Assessing the hydrologic and water quality impacts of climate change in small agricultural basins of the Upper Chesapeake Bay watershed

Anthony Buda

USDA Agricultural Research Service

stac Chesapeake Bay Program's
Scientific and Technical Advisory Committee

The Development of Climate Projections for Use in Chesapeake Bay Program Assessments

Monday, March 7, 2016

Westin Hotel
Annapolis, MD

1:40 to 2:00 PM

Today’s presentation

Upper Chesapeake Bay climate assessment

Upper Chesapeake LTAR

A brief overview of the four basins comprising the Upper Chesapeake LTAR location in Pennsylvania.

Climate change projections

Future climate predictions for the Mahantango Creek basin using statistically downscaled data.

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2012)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3603

RMetS
Royal Meteorological Society

An asynchronous regional regression model for statistical downscaling of daily climate variables

Anne M. K. Stoner,[a*] Katharine Hayhoe,[a,b,c] Xiaohui Yang[b] and Donald J. Wuebbles[d]

[a] *Climate Science Center, Texas Tech University, Lubbock, TX, USA*
[b] *ATMOS Research & Consulting, Lubbock, TX, USA*
[c] *Department of Political Science, Texas Tech University, Lubbock, TX, USA*
[d] *Department of Atmospheric Science, University of Illinois at Urbana-Champaign, Urbana, IL, USA*

Modeling hydrology and water quality

An approach to predicting the effects of climate change on hydrology and water quality with the SWAT model.

SWAT
Soil & Water Assessment Tool

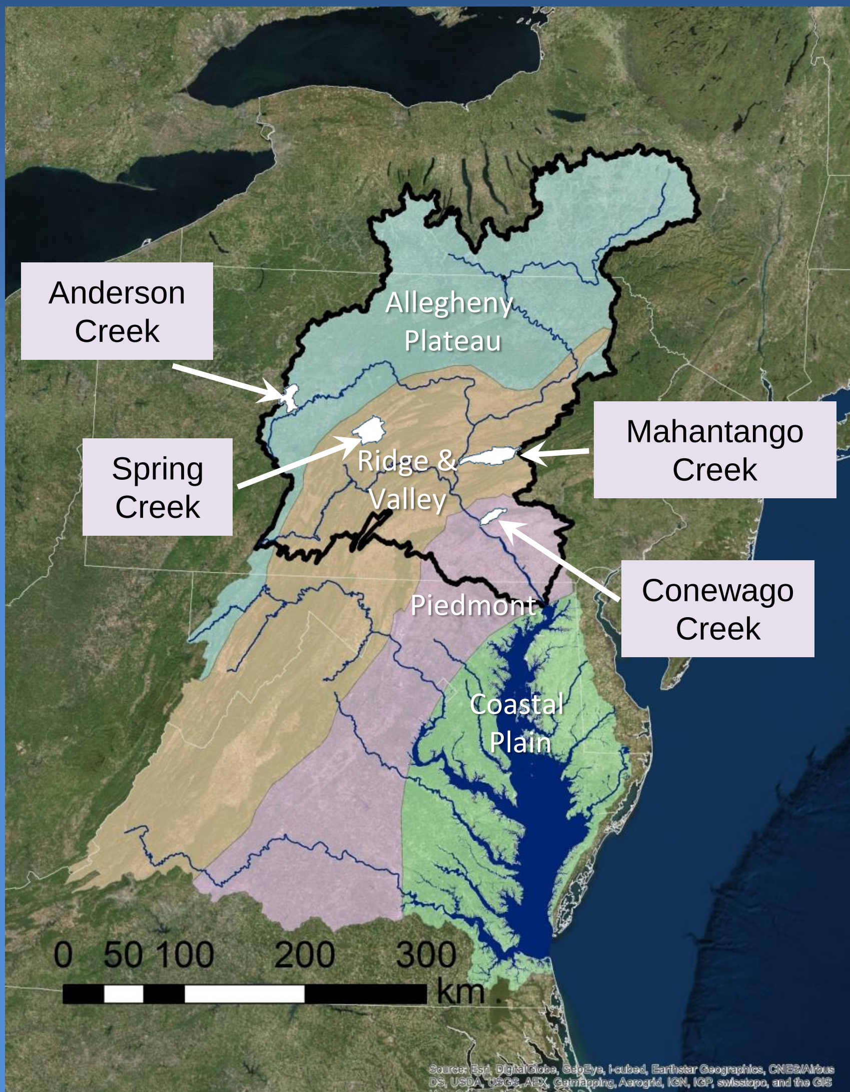
USDA's LTAR Network

serving as a sentinel to changes in climate and hydrology

LTAR Shared Research Strategy, 2013

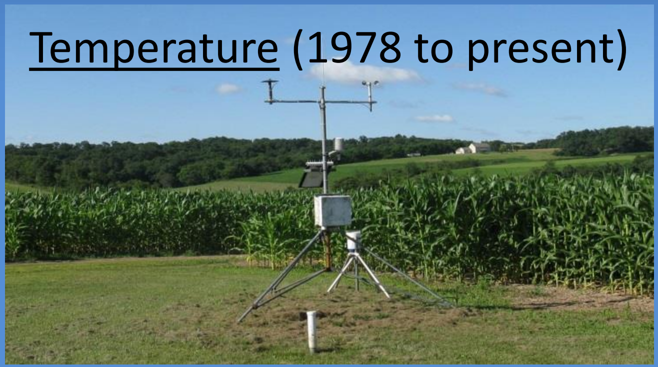
Upper Chesapeake Bay LTAR

Four basins typifying variable physiography and farming



The Mahantango Creek Watershed

an ideal place to assess long-term trends in hydroclimate



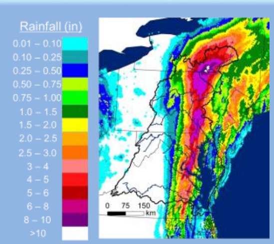
Buda et al., 2011a, b (WRR)

Significant hydroclimatic trends in WE-38

Steadily rising temperatures and a lengthening growing season are consistent with a warming climate.

At the basin level, evapotranspiration increases represent the clearest change in hydroclimate over the past 45 years.

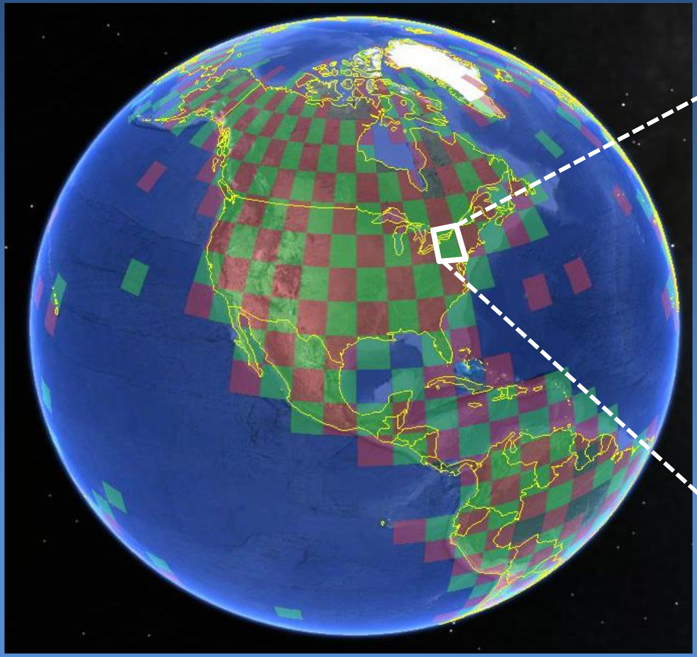
More intense rain storms in the fall have led to augmented streamflow during a time when flows are normally low.

