TETRA TECH

BMP Performance under a Changing Climate – Evaluating Resilience

Monitoring and Assessing Impacts of Changes in Weather Patterns and Extreme Events on BMP Siting and Design

Annapolis, MD | September 7, 2017

Dr. Jon Butcher, Tetra Tech

complex world | CLEAR SOLUTIONS™

The Issue

- Nonpoint water quality problems are addressed by specifying type and number of best management practices (BMPs) to reduce pollutant loads
- These plans are based on historic conditions and observed BMP performance
- Need to understand how BMP performance may be affected by change to make resilient decisions

Goal of Our Work

- Systematic analysis approach to assess sustainability and resilience of BMPs used to implement water quality management plans

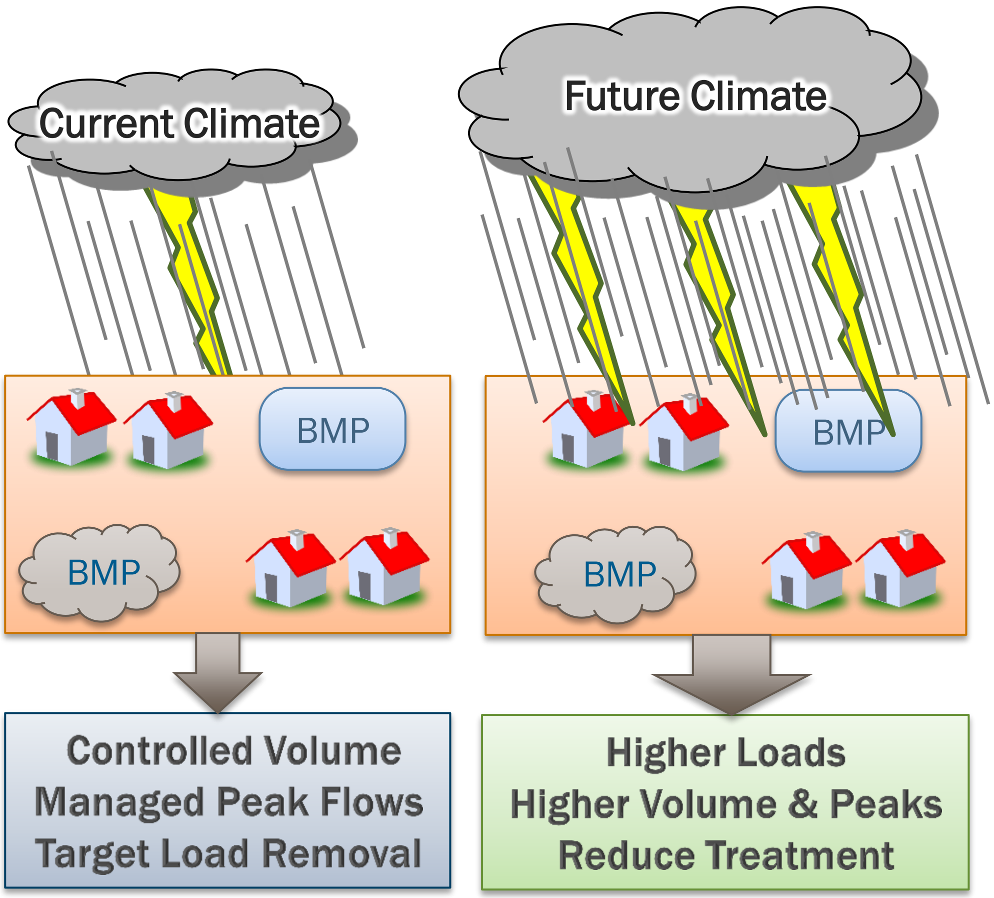
Photo courtesy of USDA NRCS

Management Practices

- Different types of BMPs are used in different systems (ag, urban, forestry) for a variety of purposes (flow, sediment, nutrients, etc.)
- Different BMPs work by a variety of mechanisms – physical retention, filtration, biological uptake
- Those mechanisms determine how they are sensitive to different climate drivers (rainfall volume and intensity, temperature, soil moisture, etc.)

