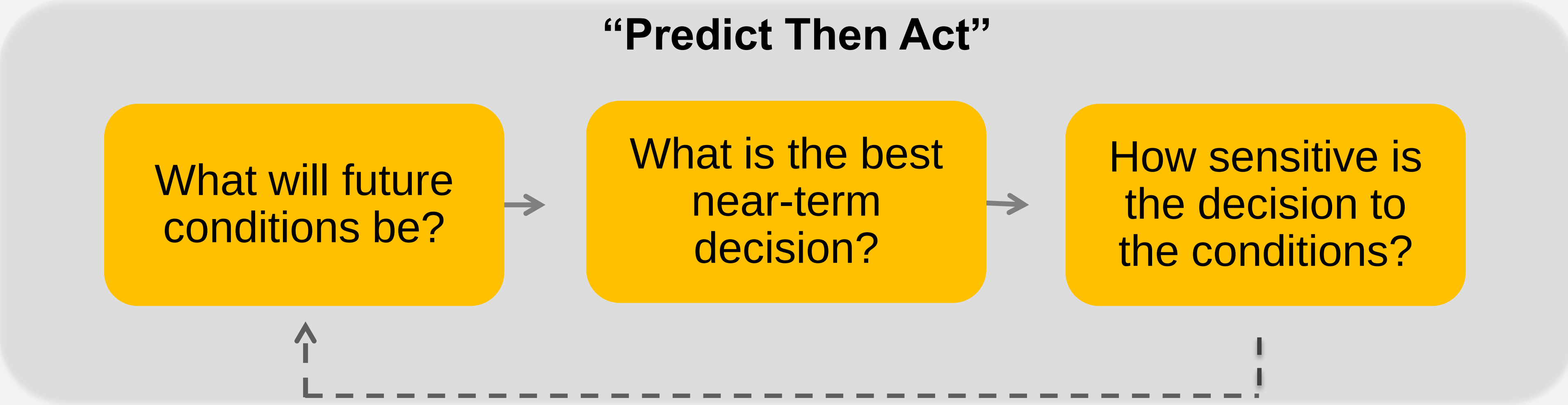
Application of Robust Decision Making: Patuxent River Case Study

Susan Julius, Tom Johnson, Gary Shenk, Lewis Linker (EPA)
Jordan Fischbach, Edmundo Molina, and Rob Lempert (RAND)

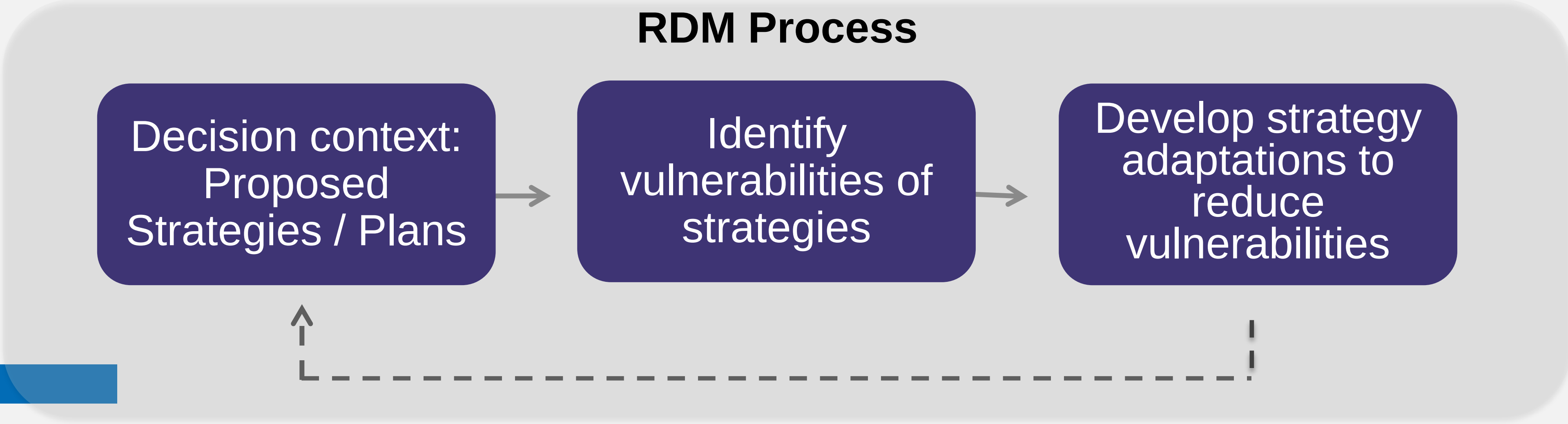
March 19th, 2014

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?

