Guidance model for resilient water resources planning and design

Guillermo Mendoza, PhD and Kristin Gilroy, PhD
Institute for Water Resources, US Army Corps of Engineers

HYDROPREDICT
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SPECIAL SESSION 3

CHOOSING MODELS FOR RESILIENT WATER RESOURCES MANAGEMENT

WATER PARTNERSHIP PROGRAM (WPP)/TWIWA
THE WORLD BANK

ALLIANCE FOR GLOBAL WATER ADAPTATION
CORE TECHNICAL - ADVISORY TEAM
U. Of Massachusetts-Amherst (Dr.Brown & students+)
World Bank Water Anchor
Conservation International (Dr. Matthews)
Institute for Water Resources, USACE

Challenges for WRM under Climate Change

- Extremes and about specific decision metrics.
- Principal medium by which climate change impacts will be felt and mitigated
- A real possibility that floods and droughts will have greater magnitude, duration, and frequency
  - Paleo-climatic data in the US show longer droughts than observed in 100 years of hydrology data (Laird *et al*. 1996);(Woodhouse and Overpeck, 1998)
- Past and existing planning, design, and operation are based on stationary statistics

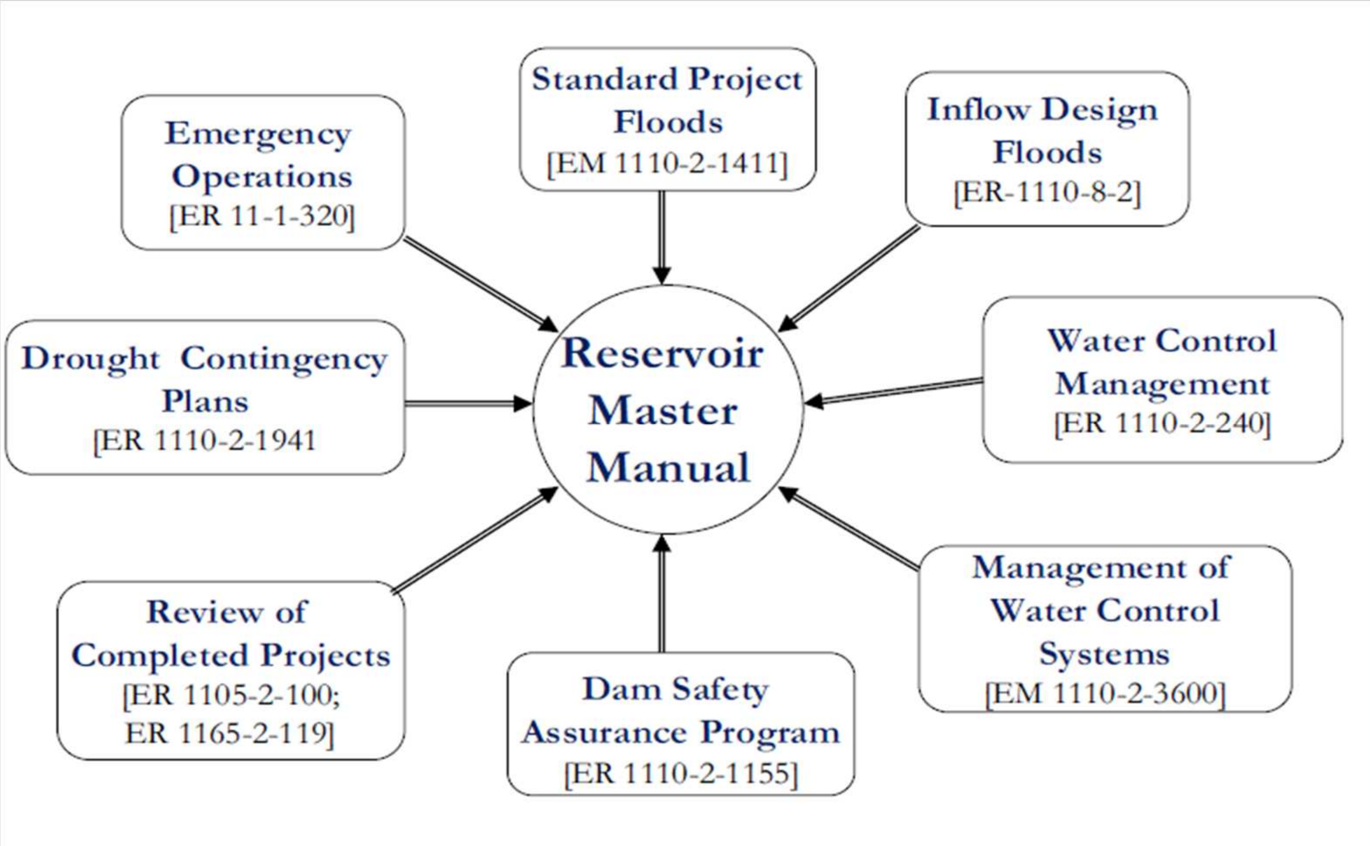
Increasing use of GCMs and RCM downscaling

- **Changes in climate have the potential to alter risks beyond what has been planned for**
- **GCM projections provide information about climate means, but not extremes**
  - **Extremes are most relevant for risk**
  - **GCM projections of climate means do not delimit the range of uncertainty**
  - **Variability a particular problem**
- **Spend a lot of money but critical variables for design and planning may be lacking, and little improvement in certainty**
  - **modeling and analysis must be guided by problem solving for decision making**

Planning and Design under different future climate states

- Planning
  - Project justification relies on frequency analysis
  - Multi-objectives and values, and stronger interest groups
- Design
  - FRM
    - Frequency Analysis and EAD
    - Standard Design Floods
  - Infrastructure Integrity
    - Probable Maximum Flood (PMF)
  - Water Supply
    - Storage-Yield-Performance (reliability, production, deficits,…)
- Operations
  - Flexibility for alternate operations (adaptive management)
    - Operation rule curve adjustment (engineering & policy)
    - New authorities/purposes (engineering & policy)

Water Resources Managers often have Engineering guidance



Principles and Guidelines
[USWRC 1983]