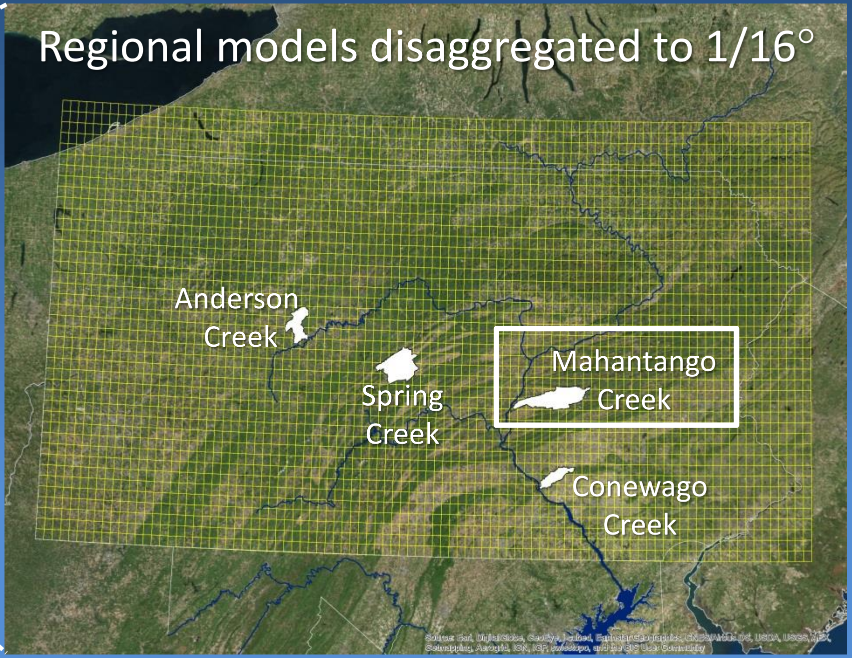


Snowmelt runoff events are declining in winter whereas in summer, low flow periods are expanding in duration.

Climate change in the Upper Chesapeake

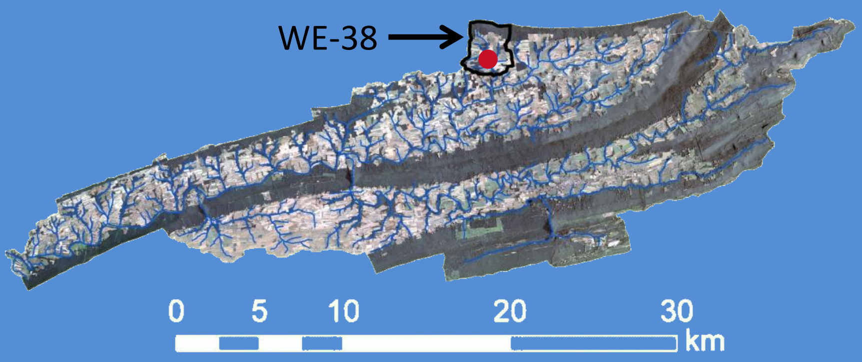
Using downscaled data to project future climatic conditions





Downscale 9 models from the Coupled Model Inter-comparison Project Phase 5 (CMIP5) for the business as usual (RCP 8.5) and stabilization (RCP 4.5) emissions pathways.

Mahantango Creek watershed



Hayhoe et al., 2007 (Climate Dynamics); Stoner et al., 2013 (International J. Climatology)

We obtained climate projections from nine different climate models

Climate models recommended by Katharine Hayhoe

- CCSM4 — NCAR UCAR CESM Community Earth System Model
- HadGEM2-CC — enes European Network for Earth System Modelling
- inmcm4 — Russian Academy of Sciences Institute of Numerical Mathematics
- CSIRO-Mk3-6-0 — CSIRO; Australian Government Bureau of Meteorology
- CNRM-CM5 — Meteo France: Toujours un temps d'avance
- MIROC5 — ICES Foundation: International Centre for Earth Simulation
- IPSL-CM5A-LR — Institut Pierre Simon Laplace: IPSL Climate Modelling Centre
- MRI-CGCM3 — Meteorological Research Institute, Japan Meteorological Agency
- MPI-ESM-LR — Max-Planck-Institut für Meteorologie

Daily climate variables

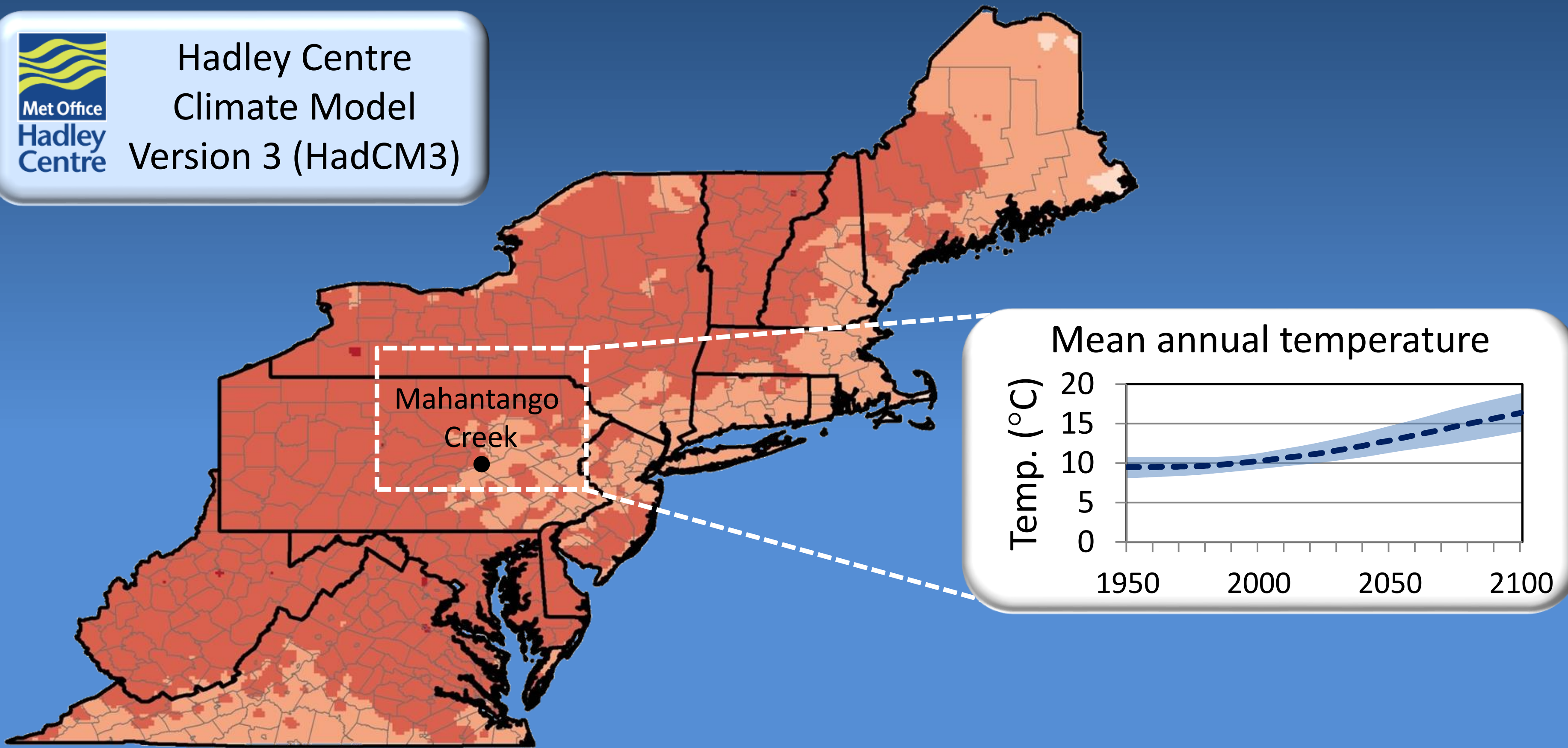
Mean temp. (°C)	Max temp. (°C)	Min temp. (°C)
Solar radiation (MJ/m^2)	Precip. (mm)	Wind speed (m/s)

