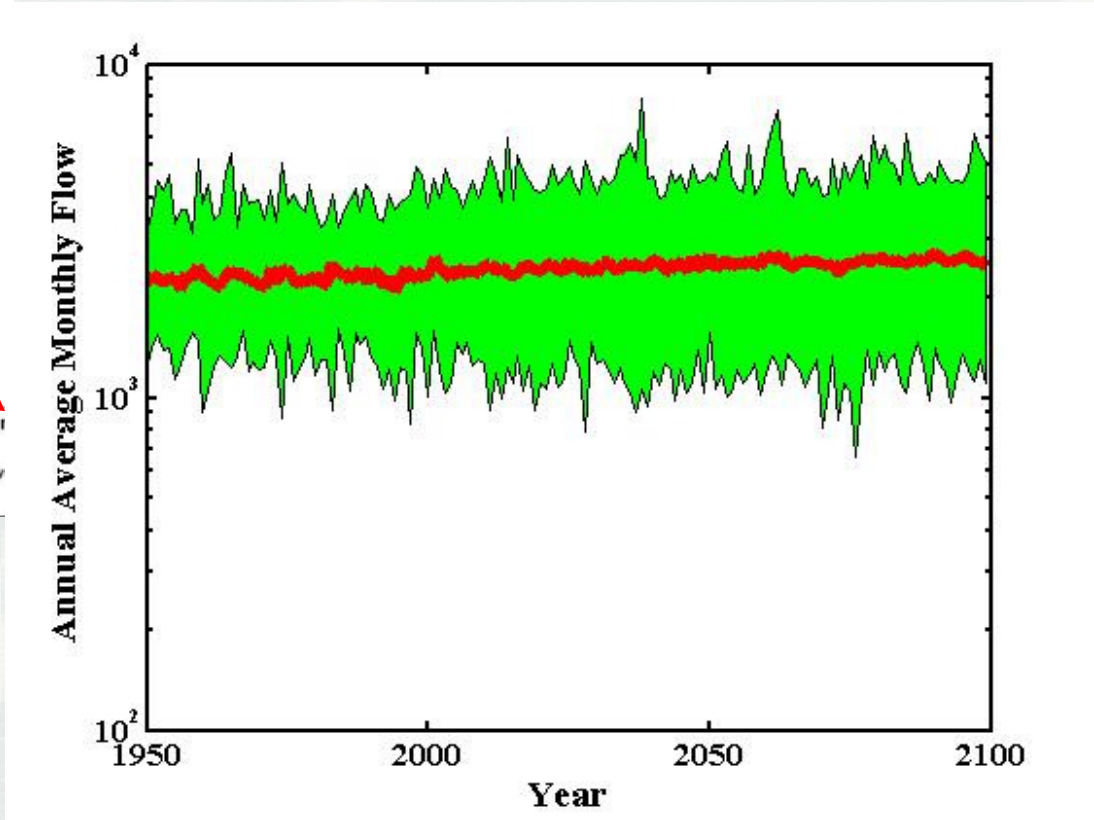
Hydrologic Projections
Phase 1 Complete
(Example) HUC 0509 – Middle Ohio



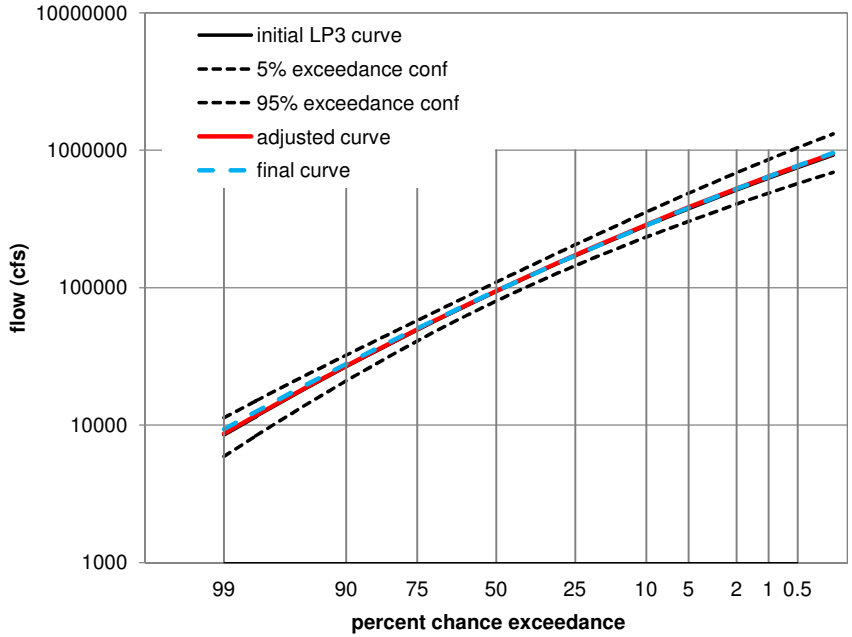


Hydrologic Projections
Phase 2 Ongoing
(Example) HUC 0509 – Middle Ohio





Discussion FDA Analysis



Beth Faber developed adjustment tool – May 2013

SPK Example Summary Output

Sutter Feasibility Pilot Study -- Without Project

	Stream Name	Damage Reach Name	Beginning Station	End Station	Bank	Index Location Station	Description			
	Feather	Yuba City	0	11767	Both	0.5	Yuba City			
	Without	**Without+5%**	**Without+10%**	**Without+15%**	**Without+20%**	**Without+25%**	**Without+30%**	**Without+35%**	**Without+40%**	**Without+45%**
1% CNP	0.6013	0.5881	0.5742	0.5606	0.5440	0.5251	0.4964	0.4661	0.4176	0.3351

Target Stage Annual Exceedance Probability										
Median	0.0351	0.0355	0.0372	0.0384	0.0401	0.0412	0.0425	0.0444	0.0487	0.0547
Expected	0.0383	0.0390	0.0404	0.0418	0.0433	0.0450	0.0470	0.0492	0.0525	0.0578
Long-Term Risk										
10YR	0.3231	0.3281	0.3379	0.3478	0.3578	0.3687	0.3817	0.3960	0.4167	0.4489
30YR	0.6898	0.6300	0.6433	0.6565	0.6695	0.6834	0.6994	0.7165	0.7402	0.7745
50YR	0.8578	0.8631	0.8727	0.8820	0.8907	0.8997	0.9097	0.9196	0.9325	0.9492
Conditional Non-Exceedance Probability by Events										
10.0%	0.8490	0.8480	0.8453	0.8422	0.8390	0.8362	0.8329	0.8293	0.8229	0.8118
4.0%	0.7568	0.7532	0.7450	0.7381	0.7229	0.7223	0.7137	0.7033	0.6909	0.6706
2.0%	0.6738	0.6688	0.6622	0.6565	0.6486	0.6421	0.6321	0.6204	0.5993	0.5667
1.0%	0.6013	0.5881	0.5742	0.5606	0.5440	0.5251	0.4964	0.4661	0.4176	0.3351
0.4%	0.4074	0.3828	0.3545	0.3211	0.2941	0.2656	0.2266	0.1961	0.1576	0.1175
0.2%	0.2272	0.2080	0.1867	0.1623	0.1462	0.1323	0.1148	0.1041	0.0933	0.0844

Climate Change Adaptation Training

Hydrologic Impacts Under Climate Change Training Class (Pilot January 15-17, 2013).

Crop Irrigation Requirements (CIR) under Climate Change Training Course (Pilot March 5-7, 2013)

Additional training being developed.

- Sedimentation Impacts Analysis
- Ecological Impacts Analysis

Discussion