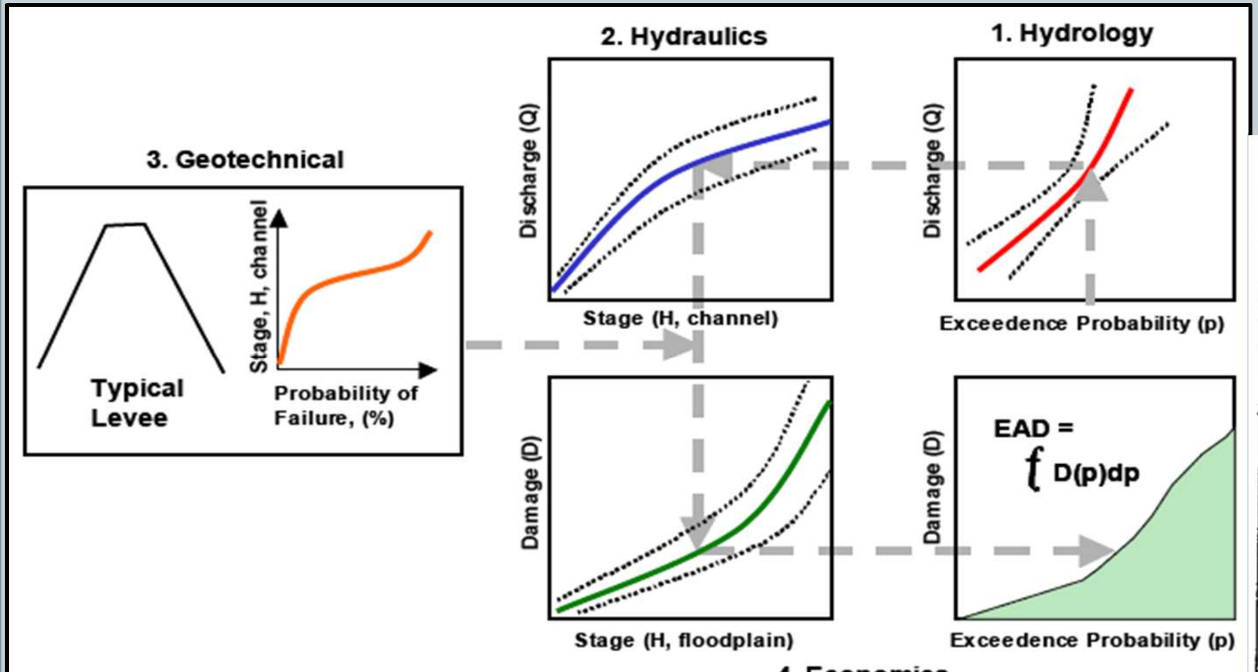
1. Identifying problems & opportunities
2. Inventorying & forecasting conditions
3. Formulating alternative plans
4. Evaluating alternative plans
   (NED, EQ, RED, OSE)
5. Comparing alternative plans
6. Selecting a plan

Increased peak flow in Flood Risk Management (high flow extremes)

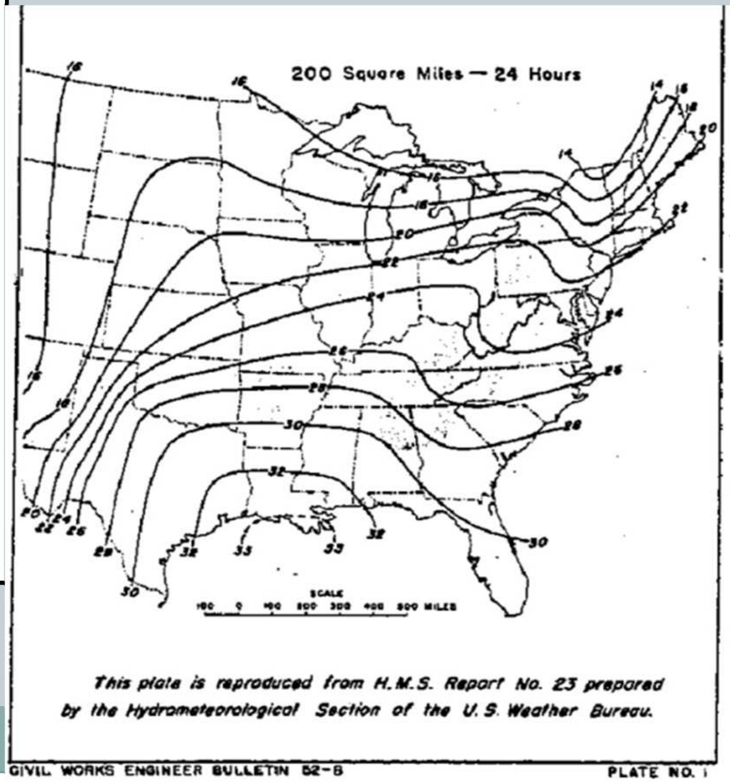
- Flood Risk Management

$$E[X] = \int_{-\infty}^{\infty} x f_X(x)\, dx$$

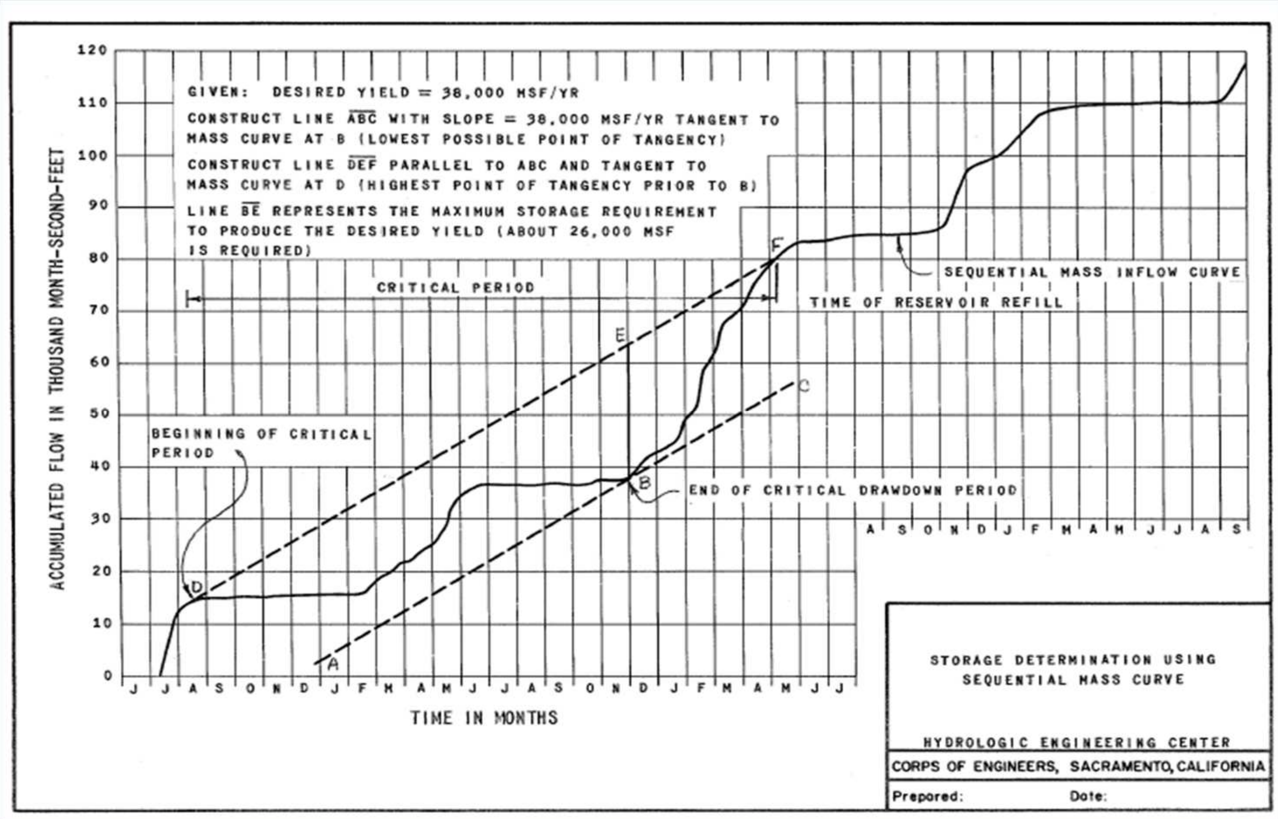
- Infrastructure Integrity (PMF for spillways)
  - PMP
    - Moisture maximization
    - Transposition
    - Envelopment

