

An aerial photograph of a river system, likely the Patuxent River, showing a complex network of channels and tributaries. The water is a deep blue, contrasting with the surrounding green and brownish terrain. A dark blue horizontal band is overlaid on the bottom portion of the image, serving as a background for the text.

Managing Water Quality In the Face of Uncertainty:

Patuxent River Urban Stormwater Case Study

Jordan Fischbach, Edmundo Molina, and Rob Lempert

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Robust Decision Making (RDM) Works Under Deep Uncertainty by Running the Analysis Backwards

“Predict Then Act”

What will future conditions be?

What is the best near-term decision?

How sensitive is the decision to the conditions?



RDM Process

Decision context:
Proposed
Strategies / Plans

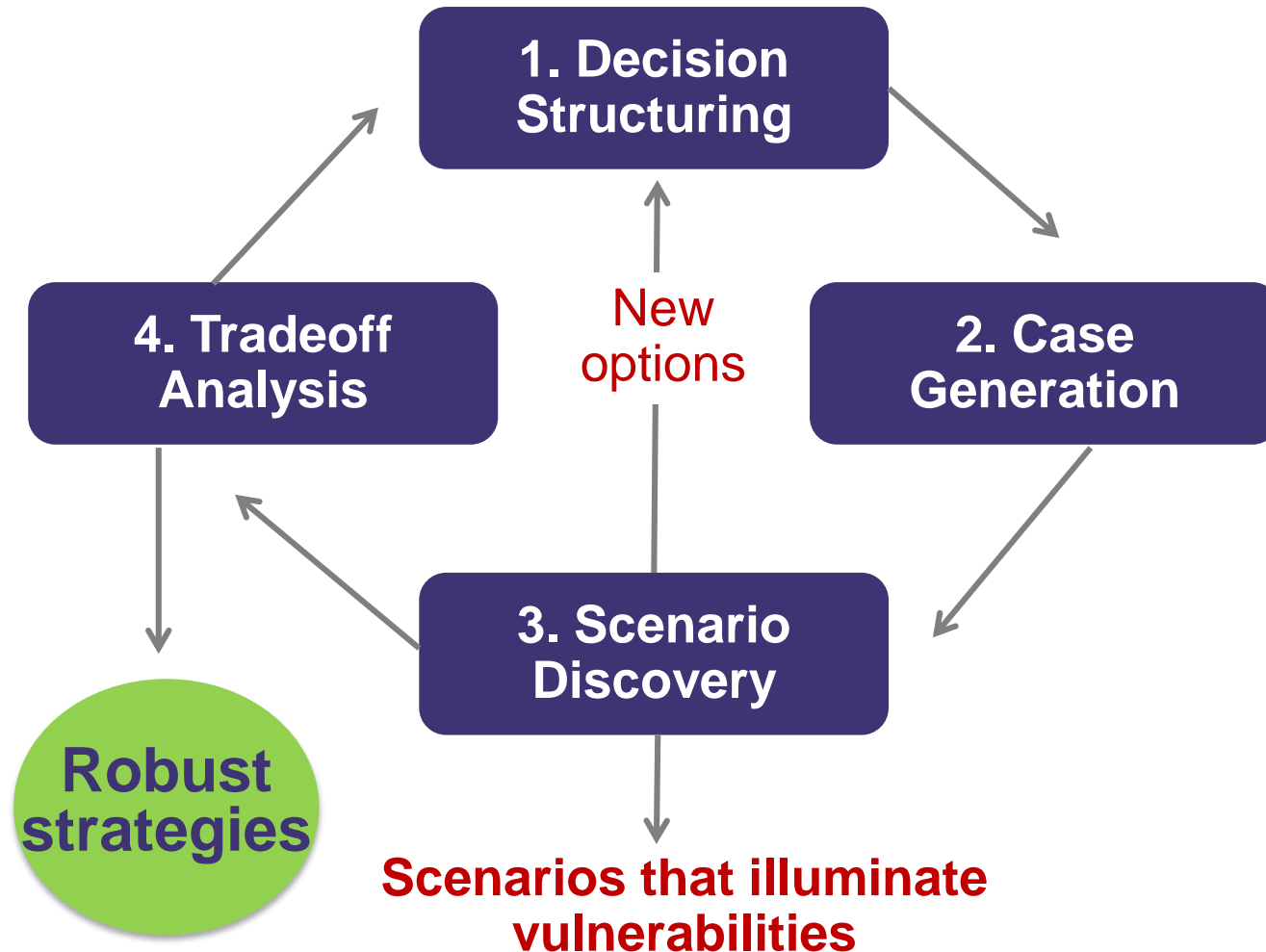
Identify
vulnerabilities of
strategies

Develop strategy
adaptations to
reduce
vulnerabilities



RDM Uses Analytics to Facilitate New Conversations Between Decisionmakers

RDM is *iterative*; analytics facilitate stakeholder deliberation



Part of a Larger Effort to Explore Application of RDM for EPA Water Quality Implementation and Adaptive Management



Managing Water Quality in the Face of Uncertainty

A Robust Decision Making Demonstration for EPA's National Water Program

Jordan R. Fischbach, Robert J. Lempert, Edmundo Molina-Perez, Abdul Ahad Tariq, Melissa L. Finucane, Frauke Hoss

