Building Resilience to a Changing Climate:

A Technical Training in Water Sector Utility Decision Support

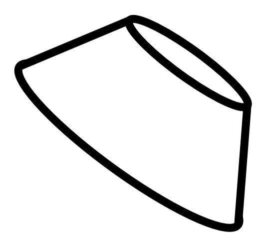
WUCA
Water Utility Climate Alliance

Methods for Decision Making Under Conditions of Deep Uncertainty (DMDU)

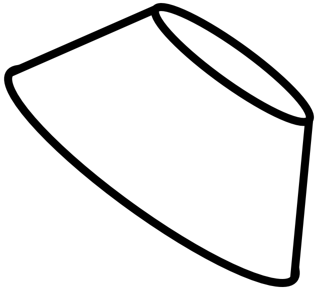
Michelle Miro, RAND

You’ve Received Much Advice So Far

- Past climate is no longer a reliable predictor of future, or even *current*, climate, but no one is sure exactly how climate has and will change
- Climate models are helpful when used appropriately, but far from perfect
  (But they are probably a lot better than economic models!)
- Don’t wait for uncertainties to be resolved -- that won’t happen anytime soon.
- Consider multiple objectives (reliability, cost effectiveness, equity, …)
- Many decisions will prove effective or provide benefits under multiple possible future conditions
  - Don’t mistake
    - Well-characterized risk
    - For deep uncertainty



<u>Deep uncertainty</u> occurs
when the parties to a decision
do not know or do not agree on
the likelihood of alternative futures
or how actions are related to consequences



DMDU Methods and Tools Provide Water Managers Means to Take This Advice

Basic DMDU principles

1. Consider multiple futures, not one single future, in your planning. Choose these futures to stress test your organization's plans
2. Seek robust plans that perform well over many futures, not optimal plans designed for a single, best-estimate future
3. Make your plans flexible and adaptive, which often makes them more robust
4. Use your analytics to explore many futures and options, not tell you what to do

There are many ways, small and large,
to fold these principles into your organization.

Traditional Risk Management Works Well When Uncertainty is Limited

"Predict then Act"

What will future conditions be? → What is the best near-term decision? → How sensitive is the decision to the conditions?

Predict

Act

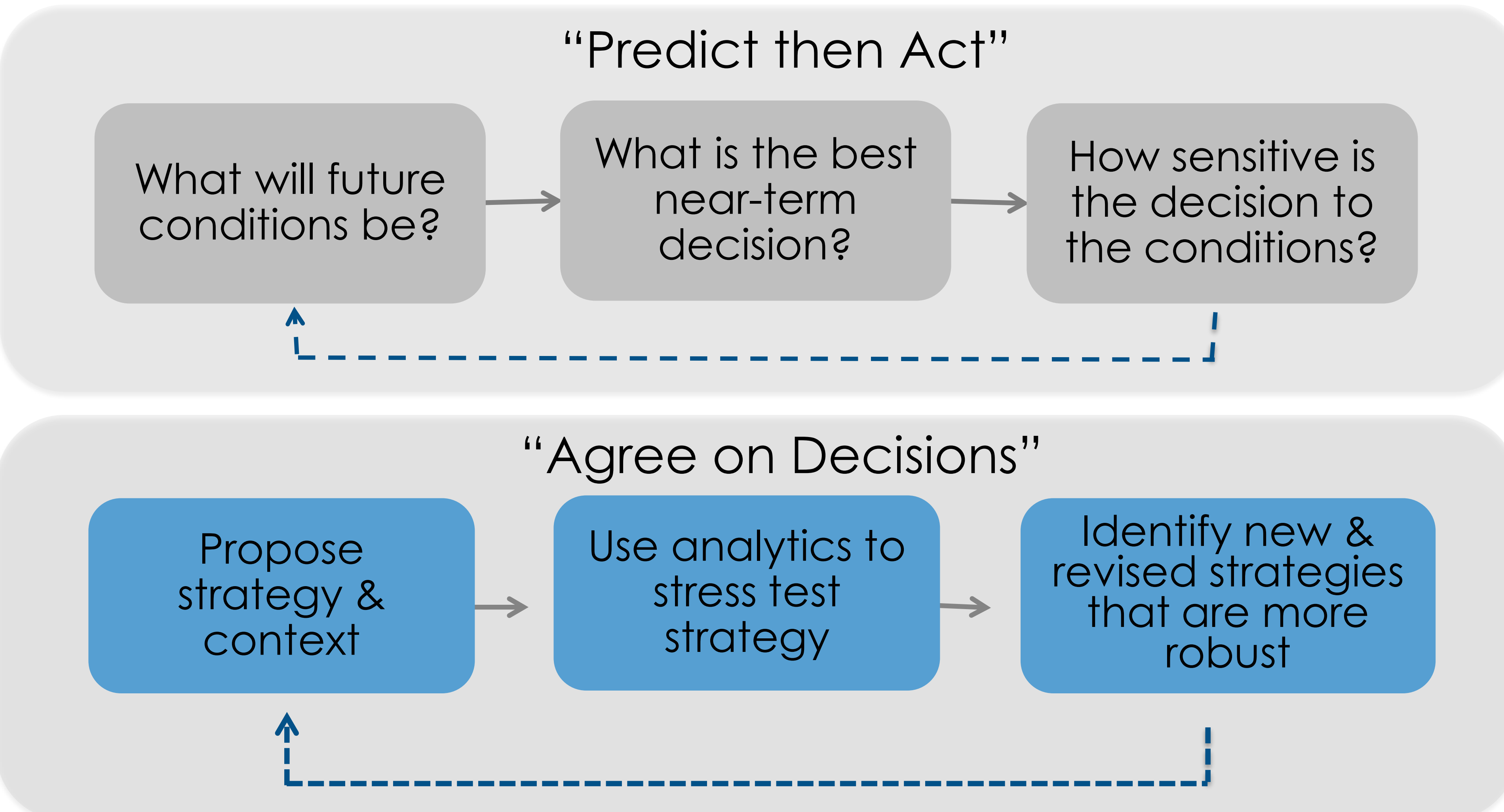
These are sometimes called "optimization methods"

“Predict then Act” Can Break Down When Uncertainties are Deep

Under conditions of deep uncertainty:

- Uncertainties are often underestimated
- Competing analyses can contribute to gridlock
- Misplaced concreteness can blind decision makers to surprise

Under Deeply Uncertain Conditions, Often Useful to Run the Analysis " Backwards"



Kalra, N., S. Hallegatte, R. Lempert, C. Brown, A. Fozzard, S. Gill and A. Shah (2014). *Agreeing on Robust Decisions: A New Process for Decision Making Under Deep Uncertainty*. WPS-6906, World Bank.