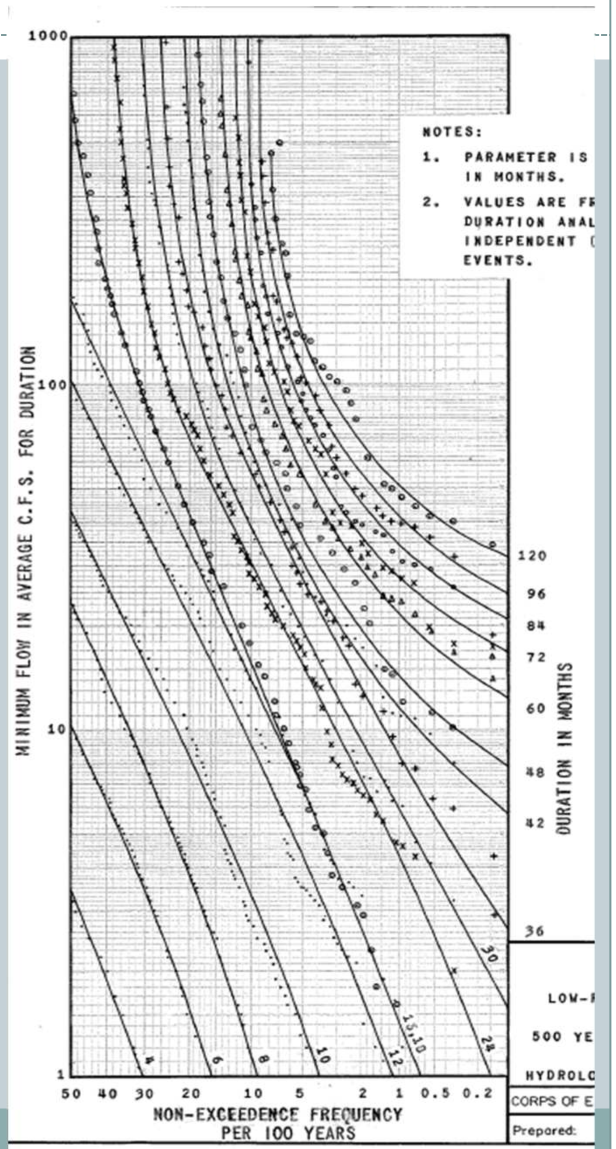


Source: Adapted from Moser (1997)



Reduced flows for Water Supply (low flow extremes)

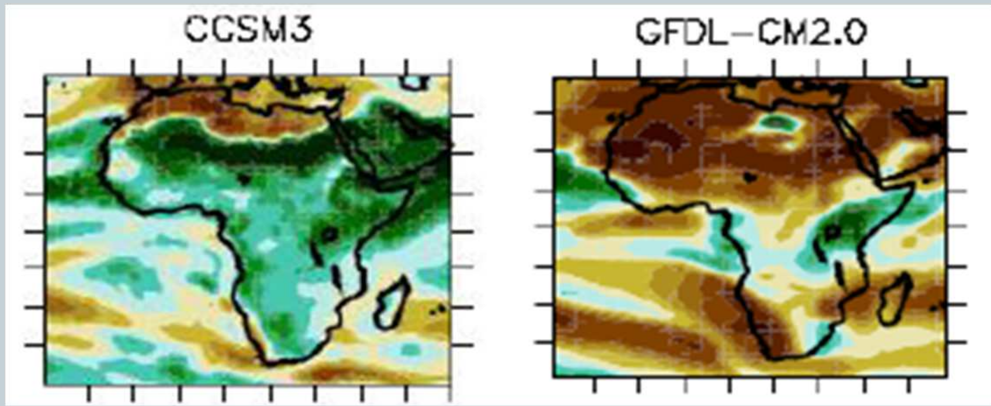




GCM (and thus RCMs) produce a wide range of outputs

- Coupled Model Inter-comparison Project Phase 5 (CMIP5) [http://cmip-pcmdi.llnl.gov/cmip5/index.html]
  - Assess mechanisms that result in model differences […] associated carbon cycle and clouds.
  - Examine climate "predictability" and explore the model ability to predict climate on decadal time scales (short term).
  - Determine why similarly forced models produce a range of response

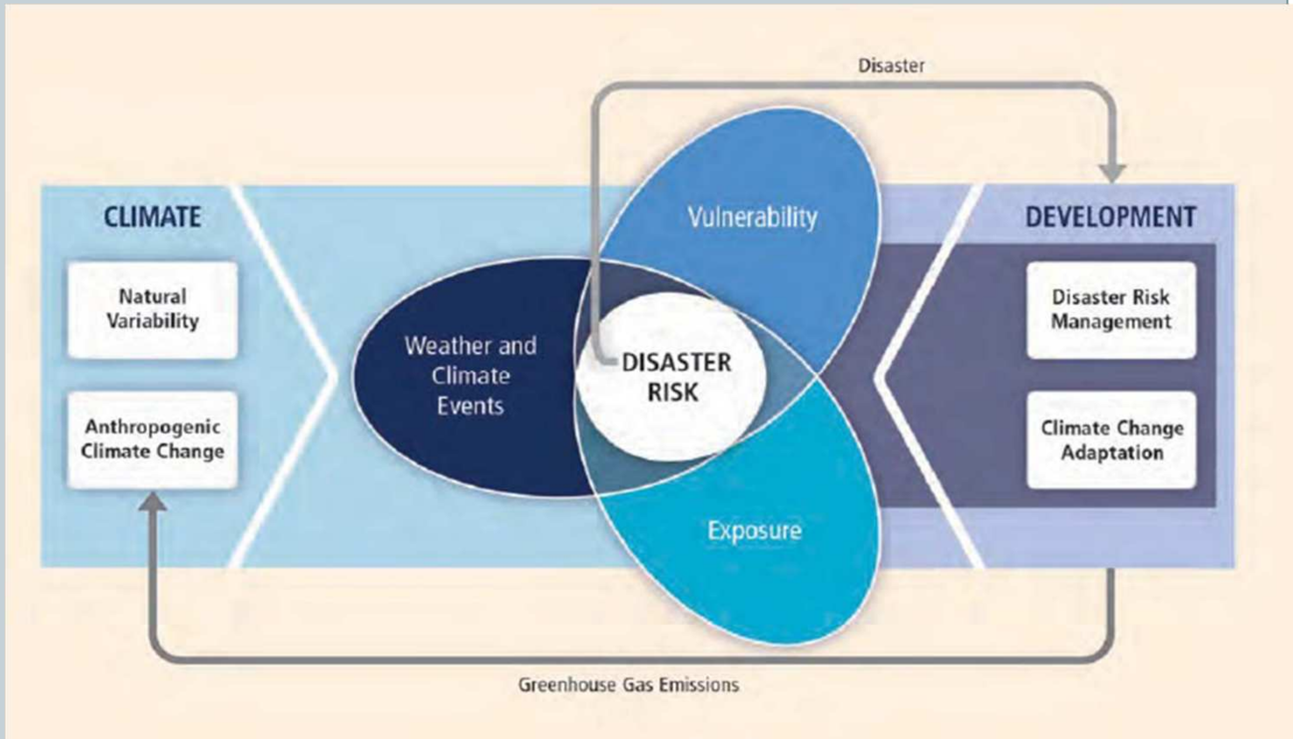
- Are climate models "ready for **prime time?** Kundzewicz and Stakhiv (2010)