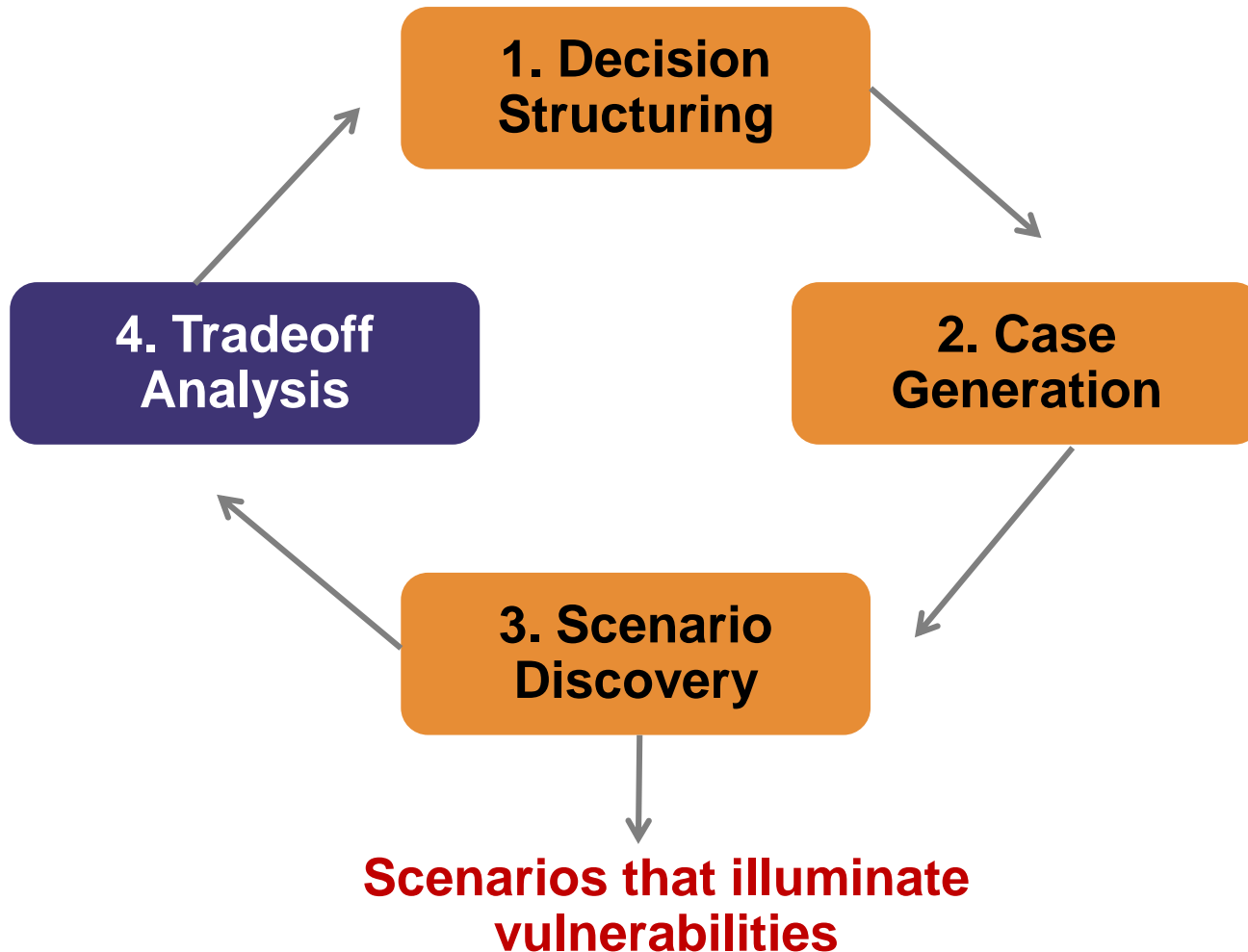


Three pilot case studies:

- I. Urban stormwater management in Maryland's Patuxent River
- II. Agricultural runoff in the Illinois River
- III. BMP implementation in Los Angeles (Tujunga Wash)

Today's presentation focuses on the Patuxent River case study

This Effort Focused on Vulnerability Analysis and Scenario Discovery

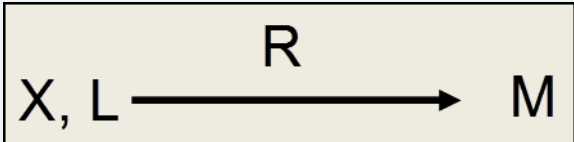


The Patuxent is a Highly Urbanized Watershed With Stormwater Management Challenges

- Climate change and urban growth can exacerbate water quality challenges:
 - Higher precipitation in winter and spring increases pollutant flow
 - Higher temperatures reduce capacity of bay grasses to grow
 - Urban growth transforms forest and farmland into developed areas



“XLRM” Framework Helps Organize Key Factors Considered in the Analysis

Uncertain Factors (X)	Policy Levers (L)
What uncertain factors outside decision makers' control affect their ability to pursue their goals?	What actions might they take to pursue their goals?
Relationships (R)	Performance Metrics (M)
How might policy levers (L) and uncertainties (X) be related to decision makers' goals (M)? 	What are decision makers trying to achieve?

Scoping Using the “XLRM” Framework

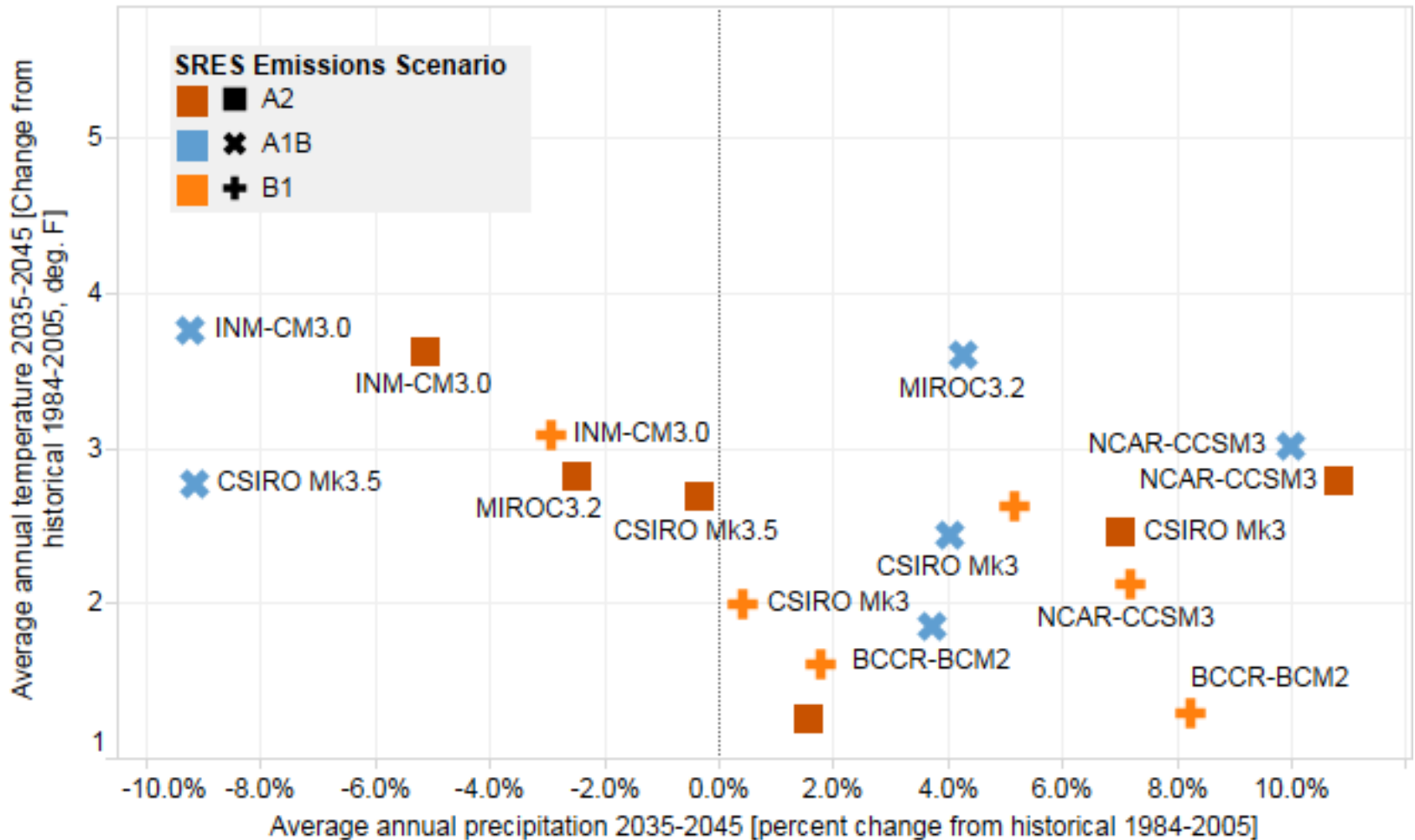
Uncertain Factors (X)	Policy Levers (L)
<p>Hydrology and climate change</p> <ul style="list-style-type: none"> • Observed historical hydrology • Downscaled climate scenarios <p>Land use</p> <ul style="list-style-type: none"> • Population growth (2010-2050) • Infill, sprawl <p><i>Evapotranspiration model parameters</i> <i>BMP effectiveness</i></p>	<p>MDE Phase II Watershed Implementation Plan BMPs, including:</p> <ul style="list-style-type: none"> • Stormwater management-filtering practices • Stormwater management-infiltration practices • Urban stream restoration • Urban forest buffers
System Model Relationships (R)	Performance Metrics (M)
<p>Phase 5.3.2 Chesapeake Bay Model</p> <ul style="list-style-type: none"> • Airshed model • Land use change model • Scenario builder • Watershed model (Patuxent only) 	<p>Metrics</p> <p>Nitrogen delivered loads Phosphorus delivered loads Sediment delivered loads Implementation costs (extended analysis only)</p> <p>Targets: Phase II WIP TMDLs</p>