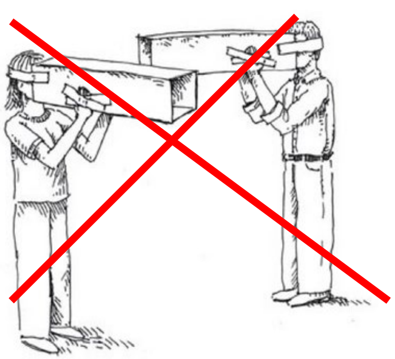
DMDU Helps People Use Computers to Make Better Decisions, Not Better Predictions

Strategy & Context → Stress Test → New & Revised Strategies

"Backwards" analysis can help focus on important questions under deep uncertainty

- Can a robust and flexible strategy perform well over a wide range of futures?
- What uncertainties are most important in determining the success or failure of our plans?
- What actions do we need to take now in order to keep future options open?
- What actions can we postpone?

Consider multiple futures



Outline

Introduction

DMDU Methods

Getting Started

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DMDU Methods

- Scenario planning
- Adaptive pathways
- RDM and variants

Getting Started

Humans Are Avid Scenario Builders

The ability to create and share scenarios represents a key difference between humans and other animals

Suddendorf (2013)

We:

Tell stories

Imagine each other's experiences

Contemplate potential explanations

Reflect on moral dilemmas

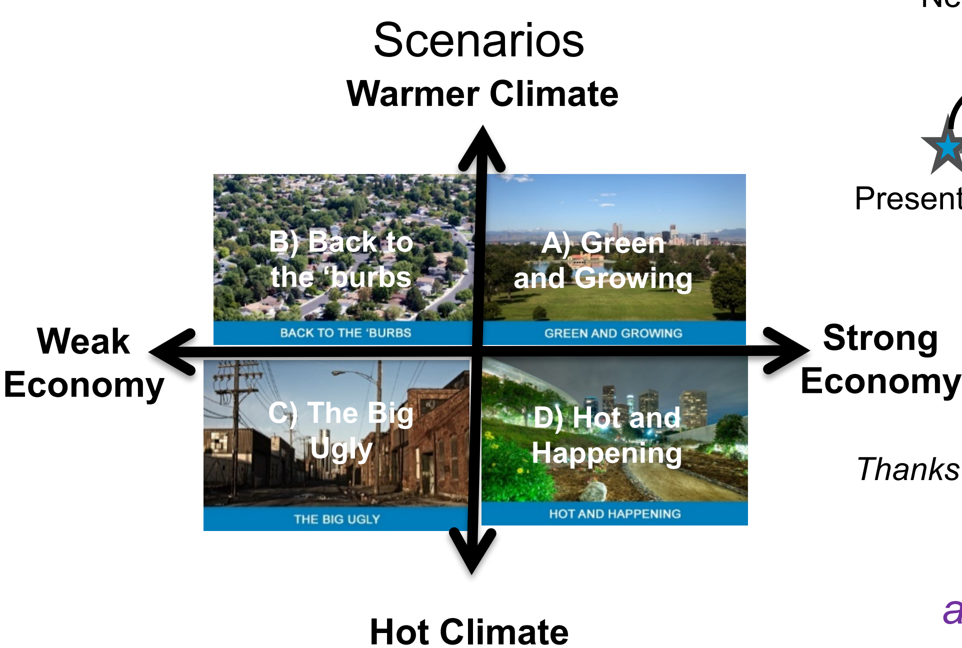
Scenarios provide benefits, for instance:

They can reduce over-confidence

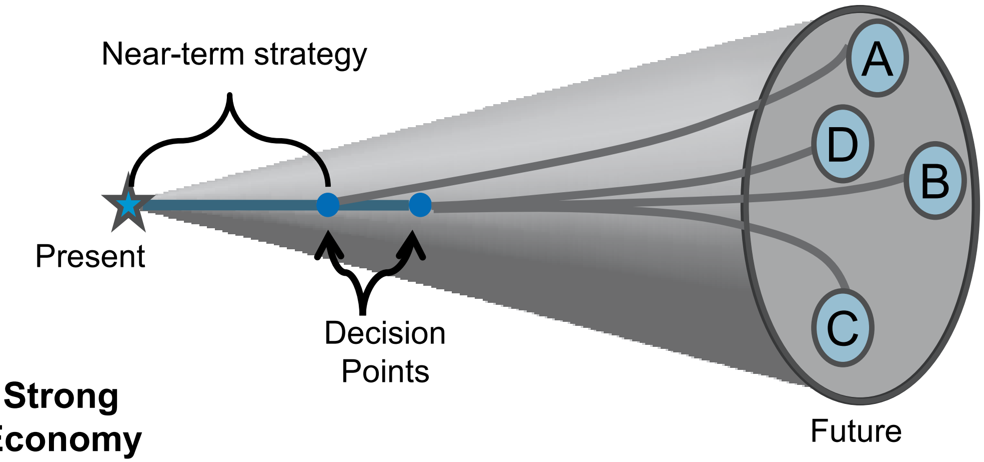
Scenario Planning Develops Robust Strategies From Scenarios People Create

Steps in scenario planning:

1. Identify decision challenge
2. Chose key driving forces, those most important and uncertain
3. Flesh out scenario narratives
4. Use scenarios to develop a robust adaptive plan



Robust, adaptive strategy



Thanks to Laurna Kaatz

Sometime called "story and simulation" approach because people chose the stories and then flesh them out with simulation models

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Getting Started

Adaptive Pathways Provides Framework for Developing Contingency Plans

House by C-7 canal

Coastal gate for C-7 canal

Adaptive pathways:

- Recommended by California's 2018 Sea Level Rise Guidance
- Recently used to examine urban flooding in Miami

Steps include identifying:

1. SLR thresholds at which damage occurs
2. Year when those thresholds are reached in various scenarios (called "adaptation tipping points")
3. Signposts indicating which scenario is occurring

Adaptation Tipping Points

Risk Reduction Options	Damage Threshold	Year threshold reached: Low SLR[1]	Year threshold reached: High SLR[2]
Current infrastructure	*0 ft*	*2018*	*2018*
Local pumps and gates	0.50 ft	~2050	~2025
Large regional pumps	0.55 ft	~2050	~2025
Raise buildings 6 feet	1.56 ft	> 2065	2050
Raise buildings 8 feet	n/a	> 2065	> 2065