Change in annual rainfall in 2080-2100 (wrt 1980-2000) in Africa (IPCC, 2007).

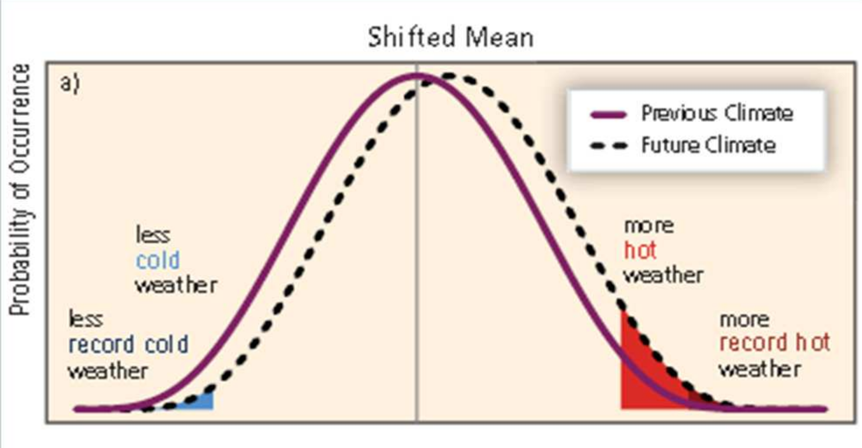
IPCC Special Report Mgmt Risks of Extreme Events & Disasters (SREX)

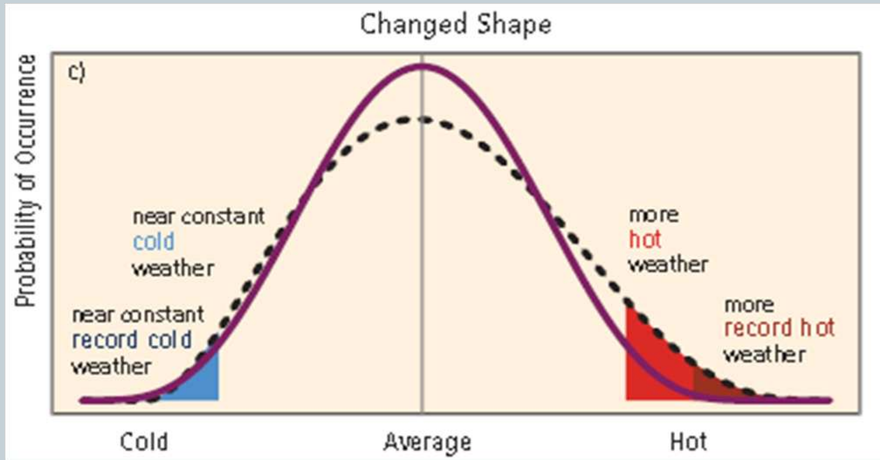
- SREX IPCC report:
  - In the mid-term current variability is greater than projections
  - Character & impact
    - Extremes
    - Exposure
    - Vulnerability
- Adaptation& DRM
- Science<->Policy
  - social, economic, environmental, poverty,...
  - participatory processes

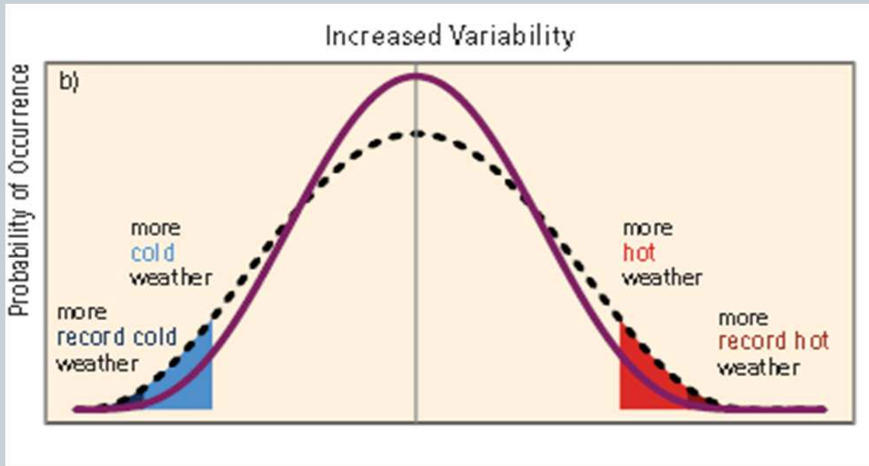


Managing water resources for alternate climate statistics

- Eg. Statistically significant trends in the number of heavy precipitation events in some regions. It is likely that more of these regions have experienced increases than decreases, although there are strong regional and subregional variations in these trends. Source: 2012 IPCC SREX report [3.3.2]

