Managing Water Quality in the face of Climate Change Uncertainty:

Case Studies of Robust Decision Making

Susan Julius, Thomas Johnson (USEPA)
Rob Lempert, Jordan Fischbach (Rand Corp)

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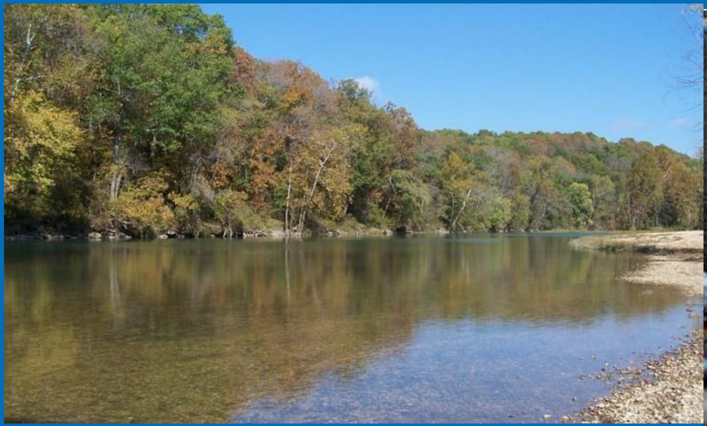
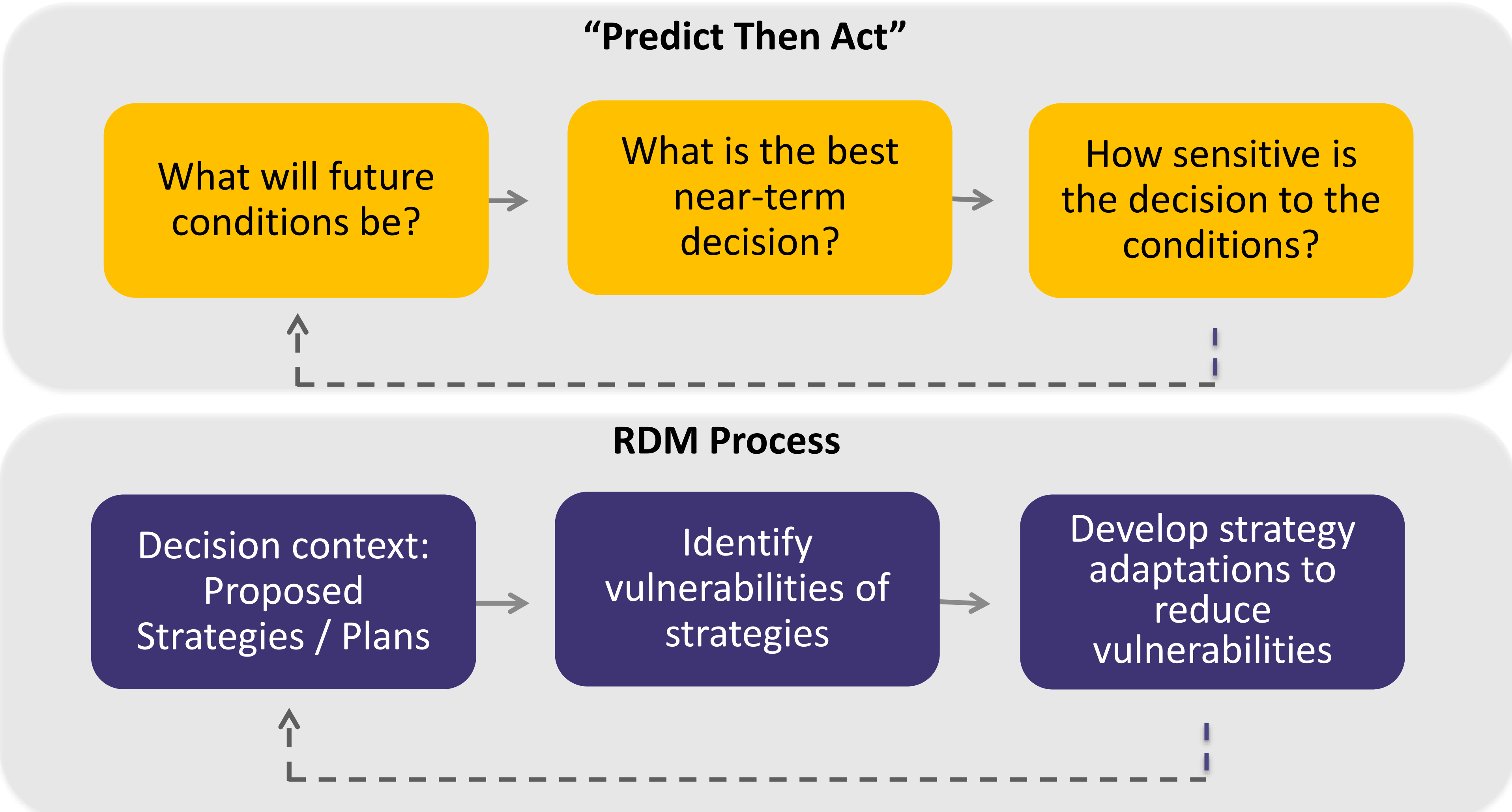



Robust Decision Making (RDM) Works Under Deep Uncertainty by Running the Analysis Backwards