Mid-century temperatures will be warmer

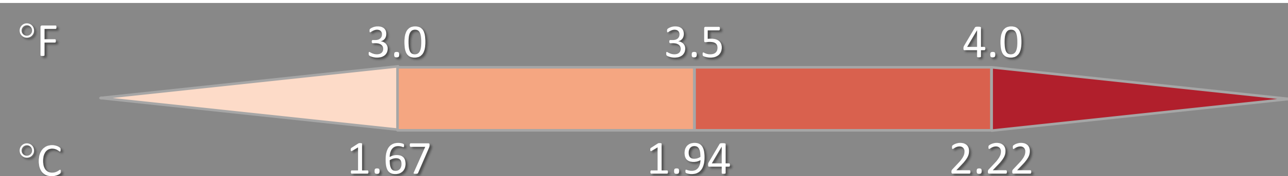
with increases of about 2 ℃ relative to 1960-1989

Met Office Hadley Centre

Hadley Centre Climate Model Version 3 (HadCM3)

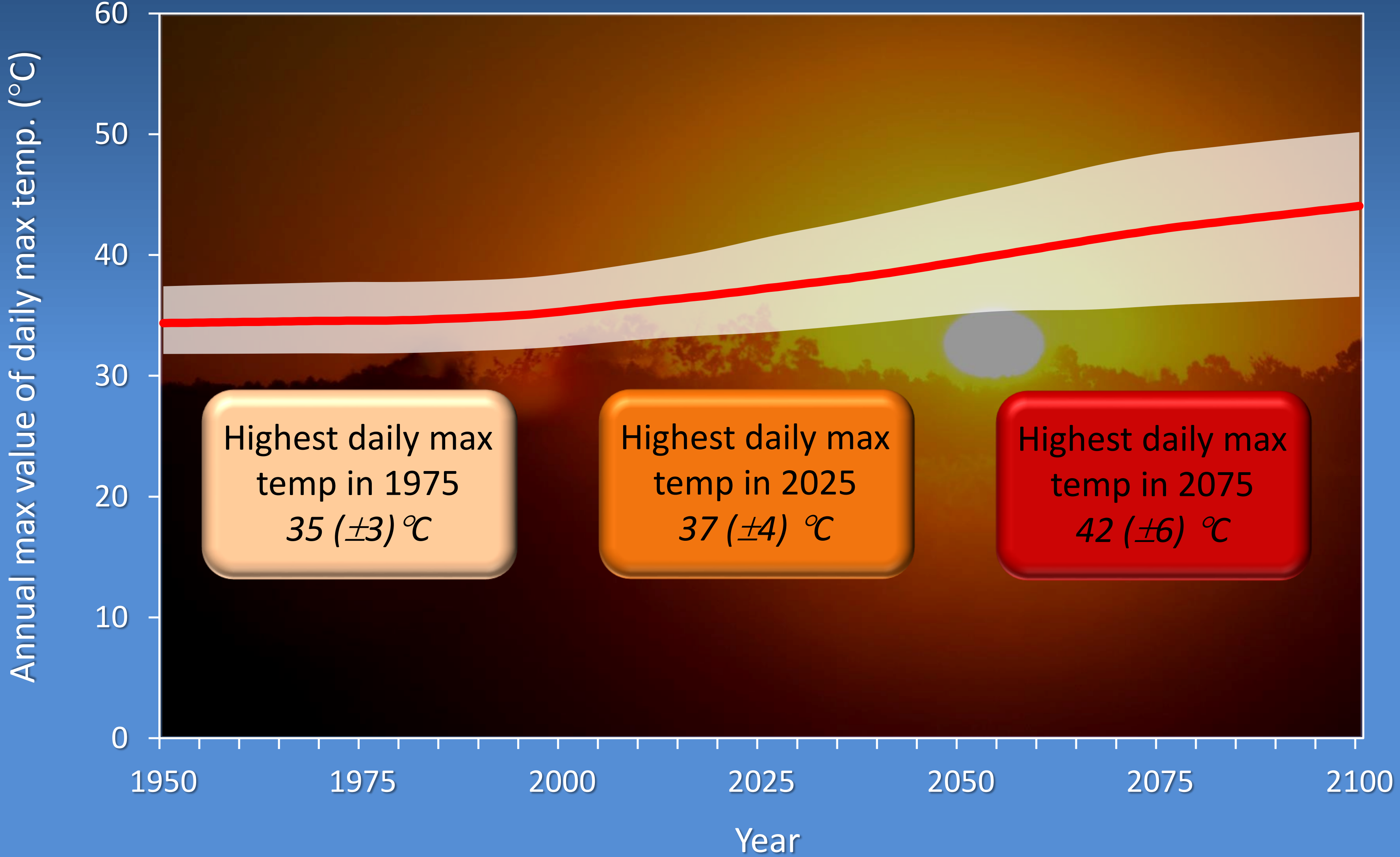


Mid-century (2015 to 2044) increase in mean annual temperature



A warmer climate means more extremes

daily max temperatures may approach 42 ℃ by century's end

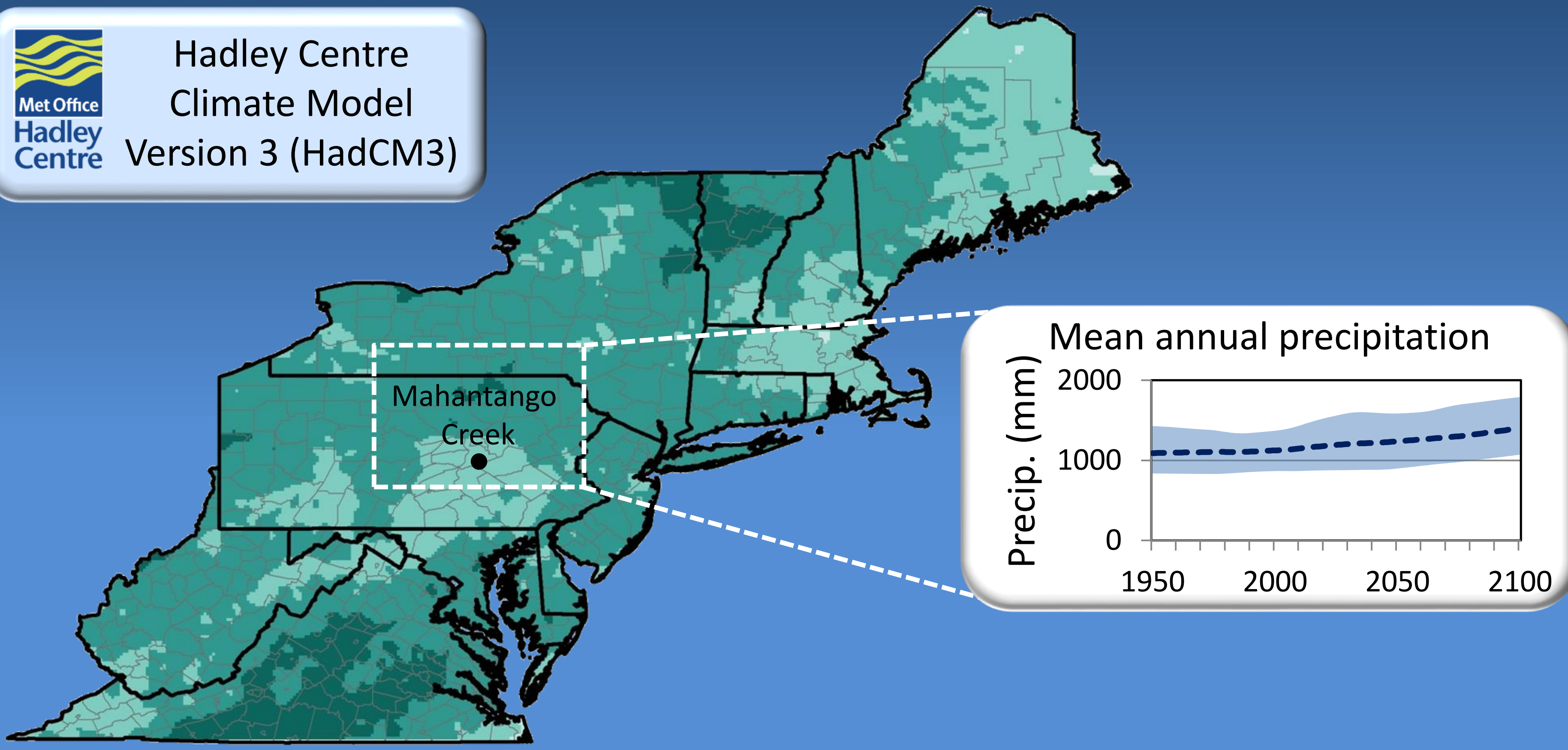


Mid-century will be wetter

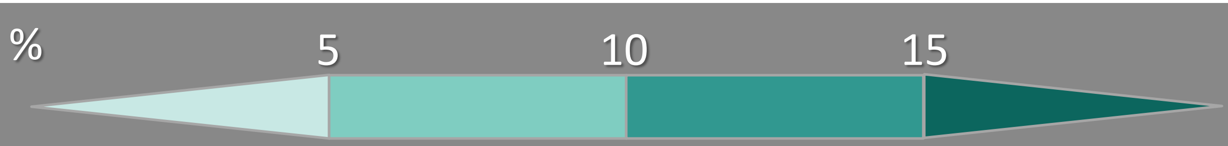
increases will range from 5 to 15% relative to 1960-1989

Met Office Hadley Centre

Hadley Centre Climate Model Version 3 (HadCM3)