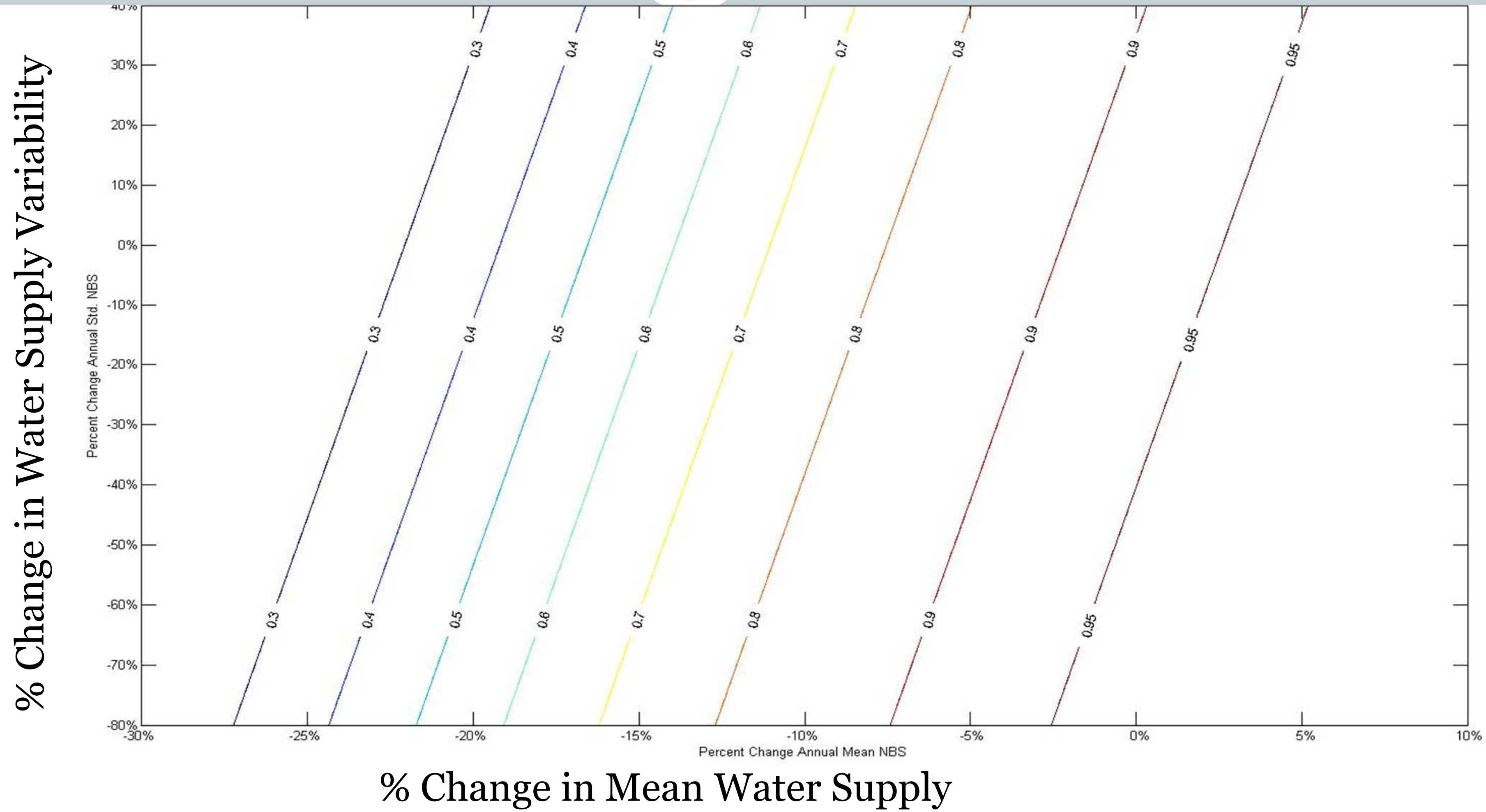






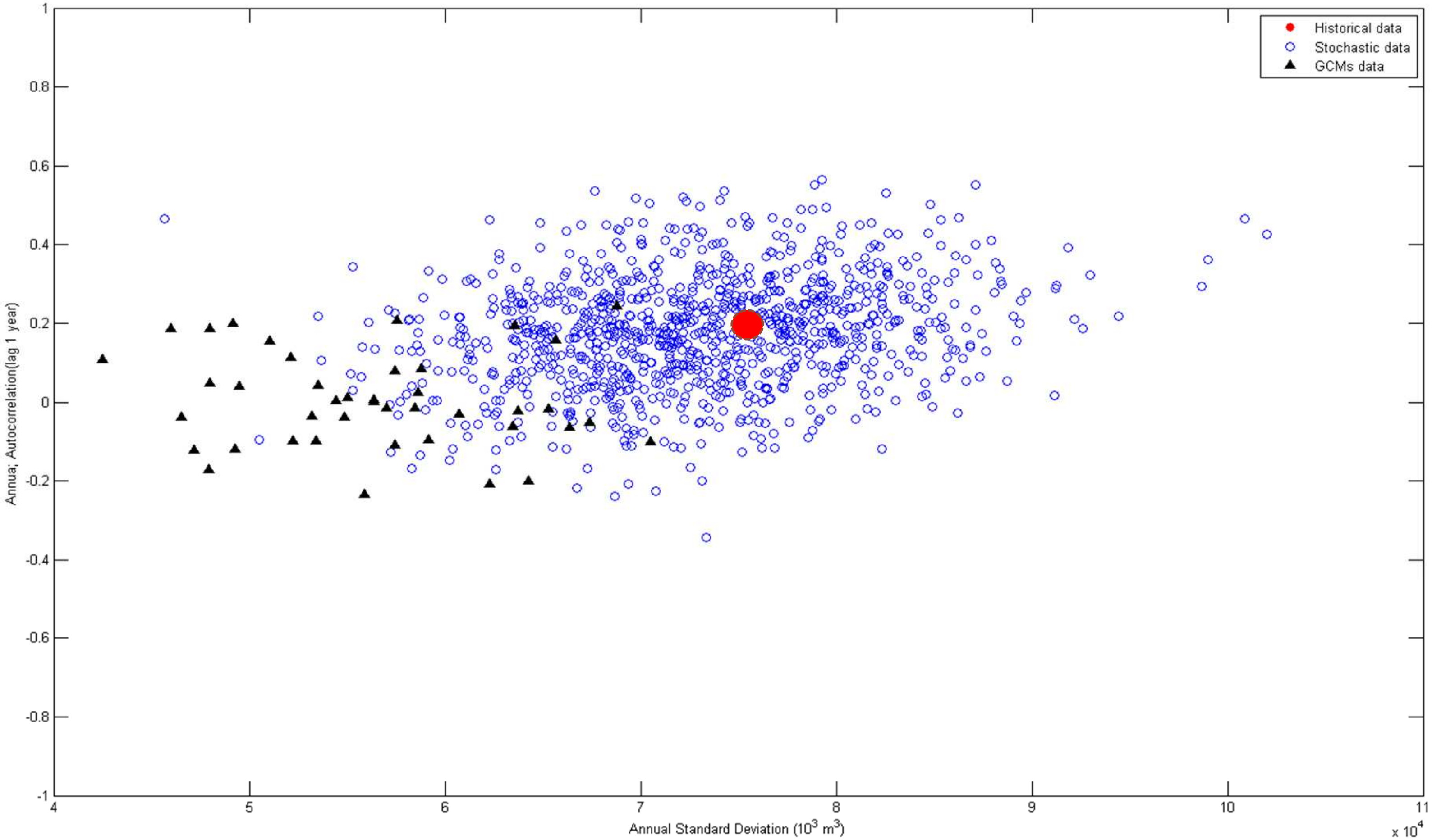
Source: 2012 IPCC SREX report

Reservoir Reliability and climate change



Risk of Underestimated variability

Autocorrelation



Standard Deviation

Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University.