RDM facilitates conversations among Decisionmakers

1. Decision Structuring

4. Tradeoff Analysis

New options

2. Case Generation

3. Scenario Discovery

Robust strategies

Scenarios that illuminate vulnerabilities

RDM works better than traditional decision methods under deep uncertainty

Traditional		RDM
Focus on predictions	⟷	Focus on strategy vulnerabilities
Encourage bias and gridlock	⟷	Inclusive and transparent process
Produce brittle solutions	⟷	Produce robust solutions

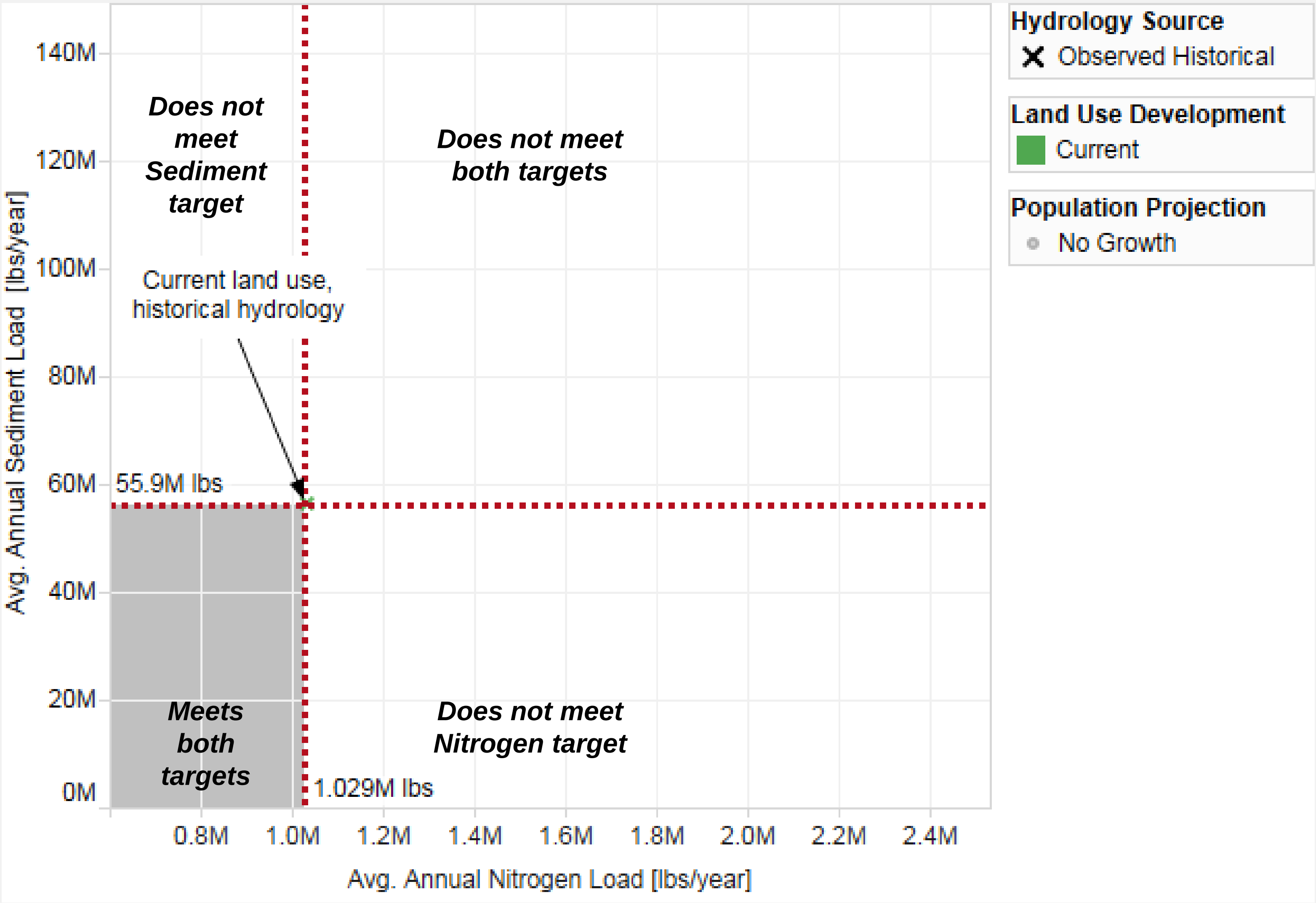
We applied RDM to stormwater management in the Patuxent River