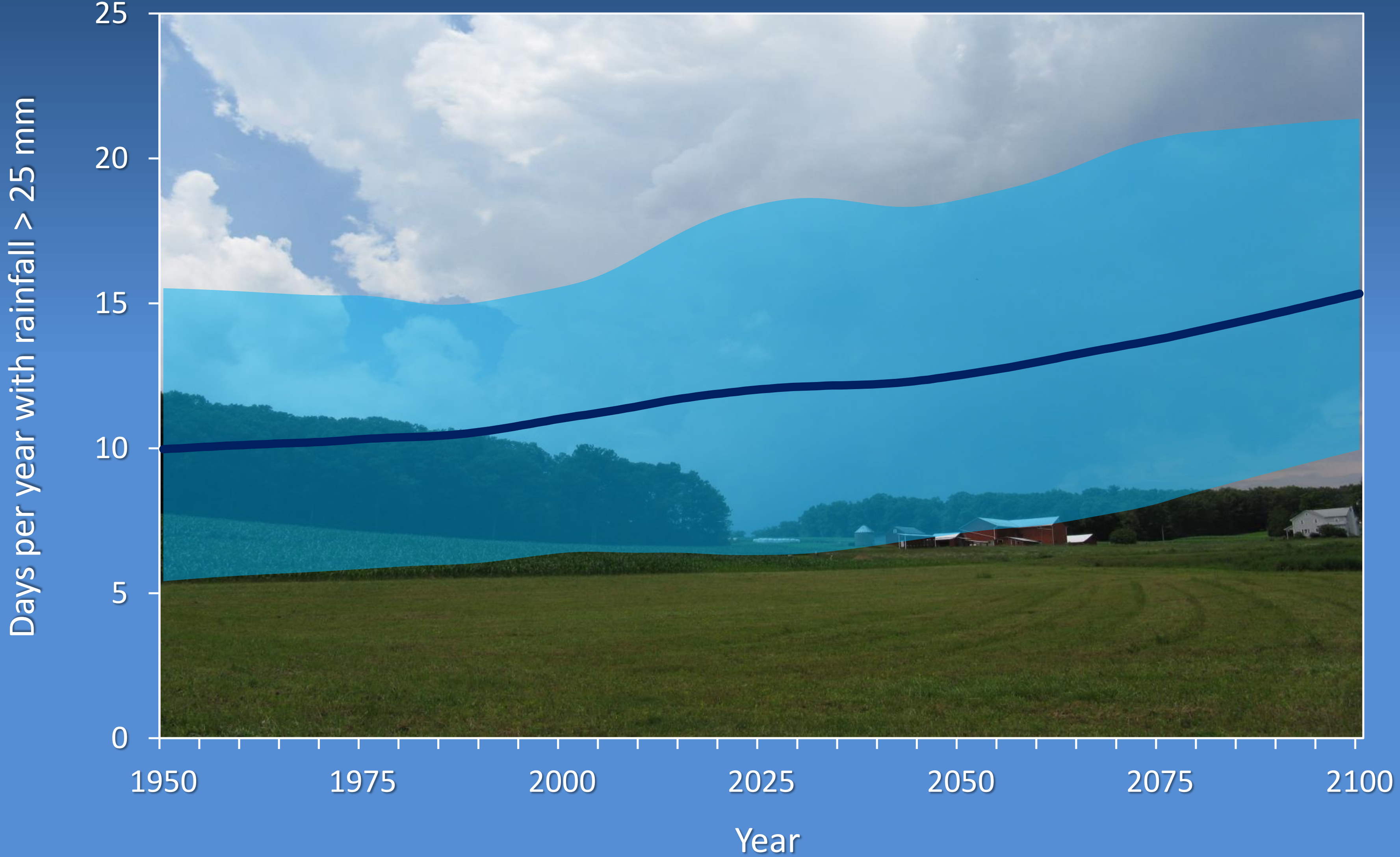


Mid-century (2015 to 2044) increase in mean annual precipitation



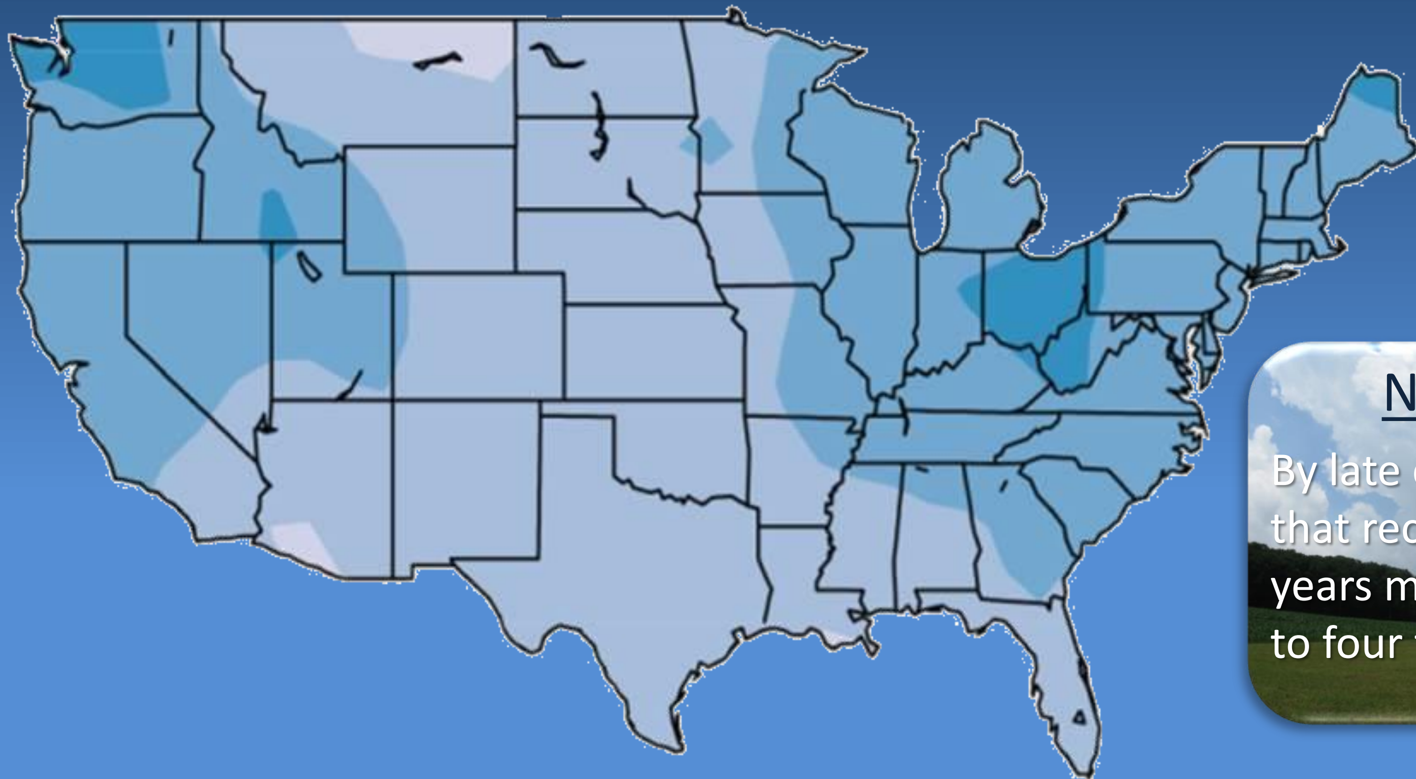
Daily rains of 25 mm will be more routine

with 5 more such days by the year 2100



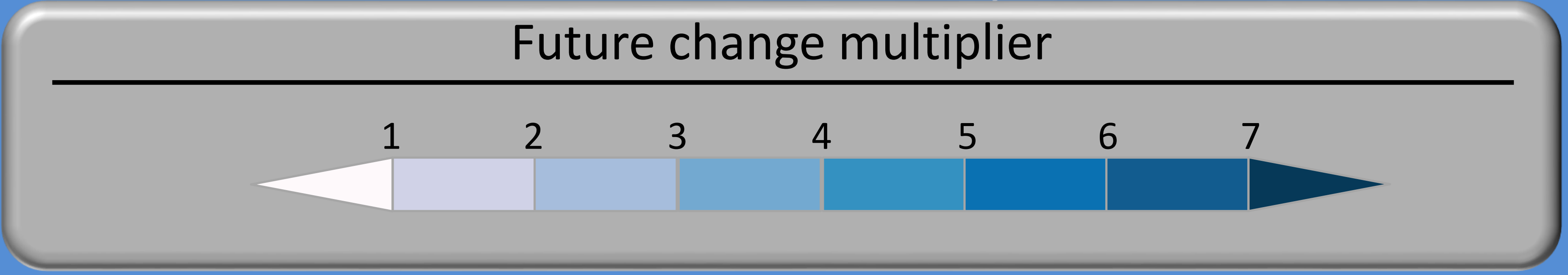
More frequent 20-yr storms (~127 mm/d)

with a 3-fold increase in frequency expected by 2100



Northeast

By late century, events that recurred once in 20 years may happen three to four times as often.

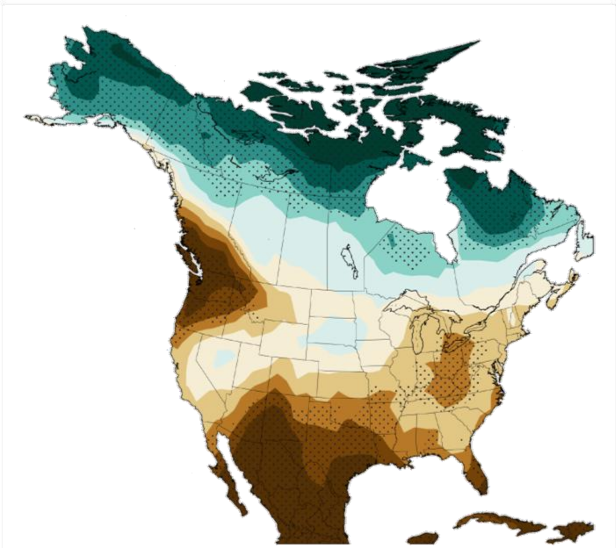