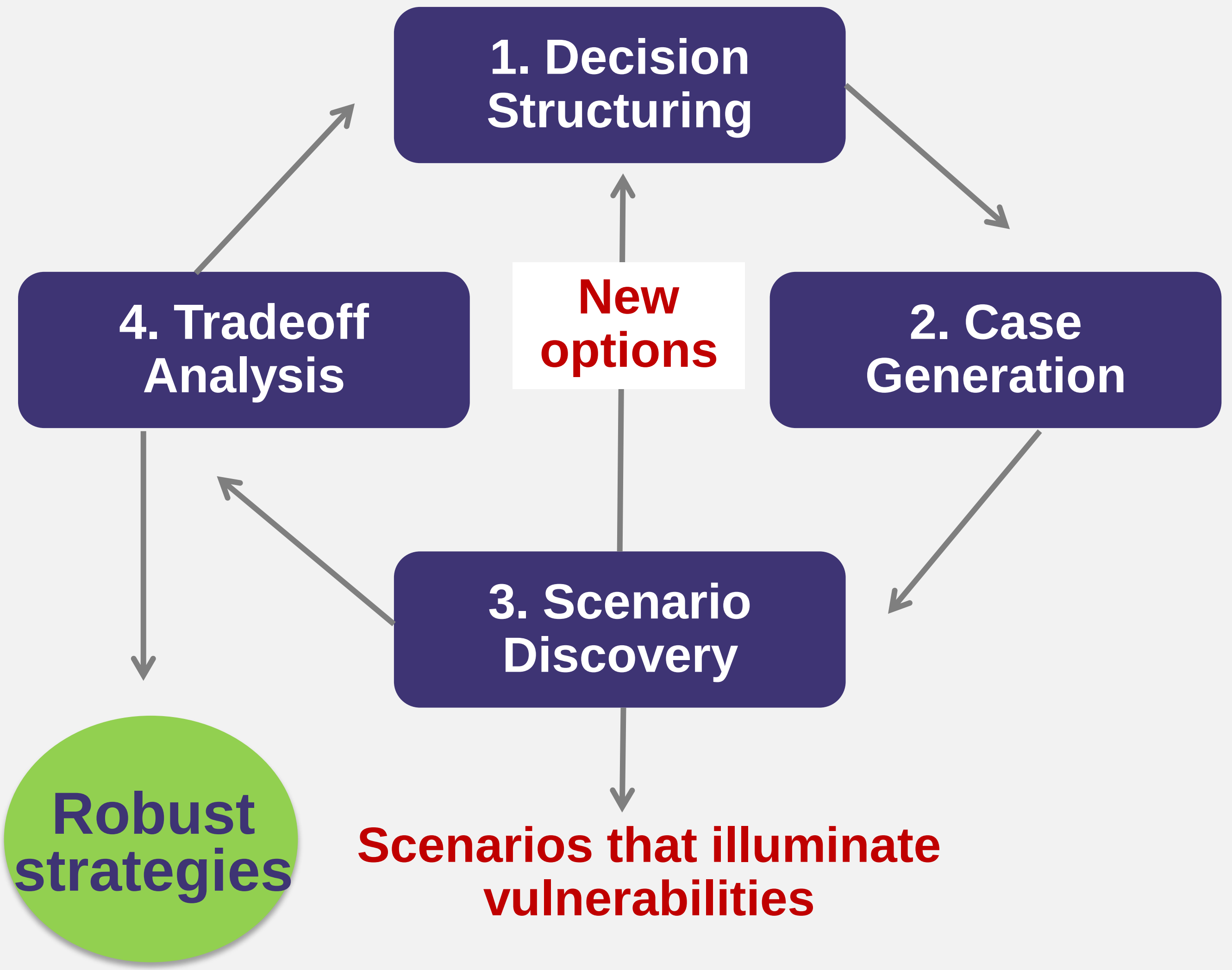


RDM Process

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



1. Decision Structuring

2. Case Generation

3. Scenario Discovery

4. Tradeoff Analysis

New options

Robust strategies

Scenarios that illuminate vulnerabilities

The Study is Part of a Larger Effort to Explore the Application of RDM

Three case studies that explore the application of RDM to inform EPA’s water quality regulatory decisions

I. Urban stormwater management in Maryland’s Patuxent River

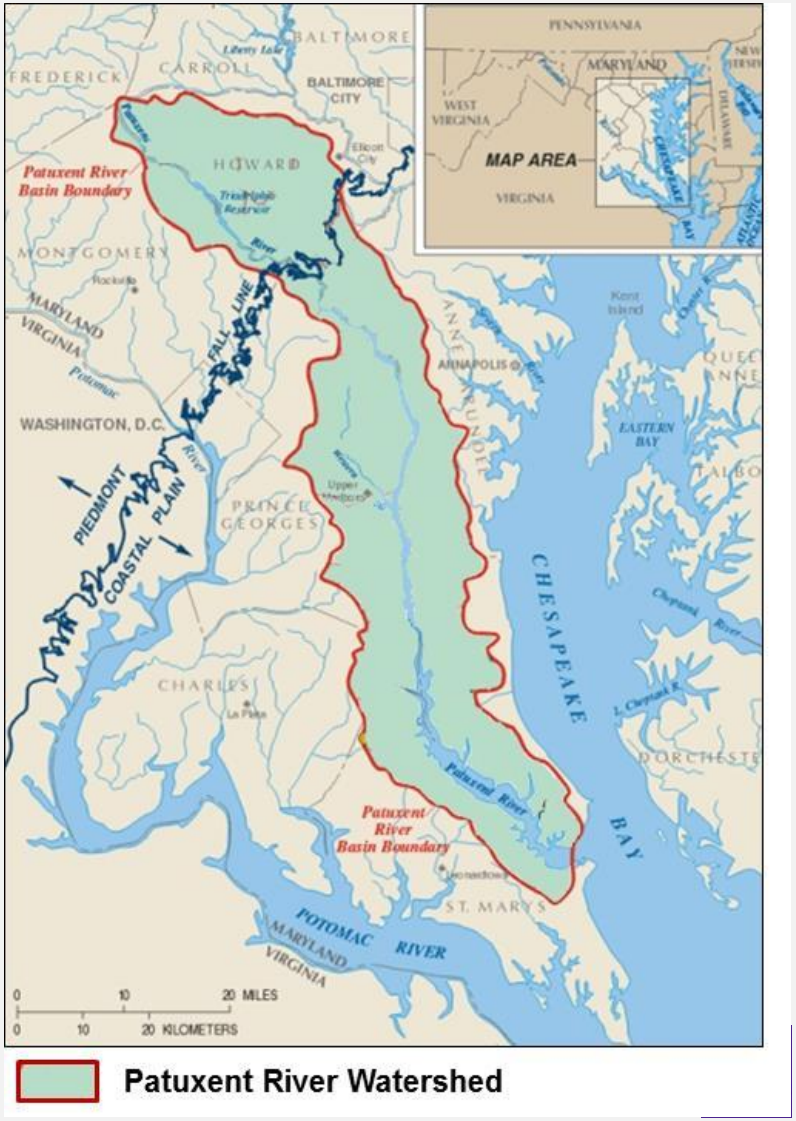
II. Best management practices for agricultural runoff in the Illinois River

III. Third case study to be selected

This presentation will focus on the Patuxent River case study

Our Approach to the Patuxent River Case Study

- Focus: Urban stormwater
- Use Patuxent version of the Chesapeake Bay Watershed Model
- Scope the case study (land use change scenarios, measures of merit, BMPs to consider)
- Complete RDM analysis using the modeling results



Scoping Using the XLRM Framework

Uncertain Factors (X)

Hydrology and climate change

- Observed historical hydrology (1984-2005)
- Downscaled climate scenarios
    - 2035-2045
    - 2055-2065