- 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

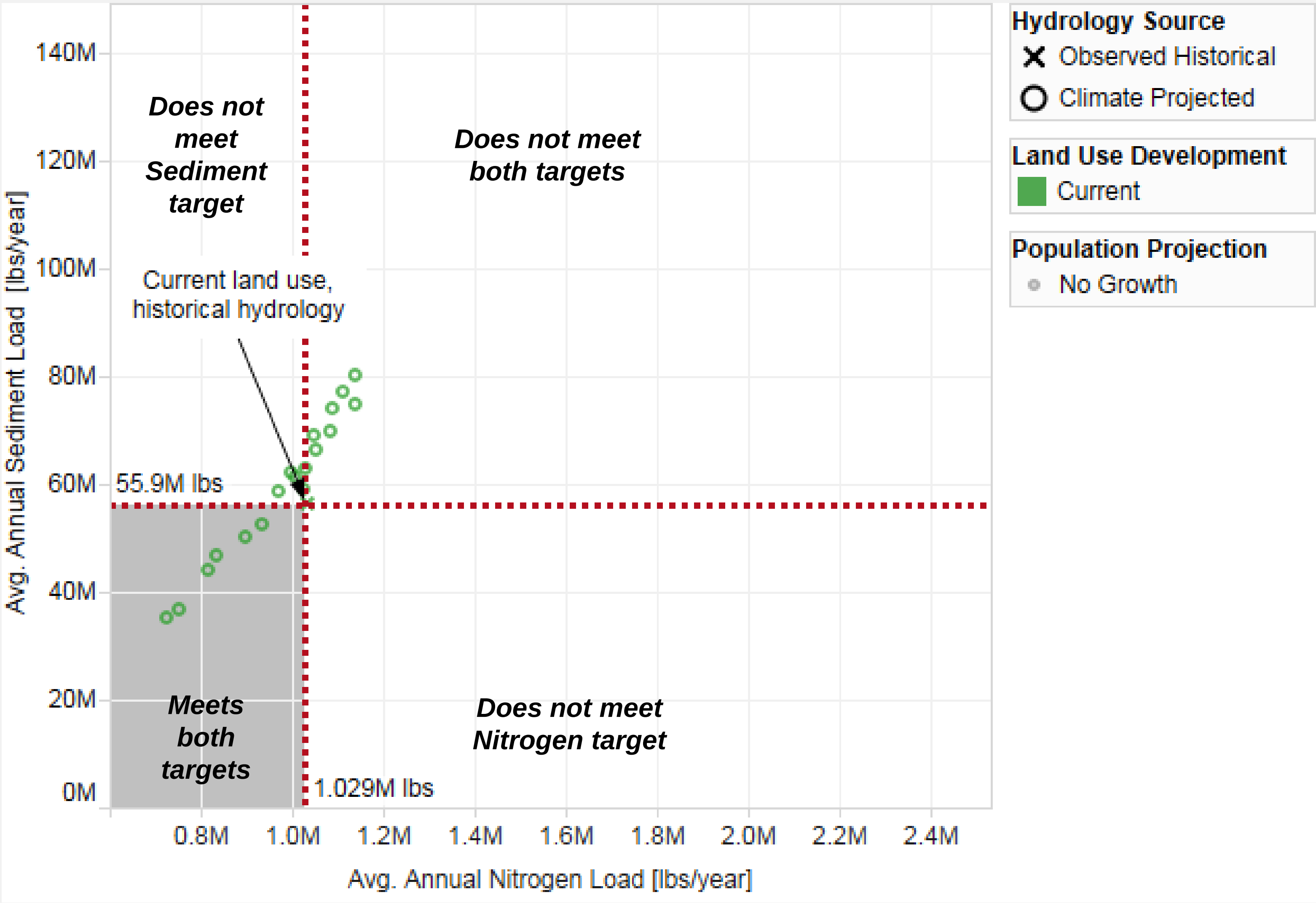
The "XLRM" approach framed the analysis

Uncertain Factors (X)	Policy Levers (L)
Hydrology and climate change • Observed historical hydrology • Downscaled climate scenarios ***Land use*** • Population growth (2010-2050) • Infill, sprawl ***Evapotranspiration model parameters***	***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)	**Performance Metrics (M)**
Phase 5.3.2 Chesapeake Bay Watershed Model • Airshed model • Land use change model • Watershed model	***Metrics*** Nitrogen delivered loads Phosphorus delivered loads Sediment delivered loads Implementation costs (extended analysis only) ***Targets:*** Phase II WIP TMDLs

