ONLINE COURSE

URBAN FORESTED WATERSHEDS

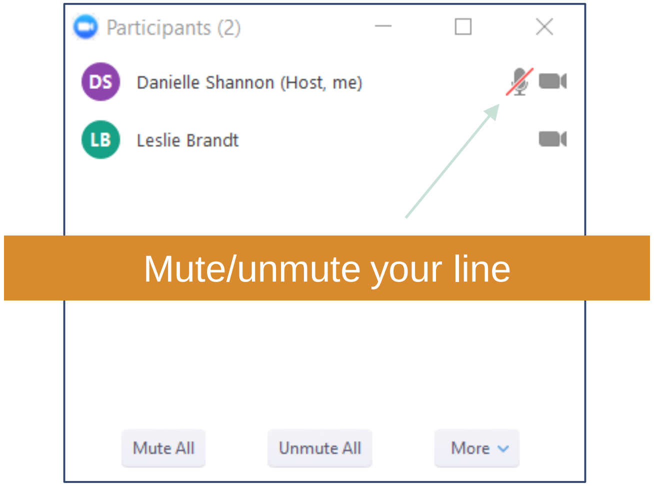
ADAPTATION PLANNING AND PRACTICES

Session 5: Step 4 Review and Step 5 Intro

Tuesday, December 4, 2018 @ 11 am ET

Web session etiquette. Please:

- If you are using a phone, turn off your computer speakers to avoid feedback and terrible noises.
- Mute your line unless you are speaking to the group.



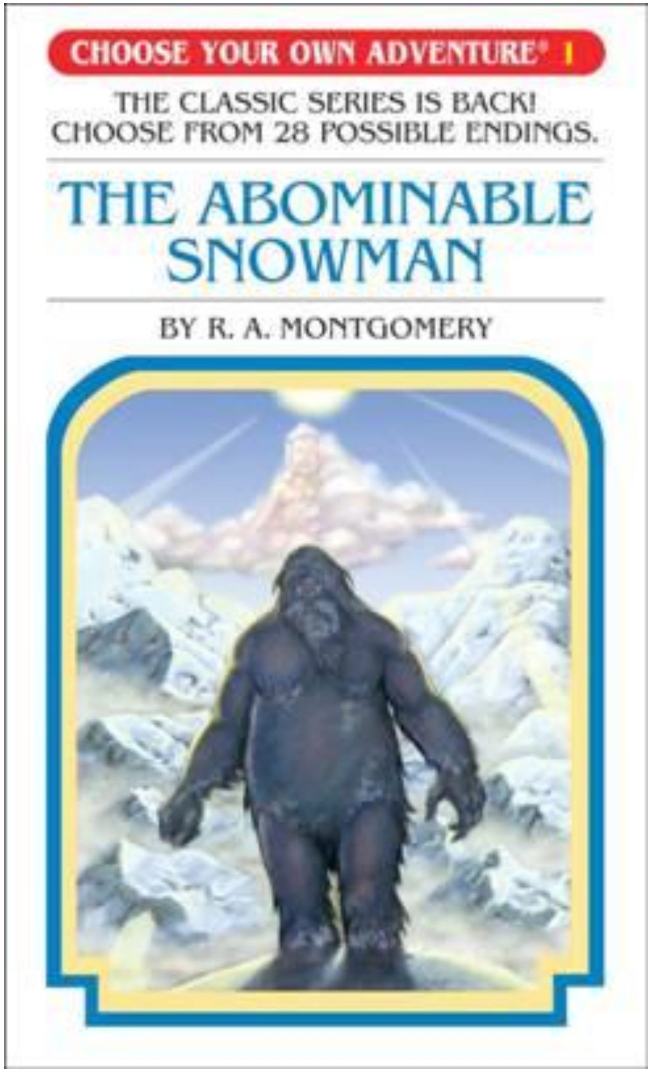
Today's Agenda

Discussion:

- Step 4 review
- Discussion: how are you adapting your forests to a changing climate?

Lecture:

- Step 5: Monitoring
- Website demo and homework



Step 4: IDENTIFY adaptation approaches and tactics for implementation.

Key Question:

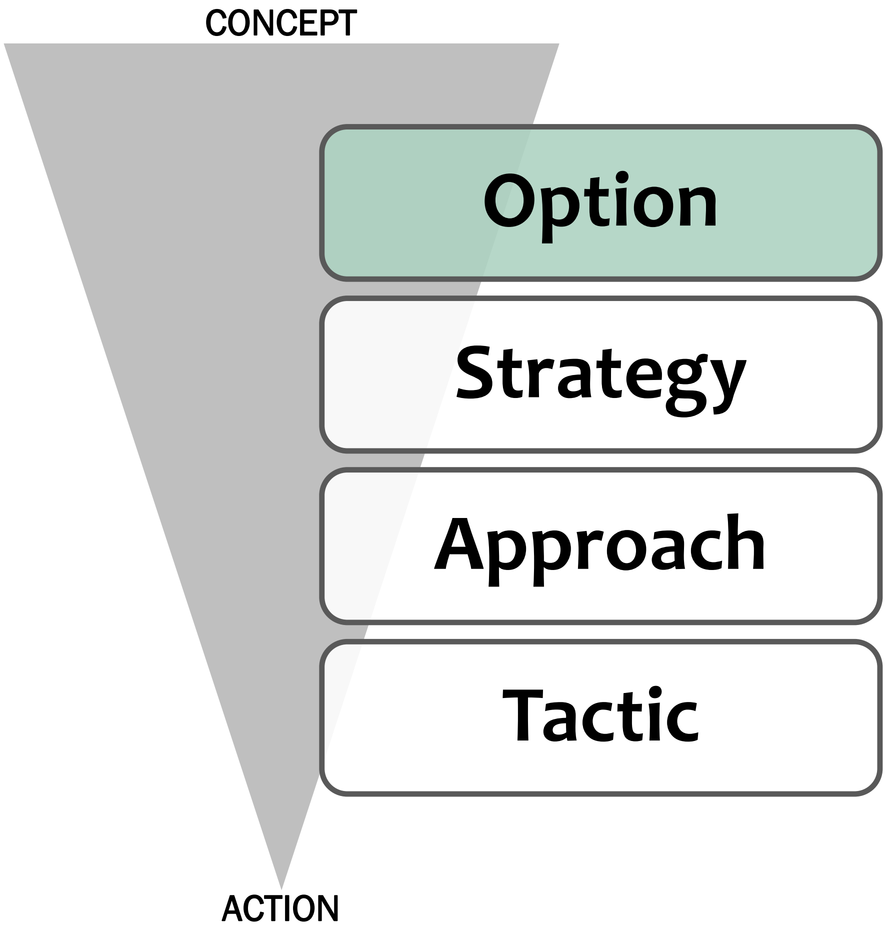
What actions can enhance the ability of the ecosystem to adapt to anticipate changes *and* meet management goals?

Adaptation Strategies & Approaches

A “menu” of possible actions that allows you to decide what is most relevant for a particular location and set of conditions.

Find in: Step 4 of online workbook, Chapter 3-4 of FAR , or
www.adaptationworkbook.org/niacs-strategies
www.adaptationworkbook.org/niacs-strategies/urban

Adaptation Strategies and Approaches

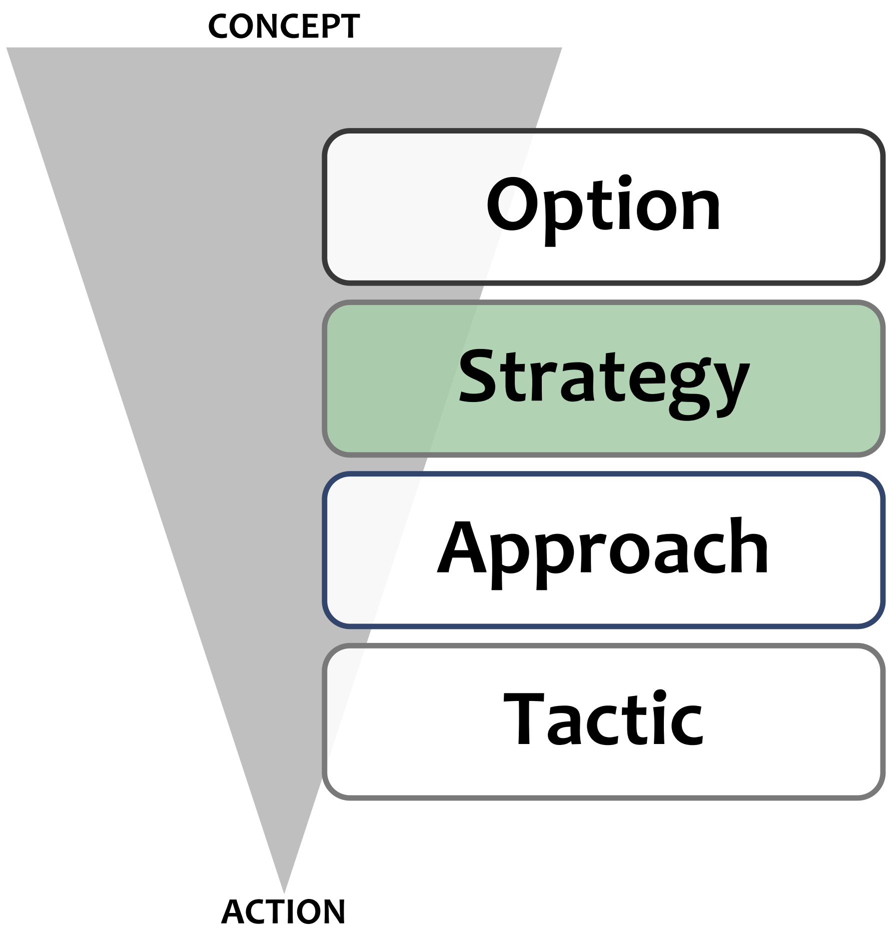


Big ideas

- Increase **resistance**
- Build **resilience**
- Facilitate **transition**

See Step 4 Course Materials for a recorded presentation that provides more details

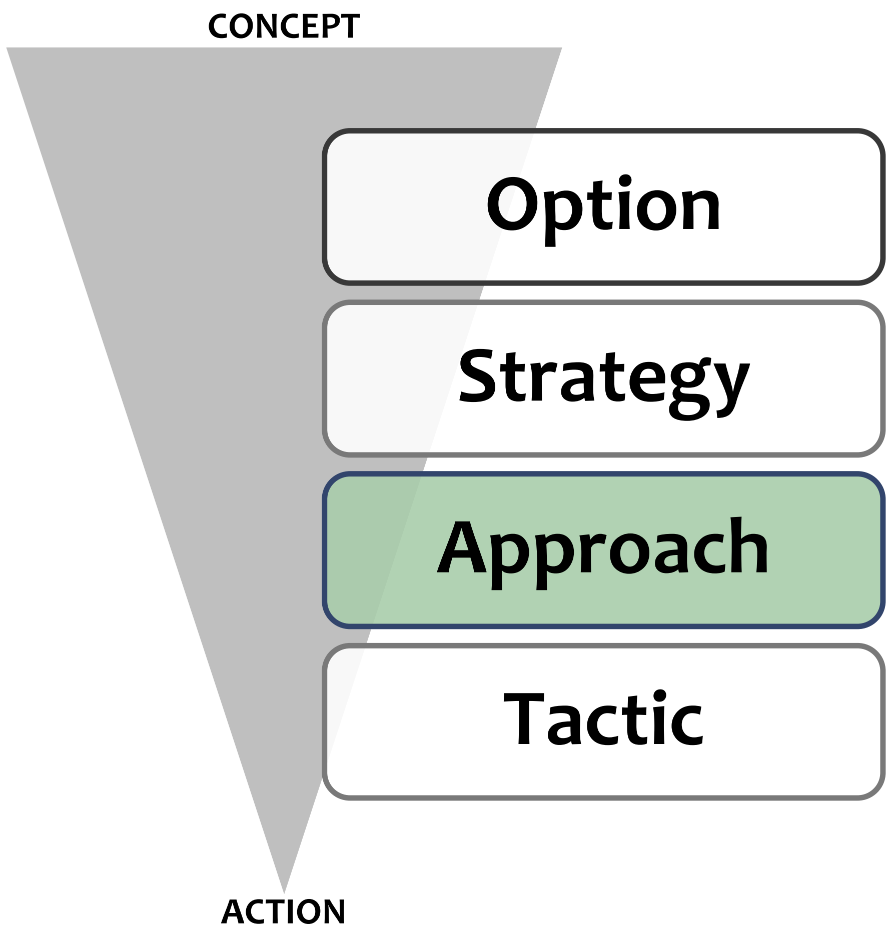
Adaptation Strategies & Approaches



Broad adaptation responses

- Sustain fundamental ecological functions
- Reduce the impact of existing biological stressors
- Maintain and enhance species and structural diversity
- Facilitate community adjustments through species transitions