Climate and BMPs

- For many engineered BMPs, if precipitation IDF changes then current sizing guides may not achieve desired result
- "Green" BMPs rely on biological processes that may respond to climate (heat, moisture) in complex ways



Literature Review – Ag BMPs

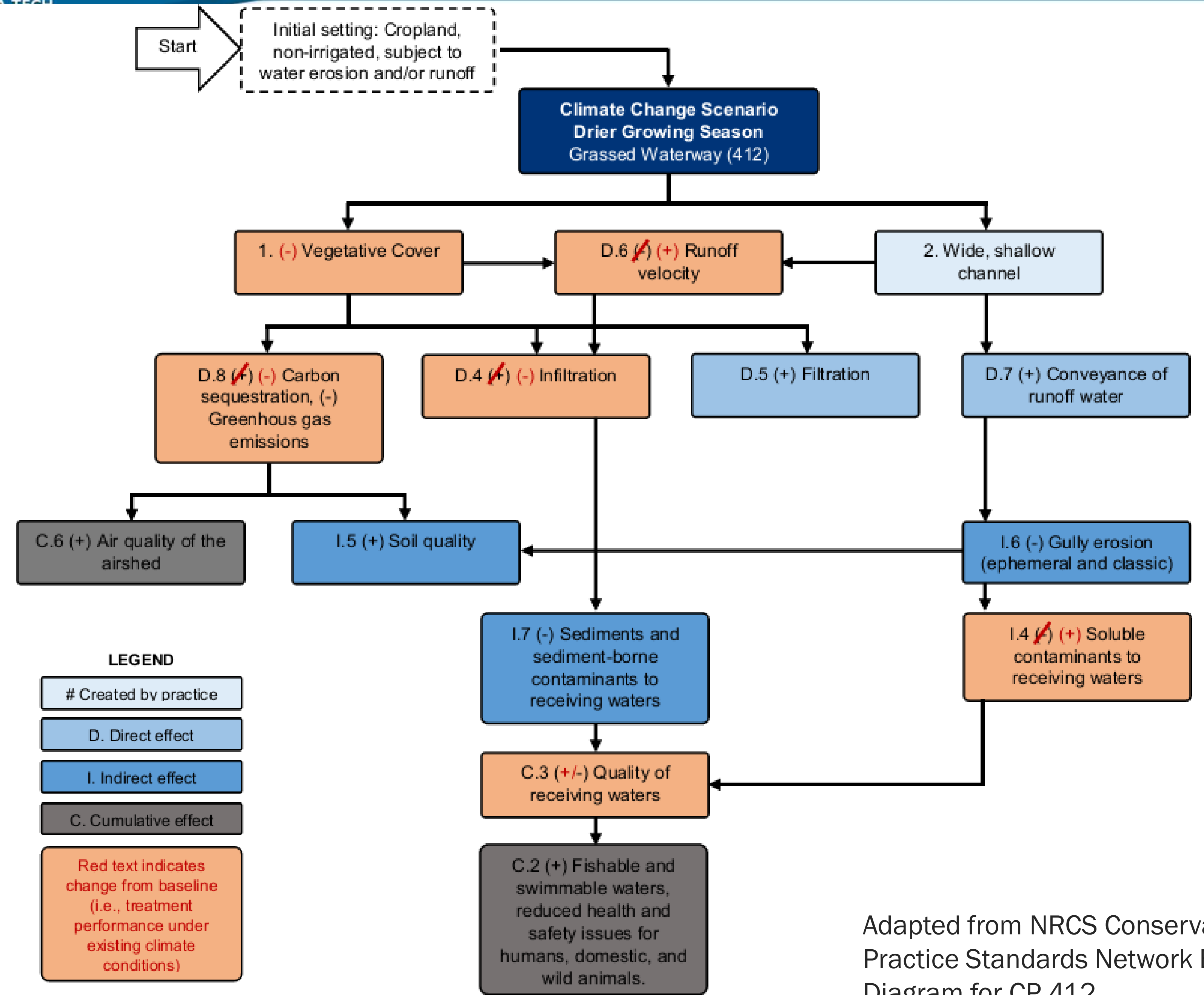
- Limited detailed studies on climate change and BMP performance – mostly conceptual
  - Nearing et al. (2005), O'Neal et al. (2005), Garbrecht et al. (2014) focus on increase in rainfall amount intensity and stress on ag BMPs
  - Others focus on increased pest risk and soil status
  - Review of Liu et al. (2016): science "is limited"
- Modeling studies of ag BMPs under future climate
  - Woznicki et al. (various studies), mostly using SWAT
  - Tend to be place-based, limited by characteristics of the models