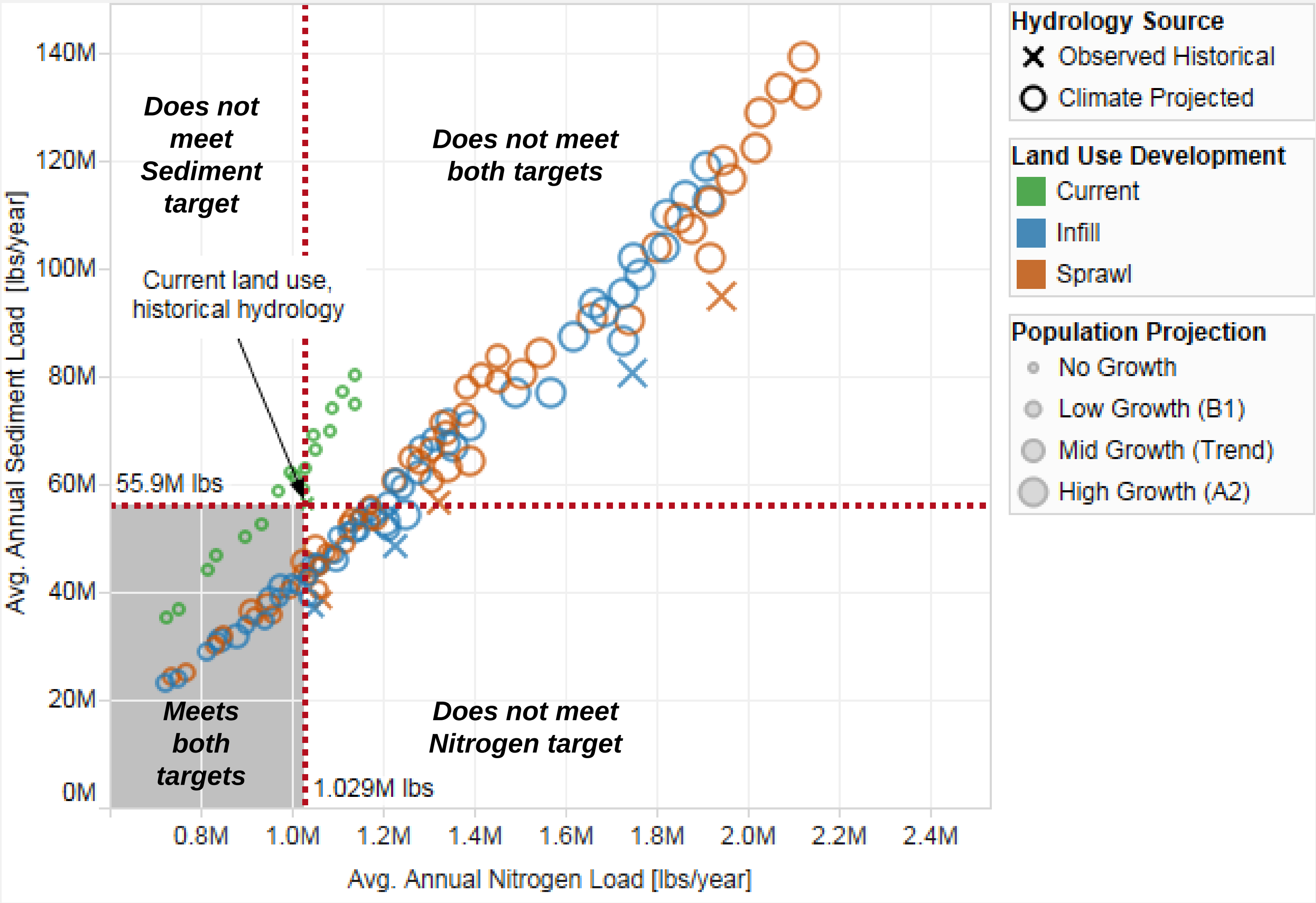
Phase II WIP Strategy meets intended target under current conditions



Climate projections affect attaining targets in some futures (2035-2045)

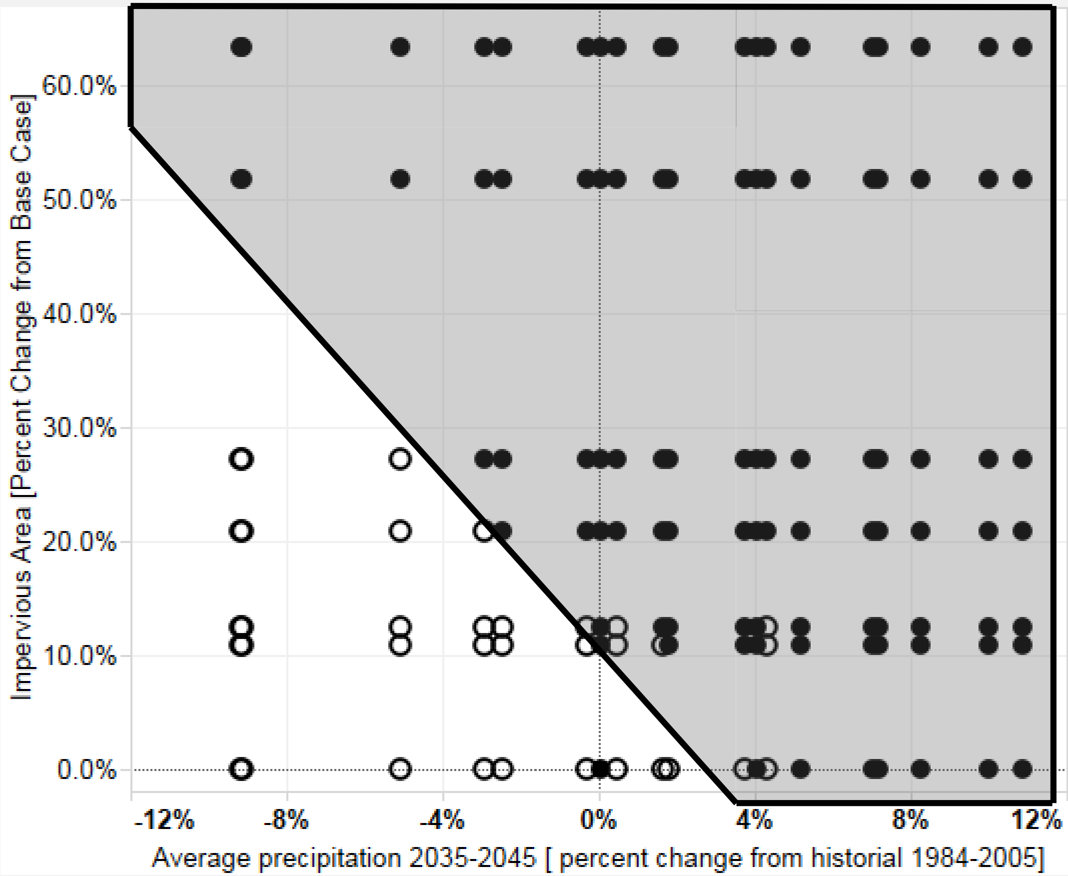


Climate and land use together lead to many stressing futures (2035-2045)