“A guidance model for resilient water resources planning and design?”

- Setting up the problem (Valdes et al., Caldwell et al., Kundzewicz & Krysanova)
  - Exposing dominant uncertain forcings
  - Is climate change the principle source for risk of failure in an uncertain future?
  - Scarce data
- Decision Scaling (Olsen and Gilroy, Stakhiv, Grijsen)
  - Start with problem identification that guides analysis
- Decision Matrix for design and planning (Olsen and Gilroy)
  - Flexible Strategies (scenario based, stress test/sensitivity analysis, low regret, adaptive plans with trigger points, status quo approaches…)
- Project justification that promotes robust decision making

Alliance for Global Water Adaptation

- Mission: Provide tools, partnerships, and technical assistance to improve effective decision making, action, governance, and analytical processes in water resources management, focusing on climate adaptation and climate change relevant scales.
- **Nov 2011 Workshop hosted by the World Bank:** "Including Climate Change in Hydrologic Design [..]"
  - Result: four working groups to develop decision tree of structured guidance but flexible to support different agencies and missions
    - 1. Hydrological and climate (Institute for Water Resources USACE)
    - 2. Economic valuation and financial instruments (World Bank WPP, European Investment Bank, and the OECD)
    - 3. Engineering and ecology (CI and the Inter-American Development Bank)
    - 4. Transboundary, trans-institutional, and allocation governance (U.S. State Department and the Environmental Law Institute)

The AGWA Decision Framework

Establish Decision Context

Problem (Extremes decision metrics)	Critical Zones/ Breaking Points	Stakeholder processes

Identify Risks: Stress Tests

Weather generator	Data & Confidence	GCM/RCM narrative	Modeling Scale & Scope

Analyze Risks: Proximity & trends to Critical zones / Breaking points

Establish dominance of climate change	Plot data & confidence	GCM/RCM narrative

Evaluate Risks / Risk 'buy-down' of WRM alternatives

Decision Matrix	Identify resilient systems	Confidence & Consequence	Multi-Metrics

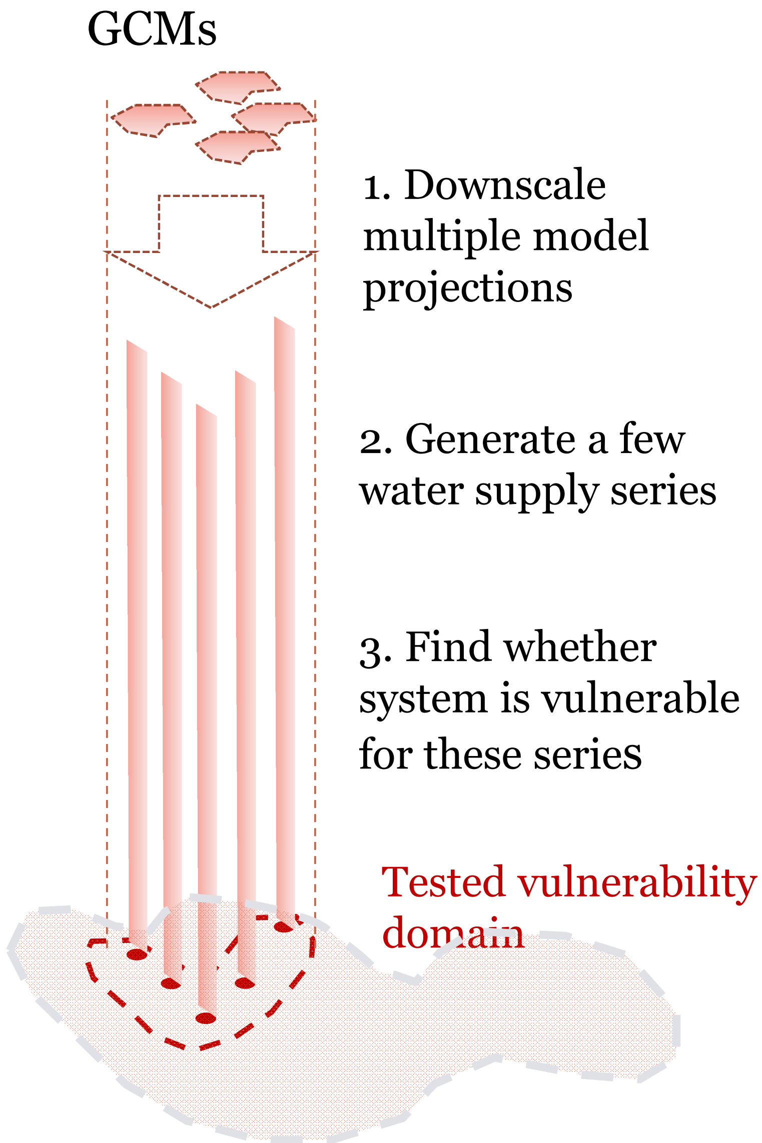
Decision matrix for Design Guidance / Planning Guidance

Robust Designs	Adaptive Management Plan (sign posts)	Appropriate Justification (real options,..)	Financing plans