Land use

- Population growth (2010-2050)
- Infill, sprawl

BMP effectiveness

Evapotranspiration model parameters

Policy Levers (L)

MDE Phase II Watershed Implementation Plan BMPs, including:

- Stormwater management-filtering practices
- Stormwater management-infiltration practices
- Urban stream restoration
- Urban forest buffers

System Model Relationships (R)

Phase 5.3.2 Chesapeake Bay Watershed Model

- Airshed model
- Land use change model
- Watershed model
- Chesapeake

Performance Metrics (M)

Metrics

Nitrogen delivered loads

Phosphorus delivered loads

Sediment delivered loads

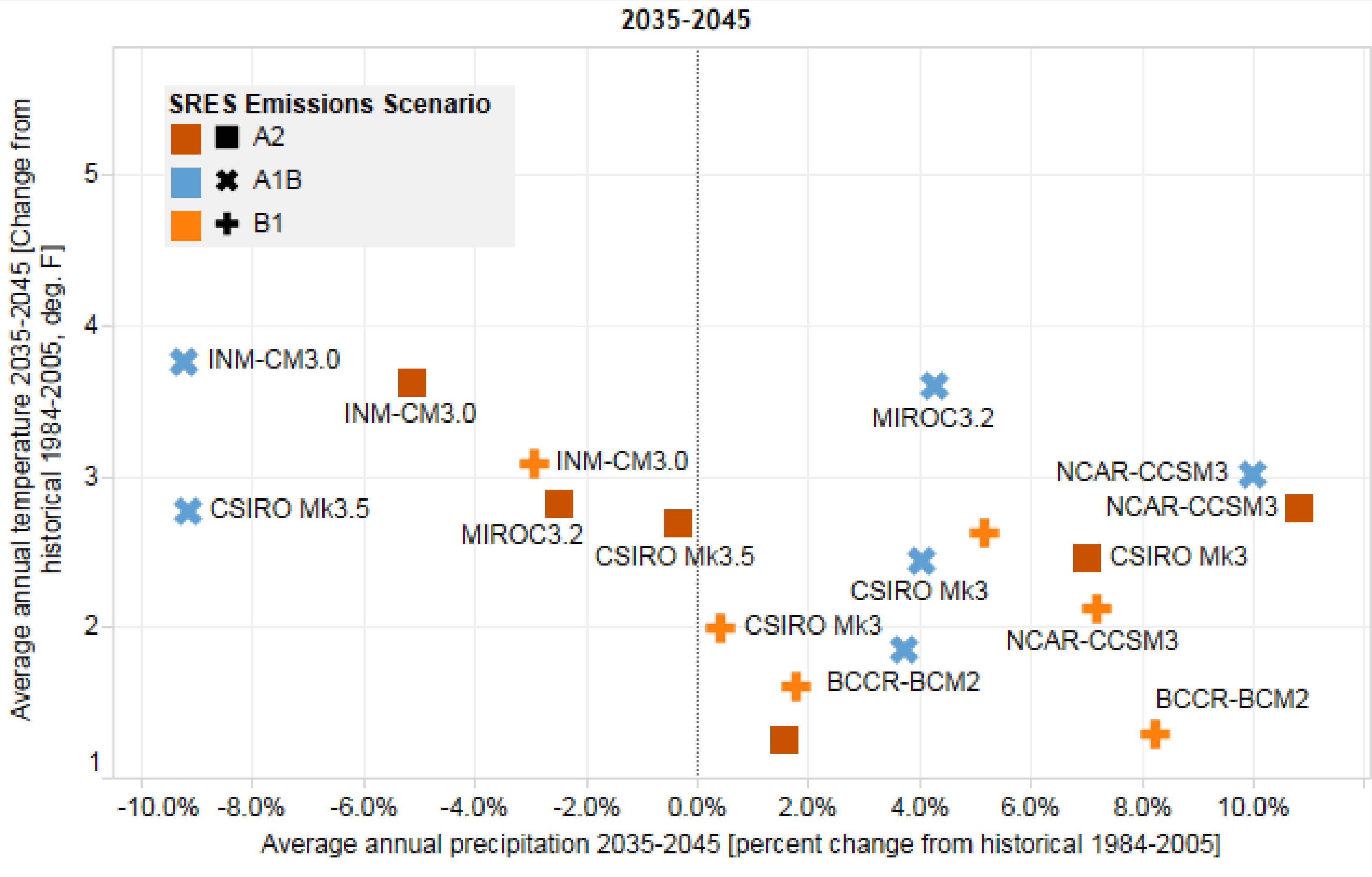
Implementation costs (extended analysis only)

Targets: Phase I WIP TMDLs and Phase II WIP TMDLs (2017 interim; 2025 final)