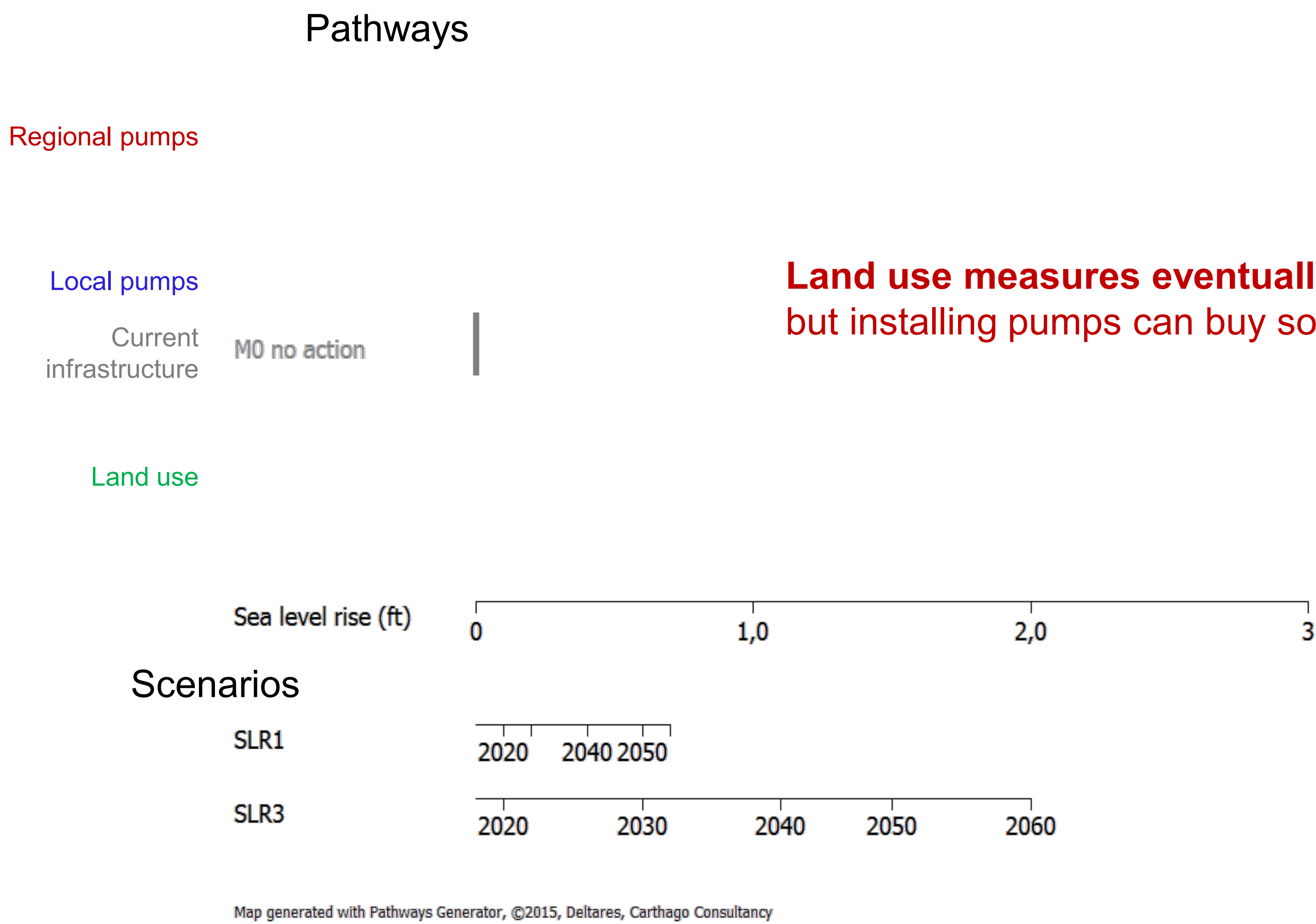
Adaptive pathways helps ask:

- Which options to deploy first?
- What options to deploy next?
- How do we make our choices less vulnerable to uncertainties about the SLR scenario?

Bouwer, Haasnoot, Wagenaar, Roscoe (2018) Assessment of alternative flood mitigation strategies for the C-7 Basin in Miami, Florida Deltares

1 - 0.76 ft in 2065
2 - 2.21 ft in 2065

Dynamic Adaptive Pathways Identifies and Compares Robust and Flexible Strategies



Land use measures eventually needed but installing pumps can buy some time.

Thanks to Kathryn Roscoe and Marjolijn Haasnoot

Adaptive pathways provides:

- A framework for strategies that adjust over time
- Compelling visualizations of these strategies

Adaptation tipping points focus on how much change your infrastructure and plans can accept

Outline

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DMDU Methods

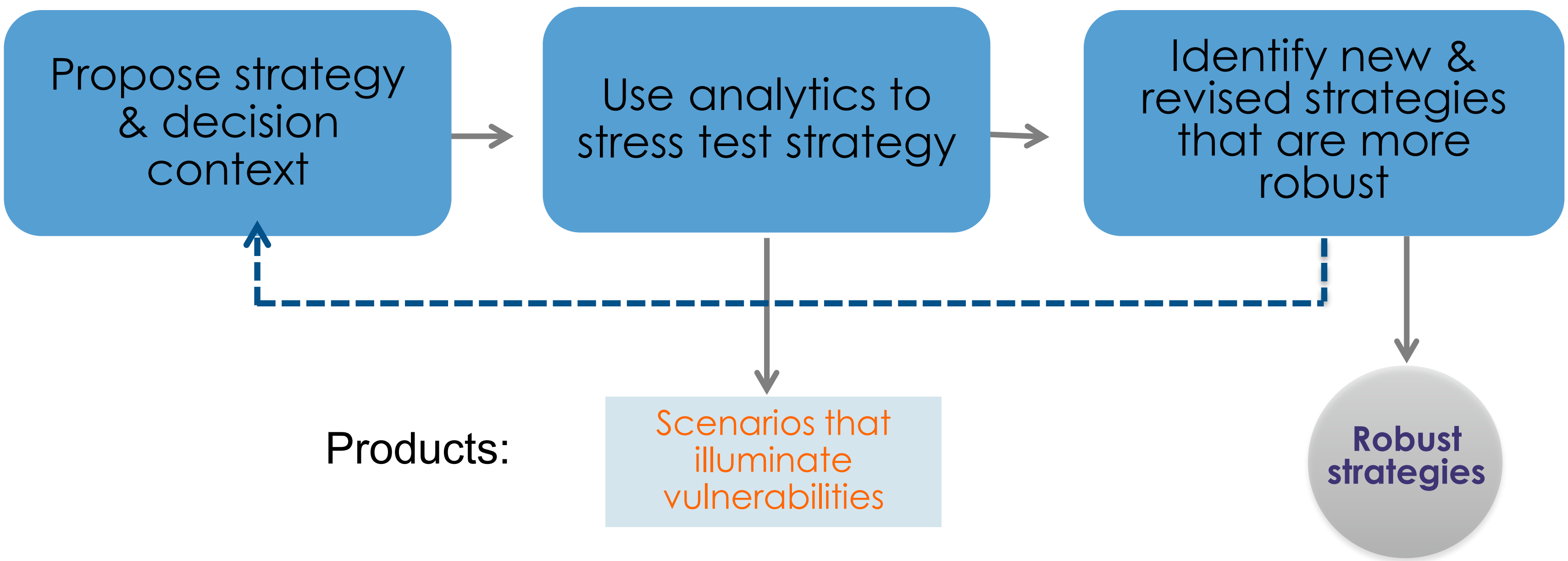
- Scenario planning
- Adaptive pathways
- RDM and variants
  - RDM
  - Decision scaling