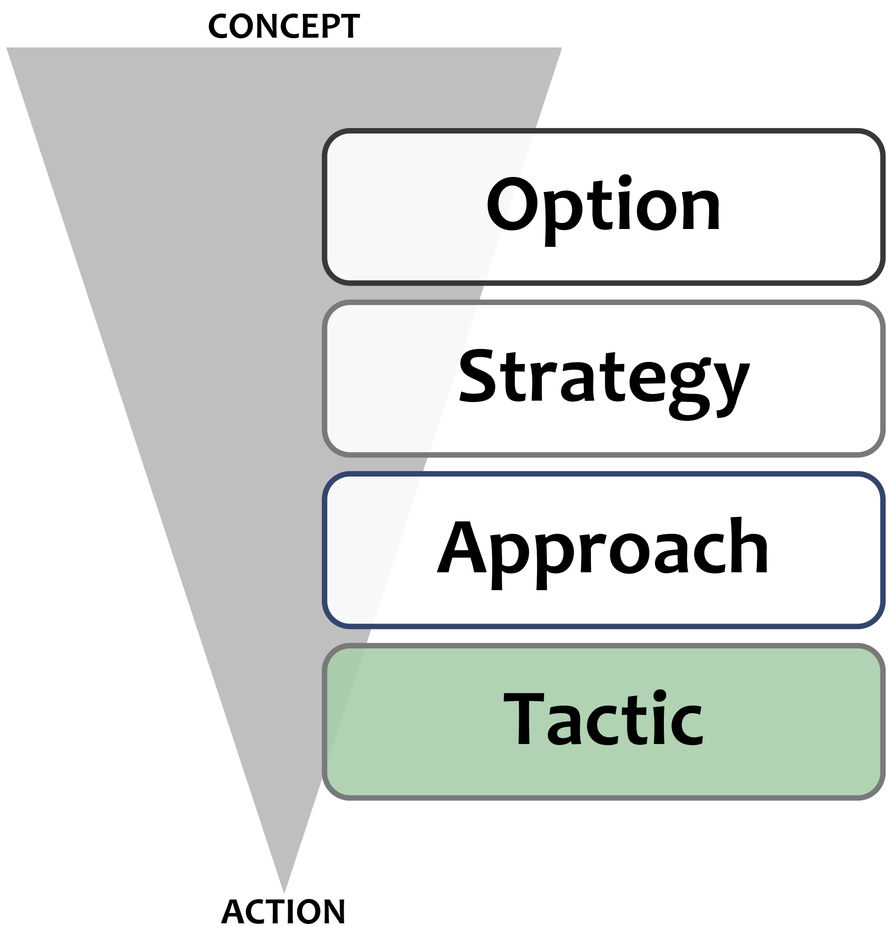
Adaptation Strategies & Approaches



<u>More specific actions</u>

- Promote diverse age classes
- Maintain and restore diversity of native tree species
- Identify and move species to sites that are likely to provide future habitat

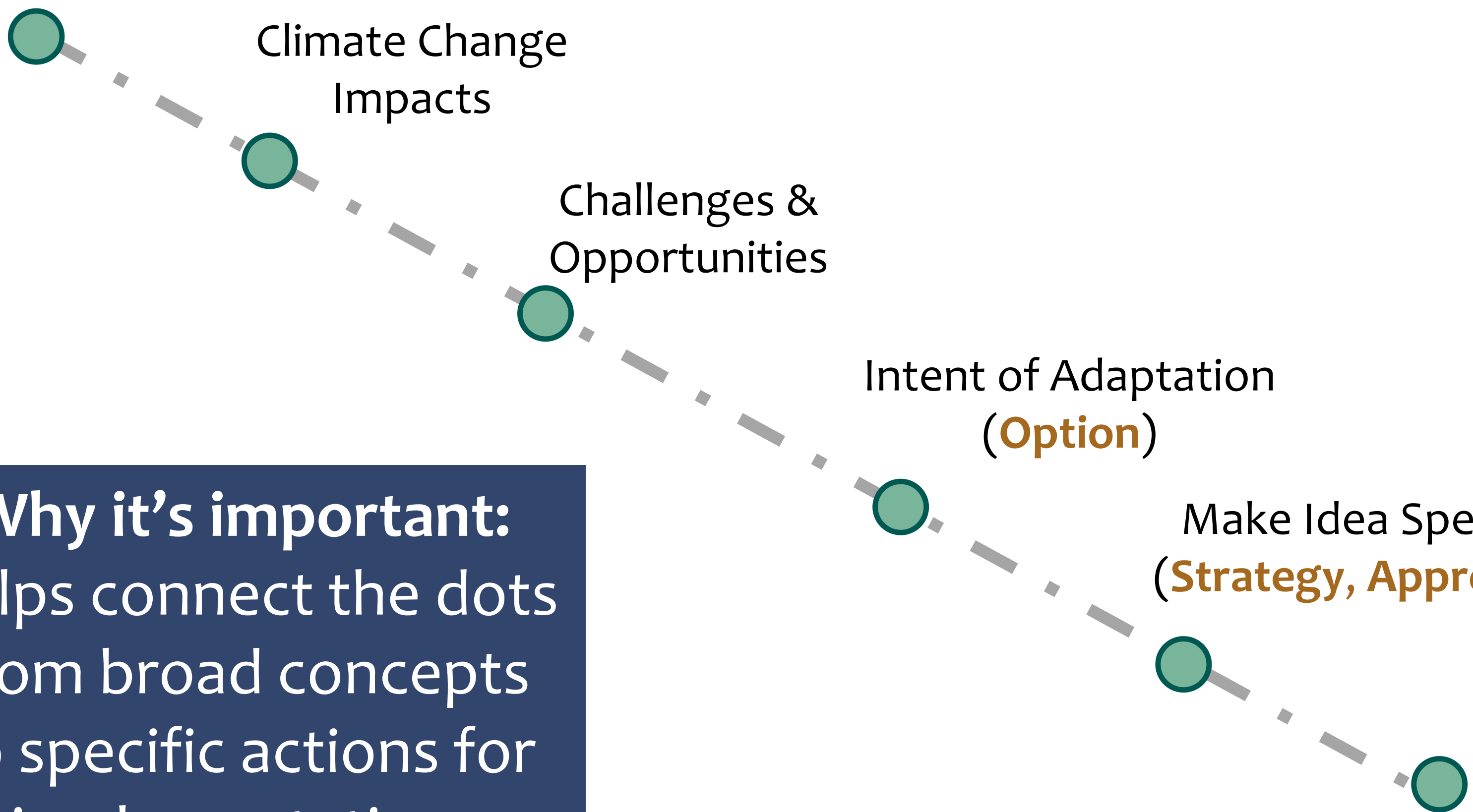
Adaptation Strategies & Approaches



Prescriptive actions selected by producer that are designed for individual site conditions and management objectives

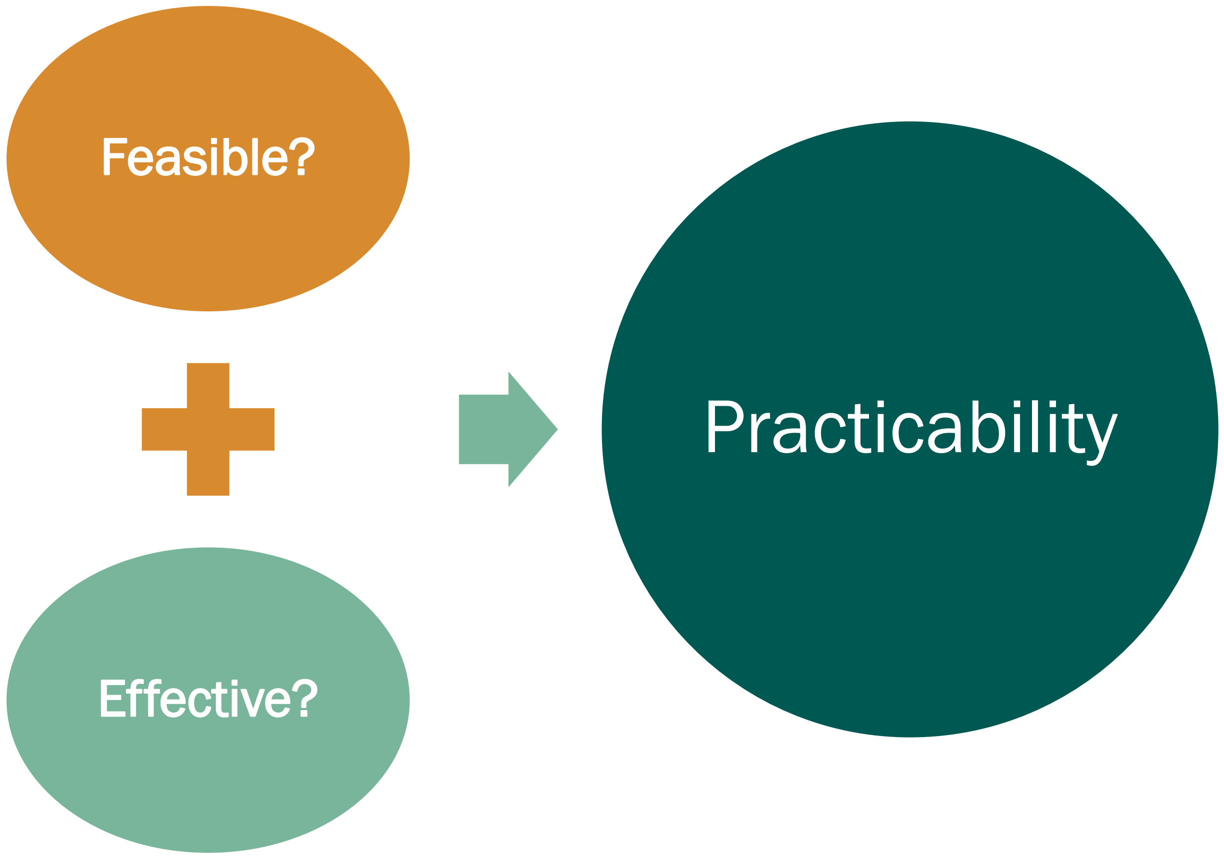
→ **YOU DECIDE!**

Adaptation Strategies & Approaches



Why it's important: Helps connect the dots from broad concepts to specific actions for implementation.

Step 4: IDENTIFY adaptation approaches and tactics for implementation.



Key Strategies You Selected:

Urban Forest

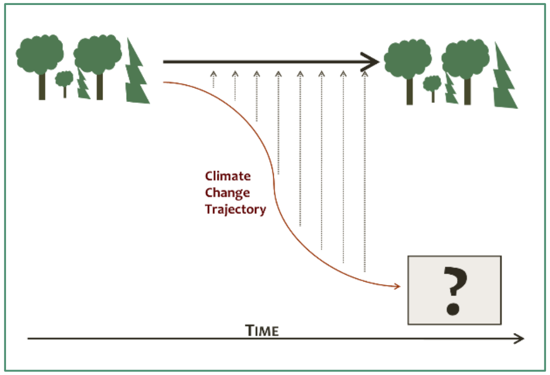
1: Sustain or restore fundamental ecological functions
2: Reduce the impact of biological stressors
3: Reduce the risk and long-term impacts of severe disturbances
4: Maintain or create refugia
5: Maintain and enhance species and structural diversity
6: Increase ecosystem redundancy across the landscape
7: Promote landscape connectivity
8: Maintain and enhance genetic diversity
9: Facilitate composition adjustments through species transitions
10: Realign urban ecosystems after disturbance

Watershed

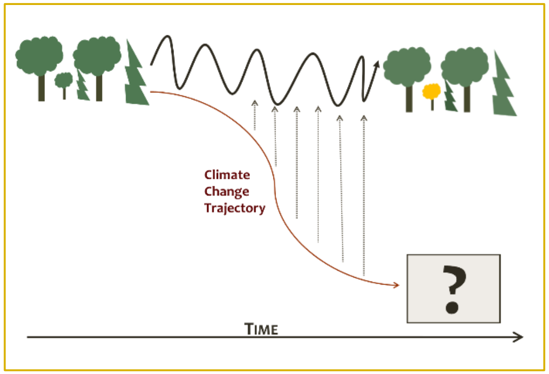
1: Sustain fundamental hydrologic processes
2: Maintain and enhance water quality
3: Maintain or restore forests and vegetative cover
4: Facilitate forest ecosystem adjustments through species transitions
5: Accommodate altered hydrologic processes
6: Design and modify infrastructure to accommodate future conditions

What Options did you select?

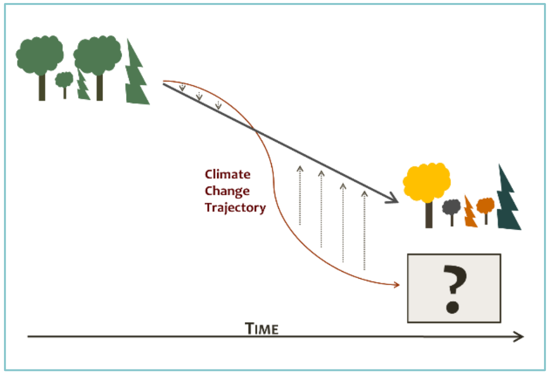
Resistance



Resilience



Transition



Tactics you evaluated but did not select?

What are some new tactics or strategies you developed that you were not doing before?

Were there challenges you had that could not be addressed?

Do others have ideas?

Were there tactics you developed that did not align with any of the strategies or approaches?

Any innovative ideas you've heard about that others are doing?

Step 5: MONITOR and evaluate effectiveness of implemented actions.