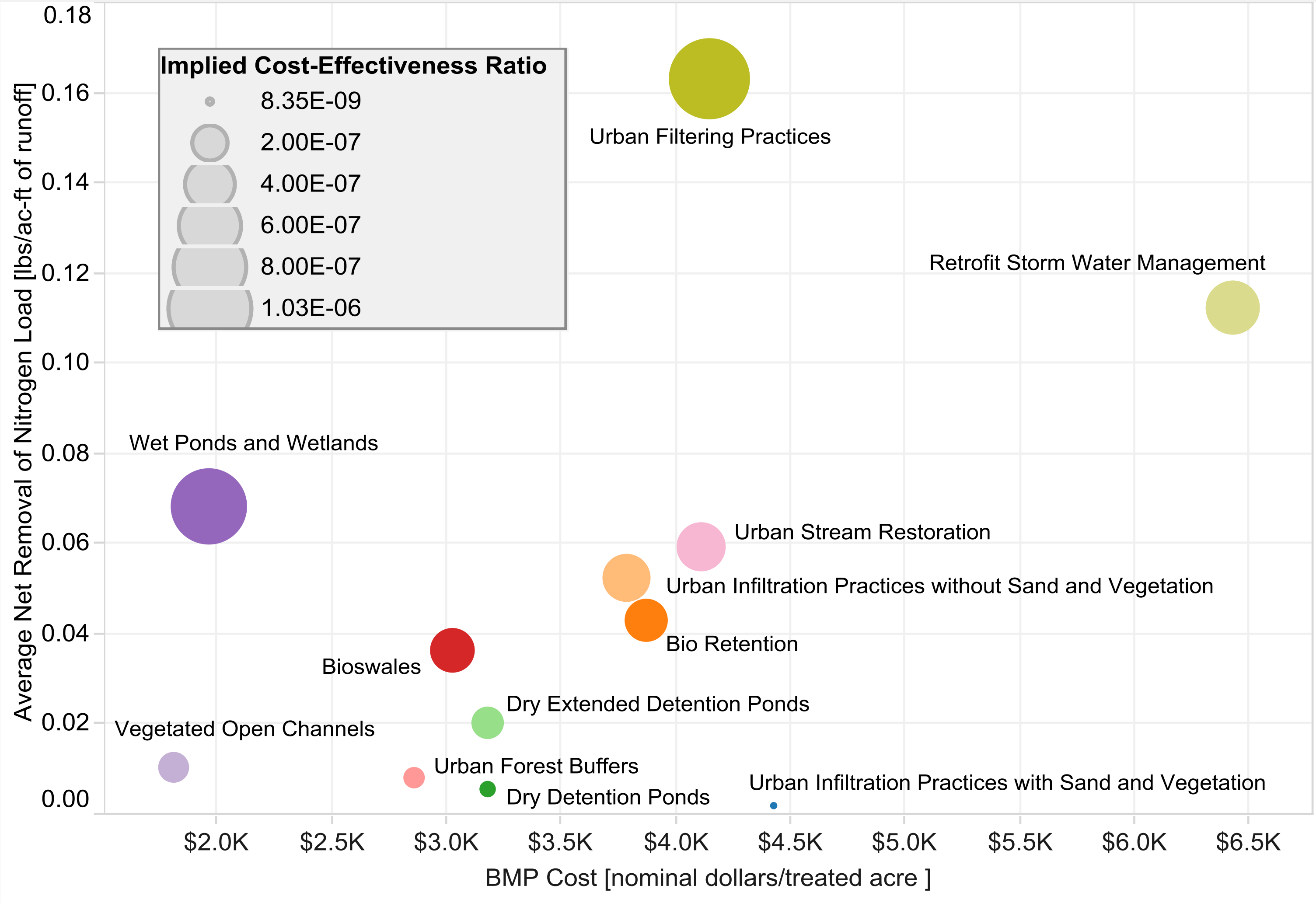


Most vulnerability explained by increases in impervious runoff (2035-2045)