Getting Started

Robust Decision Making (RDM) is a Quantitative DMDU Method

RDM is an iterative analytic process, often used in engagements with stakeholders, designed to support decision making under deep uncertainty

Process:



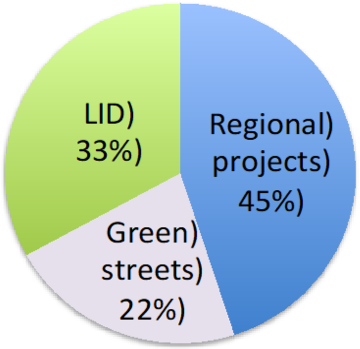
Key idea:

- Stress test strategies over many plausible paths into the future,
- Use the resulting database to identify conditions where strategies fail, and
- Use this information to identify more robust strategies

Can Los Angeles Meet its Water Quality Goals in the Face of Climate Change?

New water quality implementation plans for the
Los Angeles River* aim to meet federal standards by 2035

The Plan



Optimal distribution of BMPs
(best management practices)
assuming we know future climate!

** Study focuses on Tujunga sub-watershed: 225 square miles (165 sq. miles Los Angeles National Forest + 60 sq. miles urbanized San Fernando Valley floor)*

A. Tariq et. al., (2017) "A Climate Stress Test of Los Angeles' Water Quality Plans," Climatic Change

RDM Begins with Decision Framing

Decision makers and stakeholders deliberate over key factors in analysis

Will our expensive new water quality investments still meet water quality standards in a changing climate?

If not, what can we do about it?

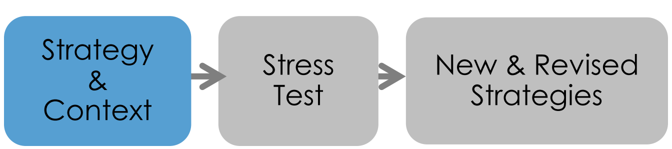
Strategy & Context → Stress Test → New & Revised Strategies

Summarize Stakeholder Discussions with ‘XLRM’ Matrix

Will our expensive new water quality investments still meet water quality standards in a changing climate?

If not, what can we do about it?

Uncertainty Factors (X)	**Policy Levers (L)**
Relationships (R)	**Performance Metrics (M)**



Summarize Stakeholder Discussions with 'XLRM' Matrix

Will our expensive new water quality investments still meet water quality standards in a changing climate?

If not, what can we do about it?

Uncertainty Factors (X)	**Policy Levers (L)**
What uncertain factors outside our control affect our ability to pursue our goals?	What actions might we take to pursue our goals?
Relationships (R)	**Performance Metrics (M)**
How might levers (L) and uncertainties (X) affect goals (M)? $X, L \xrightarrow{R} M$	What are we trying to achieve?

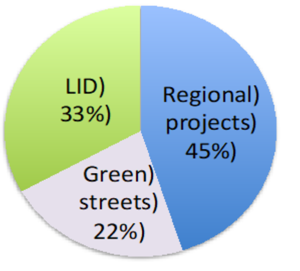
XLRM is useful independent of RDM

Strategy & Context → Stress Test → New & Revised Strategies

Summarize Stakeholder Discussions with ‘XLRM’ Matrix

Will our expensive new water quality investments still meet water quality standards in a changing climate?
If not, what can we do about it?

Uncertain Factors (X)	Policy Levers (L)
• Future climate • Future land use	• Proposed water quality plan – Regional projects – Green streets – Low impact development
Relationships (models)	**Performance metrics (M)**
• Simulation models used for regulatory assurance analysis (SUSTAIN & LSPC)	• Ability to meet zinc TMDL targets • Cost of additional BMPs • Co-benefits



Strategy & Context → Stress Test → New & Revised Strategies

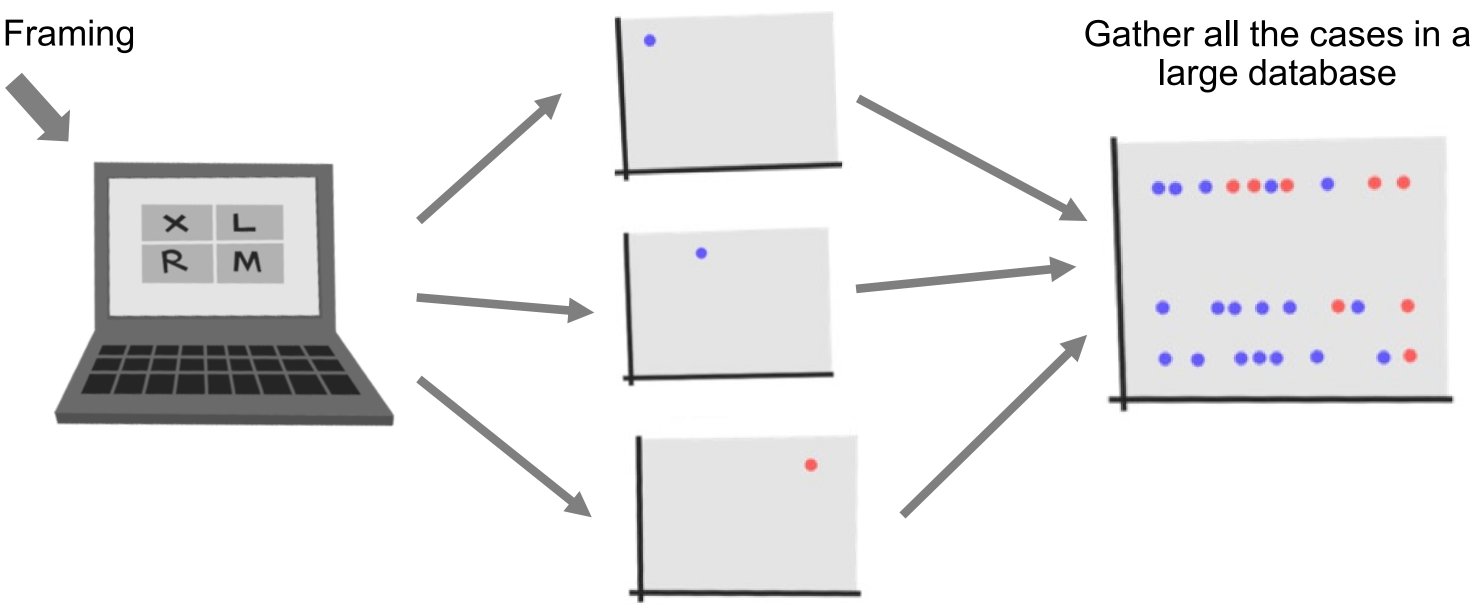
In this engagement, re-framing added new policy levers