Wuebbles et al., 2014 (BAMS); US National Climate Assessment, 2014

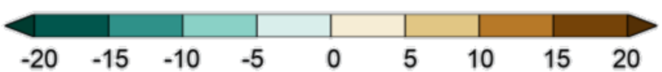
Paradoxically, the future also could be drier

Evaporative demand is likely to overwhelm inputs from rain

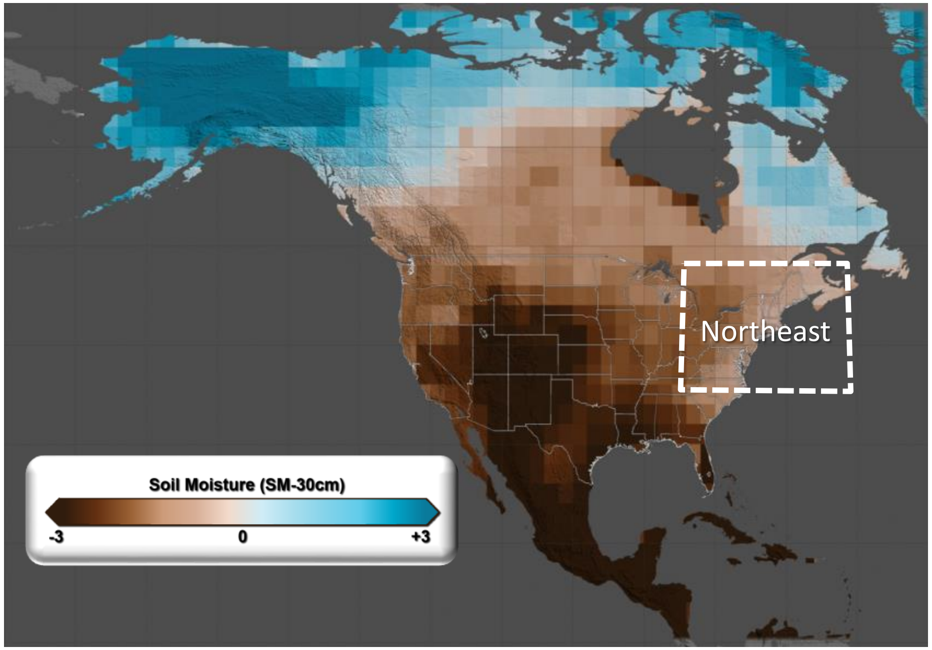
Longer dry spells



Change in max consecutive dry days (%)



Increased risk of drought



Standardized soil moisture (0-30 cm; deviations from 20th century mean) for 2090 to 2099 using the RCP 8.5 emissions scenario (Cook et al., 2015; Science Advances).