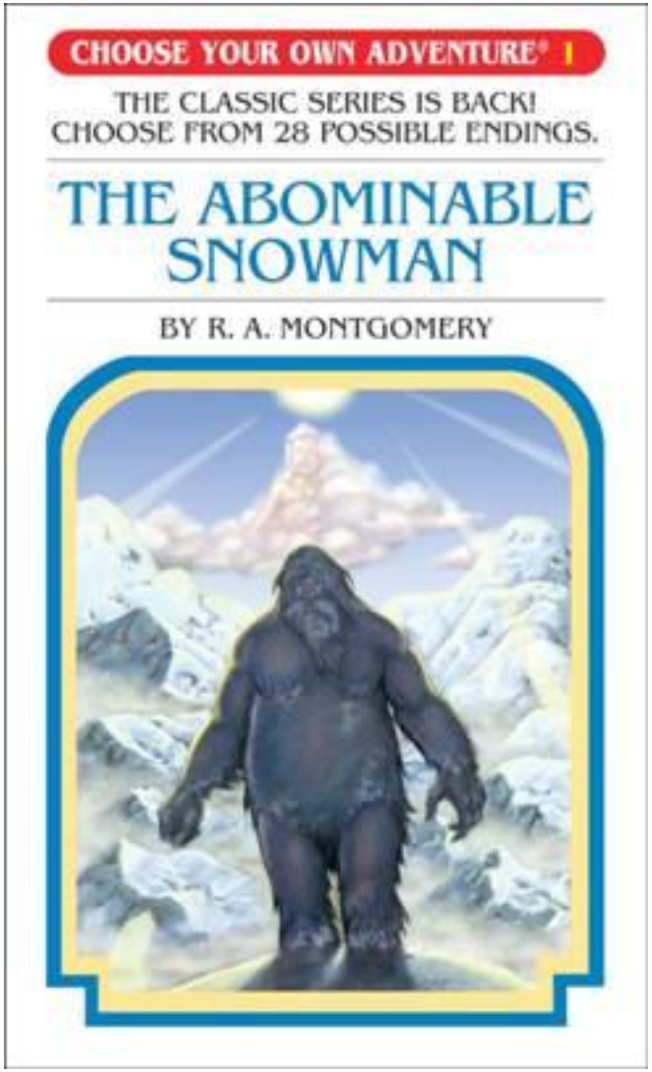
Today's Agenda

Discussion:

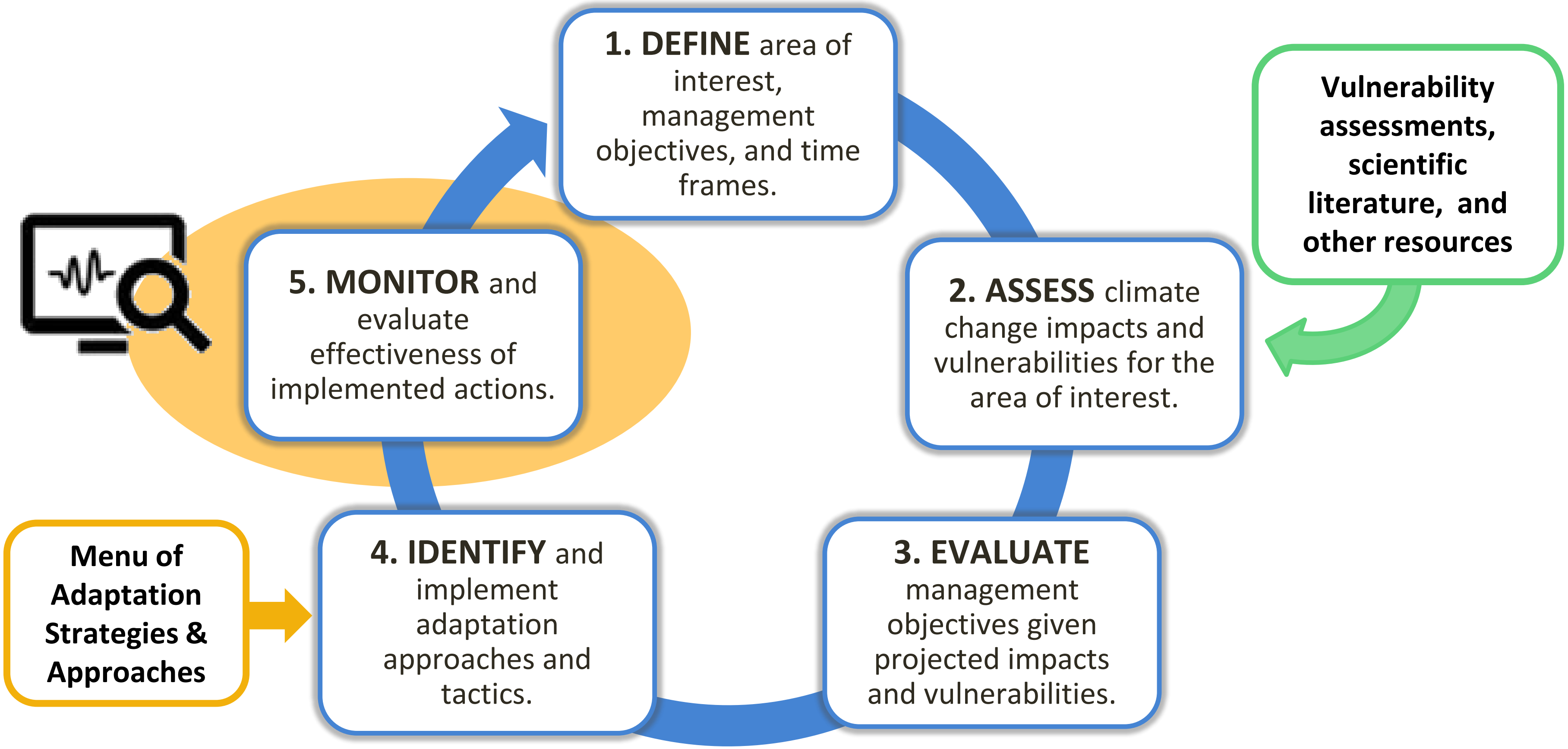
- Step 4 review
- Discussion: how are you adapting your forests to a changing climate?

Lecture:

- Step 5: Monitoring
- Website demo and homework



Today – Step 5!


1. DEFINE area of interest, management objectives, and time frames.
2. ASSESS climate change impacts and vulnerabilities for the area of interest.
3. EVALUATE management objectives given projected impacts and vulnerabilities.
4. IDENTIFY and implement adaptation approaches and tactics.
5. MONITOR and evaluate effectiveness of implemented actions.
Vulnerability assessments, scientific literature, and other resources
Menu of Adaptation Strategies & Approaches

A FEW THOUGHTS ABOUT MONITORING…

Be VERY CLEAR about your **objectives**! What question you are asking guides your monitoring approach:

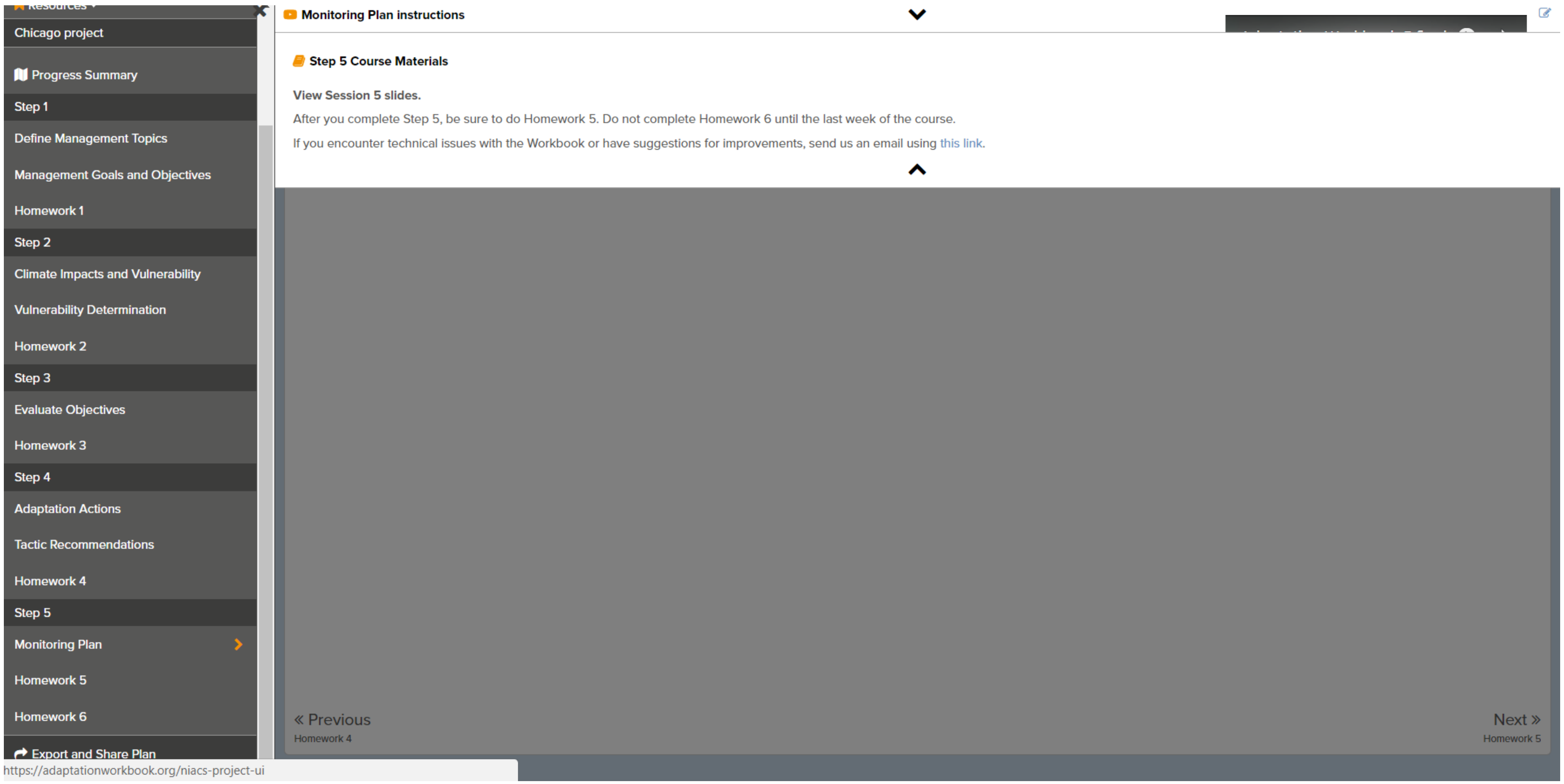
Scientific research = Is this outcome statistically significant compared to a control? Could we expect similar results elsewhere?

Impact/ response monitoring = What changes are occurring?

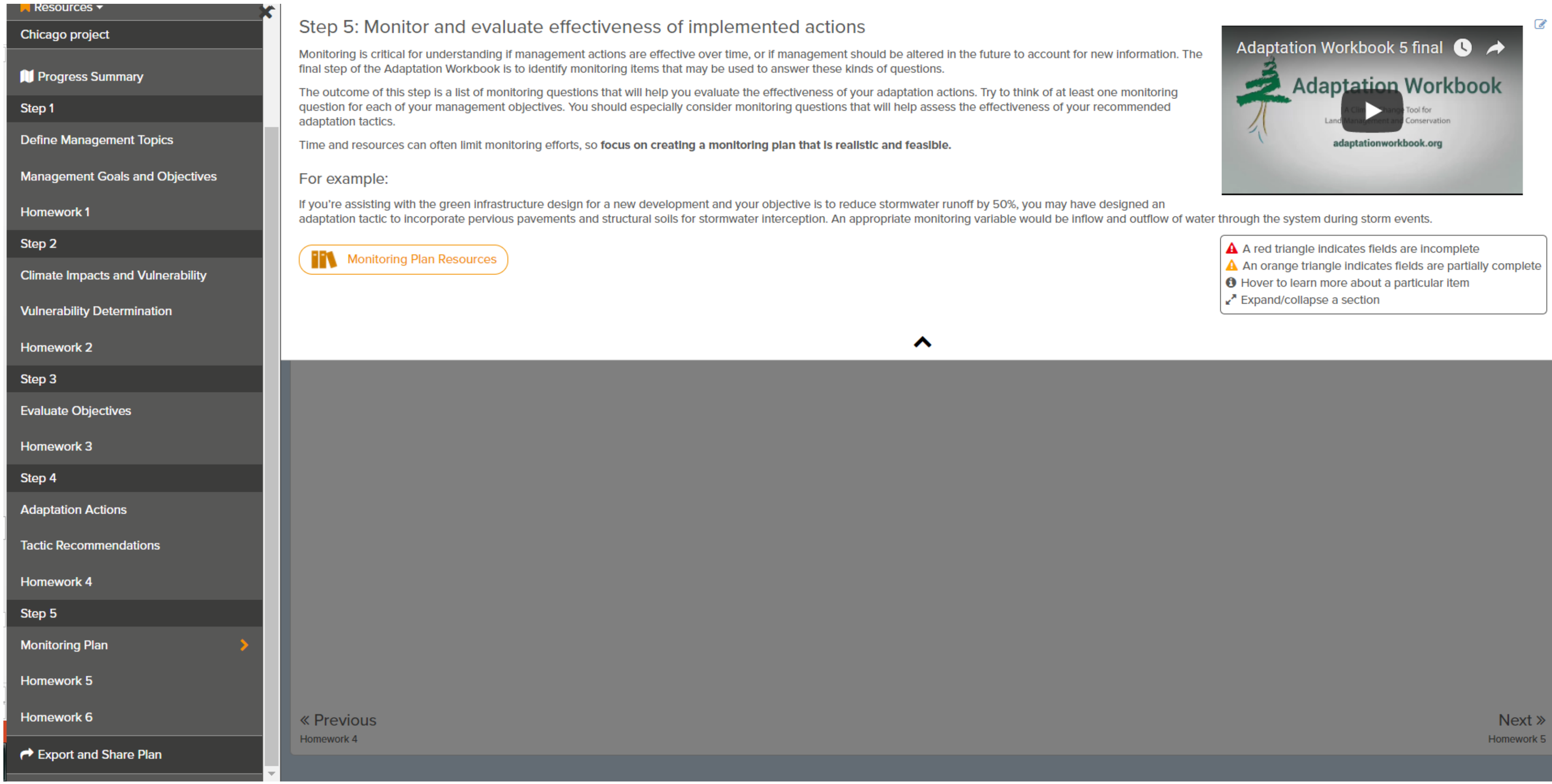
Implementation monitoring = Did we do the action?

Effectiveness monitoring = Did our actions actually have the desired effect?