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

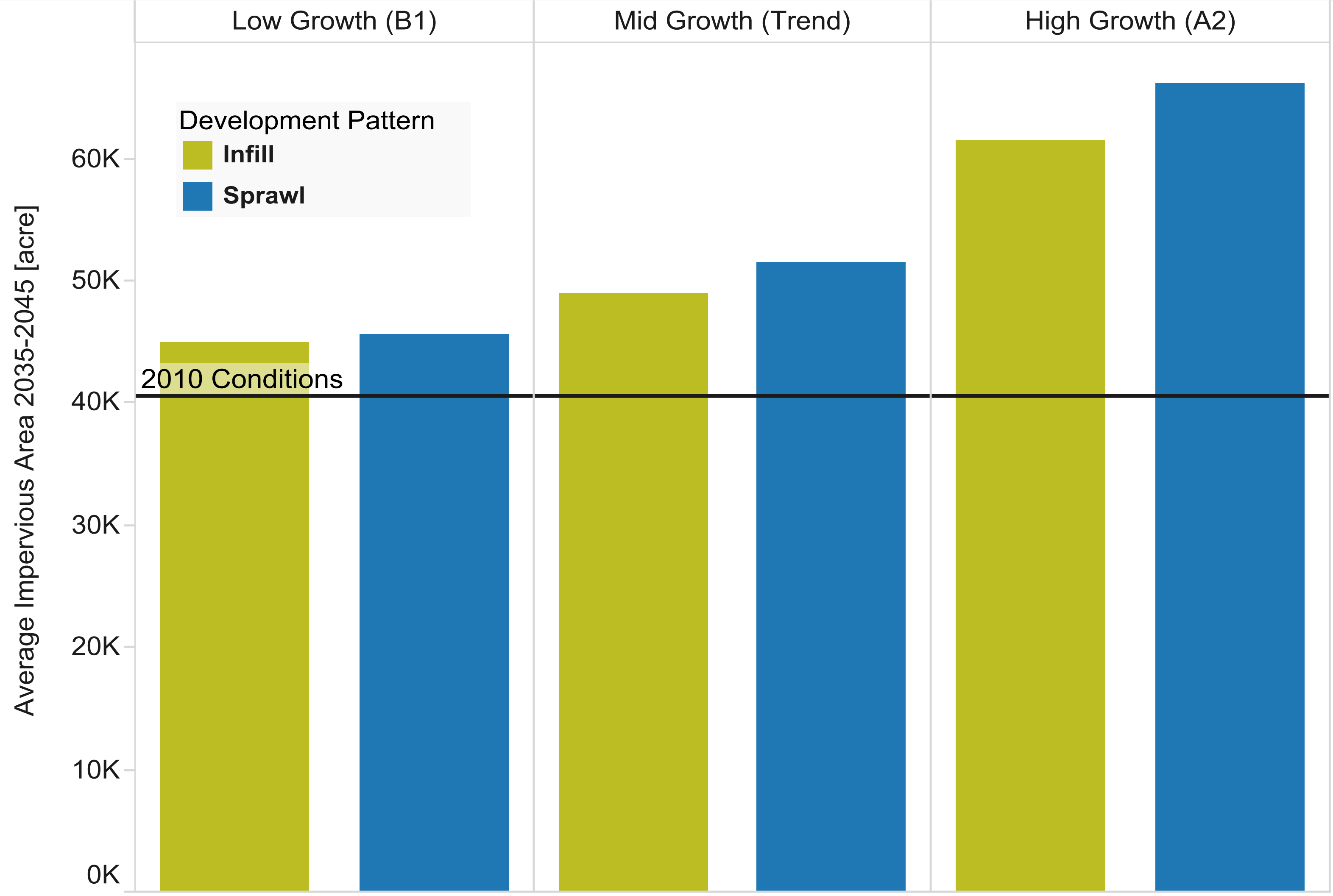
Climate Projections for Patuxent Basin Vary Widely



Population and Land Use Change Assumptions

- One baseline:
  - –Population and development patterns existing 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 WIP Stormwater Target Loads for Patuxent River

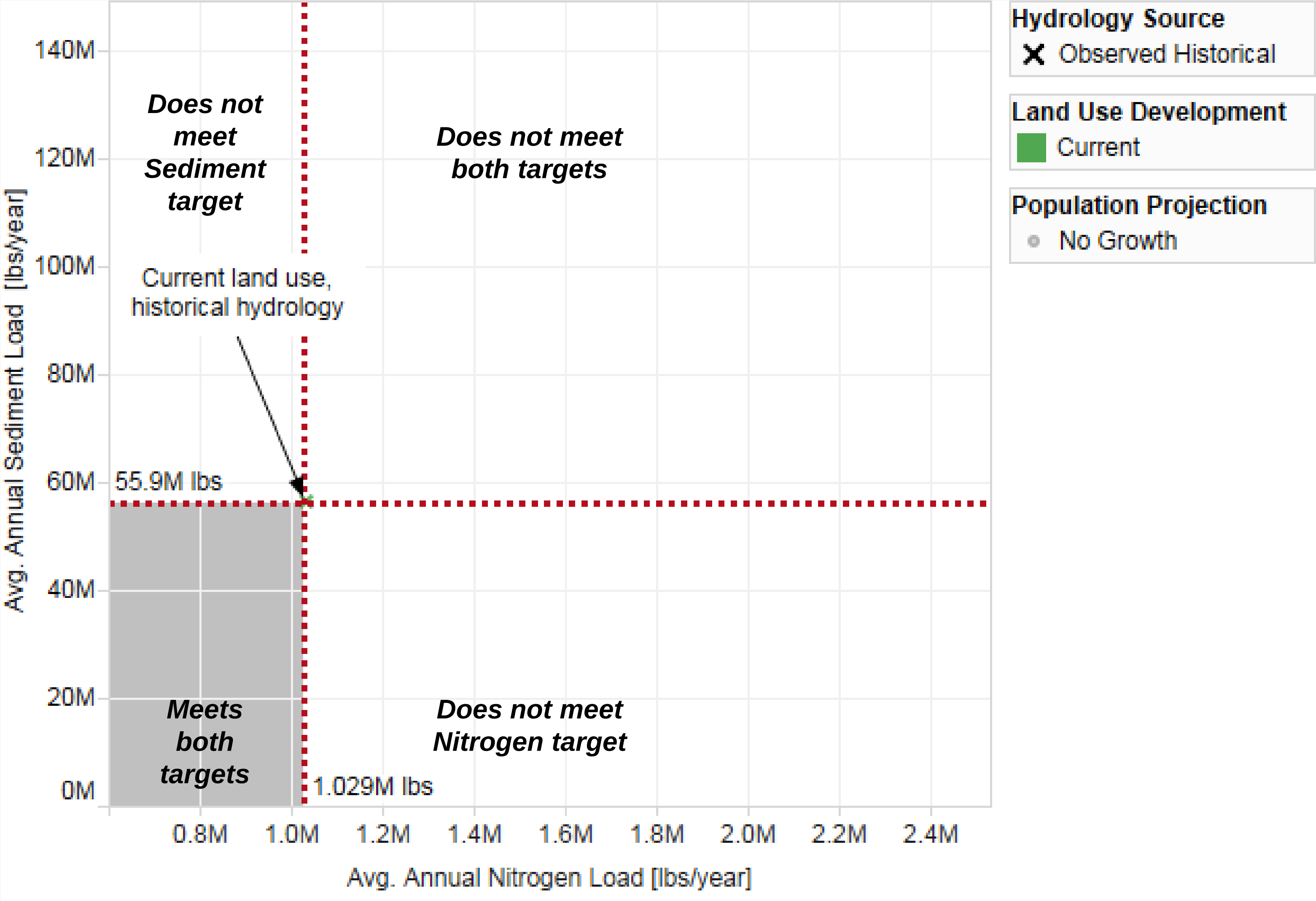
Pollutant Type	Annual Target (million pounds/year)		
	Phase I	Phase II 2017 Interim	Phase II 2025 Final
Nitrogen	2.740	1.029	1.029
Phosphorous	0.210	0.078	0.078
Sediment	85	52	55.9

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.