- 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



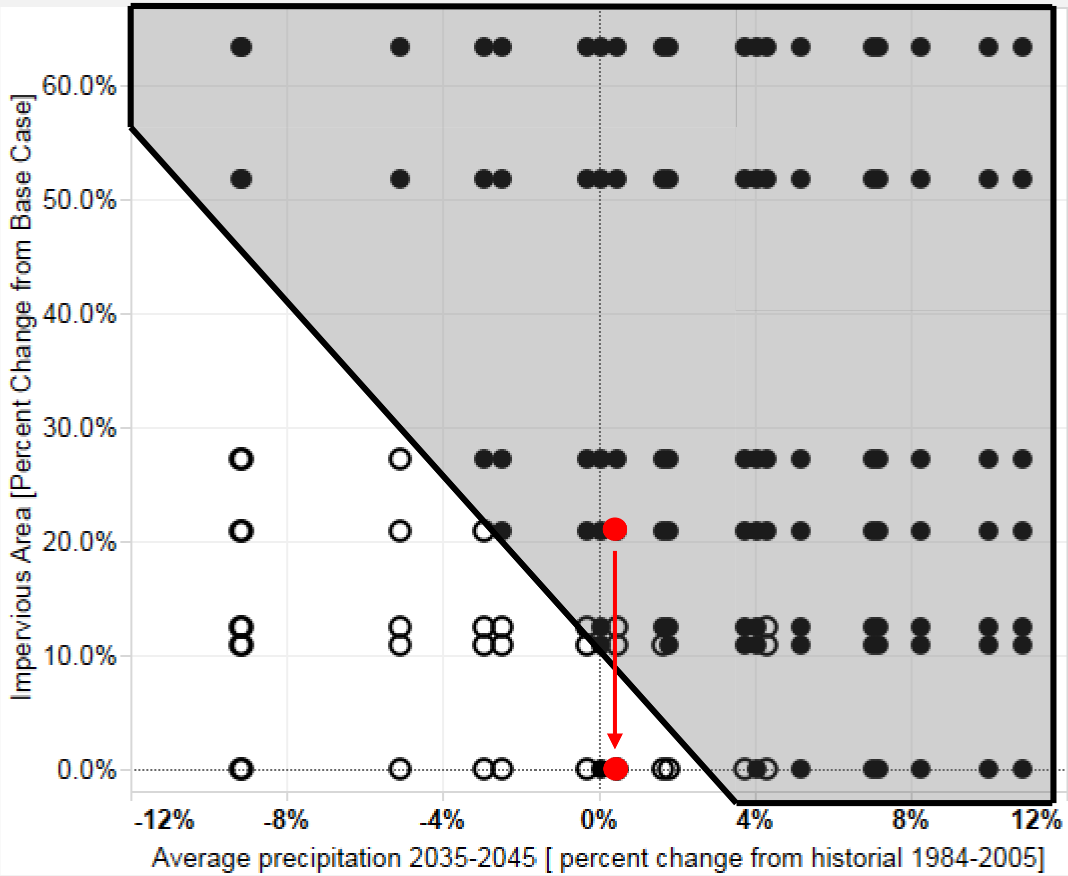
Nitrogen removal cost-effectiveness for impervious land use by BMP type



Most vulnerability explained by increase I impervious runoff (2035-2045)

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

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



United States Environmental Protection Agency

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

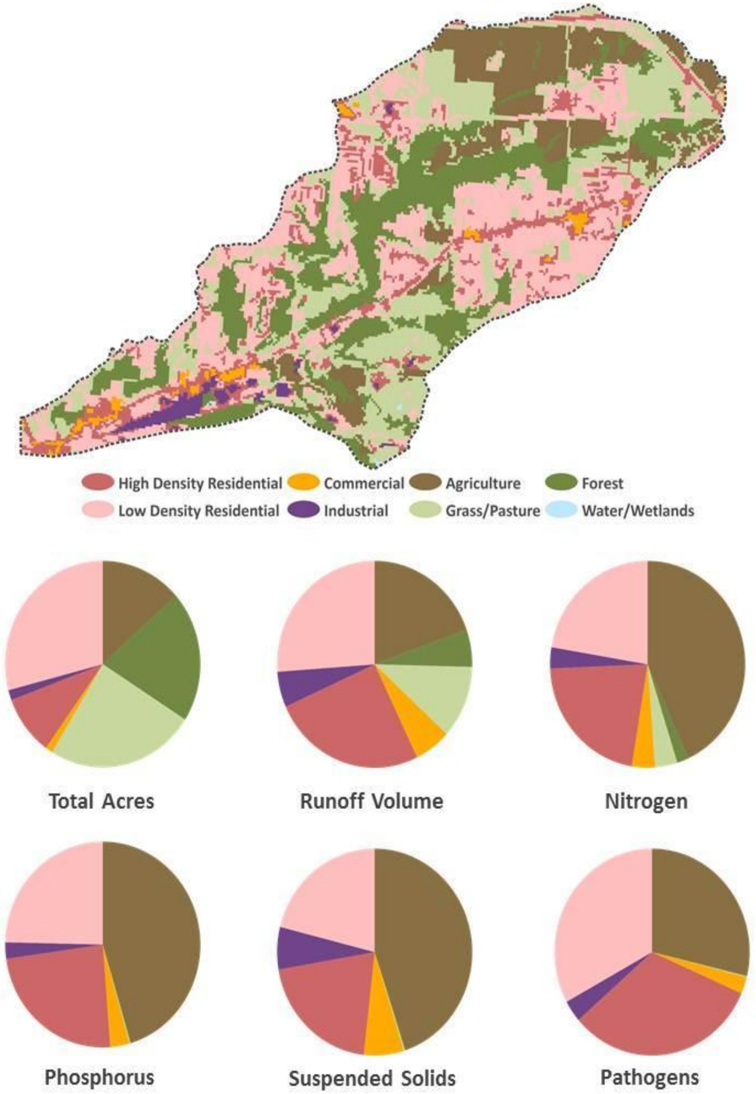
- Vulnerability is driven by increased runoff from impervious areas
  - Precip increases over historic average
  - Impervious land cover increases
  - Both precip and impervious cover increase

- 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

Illinois Case Study: How might climate change affect North Farm Creek Implementation Plan?