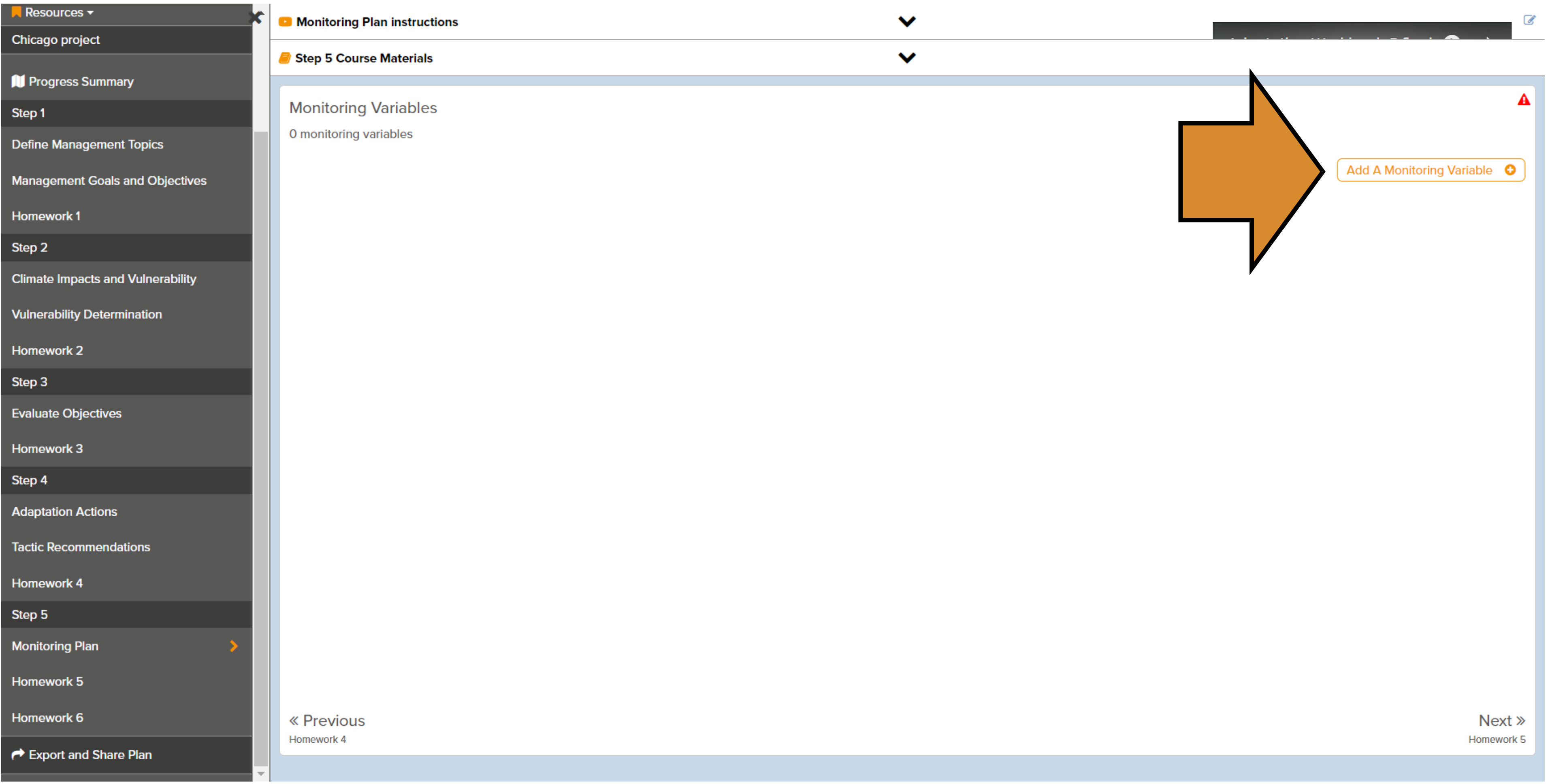
Course Material Landing Page



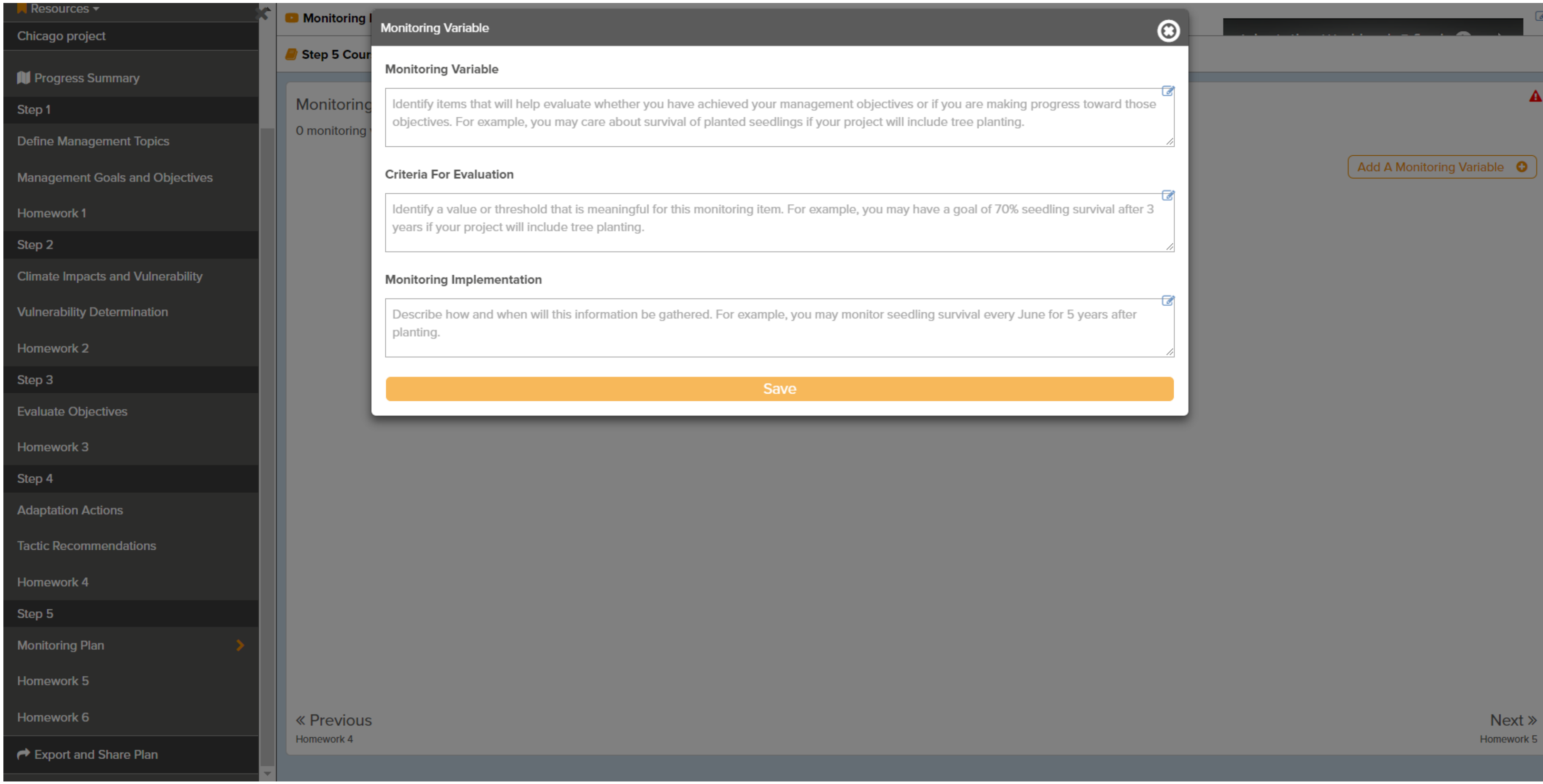
Step 5 Landing Page



Add a Monitoring Variable



Add a Monitoring Variable



Step 5: MONITOR and evaluate effectiveness of implemented actions.

Monitoring Variable	Items that can tell you whether you have achieved your management goals & objectives. If possible, use an item that also helps evaluate a particular tactic. **For example:** • Planted seedling survival

Step 5: MONITOR and evaluate effectiveness of implemented actions.

Evaluation Criteria

What is success?

What you're monitoring or measuring. What are the units on your data?

For example:

- 60% survival of non-local genotypes.

Step 5: MONITOR and evaluate effectiveness of implemented actions.

Monitoring Implementation

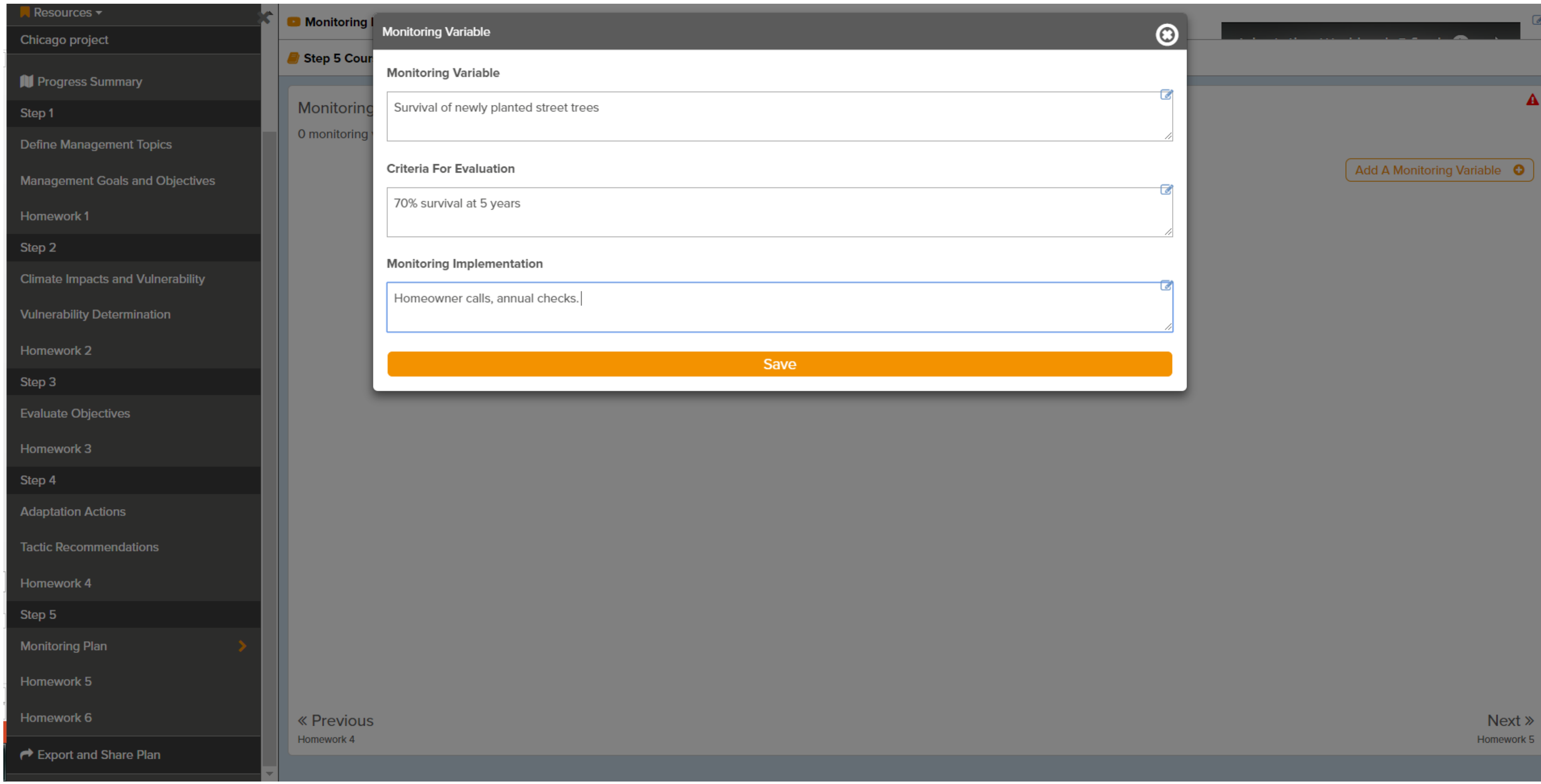
How the monitoring will actually get done.

Use existing monitoring when possible!

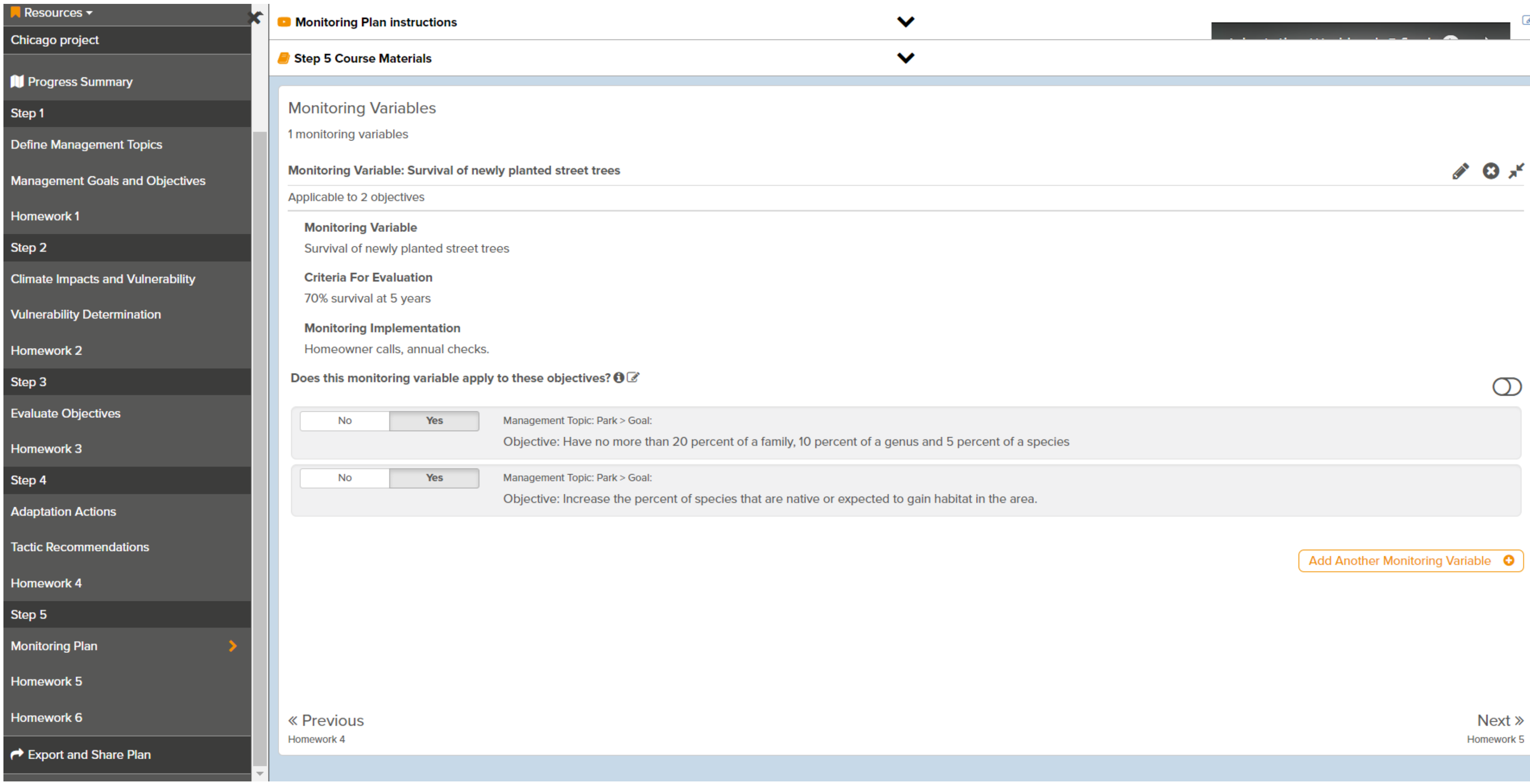
For example:

- Regular post-planting stocking surveys.
- Supplemental surveys at 10 years.