Generate Cases that Stress Test Strategy in Each of Many Plausible Futures

Run model for each off hundreds to millions of cases
Each case tests one strategy in one plausible future

Decision Framing

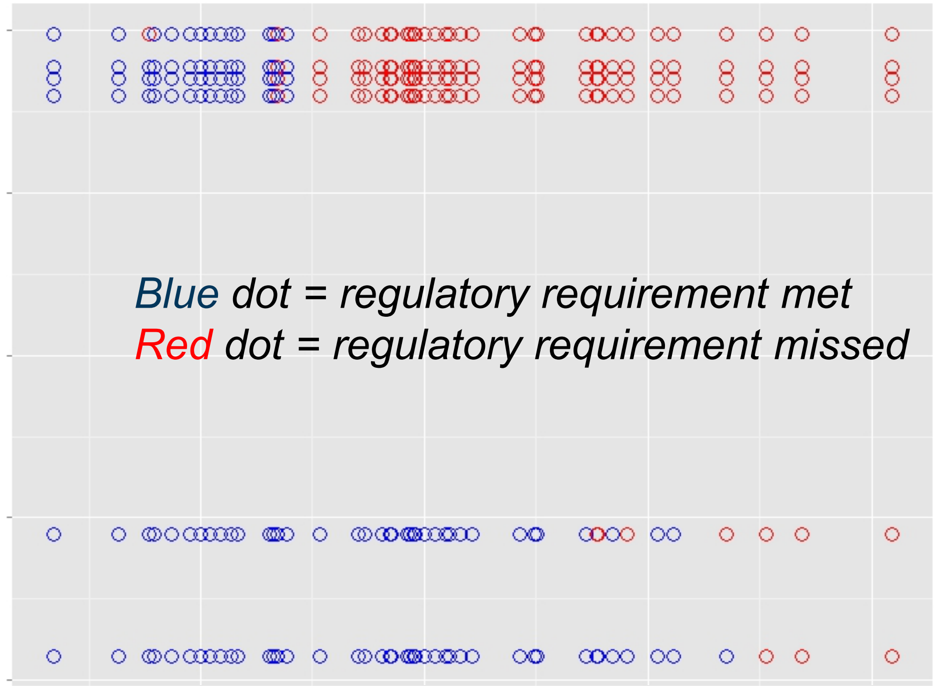
Gather all the cases in a large database



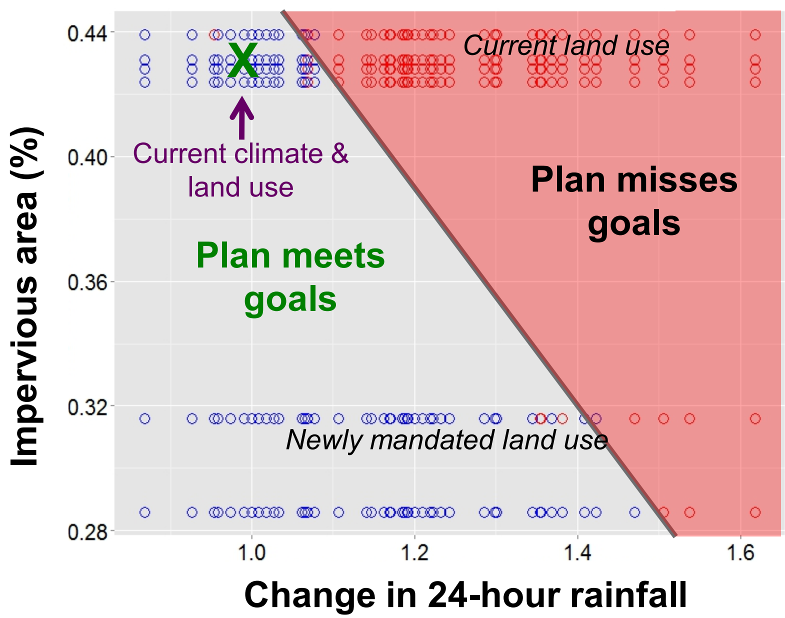
Strategy & Context → Stress Test → New & Revised Strategies

Generate Cases that Stress Test Strategy in Each of Many Plausible Futures

- Stress test Tujunga water quality implementation plan over 47 climate times 6 land use = 282 futures
- Each record in the database (a case) represents the performance of the plan in one future



Summarize All These Model Runs In a Map Showing the Stress Test Results



Computer algorithms and visualization help separate all the model runs into two sets of futures:

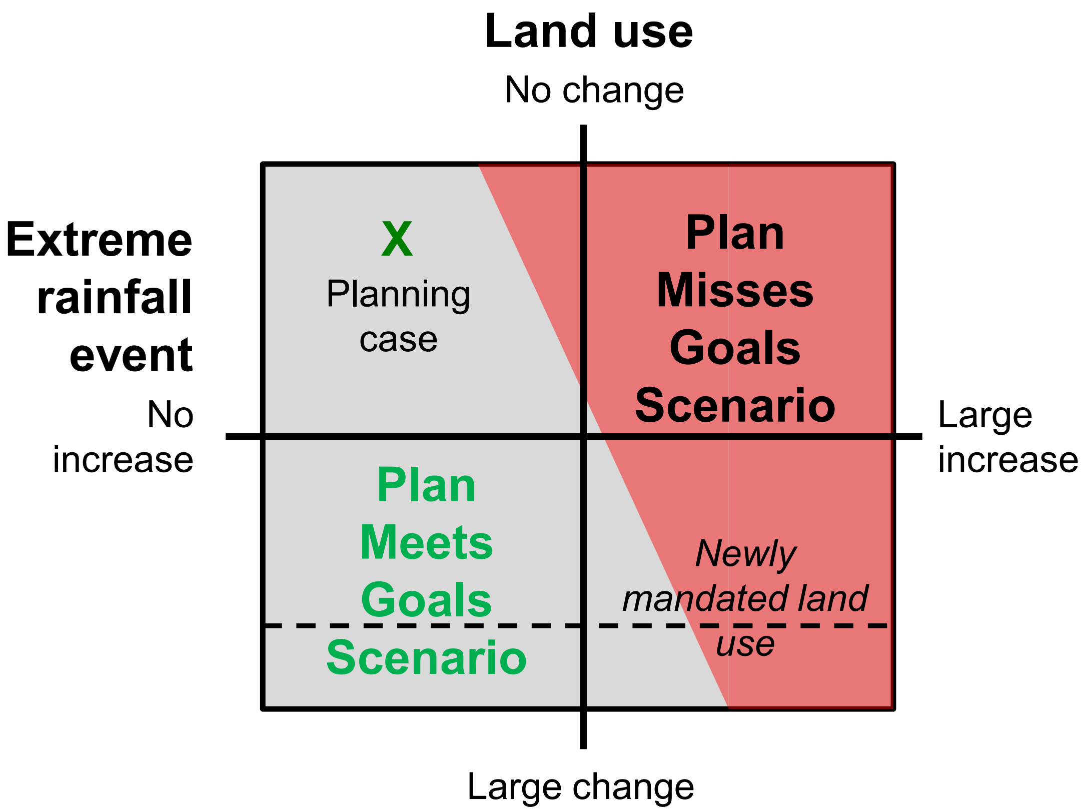
- In one set LA's water quality plan generally meets its regulatory goal
- In the second set LA's water quality plan generally fails to meet its regulatory goal