Climate Change Scenarios Used in the Study

- 6 general circulation models:
 - NCAR CCSM3, MIROC, CCSR, CSIRO Mk3, CSIRO Mk3.5 and INM, downscaled to hourly data
- 3 emissions scenarios:
 - A2, A1B and B1, downscaled to hourly data

Climate Projections for Future Patuxent Basin Hydrology Vary Widely

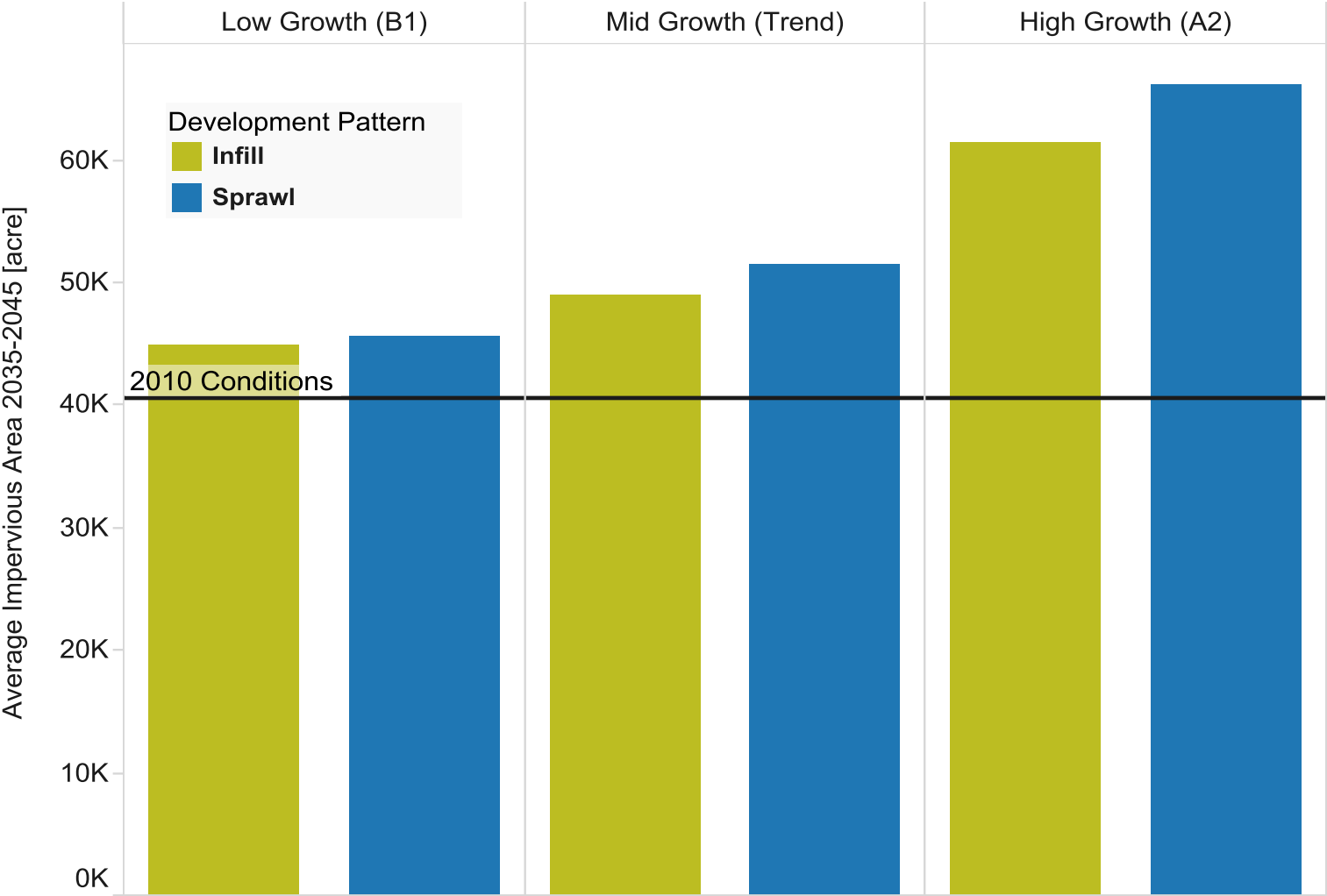
2035-2045



We Also Considered Uncertainty Related to Population Growth and Land Use

- **Baseline:** population and development patterns in 2010
- **Three Population Projections**
 - Current trends extrapolated to 2050 (mid)
 - ICLUS B1 (2050) (low)
 - ICLUS A2 (2050) (high)
- **Two Development Patterns**
 - Infill
 - Sprawl

Comparison of Land Use Change Assumptions Used in this Study

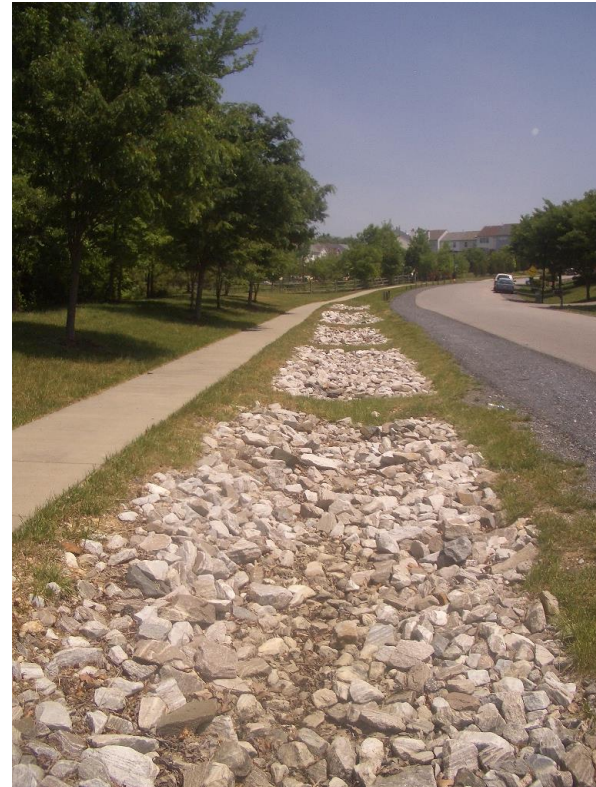


Maryland's Watershed Implementation Plan (WIP) Identified New Stormwater Targets for the Patuxent