- State of Illinois developing TMDL's for middle Illinois River
- This study builds on Dec 2012 load reduction strategy and BMP implementation plan for North Farm Creek Watershed



XLRM Framework for analysis of North Farm Creek Implementation Plan

Uncertainty Factors (X)	Policy Levers (L)

• Affects of climate change on stream flows
  - Six projections from North American Regional Climate Change Assessment Program (NARCCAP)
• BMP effectiveness
  - Intrinsic performance
  - In response to climate change
	• Draft Implementation Plan, some structural management options:
	  - Green infrastructure
	  - Grassed waterways
	  - Conservation tillage
	- Adaptive management policy responses

Relationships (R)	**Performance Metrics (M)**

• SWAT model of North Farm Creek, calibrated to meet current water quality	• TMDL compliance for:
	  - Nitrogen
	  - Phosphorus
	  - Suspended solids

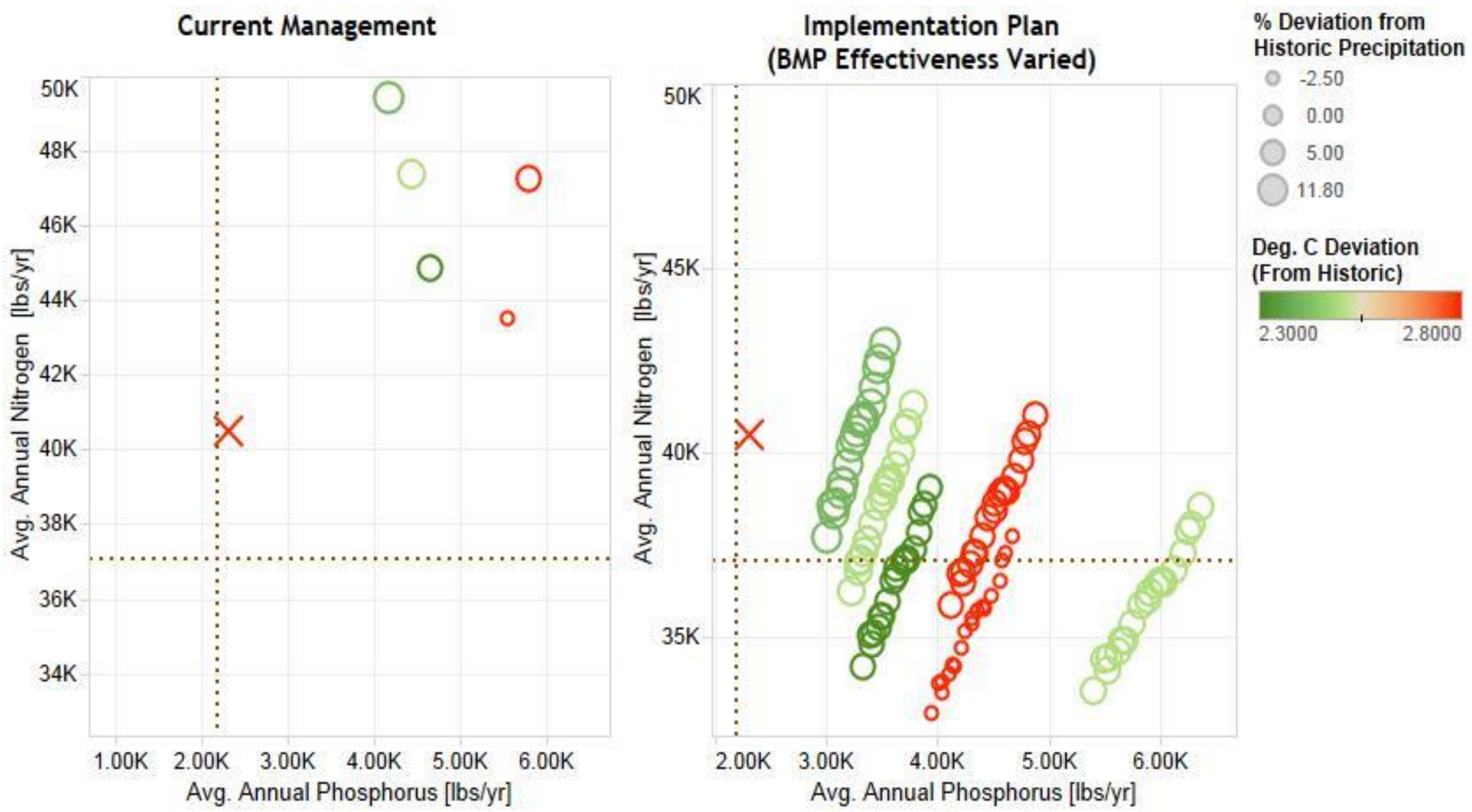
Initial analysis considers important structural BMPs from Implementation Plan

Implementation plan includes

- Structural and non-structural management options
- Implementation in three phases:
  1. Non-structural (Years 0-3)
  2. Structural (Years 3-10)
  3. Monitoring and adaptive management (Years 10-20)