The algorithms and visualizations also identify the combination of uncertainties *most important* in distinguishing these two sets of futures

We can use this scenario map to orient ourselves

Use the Database of Cases to Identify Policy-Relevant Scenarios

Results of this stress test can be interpreted as two scenarios



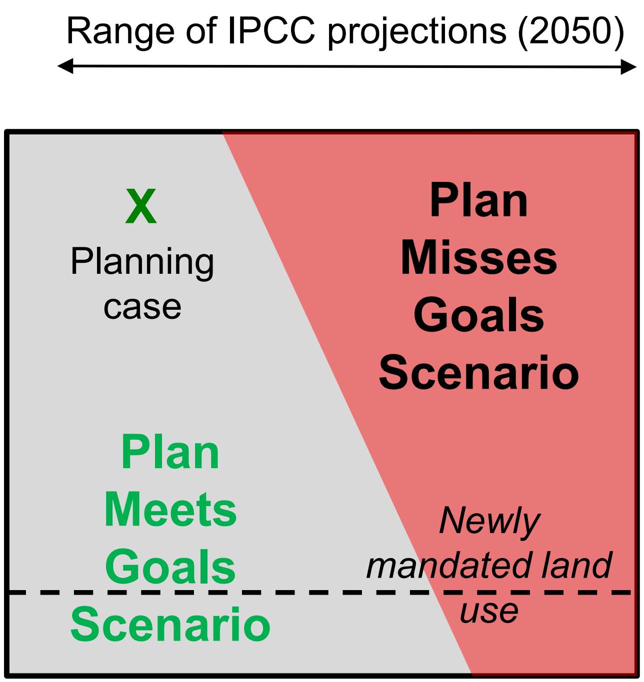
- Scenarios emerge from the analysis. They aren't inputs to it
- Scenarios show high-confidence information. People who disagree about the likely future can agree on the conditions in which LA's plan would met or miss its regulatory goals

Note that scenario driving forces depend both on climate and socio-economic uncertainties

Strategy & Context → Stress Test → New & Revised Strategies

Use Available Scientific Information to Consider Whether The Vulnerable Scenario is Significant

Compare Available Science to The "Plan Misses Goals" Scenario



These IPCC projections don't include any downscaling

Use Available Scientific Information to Consider Whether The Vulnerable Scenario Is Significant

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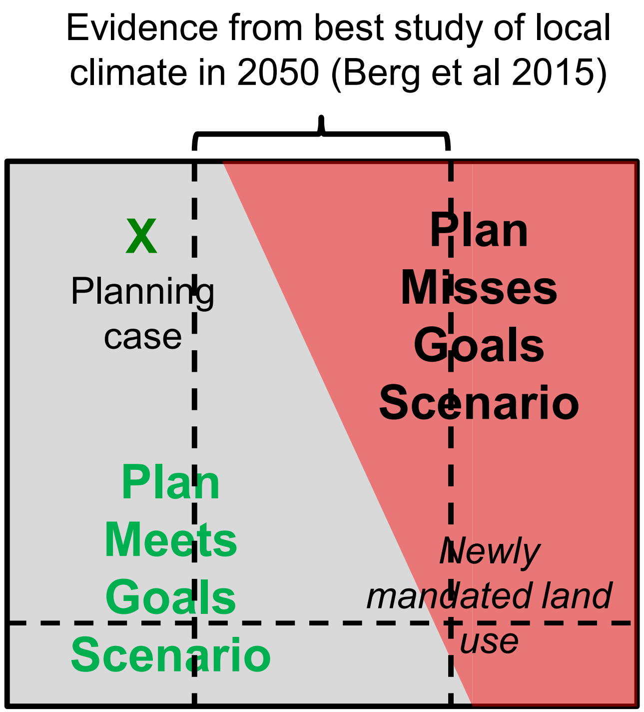


Bottom line:

- *We looked at two ways to estimate the probability of extreme precipitation events*
- *Both indicate Los Angeles' water quality implementation plan may not meet regulatory standards if the climate changes (or has changed)*

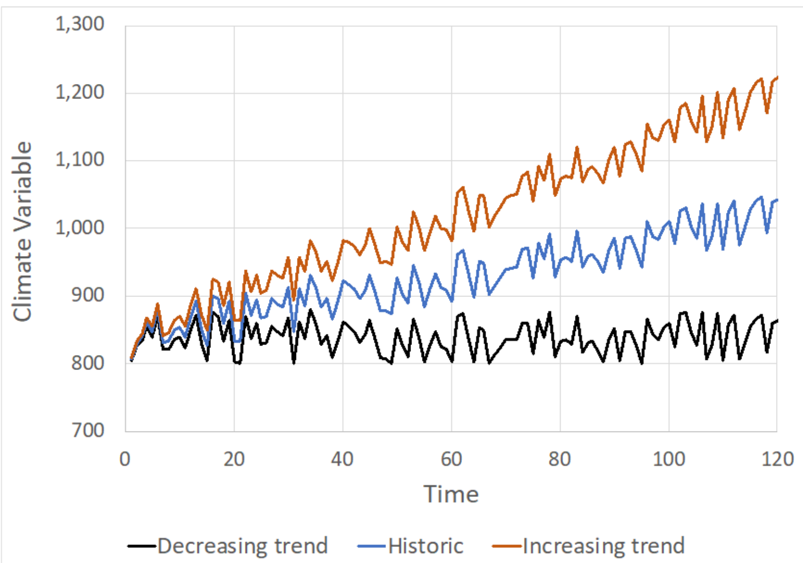
These projections involve very high resolution (2 km) downscaling