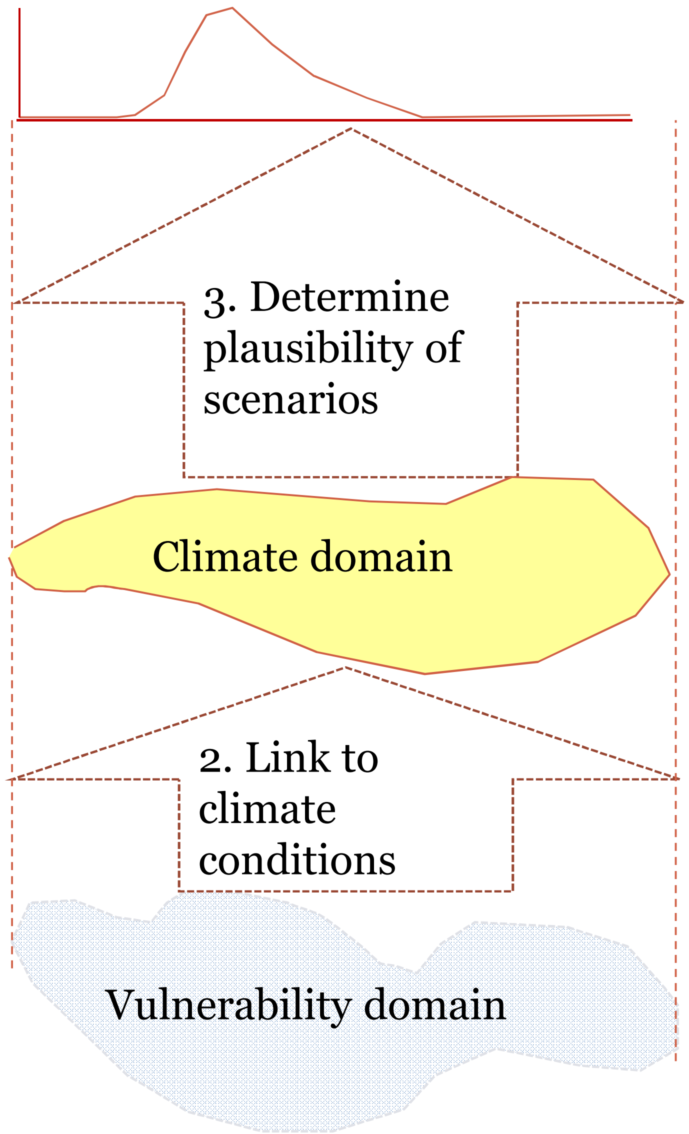
Using a weather generator

- **For identifying risks, stochastic climate/weather generation allows sampling a much wider range of plausible climate changes**
  - Allows assessment of the ability of existing projects to manage changes in climate, including changes in extremes
  - Allows identification of vulnerabilities and quantification of robustness
  - Can specify climate changes that are plausible yet would not show up in a GCM-based analysis
- **GCM projections can then "inform" the likelihood of risks that are identified**

Down Scaling



Decision Scaling



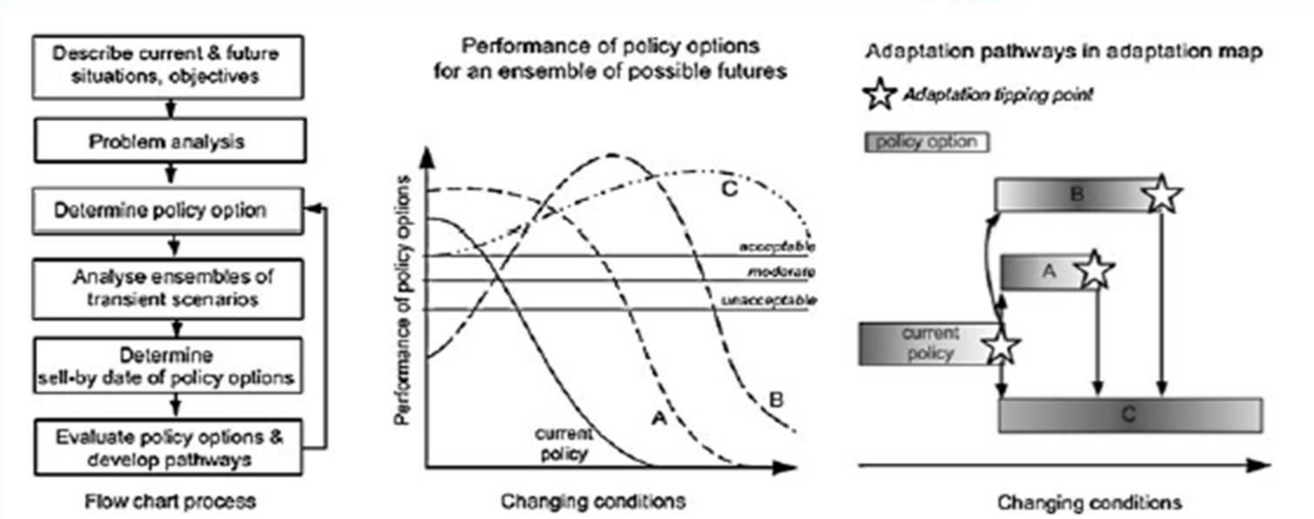
Source: Brown and Werick (2011): A decision analytic approach to managing climate risks . JAWRA

Strategies for adapting water resources management planning, design and operations

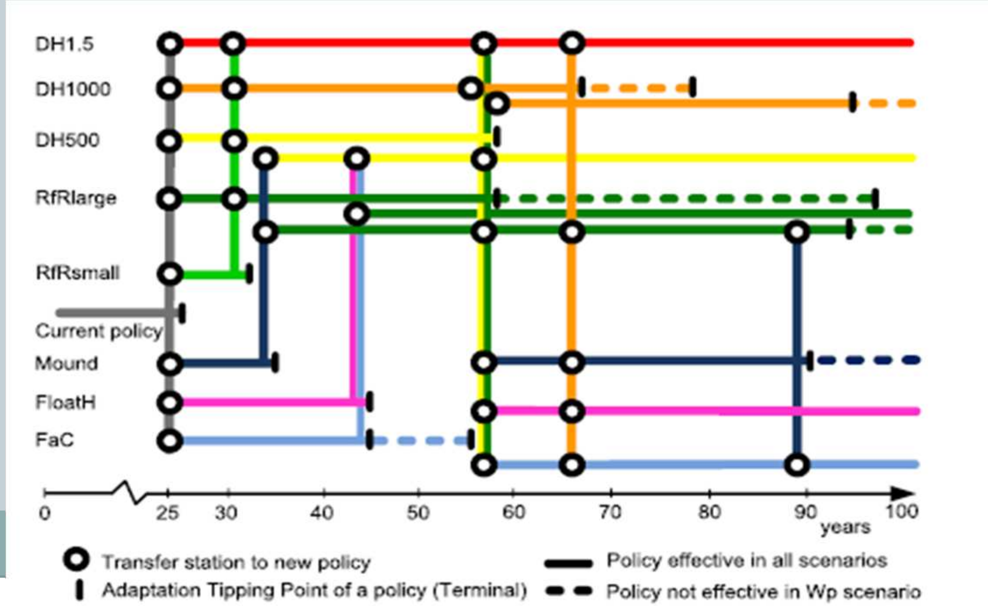
- Scenario-led risk assessment and planning
  - Computationally demanding and uncertain
  - Raising awareness of high-level risks
- Sensitivity analysis of option portfolios
  - Stress tests not limited by forecasts or existing records
  - Assess hypothetical climate states versus evidence and confidence to stress
- Scenario neutral/ accept changing levels of service/ manage water demand
  - Narrative possibilities => easy to apply
  - Low regret / 'soft' management approaches
- Safety margins/ precautionary principle
  - Easy to implement and not necessarily linked to science
  - Large opportunity costs
- Adaptive management/ modify operations/ delay investment
  - Trigger points, and timing of investments
  - Real options financing, etc.