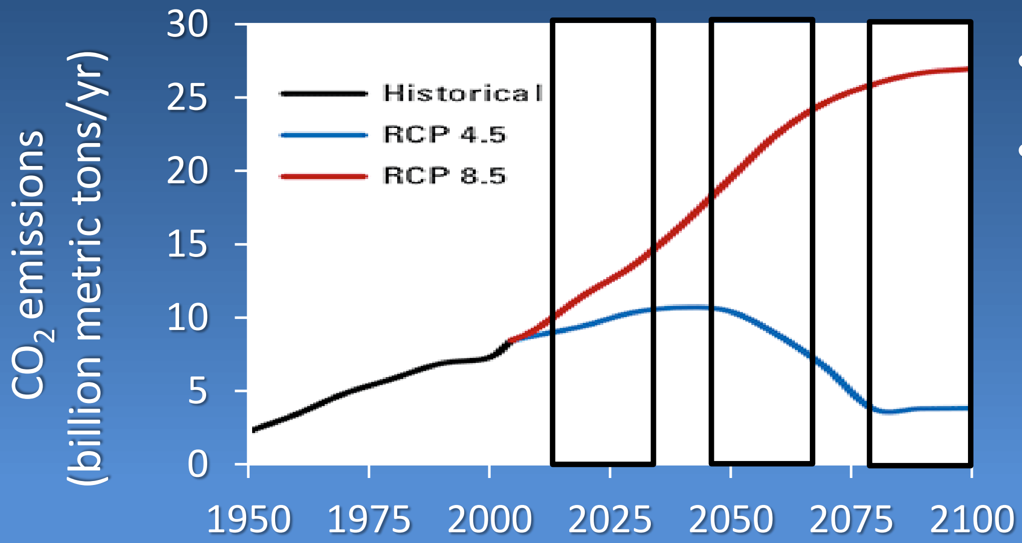
More than 80% of climate models suggest that successive dry days will rise by 5 to 10%.

<u>Take home point</u>: more rain is needed to keep pace with rising evaporative demand (Sherwood and Fu, 2014).

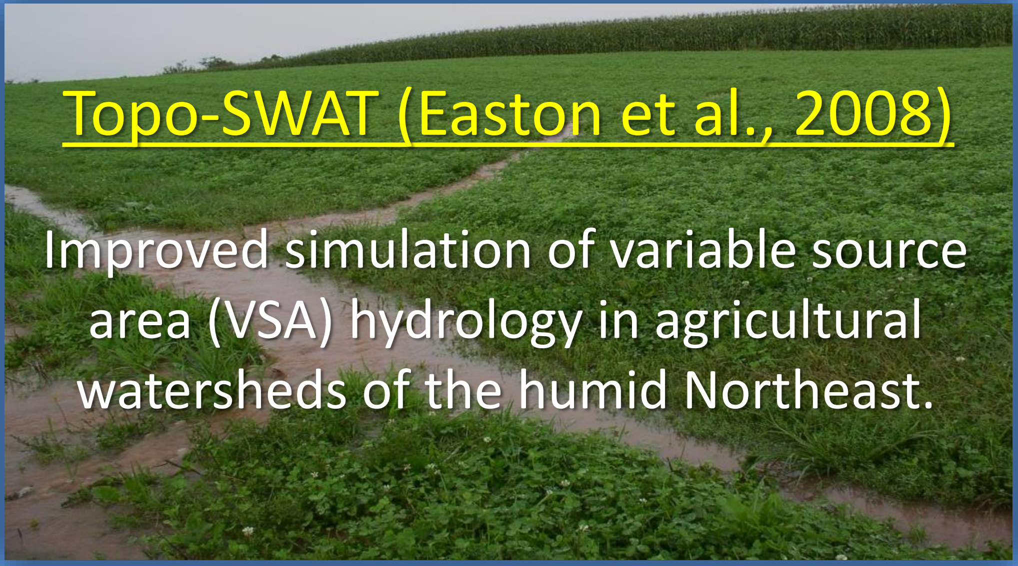
US National Climate Assessment, 2014; Sherwood and Fu, 2014

Implications for the Upper Chesapeake

Simulating potential climate change impacts in small basins



- Emissions scenarios RCP 4.5 and 8.5
- Three time frames
    1. Early century (2015 to 2034)
    2. Mid century (2045 to 2064)
    3. Late century (2081 to 2100)



Topo-SWAT (Easton et al., 2008)

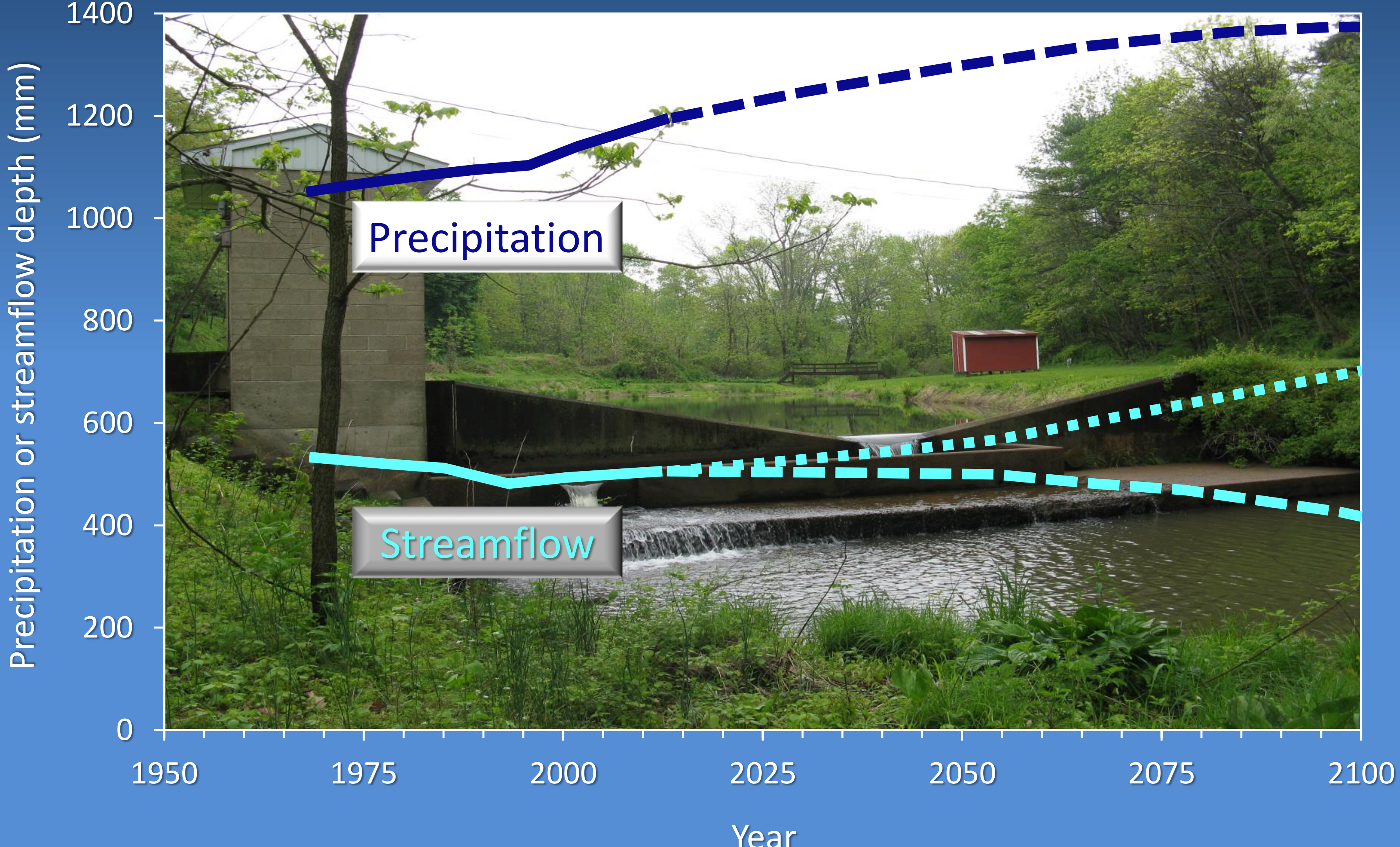
Improved simulation of variable source area (VSA) hydrology in agricultural watersheds of the humid Northeast.