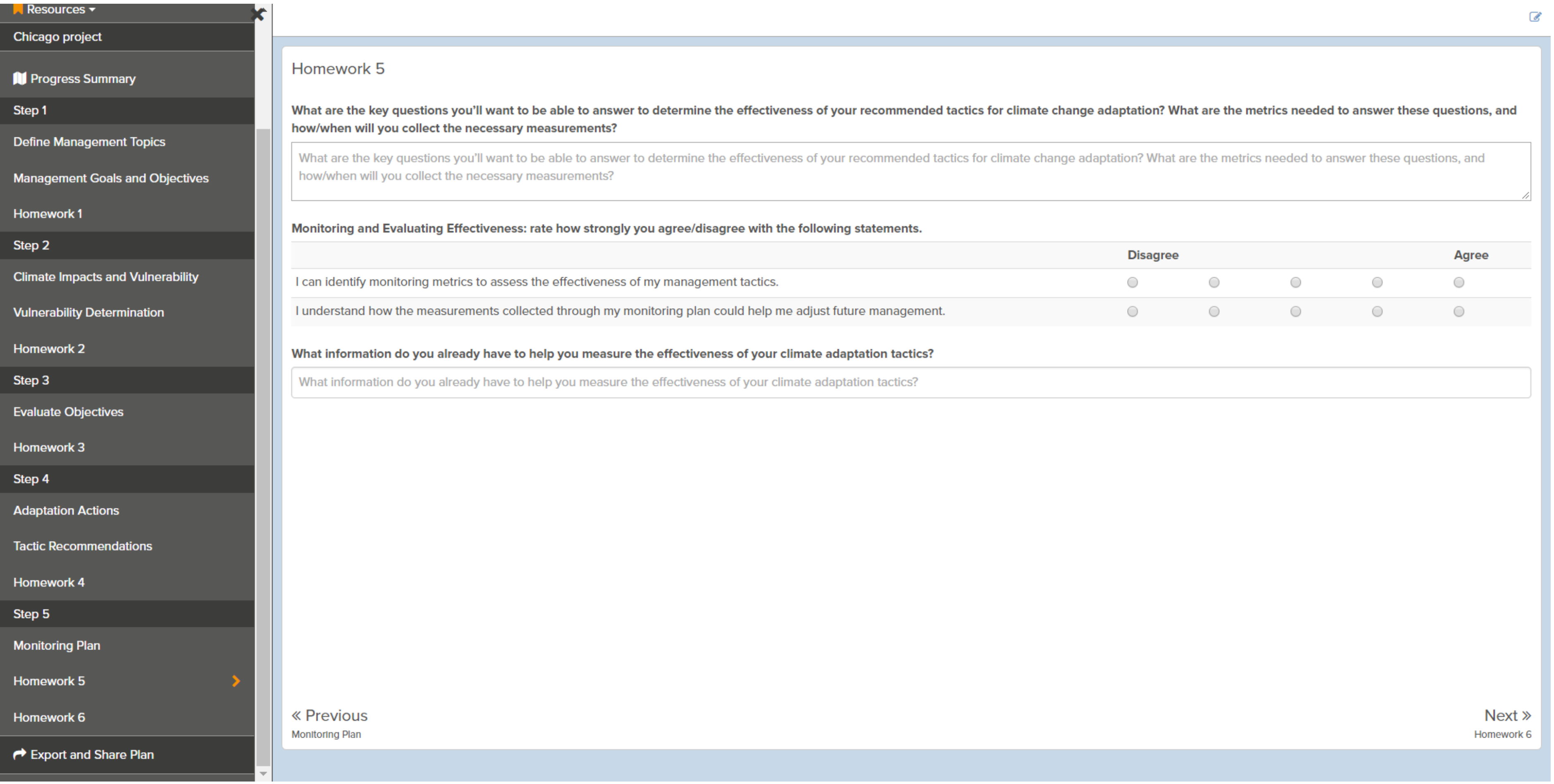
Add a Monitoring Variable



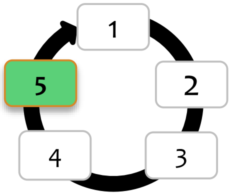
Apply to Objectives



Homework


Resources
Chicago project
Progress Summary
Step 1
Define Management Topics
Management Goals and Objectives
Homework 1
Step 2
Climate Impacts and Vulnerability
Vulnerability Determination
Homework 2
Step 3
Evaluate Objectives
Homework 3
Step 4
Adaptation Actions
Tactic Recommendations
Homework 4
Step 5
Monitoring Plan
Homework 5
Homework 6
Export and Share Plan
Homework 5
What are the key questions you'll want to be able to answer to determine the effectiveness of your recommended tactics for climate change adaptation? What are the metrics needed to answer these questions, and how/when will you collect the necessary measurements?
What are the key questions you'll want to be able to answer to determine the effectiveness of your recommended tactics for climate change adaptation? What are the metrics needed to answer these questions, and how/when will you collect the necessary measurements?
Monitoring and Evaluating Effectiveness: rate how strongly you agree/disagree with the following statements.
Disagree
Agree
I can identify monitoring metrics to assess the effectiveness of my management tactics.
I understand how the measurements collected through my monitoring plan could help me adjust future management.
What information do you already have to help you measure the effectiveness of your climate adaptation tactics?
What information do you already have to help you measure the effectiveness of your climate adaptation tactics?
« Previous
Monitoring Plan
Next »
Homework 6

EXAMPLES

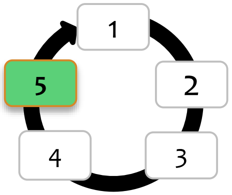


Step 5: MONITOR and evaluate effectiveness of implemented actions.

Twentymile Creek and Marengo River Priority Watershed project

Monitoring Item	Monitoring Metric	Criteria for Evaluation
Brook Trout pop (+other spp)	# fish (size, pop, catch/effort)	Maintaining or increasing populations
Channel stability	Detecting changes to Bankfull width, depth, and area	Maintaining stable channels – no change in width: depth ratio
Water temperature	Summer max, max weekly mean	Cold: < 23 C for annual max Cool: < 26 C for annual max

forestadaptation.org/cnnf-water

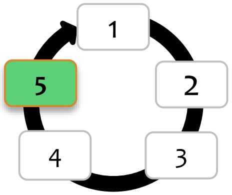


Step 5: MONITOR and evaluate effectiveness of implemented actions.

City of Columbia, MO: Street Tree Management Plan

Monitoring Item	Monitoring Metric	Criteria for Evaluation
Street Tree Survival	% survival at 3 years	70% street tree survival at 3 years.
Species Diversity	Biannual inventory of the percentage of trees that belong to a family	no more than 10% of street trees may belong to a single family
Invasive species	Presence/absence of invasive vegetation at recently disturbed sites after 1 year.	Absence of invasive species

https://forestadaptation.org/ColumbiaMO



Step 5: MONITOR and evaluate effectiveness of implemented actions.

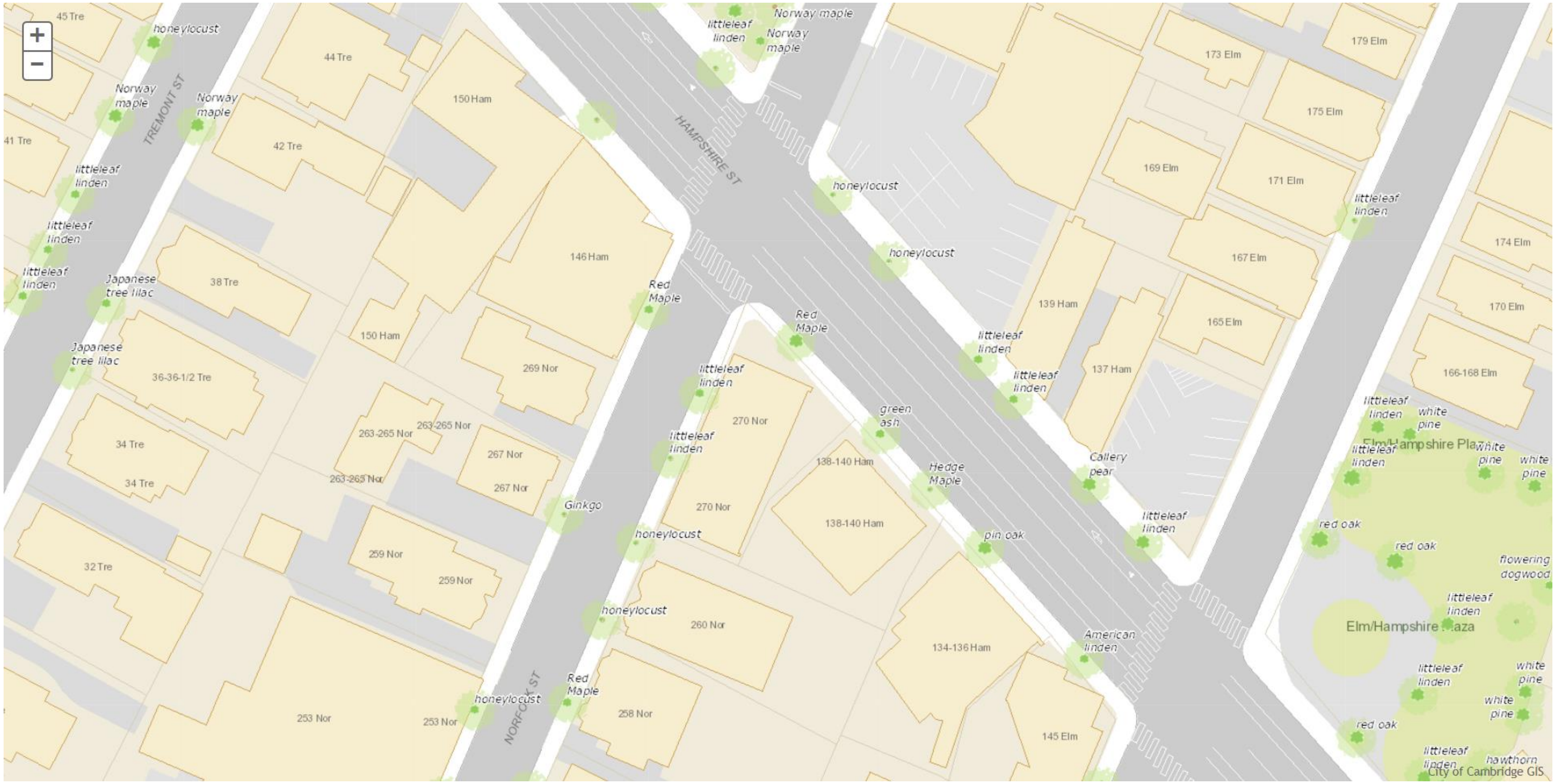
City of Goshen, IN: Goshen Tree Benefits Campaign

Monitoring Item	Monitoring Metric	Criteria for Evaluation
Whip and seedling survival	Survival (mapped using Treekeeper)	50% survival at 3 years.
Survival of balled and burlapped trees and larger plantings	Survival (mapped using Treekeeper)	85% after 3 years.
% tree canopy	Urban tree canopy assessment (remote sensing)	25% by 2025, 30% by 2030, 35% by 2035, 40% by 2040, 45% by 2045.

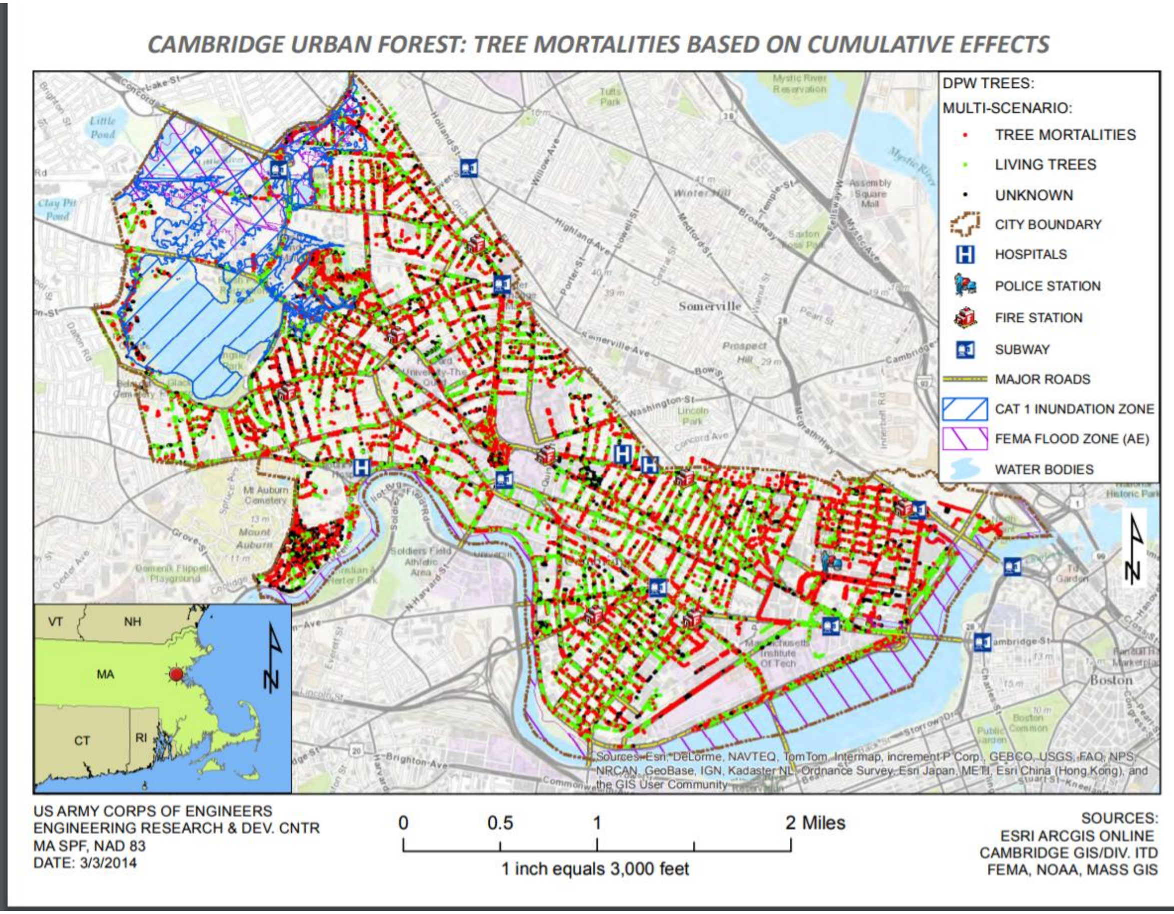
https://forestadaptation.org/GoshenIN

MONITORING TOOLS

Cambridge, MA: Cartegraph GIS Inventory



Street Tree Vulnerability Assessment



http://www.cambridgema.gov/CDD/Projects/Climate/~/media/42F2847A3DCB4706BB5981D66D0AB157.ashx