Literature Review – Urban BMPs

- Also limited, mostly focus on increased precipitation volume and intensity
  - SWMM simulations, mostly place-based and focused on precipitation
  - Semadeni-Davies et al., others, focus on mitigation needs caused by changing climate
- Adaptation strategies more advanced in Europe
- Attention to co-benefits (e.g., heat island mitigation)
- Few studies look at how combined physical and biological changes affect BMP performance

Literature….

- While the organized analysis of BMP response to climate change is limited, there is plenty of information on <u>how</u> different BMPs work (NRCS, various urban BMP studies)
- …and how they are sensitive to weather (temperature, moisture, etc.)
- This gives a basis to move forward
  - Direct effects of changes in precipitation, runoff, load
  - Indirect effects associated with effects on plant growth and soil processes in “green” practices

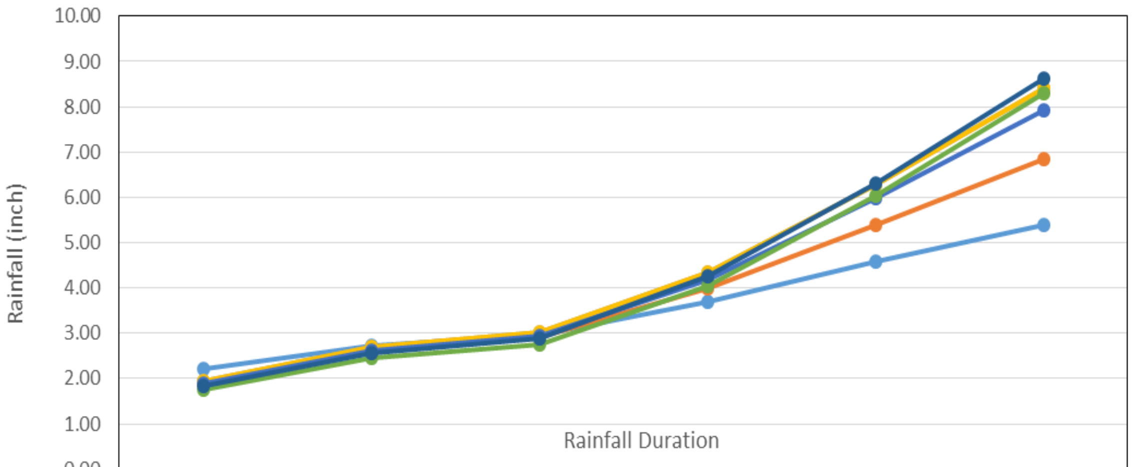


Adapted from NRCS Conservation Practice Standards Network Effects Diagram for CP 412

Potential Changes in Precipitation

- Updated 2085 IDF Curves for 25-year Recurrence Precipitation for Dauphin County, PA

Multiple climate models suggest that the 24hr 25-yr storm will increase significantly in volume from 5.4 in to up to 8.6 in.



	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
NOAA Atlas 14	2.22	2.72	2.97	3.69	4.58	5.40
HadGEM2-CC, RCP8.5	1.88	2.60	2.92	4.00	5.39	6.83
MRI-CGCM3, RCP 8.5	1.93	2.69	3.02	4.35	6.29	8.41
INMCM4, RCP 8.5	1.93	2.69	3.02	4.35	6.29	8.41
CNRM-CM5, RCP 4.5	1.89	2.63	2.95	4.19	5.97	7.93
HadGEM2-ES, RCP 4.5	1.75	2.45	2.75	4.04	6.03	8.30
BCC-CSM-1-1, RCP 4.5	1.84	2.57	2.90	4.25	6.31	8.62

Precipitation

- Direct effects
  - Existing sizing is inadequate
- Indirect effects
  - Control structures washed out
  - Bio components drowned

Sea Level Rise

Context: Sustainability and Resilience

In the Anthropocene:

- We use BMPs to make urban and agricultural landscapes *sustainable* by controlling flow and pollutant loads and allowing water resources to regenerate and approximate natural conditions
- We also need to consider *resilience* in water management – the ability to compensate for or overcome the unexpected

What Matters for BMP Resilience?