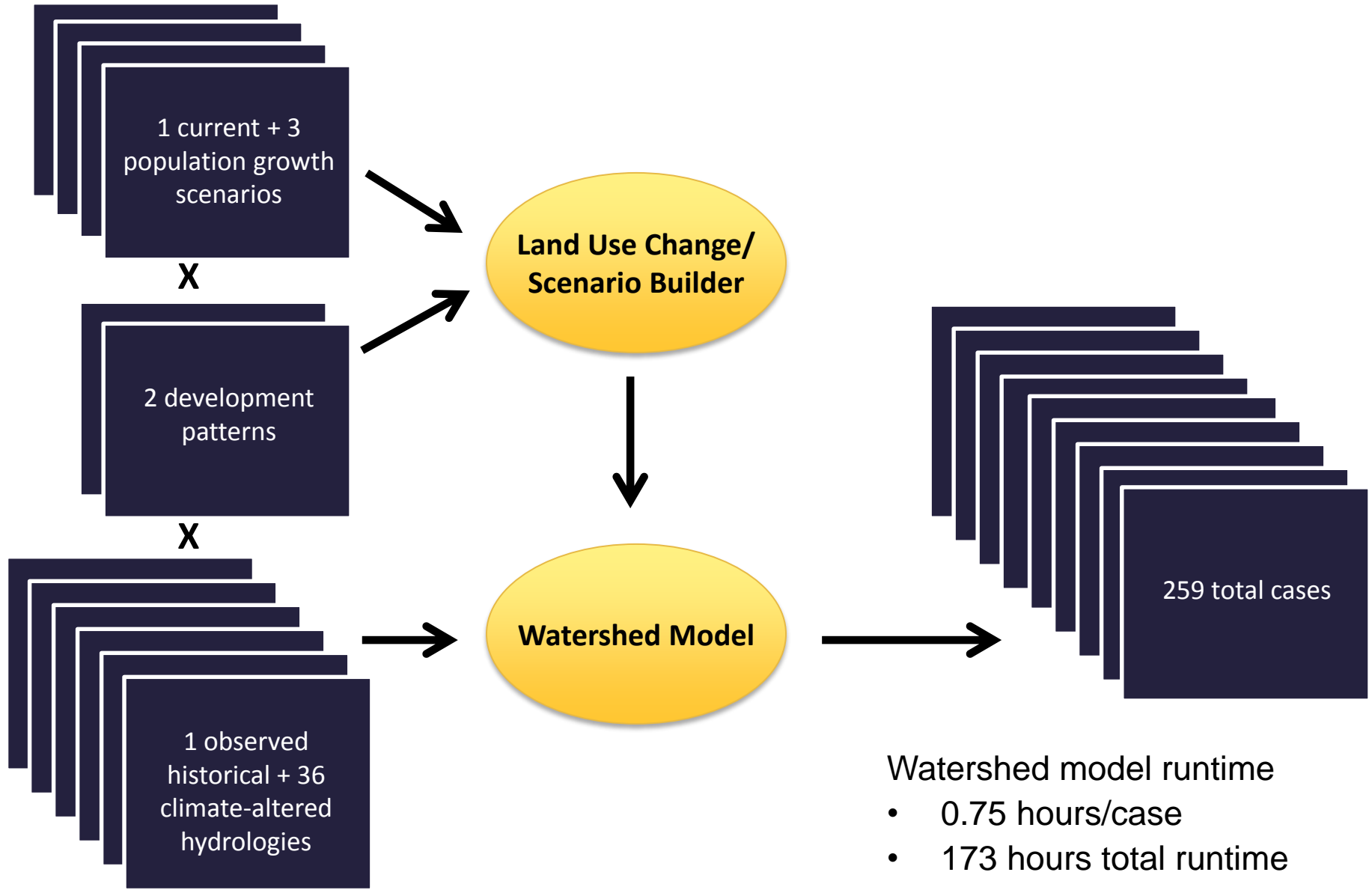
Pollutant Type	Annual Target (million pounds/year)		
	Phase I	Phase II 2017 Interim	Phase II 2025 Final
Nitrogen	2.740	1.029	1.029
Phosphorous	0.210	0.078	0.078
Sediment	85	52	55.9

Source: [Maryland Department of the Environment \(2012\)](#). Note that these thresholds are adjusted to the calibration runs of the Phase 5.3.2 model, and differ somewhat from those listed in the Phase II WIP report.