Activity	Critical area	Phasing I/II/III	Pollution removal	Cost
Nonstructural Management Options				
Education and pollution prevention programs	Watershed wide	H/C/C	Moderate	Low
Ordinance development	Watershed wide	H/C/C	Moderate	Moderate
Street & parking lot sweeping	Impervious surfaces	H/C/C	Moderate	Moderate
Pet waste education and outreach campaign	Residential areas	H/C/C	Moderate	Low
Wildlife implementation practices	Riparian areas	H/C/C	Moderate	Low
Salt management plan	Impervious salted areas watershed wide	H/C/C	High	Low
Structural Management Options				
Green infrastructure refitting	Impervious areas	M/H/C	High	High
SSO Control	East Peoria Oakwood Ave outfall	H/C/C	High	High
Disinfection of primary sewage plant effluents	Sundale Sewer Corp-Highland	H/C/C	High	High
Stabilize erosion of steep slopes	Storm sewer outfalls, steep slopes	H/C/C	High	Moderate-High
Stream bank restoration	Eroding steam banks	L/H/H	High	High
Riparian area management	Riparian areas	H/H/C	High	Moderate
Grassed waterways	Cultivated agricultural areas	H/M/L	High	Low
Conservation tillage	Cultivated agricultural areas	H/M/L	High	Low

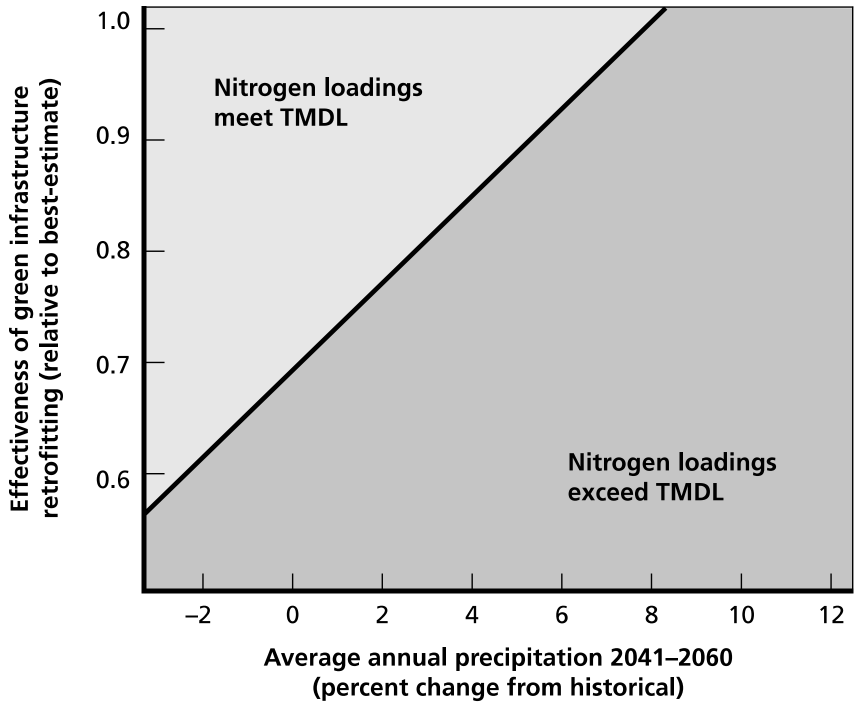
Nitrogen and Phosphorous loads for current and modeled Implementation Plan for 2040-2060



Climate change and other uncertainties could have a significant impact on the success of water quality plans

- TMDL watershed implementation plans expected to meet water quality standards if future climate resembles the past do not meet these standards over a wide range of plausible future climate conditions
- An increase in the amount of paved or impervious area cover due to future population growth, as well as worse-than-anticipated performance from stormwater BMPs, could also lead to missing future standards
  - Results of this study show loadings generally exceed the TMDL in 2014-2070 under conditions with high precipitation and low GI retrofitting BMP effectiveness

Scenario maps help examine adaptive management strategies



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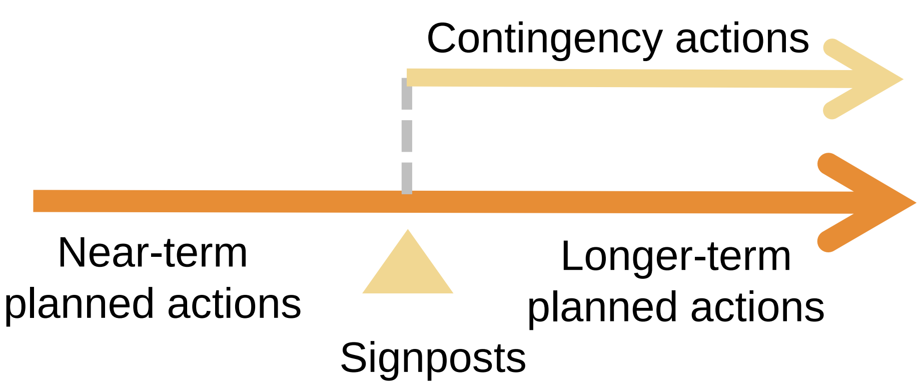
For adaptive management, monitor:

- Climate
- BMP effectiveness



North Farm Creek adaptive management strategies

- Milestones and midcourse corrections the North Farm Creek Implementation plan can adapt the plan over time to new information to improve the ability to meet the nitrogen TMDL
- At conclusion of Phase II
  - if precip seems likely to be higher than historic, and green infrastructure BMPs are performing as expected, then accelerate deployment of these BMPs in Phase III
  - If green infrastructure BMPs are not performing as well as expected at the end of Phase II but precipitation is expected to stay close to historic levels, then accelerating deployment of these BMPs might still make sense
  - If precipitation increases are expected and the green infrastructure BMPs are performing poorly, then North Farm Creek may need to explore other options, including a potential change in the nitrogen TMDL