- *Sensitivity* - Is the practice and its performance sensitive to the range of potential change?
- *Adaptability* – Can the practice be modified to be resilient to potential changes as they emerge?
- *Timeliness* – How short is the time line to adapt to changes?

Analytical Approach

- Qualitative Analyses
  - Use literature, BMP design guidance, and ecosystem process analysis to identify climate sensitivity, adaptability, and timeliness
  - Analyze climate sensitive BMPs applicable to urban, agriculture, forestry
- Quantitative Simulation Analyses
  - SWAT and APEX models of agricultural watershed and field-scale BMP performance [MN, GA]
  - SWAT and QUAL2K models of forestry BMPs [OR]
  - HSPF/SUSTAIN and RHESSys models of urban BMPs [multiple locations]

Tetra Tech

Qualitative Analysis

- Literature review and conceptual models of BMPs
- Produce linked databases of sensitivity, adaptability, and timeliness for agricultural, urban, and forestry BMPs

complex world | CLEAR SOLUTIONS™

Qualitative Analysis: Perennial Riparian Buffer

FUNCTIONS AND SENSITIVITIES

- Physical Processes: Erosion Cover, Filtration
- Biological Processes: Plant Growth
- Climate Sensitivities: Precipitation Intensity, Summer Temperature, Soil Moisture

ECOSYSTEM ANALYSIS

- How climate affects growth, filtration capacity
- How intensity of runoff affects concentrated flow, channel stability

CLIMATE CHANGE EVALUATION

- Adaptation Strategies: Extend widths, disperse flow, increase upstream erosion control, adjust species composition
- Climate Adaptation Potential: High
- Overall Climate Sensitivity: Medium
- Timeliness: Long-term, can't quickly adjust