SWAT

Soil & Water Assessment Tool

Climate change and watershed hydrology

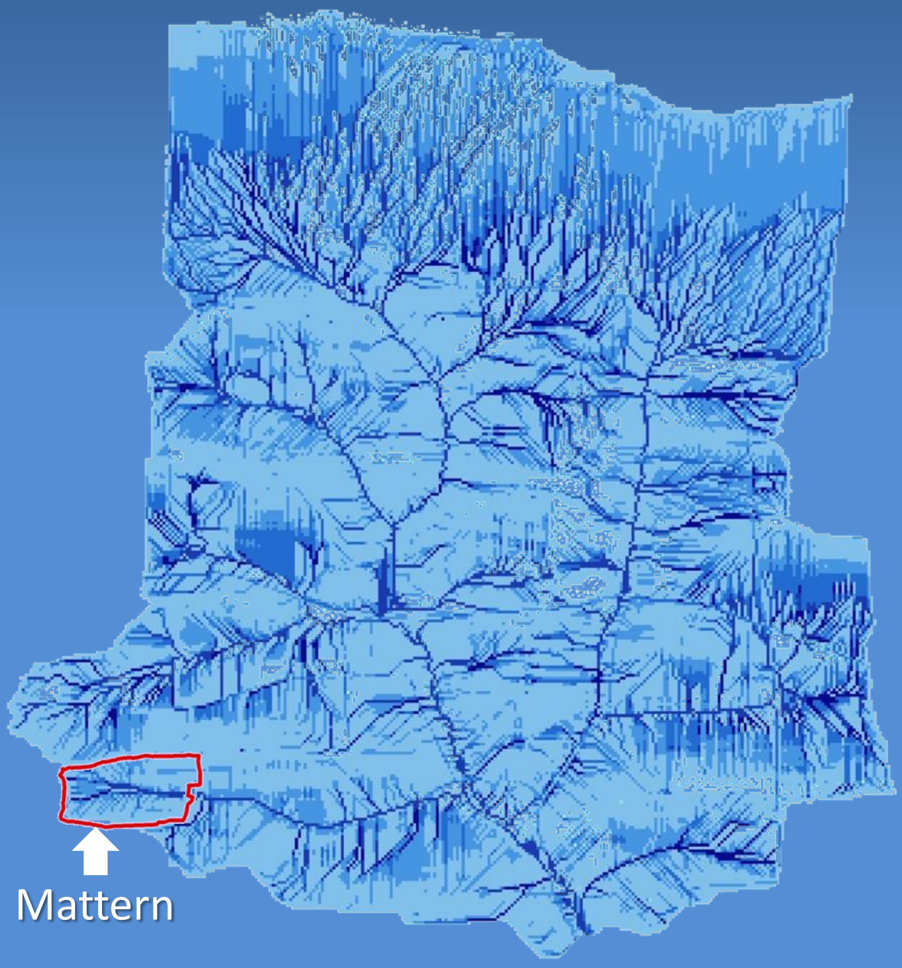
How will the water balance change with climate change?

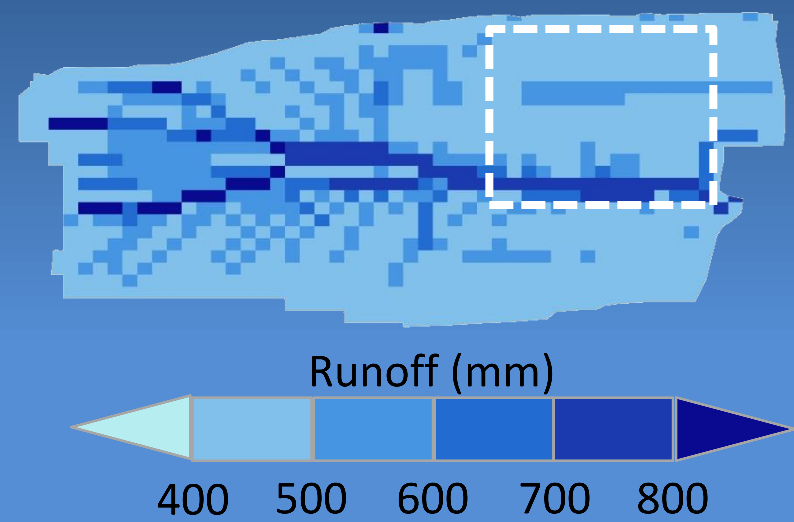


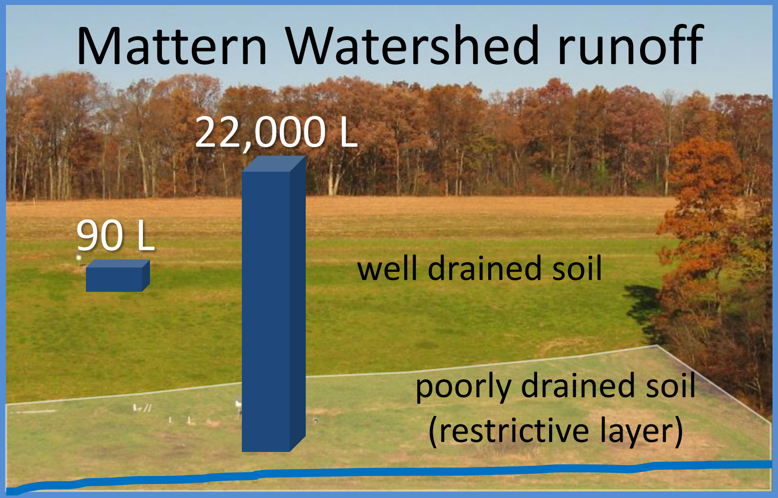
Climate change and watershed hydrology

How will climate change affect runoff generation patterns?