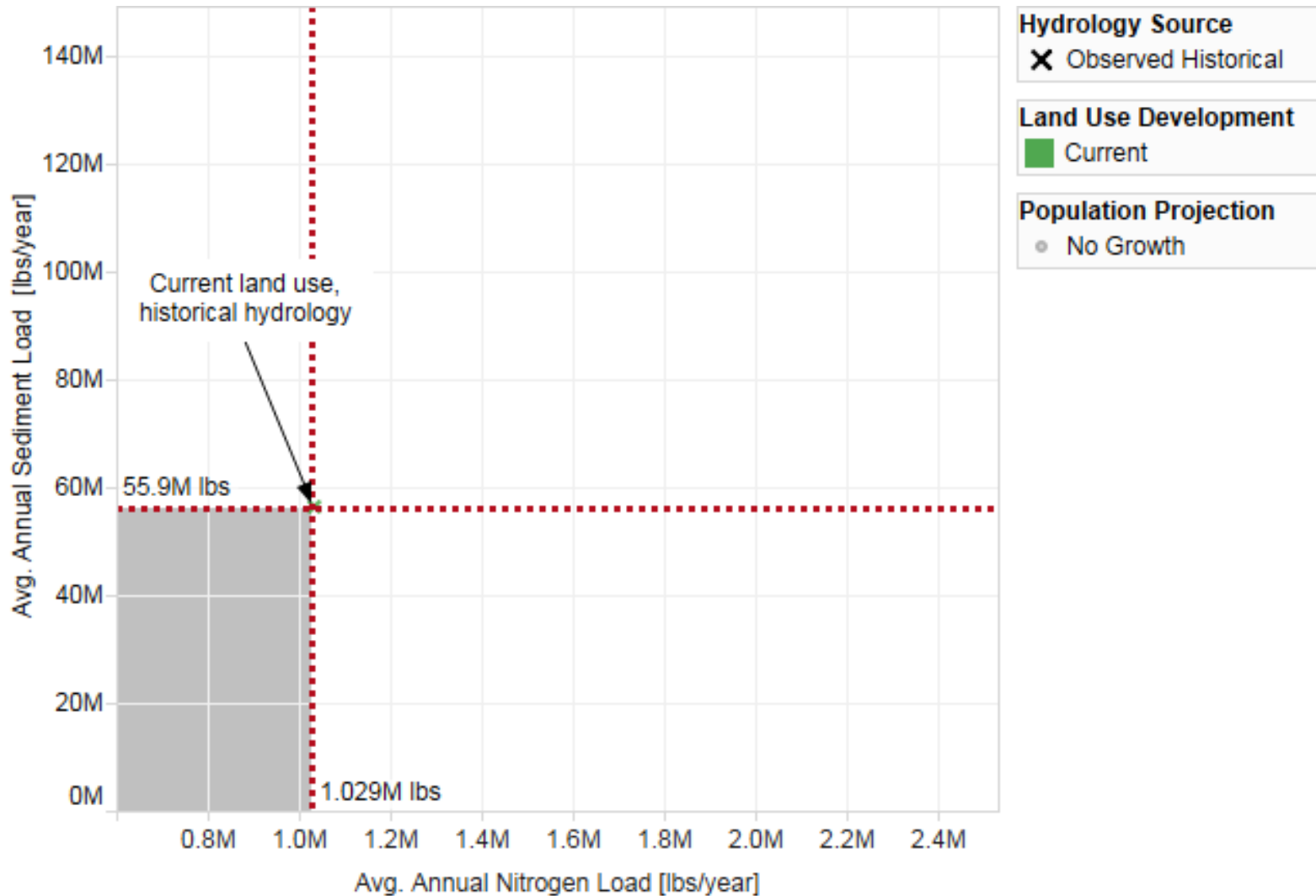
Maryland's WIP Also Identified a Series of Best Management Practices (BMPs) Designed to Meet Targets



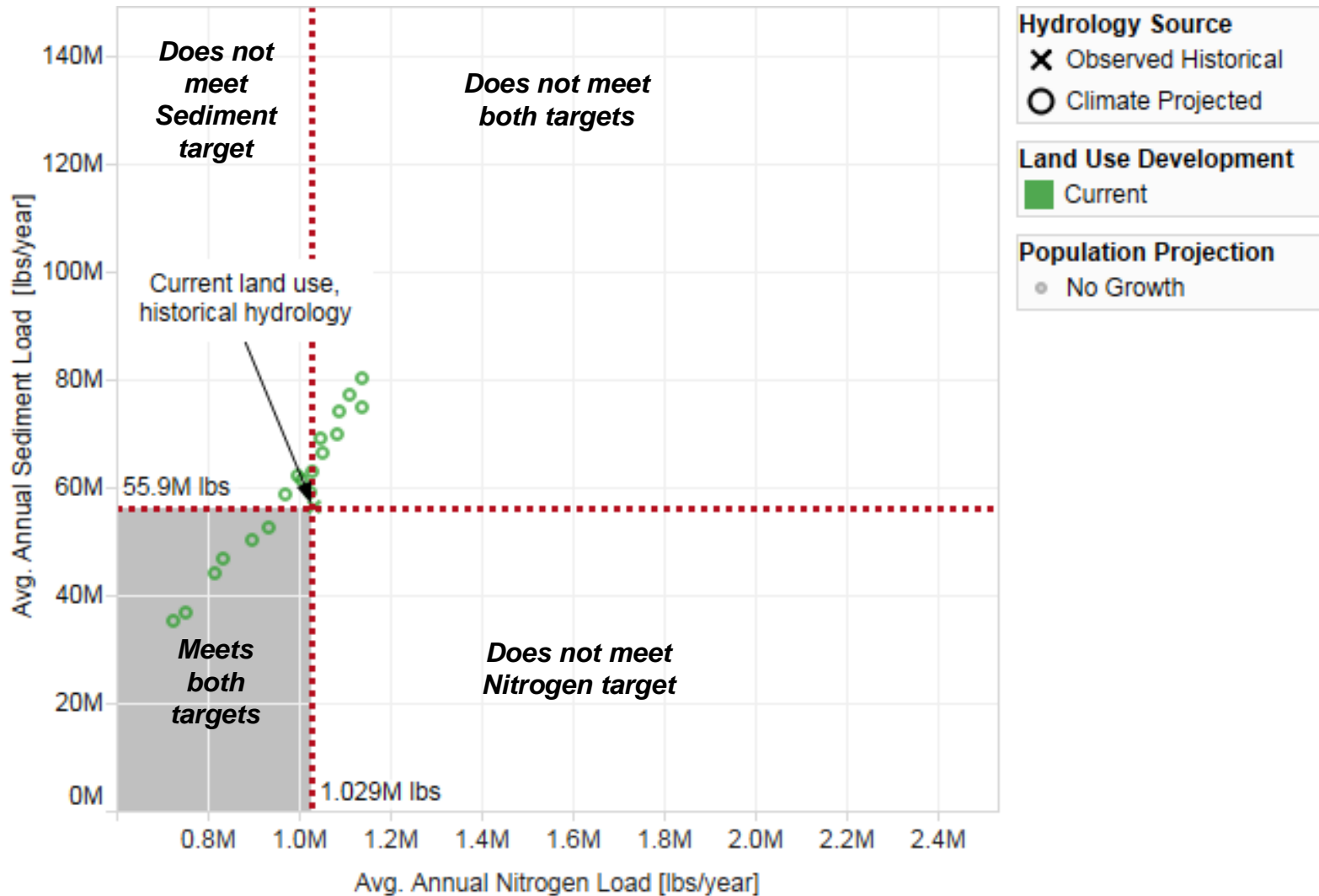
We evaluated WIP performance across a broad combination of climate and land use futures