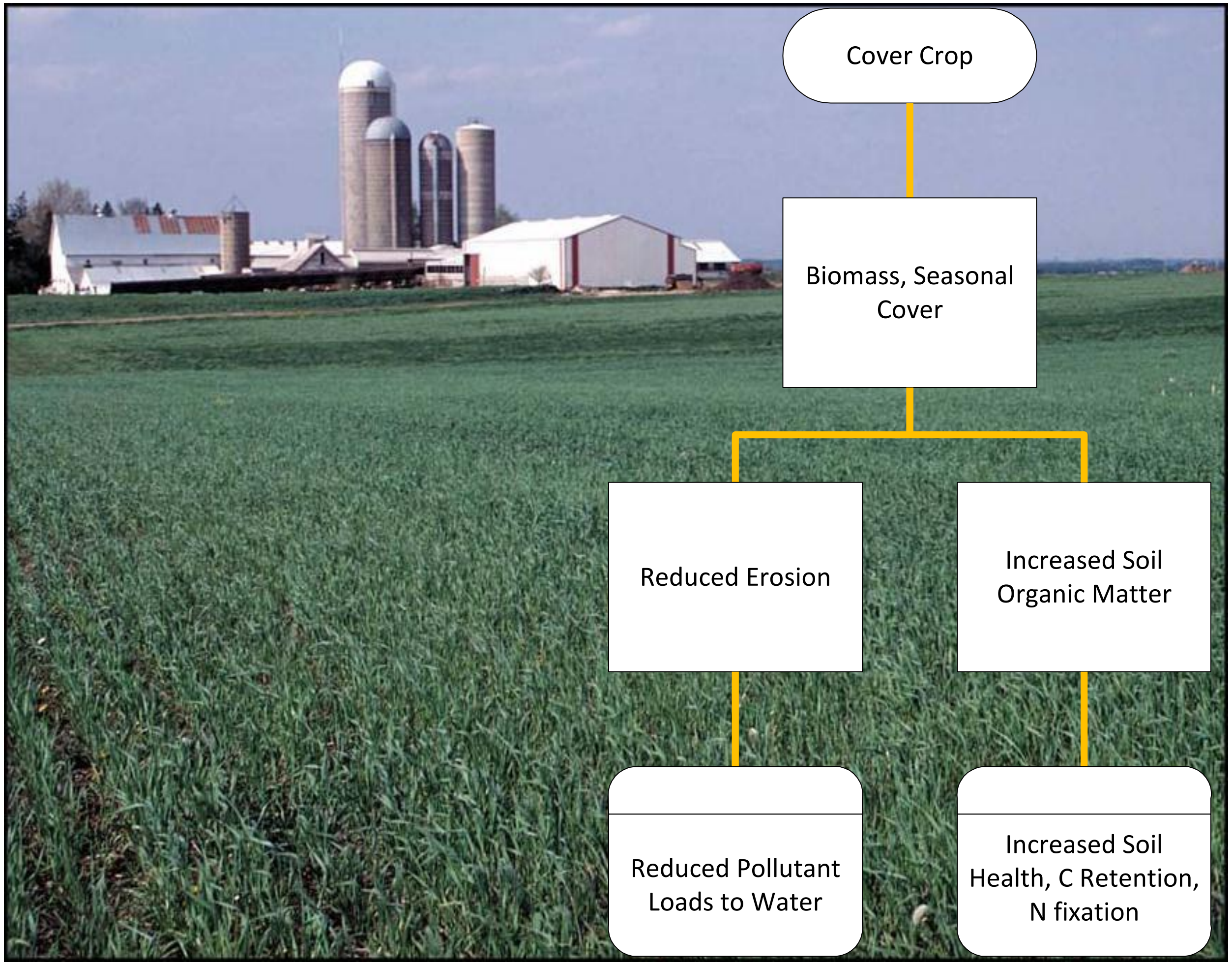
Qualitative Analysis

Demo: Qualitative Analysis Tool

Qualitative Analysis of Climate Change and Performance of Agricultural and Urban BMPs		
BMP:	***6-Two-stage ditches***	
MASTER DATABASE		
	Applicability (LU, EPA Level II Ecoregion)	* Relatively flat agricultural croplands * Most commonly found in the following ecoregions: - Great plains - Eastern prairies
	Management Adaptation Strategies	* Retrofit existing channel geometries to accommodate larger design storms * Adjust channel vegetation accordingly to regional climate conditions * Add armoring (e.g., riprap, turf reinforcement matting) to channel to accommodate higher shear stresses
	Climate Adaptation Potential	Medium
	Overall Climate Sensitivity	Low
	Flexibility/Timeliness	* Long-term * Relatively easily redesigned/rebuilt to suit changing needs
	Supporting Literature	* Mahl et al., 2015 * Roley et al., 2006 * D'Ambrosio, J.; Witter, J.; and Ward, A., 2013 * Hodaj, A., et al, 2016 * Lui et al., 2016