Best Management Practices Included in the Phase II WIP Strategy

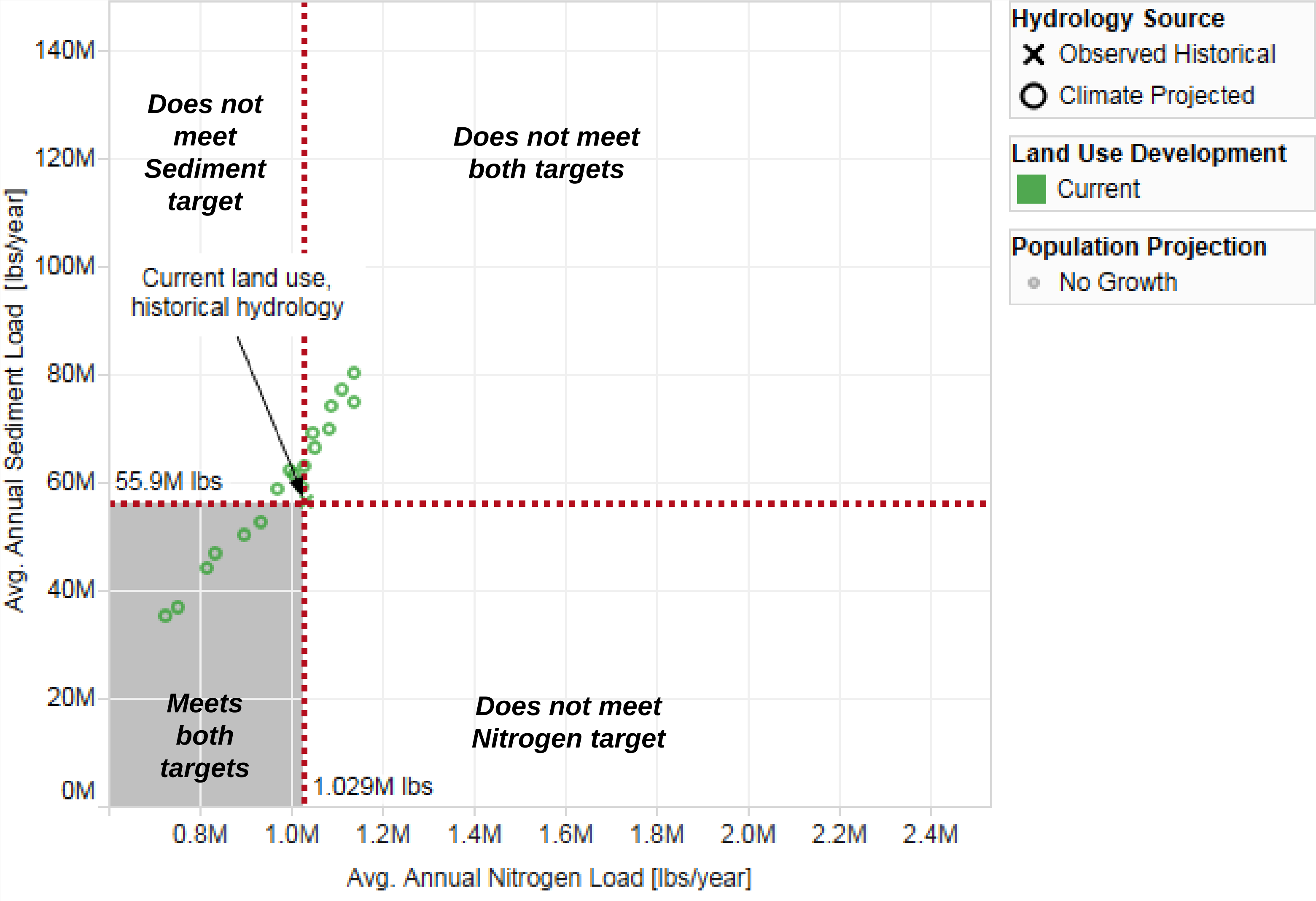
BMP Name	Unit	2012 Progress	2025 WIP	Change from 2012
Standard Stormwater Management (Gray Infrastructure)				
Dry Detention Ponds and Hydrodynamic Structures	Acres	4,857	2,885	-1,972
Erosion and Sediment Control	Acres	1,258	1,848	590
Stormwater Management Generic BMP	Acres	19,566	7,443	-12,123
Urban Nutrient Management	Acres	13,544	30,898	17,354
Urban Infiltration Practices	Acres	1,012	1,511	498
Mechanical Street Sweeping	lbs/year	-	568,089	568,089
Nature-Based Stormwater Management (Green Infrastructure)				
Bio Retention	Acres	-	2,131	2,131
Bioswales	Acres	-	1,654	1,654
Urban Forest Buffers	Acres	68	881	813
Urban Filtering Practices	Acres	1,482	9,480	7,997
Retrofit Stormwater Management	Acres	3,501	12,660	9,159
Vegetated Open Channels	Acres	-	595	595
Wet Ponds and Wetlands	Acres	4,850	7,839	2,989
Urban Stream Restoration	lbs/year	22,948	11,481,346	11,458,398