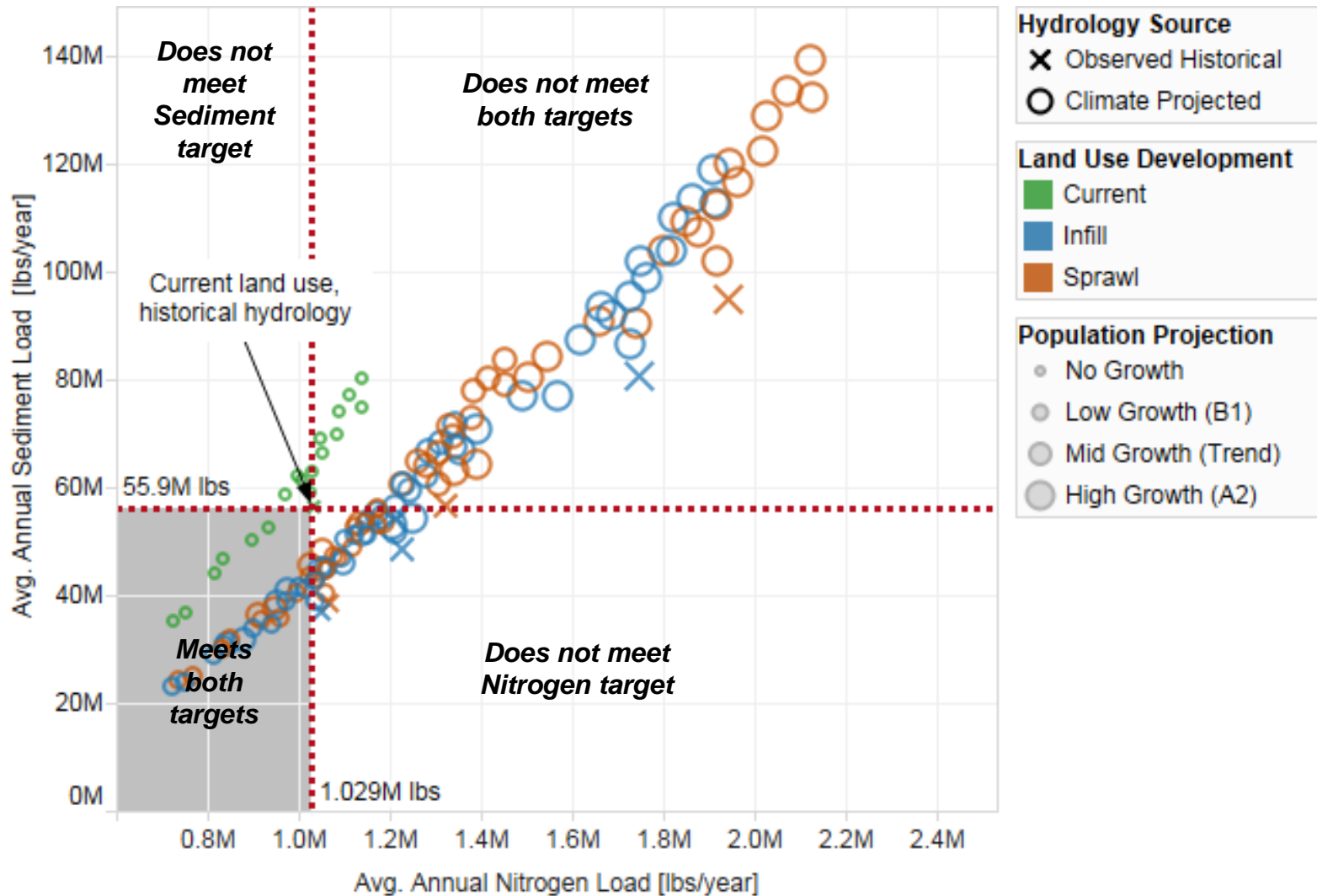
Phase II WIP Strategy Meets Intended Target In Current Conditions



Climate Projections Affect Attaining Targets in Some Futures (2035-2045)



Under Phase II WIP, Climate and Land Use Lead to Stressing Futures



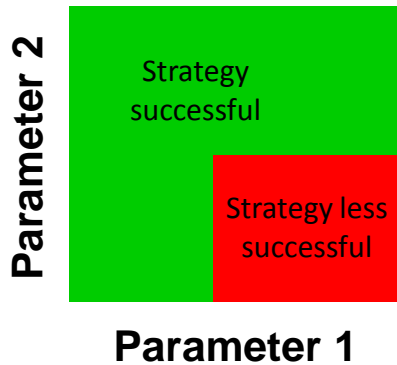
We Identified Sets of Vulnerable Futures for Two BMP Portfolios

Vulnerability Type	Number of futures exceeding the Phase II target (2035-2045 hydrology)	
	2010 Progress	Phase II WIP Strategy
Nitrogen target	114 (93%)	91 (72%)
Phosphorous target	120 (95%)	84 (67%)
Sediments target	111 (88%)	67 (53%)
Exceeding all three targets	109 (87%)	62 (49%)

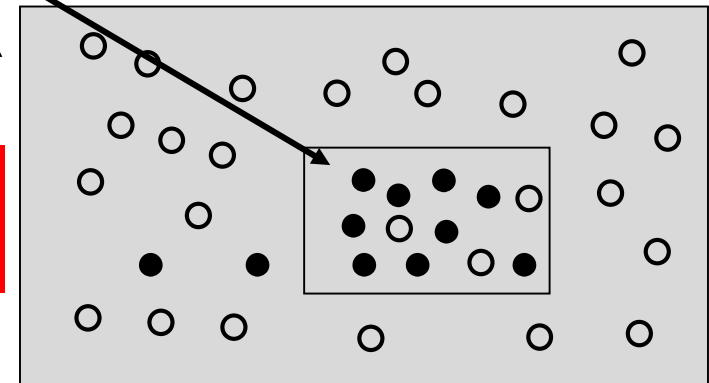
Scenario Discovery Provides an Approach for Computer-Assisted Scenario Development

Clusters represent scenarios and driving forces of interest to decision makers

1. Indicate policy-relevant cases in database of simulation results
2. Statistical analysis finds low-dimensional clusters with high density of these cases



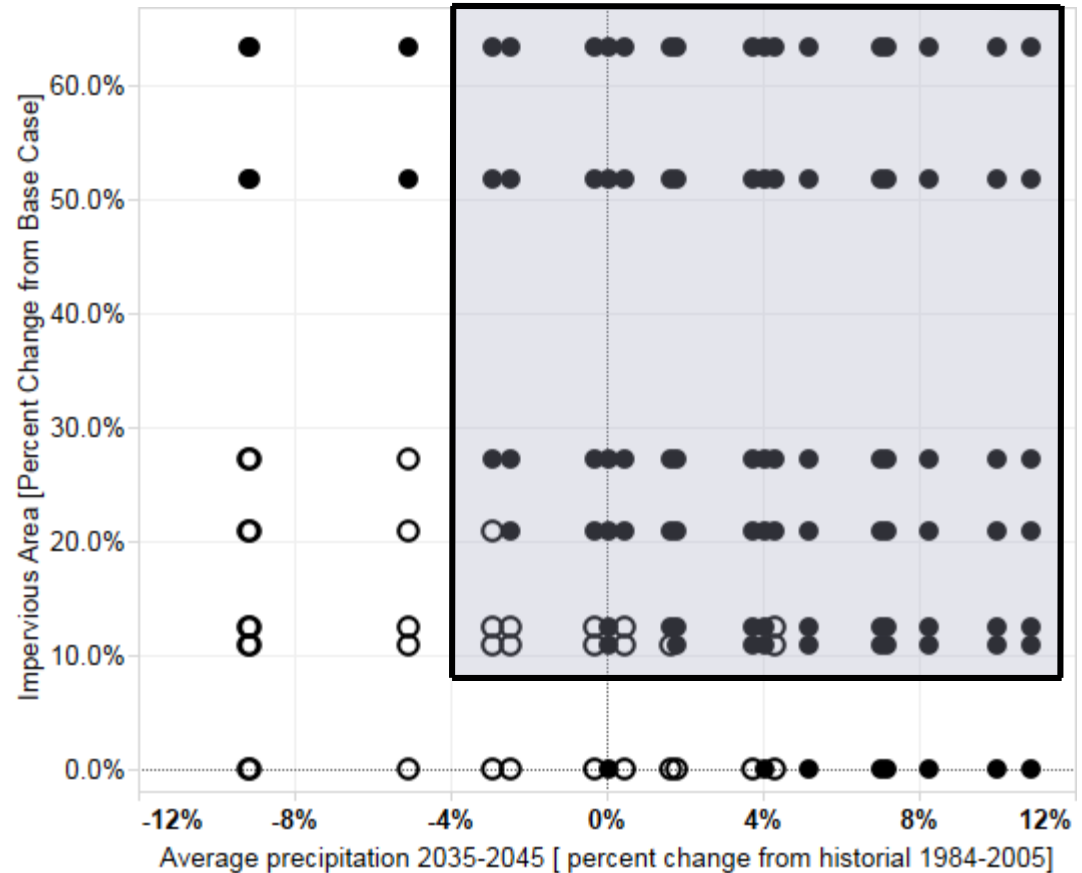
Uncertain input variable 2, e.g. Impervious Area