LiDAR Mapping

Citizen Science in Lombard, Philadelphia, Grand Rapids, and Malmo Sweden

Novice:

- 1 year of experience or less (volunteers, interns)

Intermediate:

- 1-3 years experience (volunteers, interns)

Expert:

- experienced urban forest researchers and certified arborists

Roman et al. 2017

Methods

- Volunteers received 6-7 hours of training led by experts
- Field guide provided
- Field work carried out without supervision
- Trees observed by 1 expert, 3 novices, and 3 intermediates
    - Results compared between novice/intermediate and expert
- Field crew questionnaire
    - Characteristics, level of training of participants

Roman et al. 2017

Citizen science is good for:

- Classifying site type and land use
- Dieback rating (especially low, high)
- Genus ID (especially common ones like Acer, Gleditsia, Tilia
- Number of stems
- DBH within 1 inch (2.54 cm)

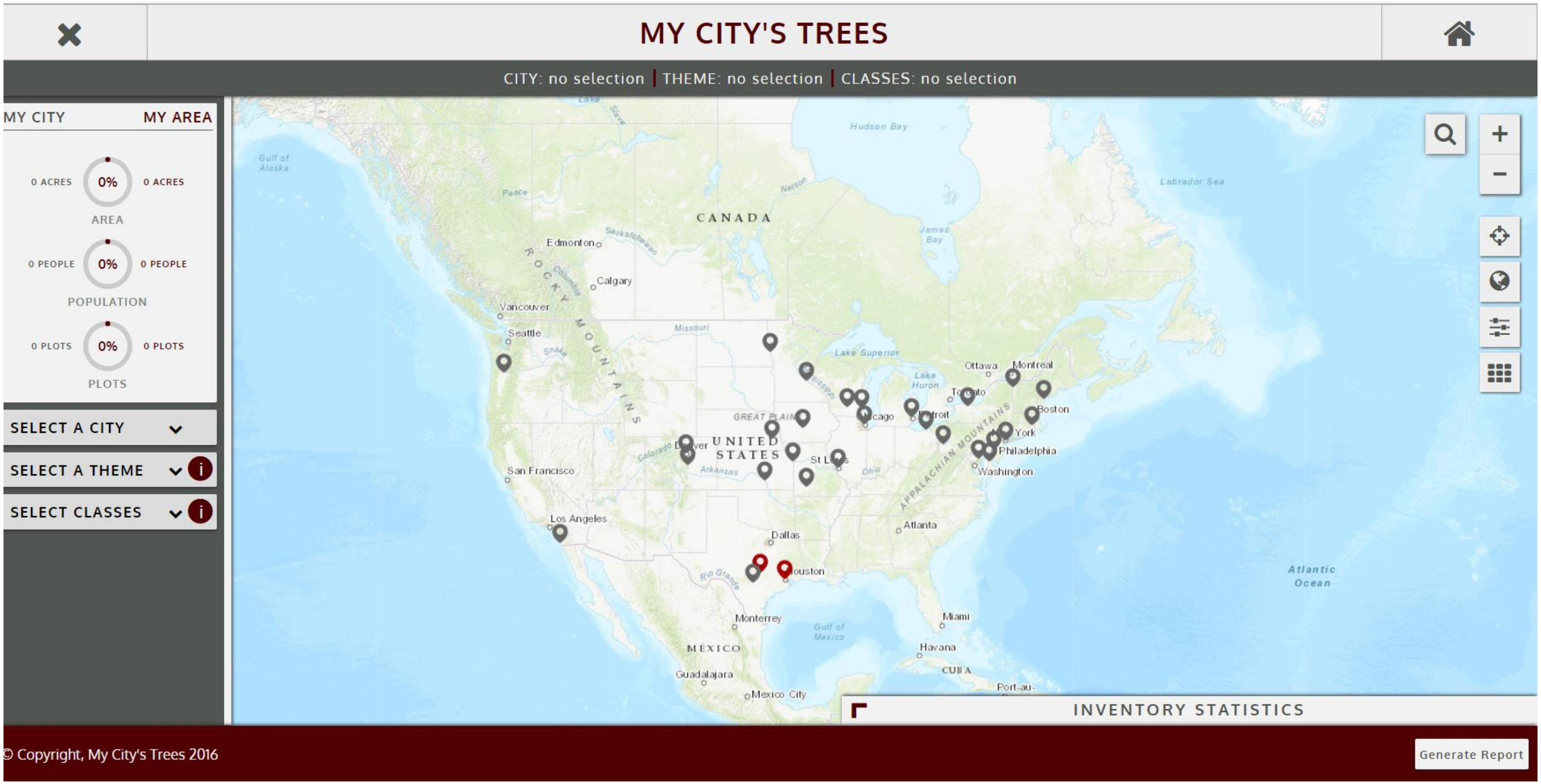
Roman et al. 2017

Did not work as well for:

- Crown transparency
- Wood condition
- Classifying trees in middle dieback categories
- Species ID
- Identifying less common genera (Amelanchier, Prunus, Syringa)
- Species within genera
- DBH of multistemmed trees
- Radial growth monitoring