Source: Wilby (2011): Using climate model output for water resource applications

Use of adaptive management pathways

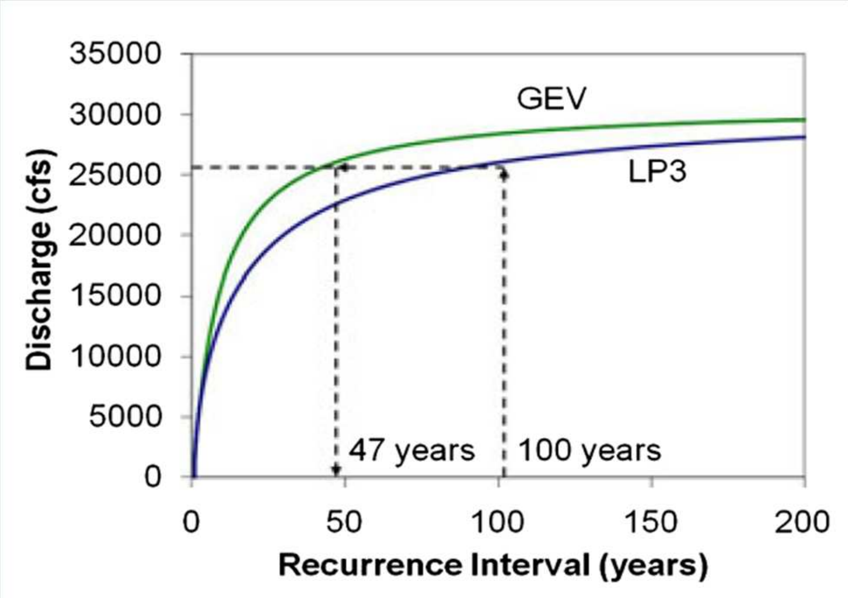


Hasnoot et al. (2010): Exploring pathways for sustainable water management
in river deltas in a changing environment



The quadruple discount dilemma justification of 'low frequency high consequence' investments

- Use of "skinny-tailed" probability distribution functions
  - Solution?: "fat-tails"
- Discount rate
  - Solution?: reduce t
- Probability x Consequence
  - Low frequency low consequence
    - Expected Annual Damages
    - Expected Value
  - Solution?: PMRM
- Economically efficient objective functions
  - Min{cost} may lead to brittle solutions
  - Solution?: min Risk Cost



Stakhiv (2011)

What's Next

- A work in progress
  - Seeking to enhance partnerships
- Two discussion Forums

10:10-10:30 Conceptual challenges and solutions for resilient WRM

Sampling Variability vs. Climate Change (J. Valdes)

Risk-informed decision making (Olsen & Gilroy)

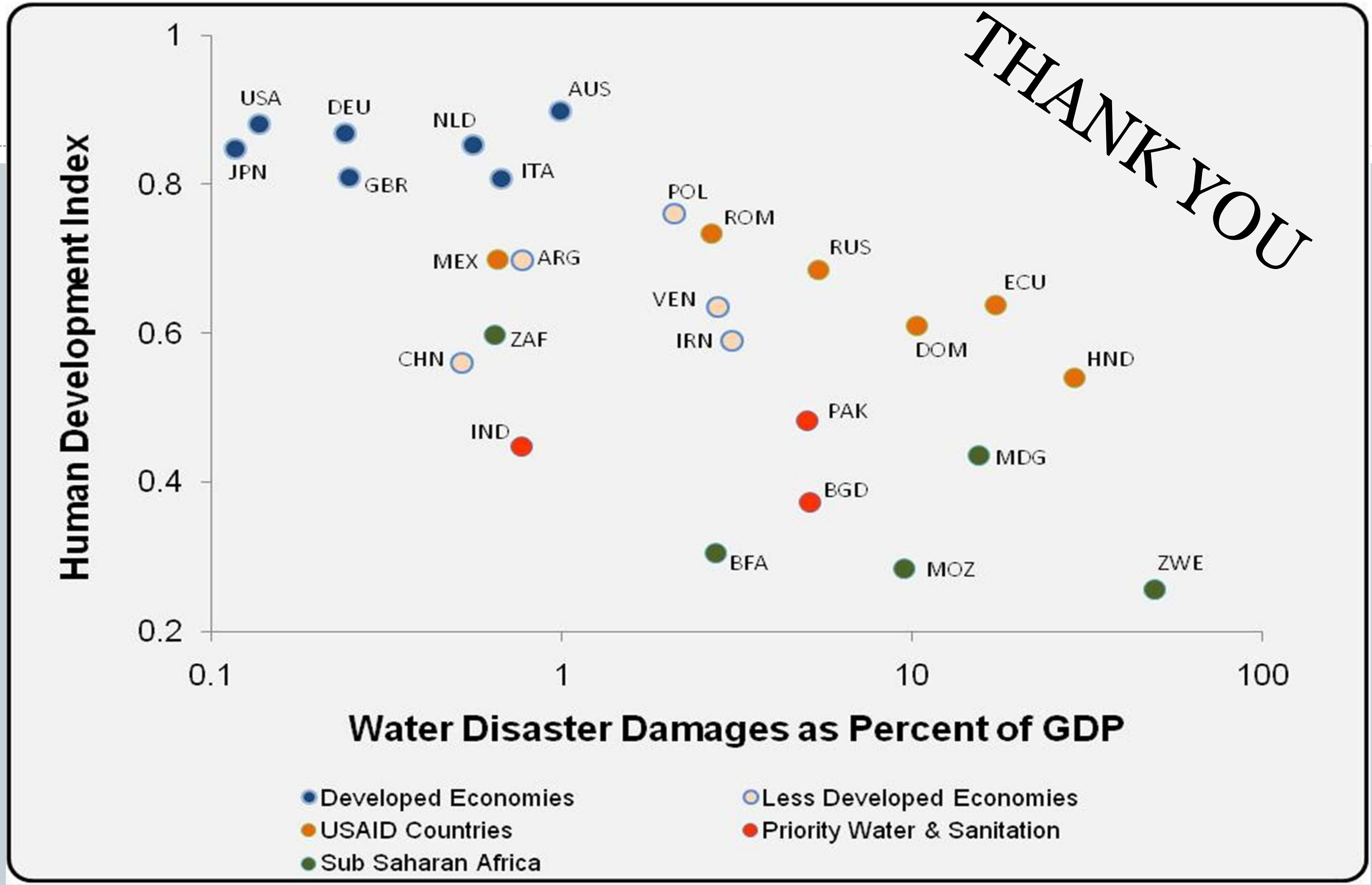
12:30-13:00 Case Studies and Pilots

Decision scaling in the GLS (Stakhiv)

Decision Scaling for Water Strategy in the Niger (Grijsen)

Modeling for resilient WRM under scarce data (Kundzewicz)

Climate vs Human effects in Africa and US (Caldwell)


THANK YOU
Human Development Index
Water Disaster Damages as Percent of GDP
1
0.8
0.6
0.4
0.2
0.1
1
10
100
USA
JPN
DEU
GBR
NLD
ITA
AUS
POL
ROM
RUS
MEX
ARG
VEN
IRN
ECU
DOM
HND
ZAF
CHN
PAK
IND
MDG
BGD
BFA
MOZ
ZWE
Developed Economies
Less Developed Economies
USAID Countries
Priority Water & Sanitation
Sub Saharan Africa