Uncertain input variable 1, e.g. Runoff

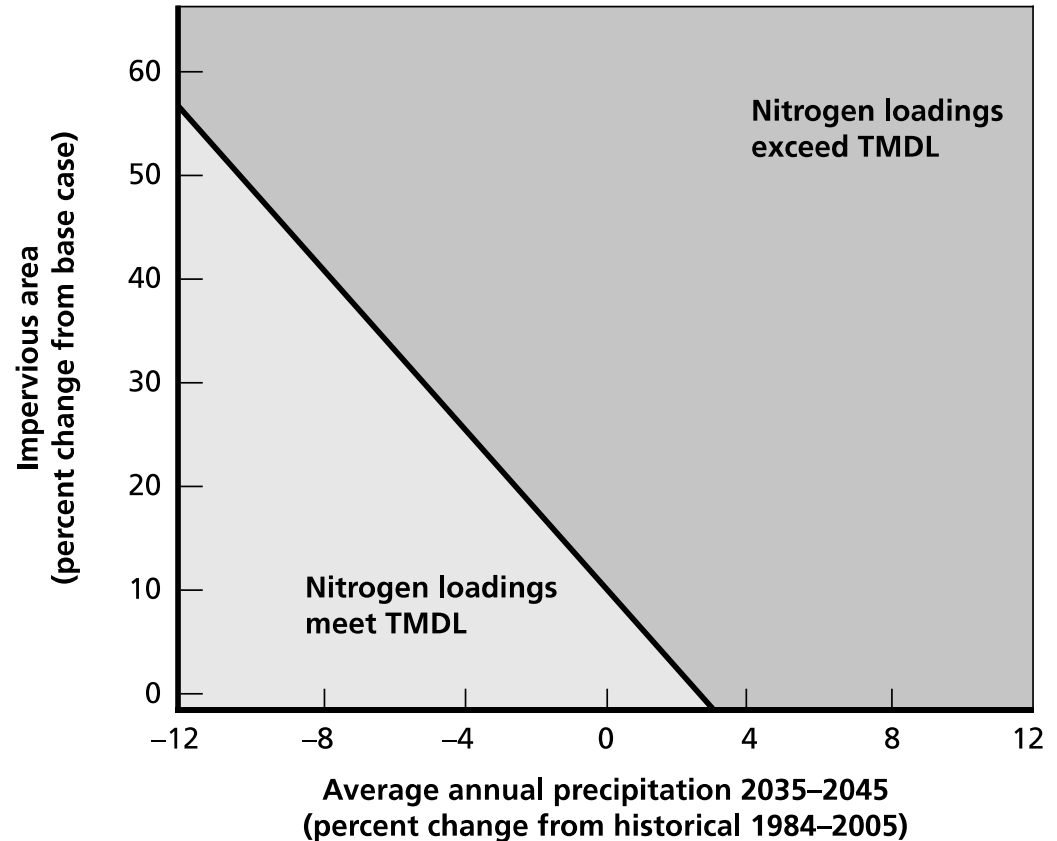
The Traditional Scenario Discovery Approach Helped Identify Clusters of Policy Relevant Cases

- Box statistics:
 - Coverage: 94%
 - Density: 95%
- Vulnerability conditions:
 - Impervious area growth higher than 10%
 - Higher than historical precipitation and less than 4% decline in precipitation



Most Vulnerability Explained by Increase in Impervious Runoff (2035-2045)

- Nitrogen vulnerability in MD's Phase II WIP:
 - Higher precipitation increases runoff, leads to higher nitrogen loads
 - Impervious area growth leads to missing target even if average precipitation declines
 - Must have low impervious area growth *as well as* precipitation declines to meet target