Strategy & Context → **Stress Test** → New & Revised Strategies

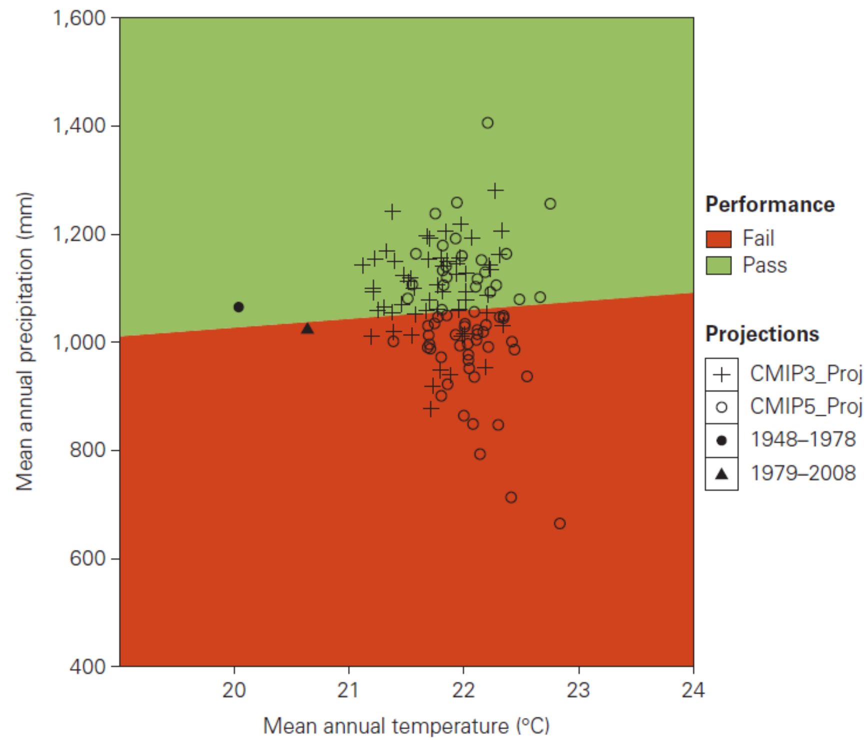
Decision Scaling, Another DMDU Method, Focuses on Climate Stress Tests

Decision scaling provides a simple way to perform a climate stress test

- Start with historical climate record
- Perturb key climate variables
- Use perturbed climate variables in hydrology models



Example results



Ray and Brown (2015)

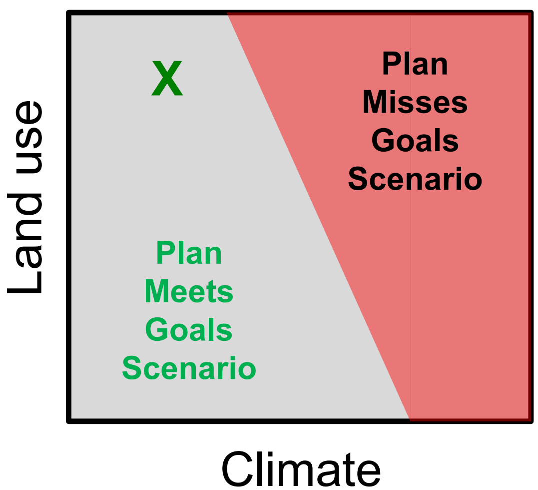
Strategy → Stress Test → New Options

Decision scaling provides a climate vulnerability analysis, without relying on extensive climate modeling

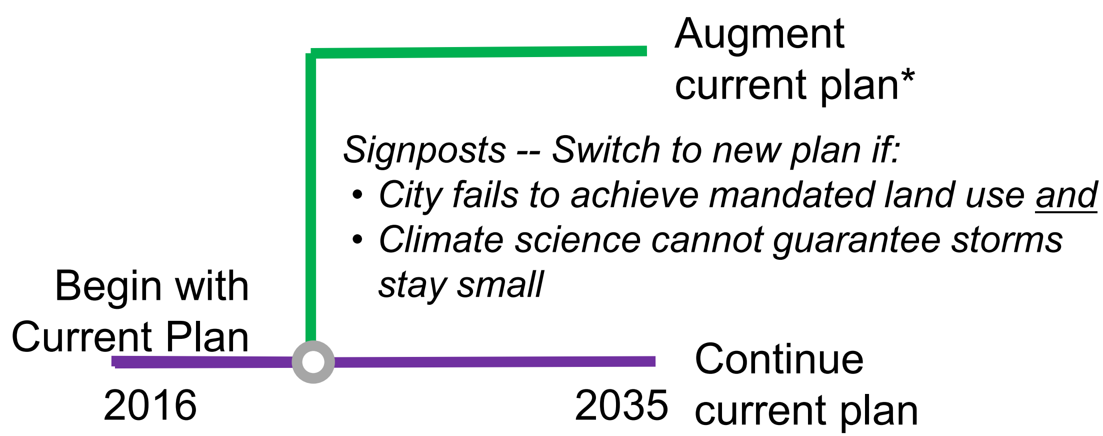
In LA Water Quality Example, Use Stress Test to Identify New Options for Reducing Vulnerabilities

Study considered an adaptive plan consisting of near-term actions, signposts to monitor, and contingent actions if signposts are observed

Vulnerability analysis informs signposts



Study identified such and adaptive plan to reduce this vulnerability



* Used optimization to identify augmented plan

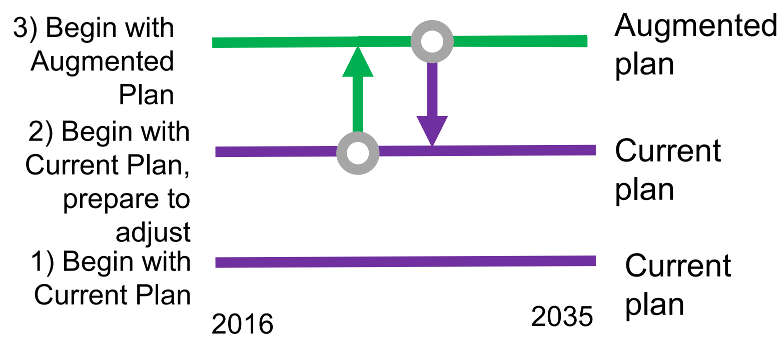
Strategy & Context → Stress Test → New & Revised Strategies

Help Decisionmakers to Compare Tradeoffs Among Alternative Strategies

Present Multi-Objective Trade Off Analysis

Compare three alternative strategies:

1. Begin with current plan, but do not prepare to adjust
2. Begin with current plan, but prepare to adjust
3. Begin with augmented plan, but prepare to adjust



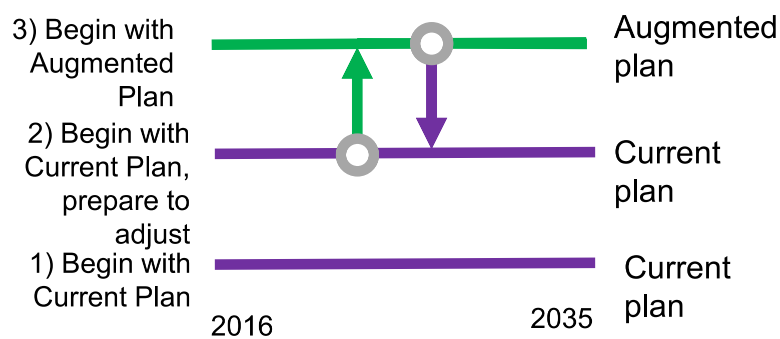
Note: RDM is designed to illuminate tradeoffs for people to evaluate, rather than dictate optimal solutions