Phase II WIP Strategy Meets Intended Target In Current Conditions



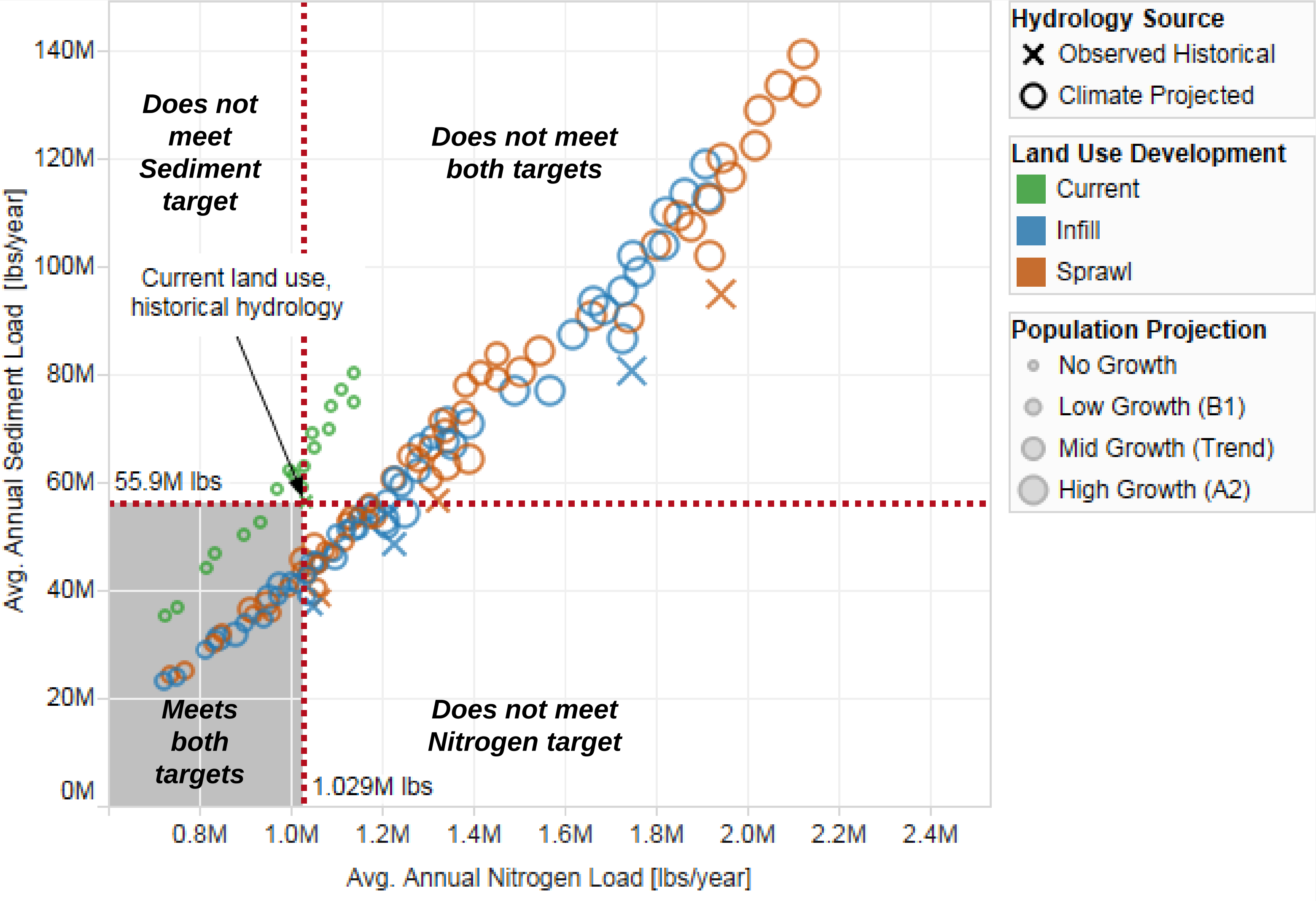
EPA
United States
Environmental Protection
Agency

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



RAND

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



2035-2045

We Identified Sets of Vulnerable Futures for Two BMP Portfolios

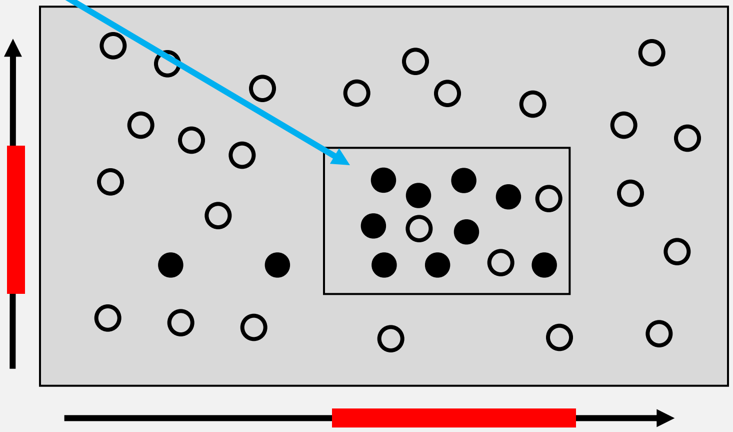
Vulnerability Type	Number of futures exceeding the Phase II target (2035-2045 hydrology)	
	2010 Progress	**Phase II WIP Strategy**
Nitrogen target	114 (93%)	91 (72%)
Phosphorous target	120 (95%)	84 (67%)
Sediments target	111 (88%)	67 (53%)
Exceeding all three targets	109 (87%)	62 (49%)