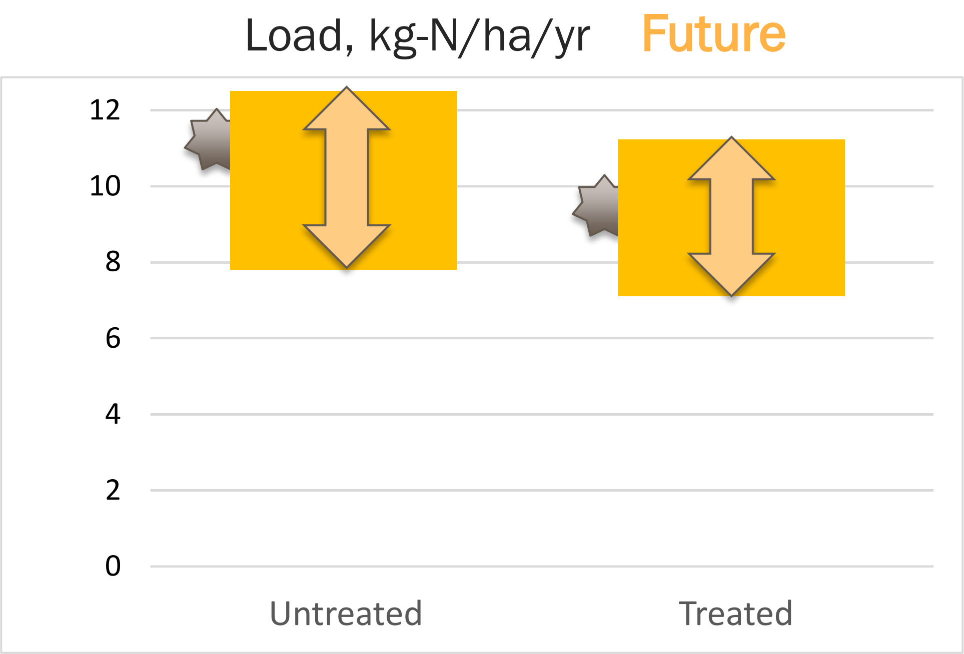
Simulation Analysis: Cover Crops

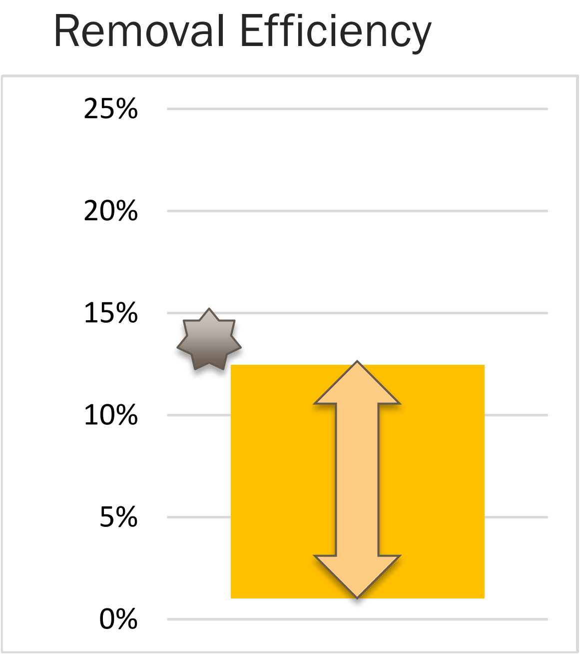
- SWAT and APEX models, GA and MN watersheds
- Cover crop: Depends on fall-winter growth performance
- Warmer winters could enhance success; drier conditions could impede functions



No-till Crops – Ichawaynochaway (GA)

- Cotton, corn, peanut rotation on sandy soils; comparison of conservation till to conventional tillage (SWAT)
- TSS removal decreases 39% to 22% due to more intense events
- Late-century TN load + or -, but removal efficiency decreases





Forthcoming Work

- Qualitative analyses and literature review (for OW)
  - Agricultural and urban BMPs
  - Forestry BMPs (focus on sediment and temperature)
- Simulation analyses – Ag (SWAT and APEX models)
  - Little Cobb River (SE MN), Ichawaynochaway Cr (GA)
  - Journal article on BMP performance Fall 2017
- Simulation analyses – Forestry (SWAT and QUAL2K)
  - Lookout Creek (OR Cascades)
  - Journal article Fall 2017
- Simulation analyses – Urban Gray and Green (SUSTAIN)
  - EPA Report forthcoming
  - Journal article Fall 2017

Best Practices for Evaluating BMPs under Deep Uncertainty

- Future (climate, land use) will affect *both* BMP performance *and* the flows and loads that BMPs must address
- BMP performance can depend on precipitation, soil moisture, temperature, and other factors
- Need to explore scenario space to look for "low regrets" solutions that are resilient against many potential futures. For BMPs sensitive to change, emphasize those that are:
  - Adaptable – can be modified according to conditions
  - Timely – have short time horizons for adaptation
  - Cost-effective – Avoid large capital costs that may not be appropriate to the actual future condition
  - Have auxiliary benefits – will be useful even if the future is different than projected

Acknowledgments

Funding for this work was provided by U.S. EPA, Office of Research and Development. Special thanks to Susan Julius and Tom Johnson.

The views expressed in this presentation represent those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

Contact: Dr. Jon Butcher
Jon.Butcher@tetratech.com
919-485-2060