Strategy & Context → Stress Test → New & Revised Strategies

Help Decisionmakers to Compare Tradeoffs Among Alternative Strategies

These strategies aim to meet two objectives:
1) ensuring water quality and 2) low cost

Plan Meets Goals Scenario	
Water quality	Cost
Yes	Highest
Yes	Slightly higher
Yes	Lowest



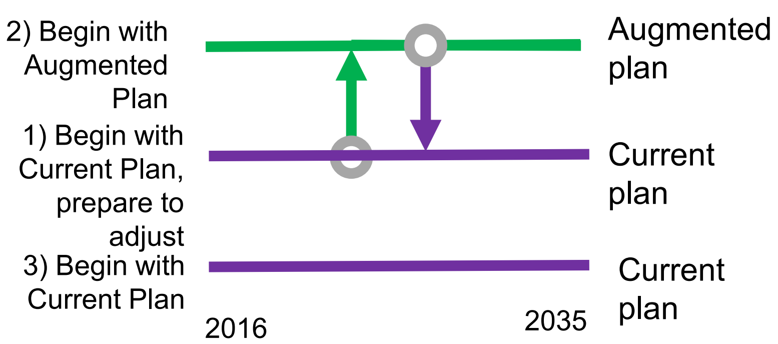
Strategy & Context → Stress Test → New & Revised Strategies

Help Decisionmakers to Compare Tradeoffs Among Alternative Strategies

The strategies perform very differently across the two scenarios

Plan Meets Goals Scenario		Plan Misses Goals Scenario	
Water quality	Cost	Water quality	Cost
Yes	Highest	Yes	Lowest
Yes	Slightly higher	Yes	Slightly higher
Yes	Lowest	No	Highest

The adaptive "Begin with current plan, but prepare to adjust" plan represents a "low regret" strategy



In general, a robust strategy is one that:

- Performs well over a wide range of plausible futures,
- Keeps options open, or
- Trades some optimal performance for less sensitivity to broken assumptions

Strategy & Context → Stress Test → New & Revised Strategies

Comparing Methods

- **Scenario planning** develops robust strategies from scenarios that people create
- **Adaptive pathways** provides a framework for developing strategies that adjust over time
  - Works especially well when the ”tipping points” are simple
- **RDM** proves useful for more complicated vulnerabilities,
  - Scenarios emerge from analysis and often depend on combinations of climate and socio-economic factors
  - Need to start with a proposed strategy
- **Decision scaling** focuses on vulnerability analysis, in particular vulnerabilities associated with climate change
  - Reduces reliance on climate models

Outline

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DMDU Methods

Getting Started

DMDU Is Part of "Mainstreaming" Climate Adaptation into Your Organization

Most important step is to get started

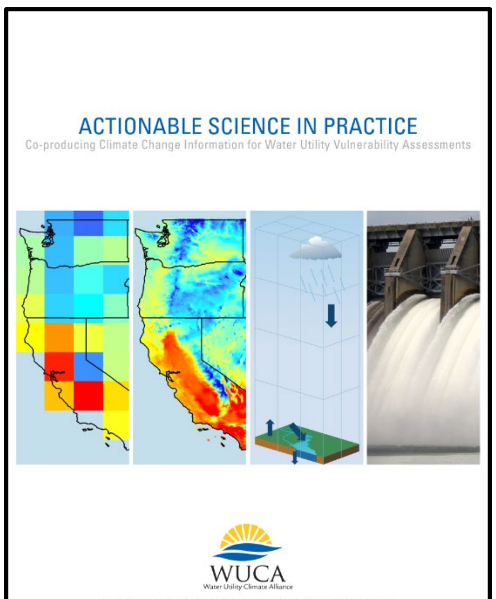
- Conduct a climate vulnerability analysis
- Use scenario planning
- Recruit a scientific climate advisory panel

You can adopt DMDU incrementally, augmenting each planning cycle

One Potential Sequence for "Mainstreaming" DMDU into Your Organization

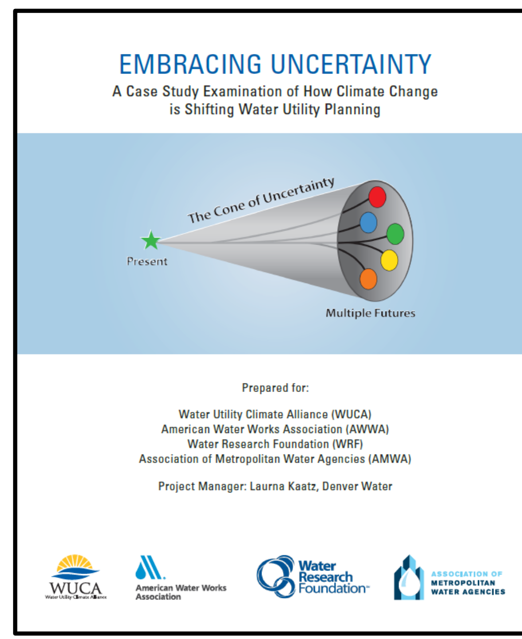
1. Embrace concepts of multiple futures, robust and flexible strategies
2. Employ qualitative methods and/or separate, piecework analyses
3. Then begin running your system models over multiple futures to i) stress test plans and ii) identify and evaluate robust and flexible plans

These WUCA documents can help



Actionable Science in Practice

Embracing Uncertainty



Resources Becoming More Available to Help Implement DMDU Methods

There now exists:

- Open source software for implementing most DMDU methods
- Increasing numbers of case studies
- Many groups able to help

THE SOCIETY FOR Decision Making under Deep Uncertainty

www.deepuncertainty.org

Some examples of RDM & other DMDU analyses

DMDU Methods and Tools Can Help Water Managers Address Today's Uncertain Conditions

Our current and future climate is not the same as past climate, and no one is sure exactly how it has and will change

1. Consider multiple futures, not one single future, in your planning. Choose these futures to stress test your organization's plans
2. Seek robust plans that perform well over many futures, not optimal plans designed for a single, best-estimate future
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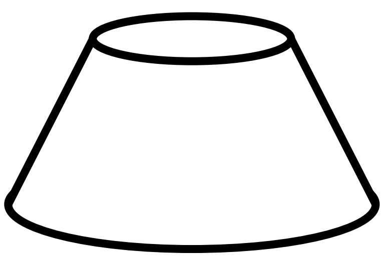

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QUESTIONS???