EPA
United States
Environmental Protection
Agency

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

Strategy successful

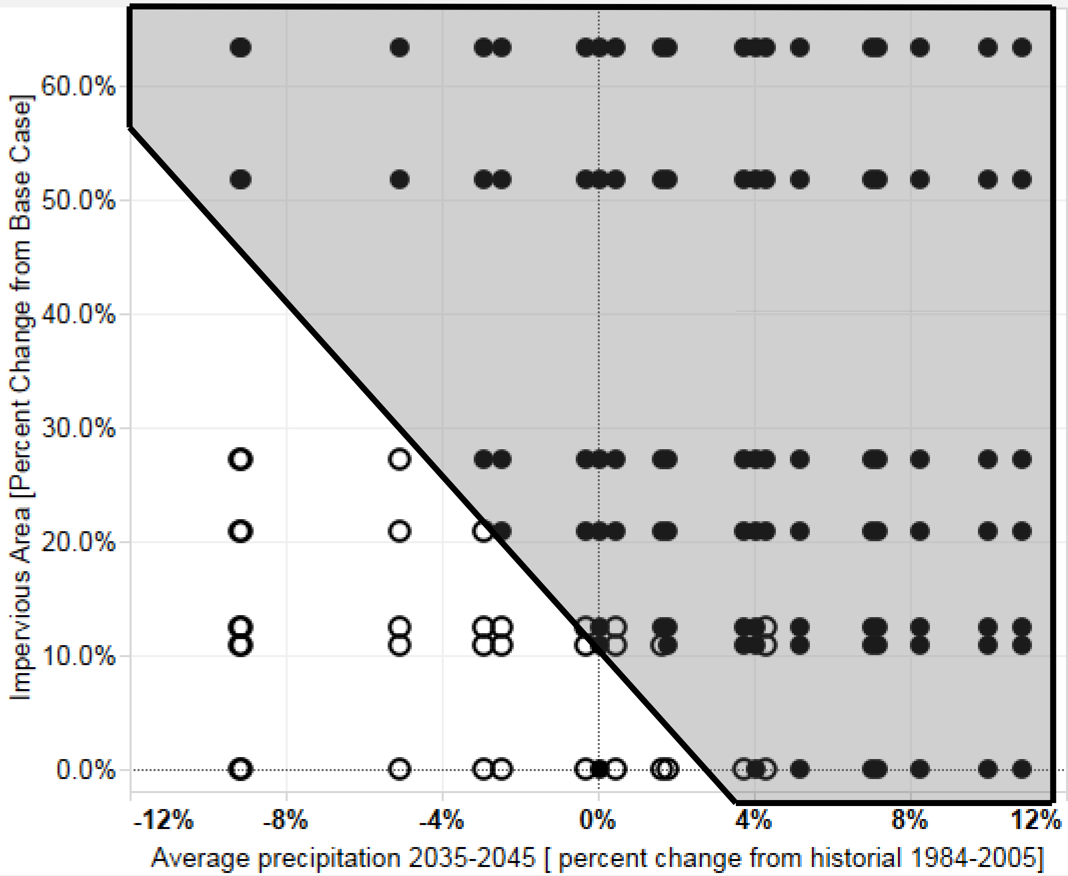
Strategy less successful

Parameter 2

Parameter 1

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

- Nitrogen's Vulnerability Region 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
  - Combination leads to many vulnerable scenarios

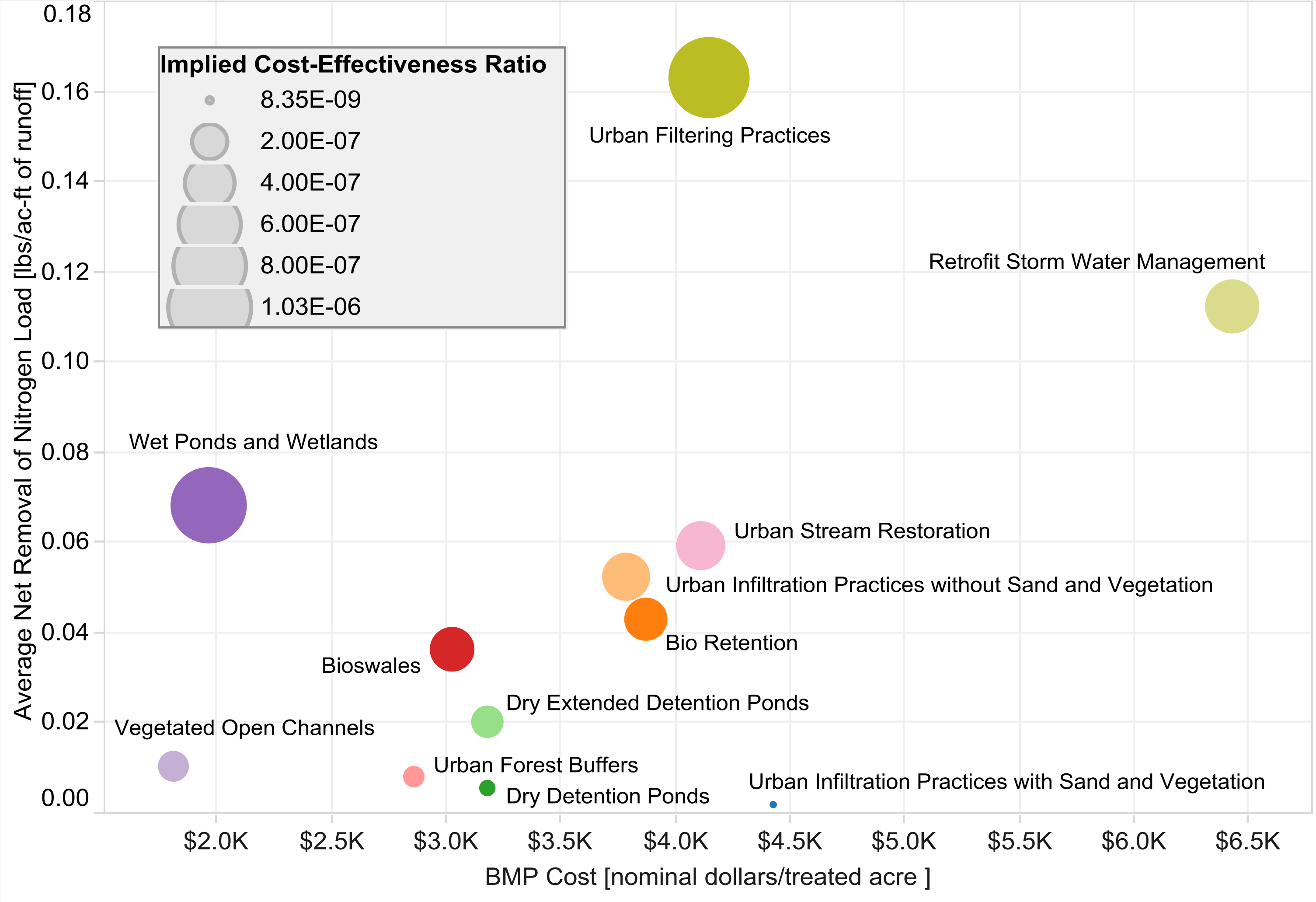


*Impervious Area Change (%) + 5.05 * Precipitation Change (%) > 11%*
OR
Impervious Runoff > 115 acre feet/year