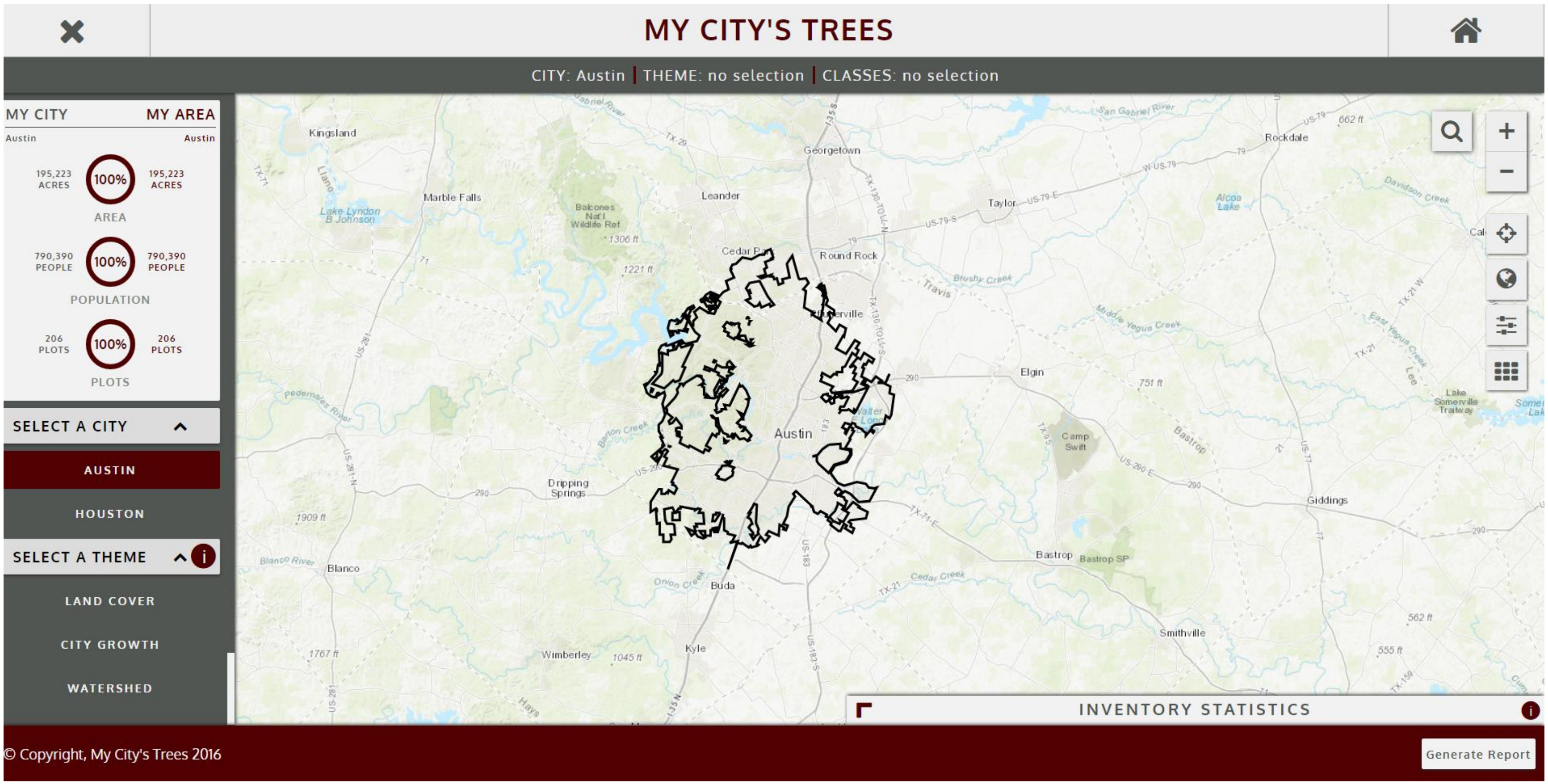
Roman et al. 2017

My City’s Trees: Urban FIA



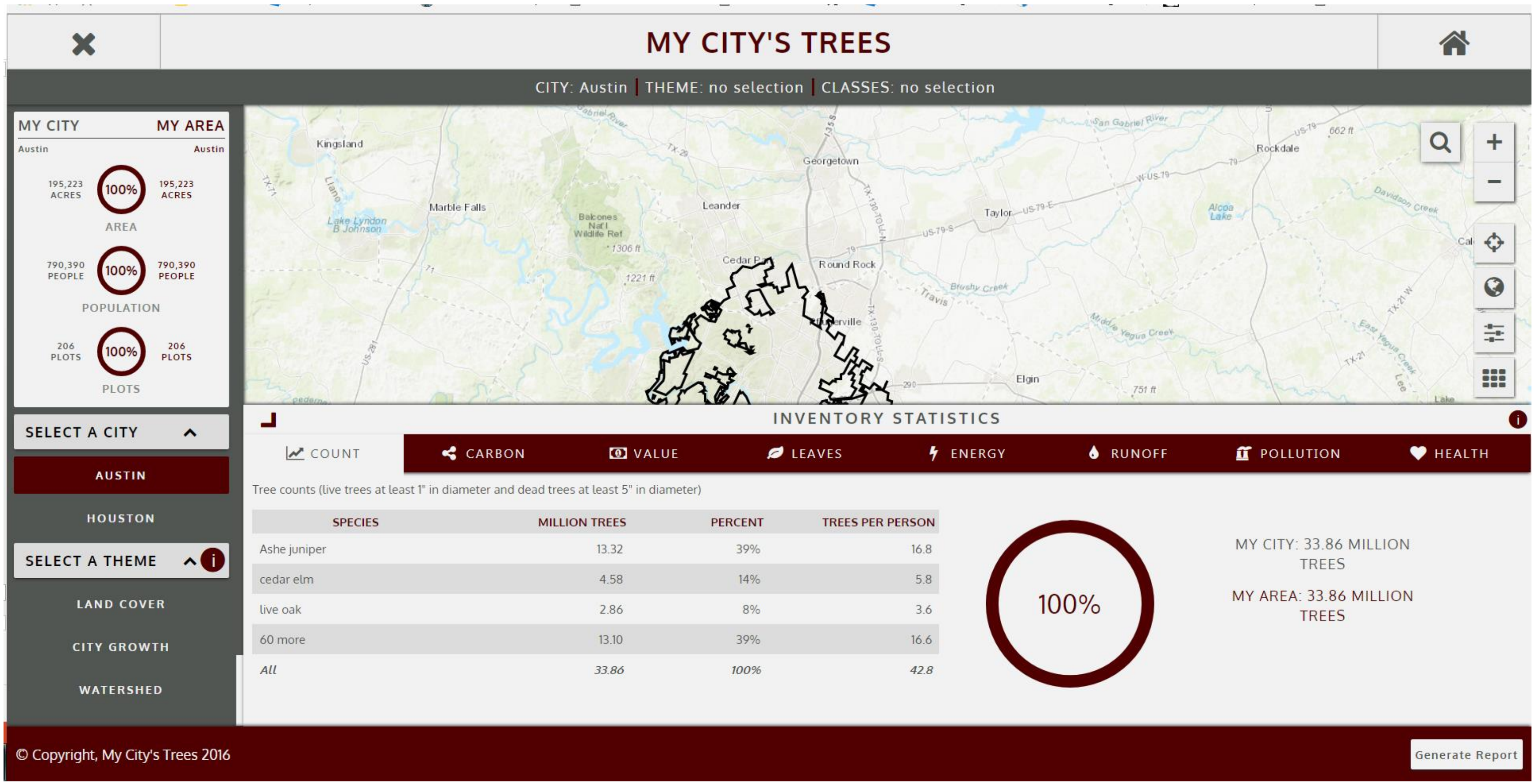
http://tfsfrd.tamu.edu/mycitystrees

Zoom in on a city



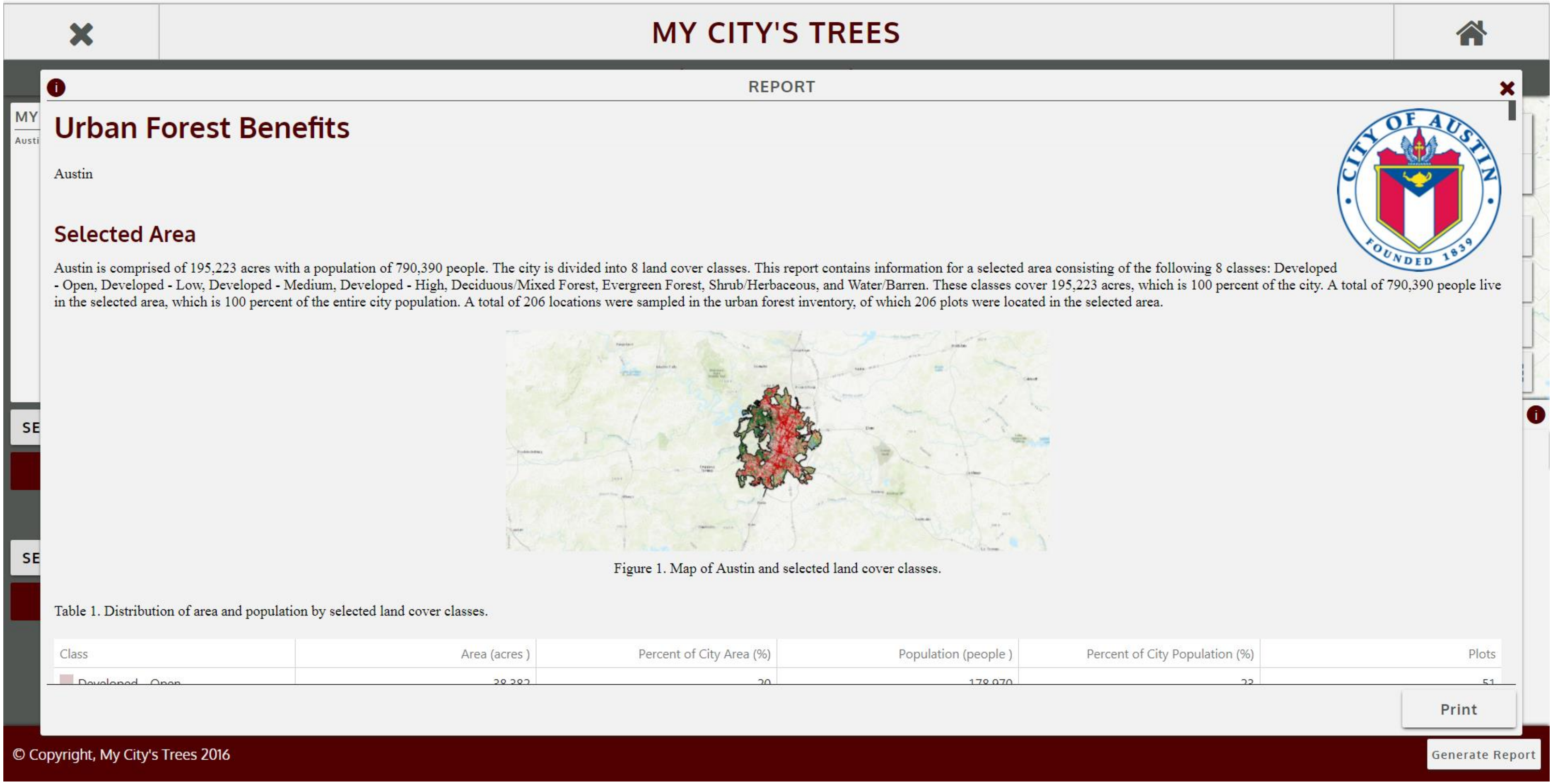
http://tfsfrd.tamu.edu/mycitystrees

Get Inventory Summaries



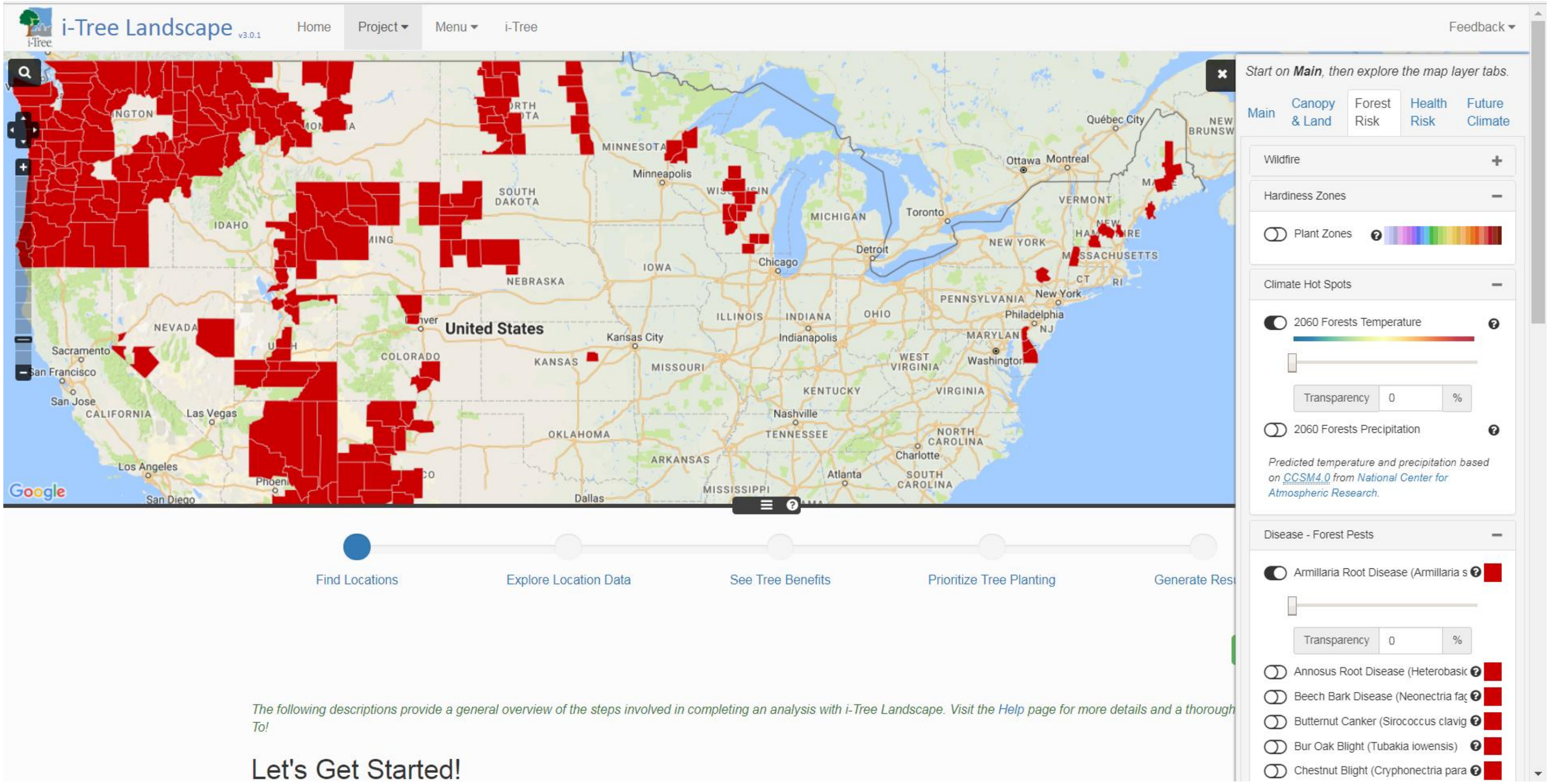
http://tfsfrd.tamu.edu/mycitystrees

Download Reports



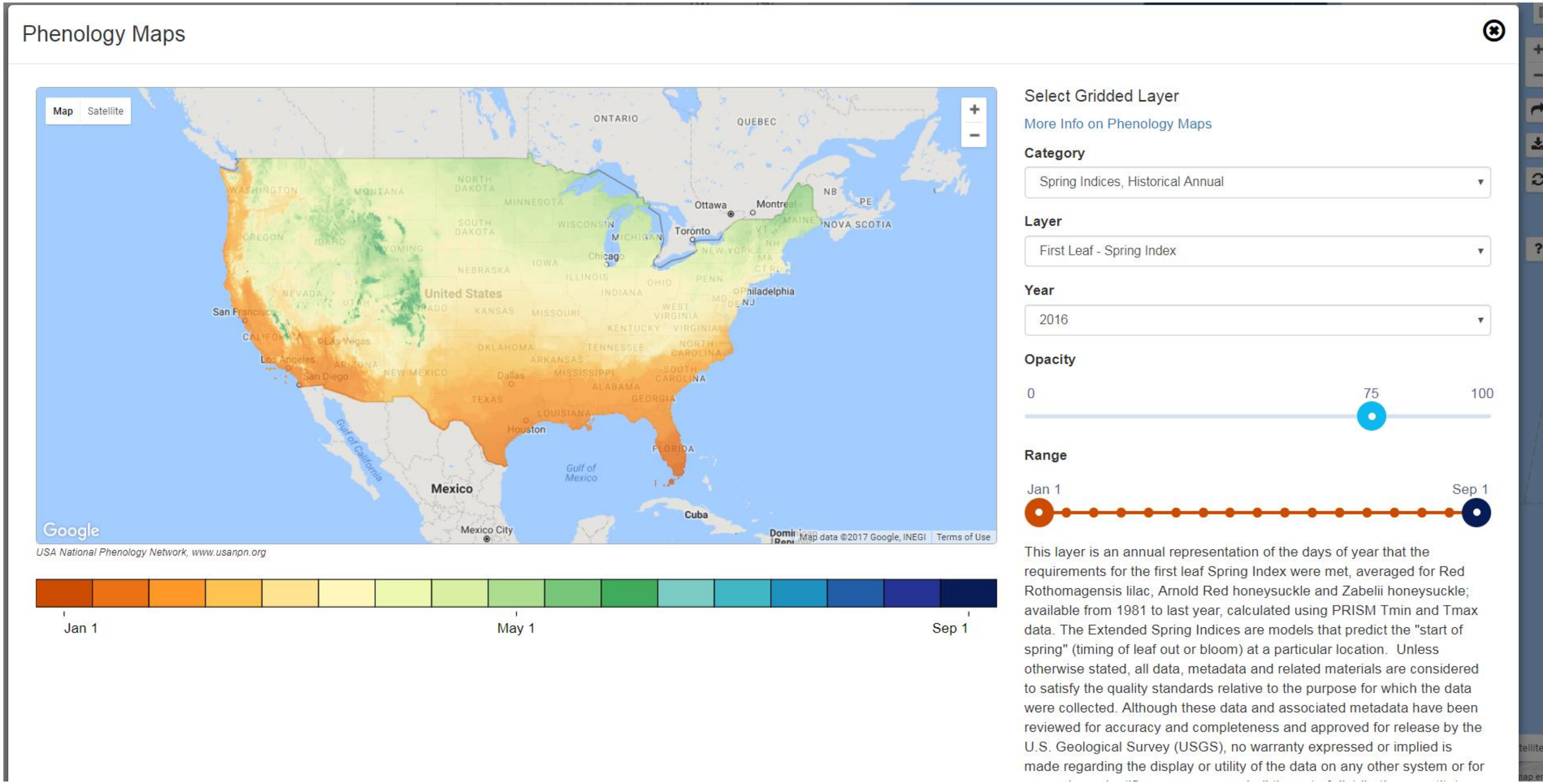
http://tfsfrd.tamu.edu/mycitystrees

I-Tree Landscape



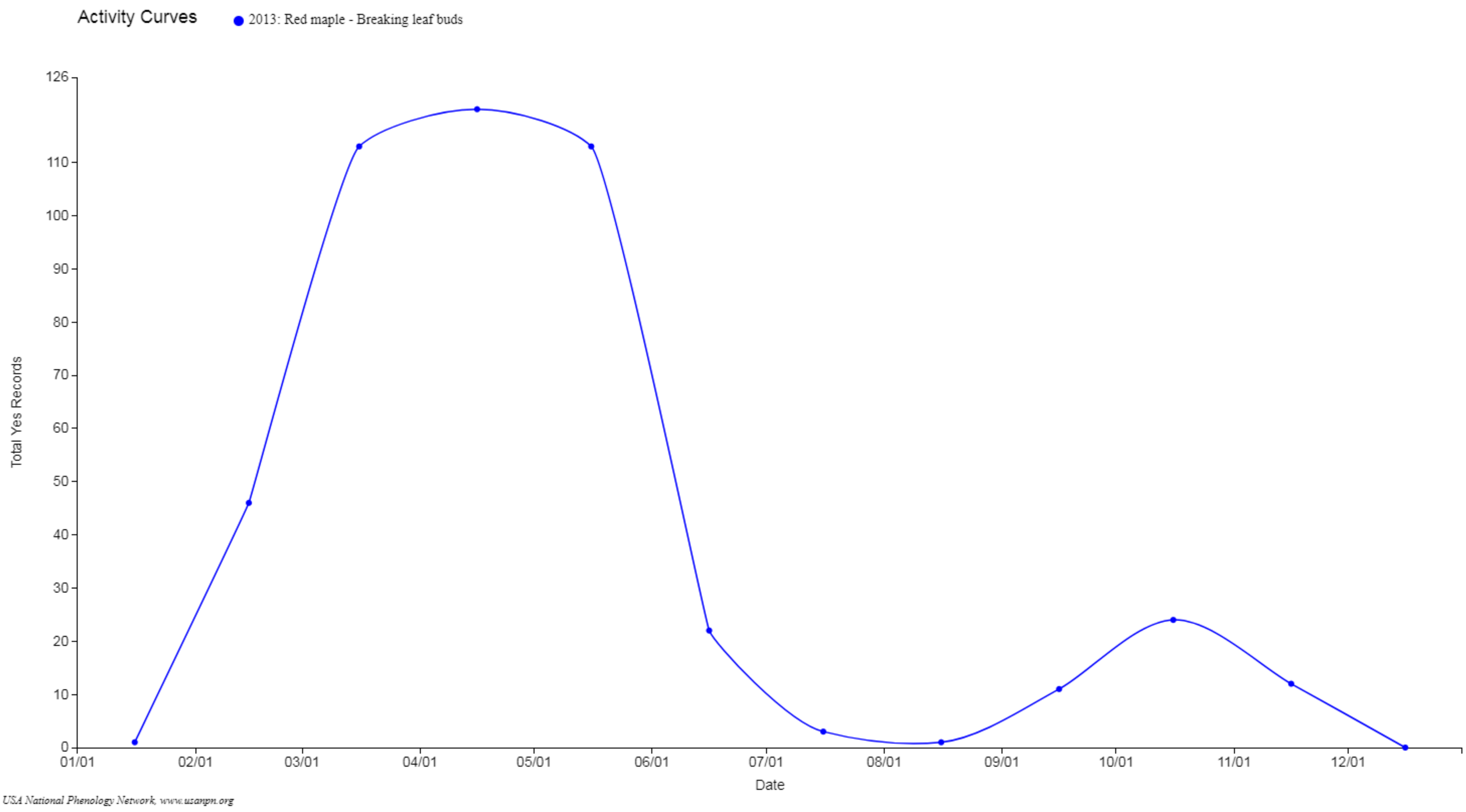
https://landscape.itreetools.org/maps/

USA National Phenology Network



https://www.usanpn.org/data/visualizations

USA National Phenology Network



https://www.usanpn.org/data/visualizations

Caroline Lake State Natural Area Adaptation Demonstration

Major concerns: Forest composition could become less diverse given climate changes

How can we better use forest inventory data to tell us:

- Are forests are at risk from climate change?
- Are management actions reducing risk?