Using Topo-SWAT to identify variable source areas (VSAs)



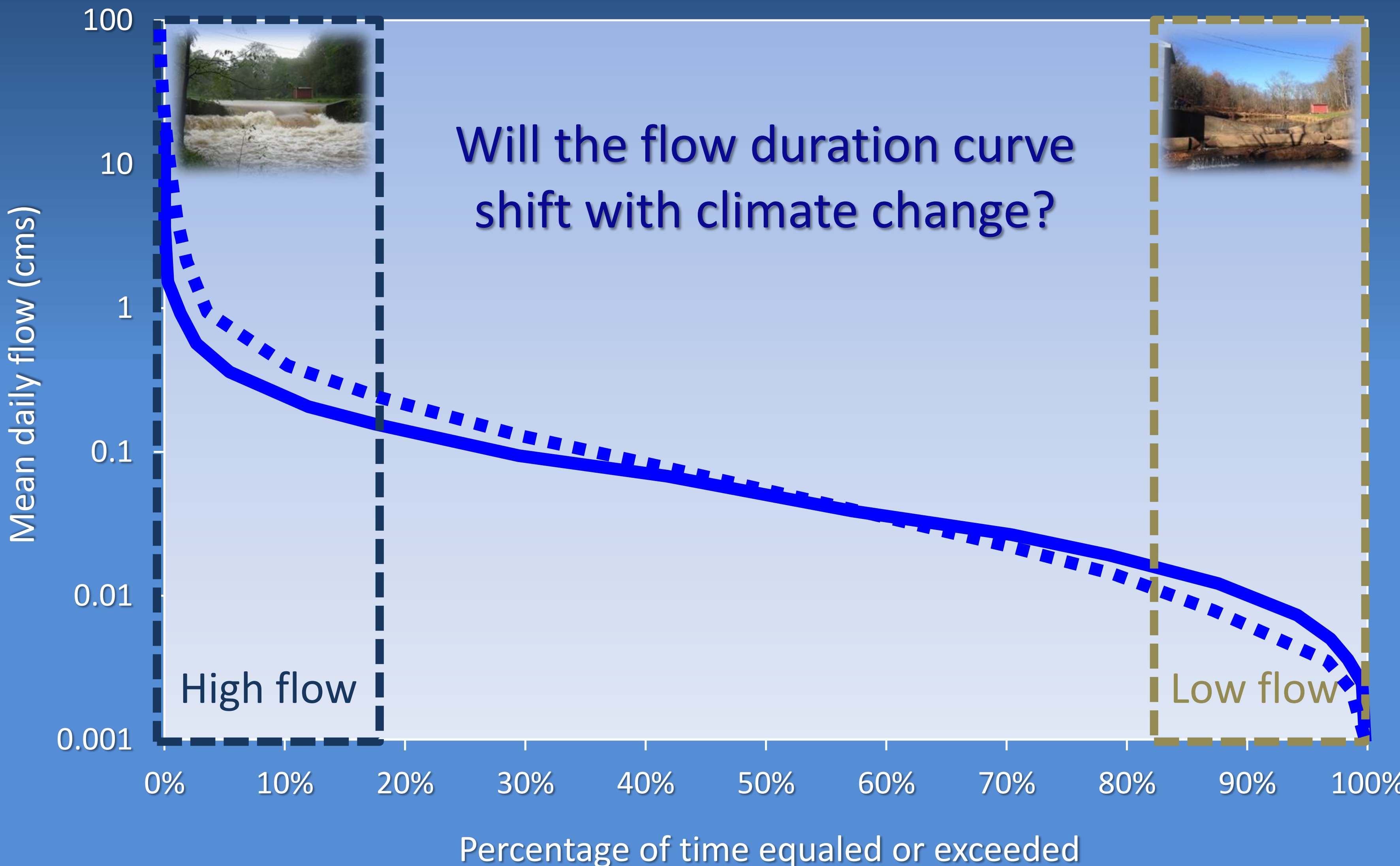




SWAT images courtesy of Tamie Veith and Amy Collick

Climate change and watershed hydrology

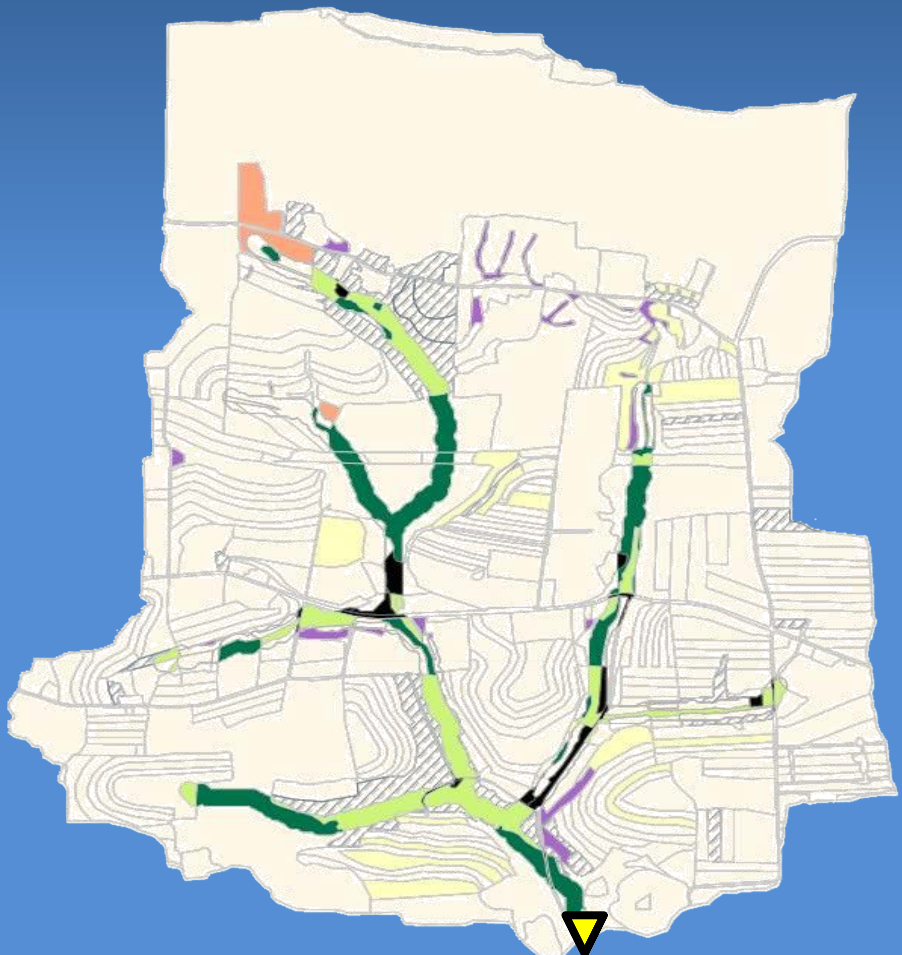
How will the frequency of floods and low flows change?



Climate change and water quality

Effects of current climate and land use on water quality

Current land management based on farmer surveys



Perennialization

- Forested buffer
- Grass buffer
- None

Conservation Cropping

- Cover crops
- No till
- Conservation tillage

Baseline land use

- No change in mgmt.

Simulate N, P, and sediment losses in runoff

Images courtesy of Tamie Veith and Amy Collick

Climate change and water quality

Relative effects of climate and land use change on water quality

Land mgmt. and BMP allocation using PA's WIP (thru 2025)

Farm Infrastructure
- Barnyard runoff

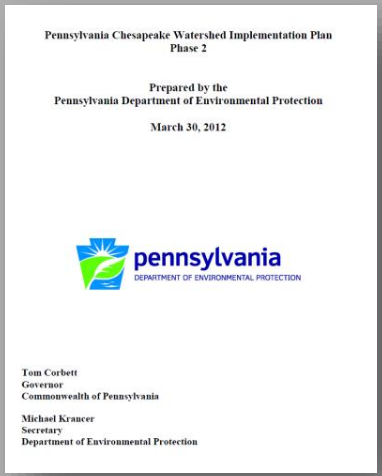
Perennialization
- Grass/forested buffer
- Forested buffer
- Grass buffer
- None
- Tree planting

Conservation Cropping
- Cover crops
- No till
- Conservation tillage

Manure/Nutrient Management
- Manure injection

Urban Stormwater Management
- Gravel road improvement

Baseline land use
- No change in mgmt.


Pennsylvania Chesapeake Watershed Implementation Plan
Phase 2

Prepared by the
Pennsylvania Department of Environmental Protection

March 30, 2012

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Tom Corbett
Governor
Commonwealth of Pennsylvania

Michael Krancer
Secretary
Department of Environmental Protection

Images courtesy of Tamie Veith and Amy Collick

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