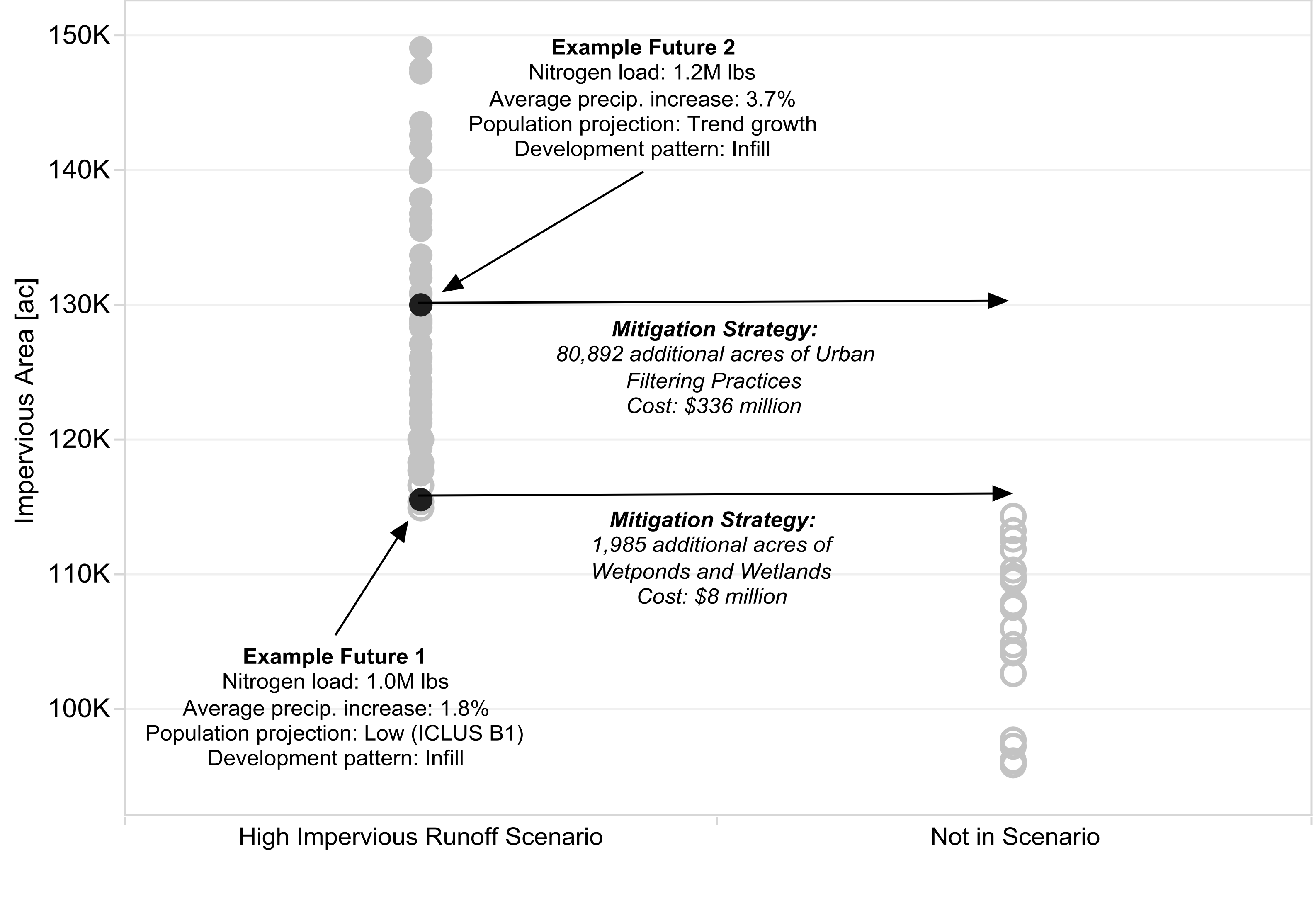
Summary of Scenario Discovery Results (2035-2045)

Metric	Scenario Definition	Coverage	Density
Standard Clustering			
Nitrogen	Impervious area runoff > 114.5 thousand ac-ft	94%	95%
Phosphorous	Impervious area runoff > 104.6 thousand ac-ft Construction area > 2.1 thousand acres	87%	90%
Sediment	Impervious area runoff > 103.6 thousand ac-ft Construction area > 3.3 thousand acres	86%	88%
Combined	Impervious area runoff > 104.6 thousand ac-ft Construction area > 3.3 thousand acres	86%	83%
Enhanced Clustering (Principal Components)			
Nitrogen	Impervious area change [%] + 5.1 * Precipitation change [%] > 11%	99%	93%
Phosphorous	Impervious area change [%] + 4.5 * Precipitation change [%] > 16%	94%	87%
Sediment	Impervious area change [%] + 1.9 * Precipitation change [%] > 27%	82%	89%
Combined	Impervious area change [%] + 1.7 * Precipitation change [%] > 27%	88%	91%

Nitrogen Removal Cost-Effectiveness for Impervious Land Use by BMP Type



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



Example Future 2
Nitrogen load: 1.2M lbs
Average precip. increase: 3.7%
Population projection: Trend growth
Development pattern: Infill

Mitigation Strategy:
80,892 additional acres of Urban Filtering Practices
Cost: $336 million

Mitigation Strategy:
1,985 additional acres of Wetponds and Wetlands
Cost: $8 million

Example Future 1
Nitrogen load: 1.0M lbs
Average precip. increase: 1.8%
Population projection: Low (ICLUS B1)
Development pattern: Infill

Conclusions

- Under historic climate and no change in land uses, Maryland Phase II WIP meets TMDL targets
  - With future population growth or precipitation increases, targets are almost always missed

- Vulnerability is driven by increased runoff in impervious areas
  - Precip increases over historic average
  - Impervious land cover increases
  - Both precip and impervious cover increase

- Consider cost-effective options to hedge against future changes
  - For example, greater investments in wetland BMPs or urban filtering practices

- Next steps
  - Monitor BMPs; test additional BMPs; adaptively manage; revisit targets

Thank you!

For more information, contact us:

Susan Julius - julius.susan@epa.gov
Tom Johnson - johnson.Thomas@epa.gov

Gary Shenk - gshenk@chesapeakebay.net
Lewis Linker - llinker@chesapeakebay.net

Jordan Fischbach - jordan_fischbach@rand.org
Edmundo Molina - edmundo_molina-perez@rand.org
Rob Lempert - robert_lempert@rand.org