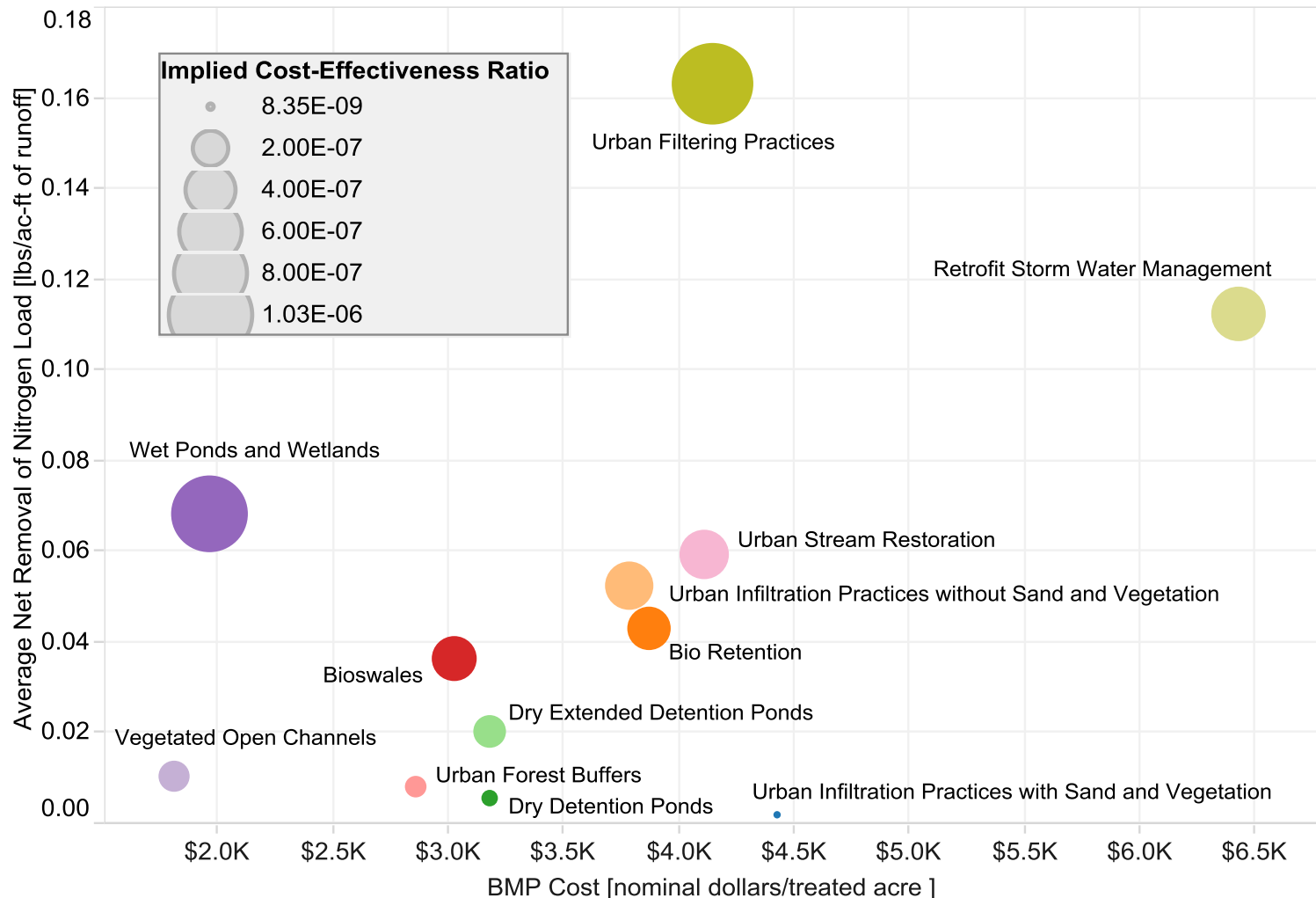
RAND RR720-S.2

$$\text{Impervious Area Change (\%)} + 5.05 * \text{Precipitation Change (\%)} > 11\%$$

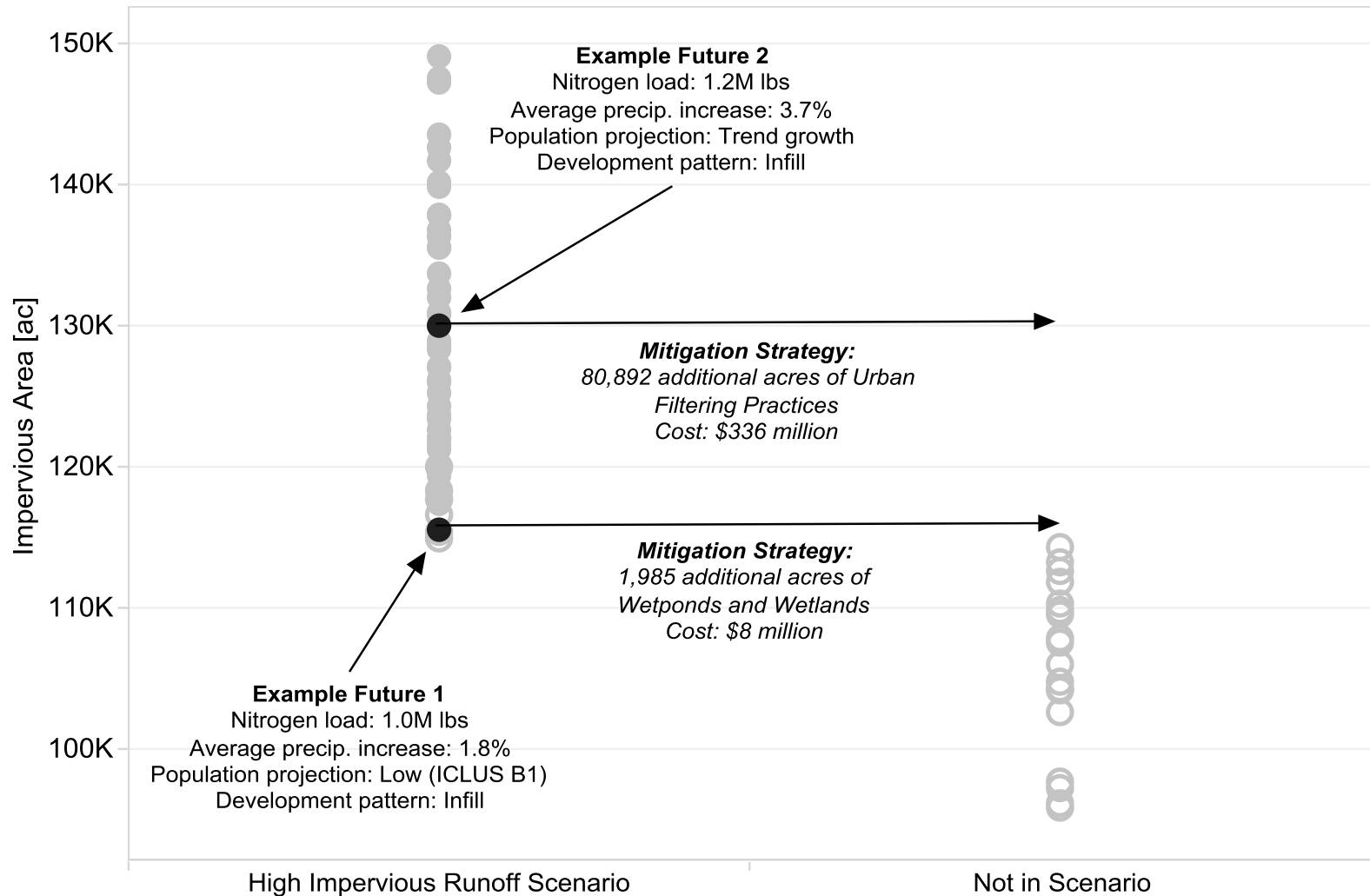
OR

$$\text{Impervious Runoff} > 115 \text{ acre feet/year}$$

We Identified Additional Cost-Effective BMPs to Help Mitigate Nitrogen Vulnerability as an Initial Next Step



Example of Mitigation Options for Two Vulnerable Futures (Nitrogen TMDL)



Insights for Uncertainty Assessment in the Chesapeake Bay

- With future impervious growth or any climate-related precipitation increase, Patuxent stormwater TMDL targets almost always missed
- Next steps for the Patuxent (or similar urban watersheds)
 - Identify cost-effective BMP options to better hedge against future changes
 - Monitor BMPs; test additional BMPs; adaptively manage; revisit targets
- Models could be better integrated and streamlined to facilitate scanning over many possible futures
- Scenario discovery using lower-resolution (steady-state) model could improve decision relevance of high-resolution simulations

Thank You!

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Water and Climate Resilience Center