Matt Dallman (TNC), find project at ***forestadaptation.org/node/659***

Climate-informed inventory: New Risk Metrics

Northern Hardwood Stand:

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)
Sugar maple	79.0	117.1	100.0	40.8
White ash	33.1	30.7	96.2	17.9
American basswood	18.5	23.7	73.1	12.3
Yellow birch	7.7	12.4	53.8	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5
Red maple	4.2	8.6	42.3	5.0
Northern red oak	1.5	0.7	42.3	3.2
American elm	0.4	0.4	34.6	2.4
Paper birch	1.9	5.3	11.5	2.0
Black ash	1.5	2.6	7.7	1.2
Black cherry	0.4	0.2	15.4	1.1
Eastern hemlock	1.2	1.9	3.8	0.8
Quaking aspen	0.8	0.6	7.7	0.8
Total	**160.2**	**220.3**		**100.0**

Climate-informed inventory: New Risk Metrics

Northern Hardwood Stand: **Low (PCM B1)**

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)	Future: Current Habitat	Change Class	At-risk Proportion of Stand (%)
Sugar maple	79.0	117.1	100.0	40.8	0.8	No Change	0.0
White ash	33.1	30.7	96.2	17.9	1.6	Increase	0.0
American basswood	18.5	23.7	73.1	12.3	1.1	No Change	0.0
Yellow birch	7.7	12.4	53.8	7.0	0.8	Decrease	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5	1.0	No Change	0.0
Red maple	4.2	8.6	42.3	5.0	1.0	No Change	0.0
Northern red oak	1.5	0.7	42.3	3.2	1.3	Increase	0.0
American elm	0.4	0.4	34.6	2.4	2.3	Increase	0.0
Paper birch	1.9	5.3	11.5	2.0	0.7	Decrease	2.0
Black ash	1.5	2.6	7.7	1.2	0.7	Decrease	1.2
Black cherry	0.4	0.2	15.4	1.1	2.4	Large Increase	0.0
Eastern hemlock	1.2	1.9	3.8	0.8	1.2	Increase	0.0
Quaking aspen	0.8	0.6	7.7	0.8	0.6	Decrease	0.8
Total	**160.2**	**220.3**		**100.0**		***Proportion at-risk:***	***11.0***

Climate-informed inventory: New Risk Metrics

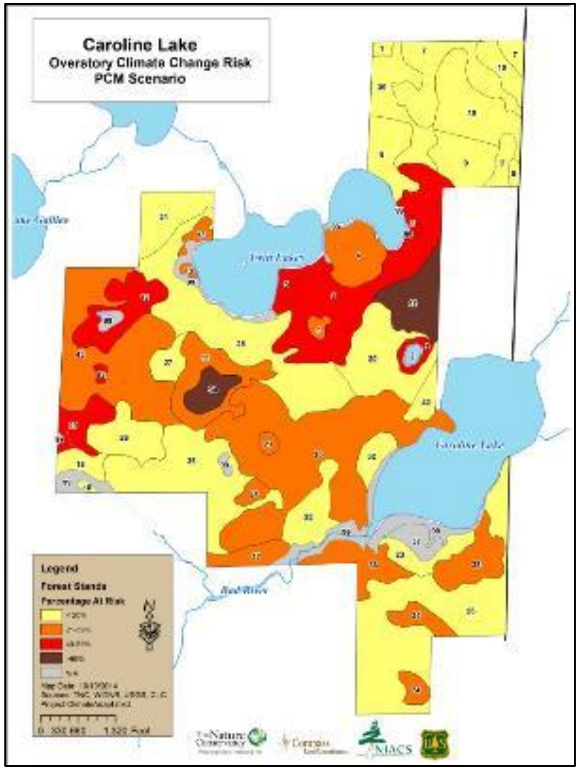
Northern Hardwood Stand:

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)	Low (PCM B1): Future: Current Habitat	Low (PCM B1): Change Class	Low (PCM B1): At-risk Proportion of Stand (%)	High (GFDL A1F1): Future: Current Habitat	High (GFDL A1F1): Change Class	High (GFDL A1F1): At-risk Proportion of Stand (%)
Sugar maple	79.0	117.1	100.0	40.8	0.8	No Change	0.0	0.3	Large Decrease	40.8
White ash	33.1	30.7	96.2	17.9	1.6	Increase	0.0	1.9	Increase	0.0
American basswood	18.5	23.7	73.1	12.3	1.1	No Change	0.0	1.4	Increase	0.0
Yellow birch	7.7	12.4	53.8	7.0	0.8	Decrease	7.0	0.2	Large Decrease	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5	1.0	No Change	0.0	0.4	Large Decrease	5.5
Red maple	4.2	8.6	42.3	5.0	1.0	No Change	0.0	0.6	Decrease	5.0
Northern red oak	1.5	0.7	42.3	3.2	1.3	Increase	0.0	1.1	No Change	0.0
American elm	0.4	0.4	34.6	2.4	2.3	Increase	0.0	3.2	Large Increase	0.0
Paper birch	1.9	5.3	11.5	2.0	0.7	Decrease	2.0	0.2	Large Decrease	2.0
Black ash	1.5	2.6	7.7	1.2	0.7	Decrease	1.2	0.6	Decrease	1.2
Black cherry	0.4	0.2	15.4	1.1	2.4	Large Increase	0.0	1.4	Increase	0.0
Eastern hemlock	1.2	1.9	3.8	0.8	1.2	Increase	0.0	0.4	Large Decrease	0.8
Quaking aspen	0.8	0.6	7.7	0.8	0.6	Decrease	0.8	0.2	Large Decrease	0.8
Total	**160.2**	**220.3**		**100.0**		***Proportion at-risk:***	***11.0***		***Proportion at-risk:***	***63.0***

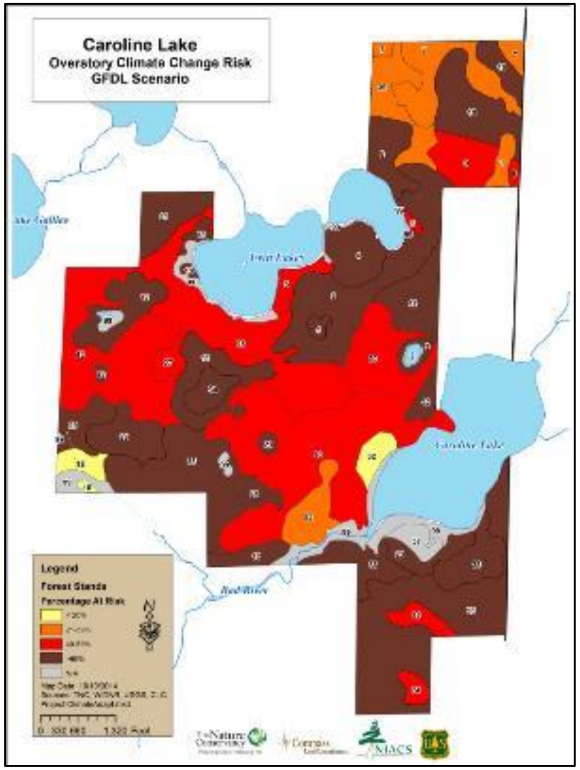
Climate-informed inventory: Risk Maps

Risk by stand: overstory

Low (PCM B1)



High (GFDL A1F1)



“100 year” storms and floods

- Current streamflow
- Using stream channel capacity to manage future risks to infrastructure
- Terminology
- Future projected 100y flow
- Tools you can use

Image: American Forests

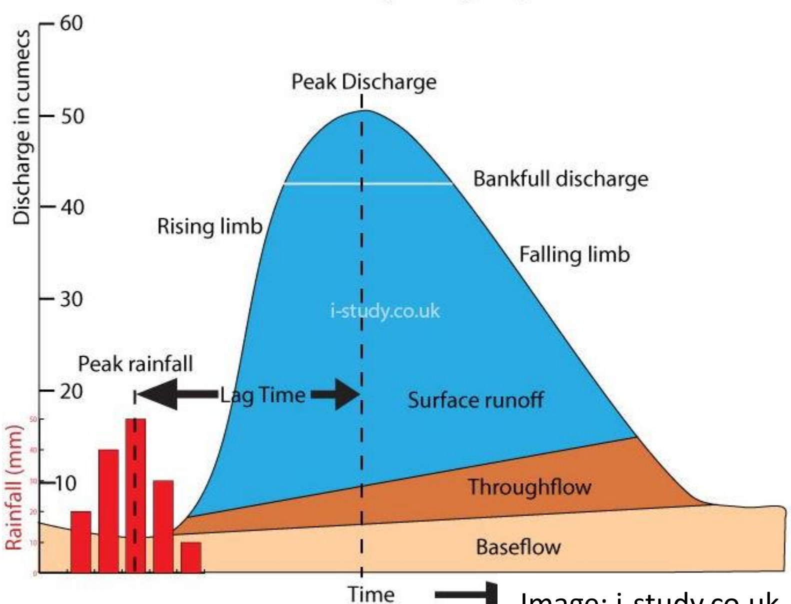
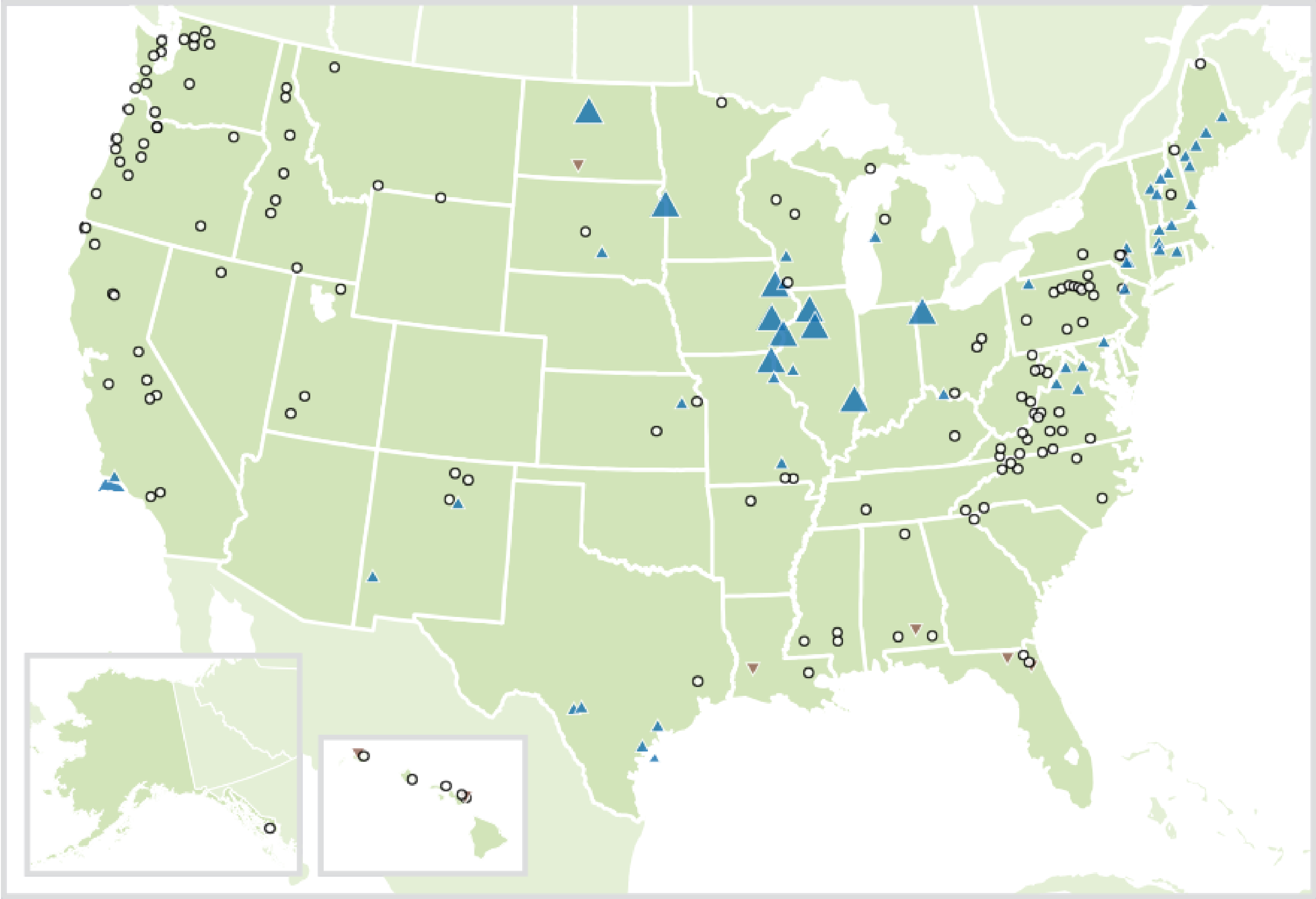


Image: i-study.co.uk

Wobus et al, 2017; Mills et al, 2018

Annual Average Streamflow in the United States, 1940–2014

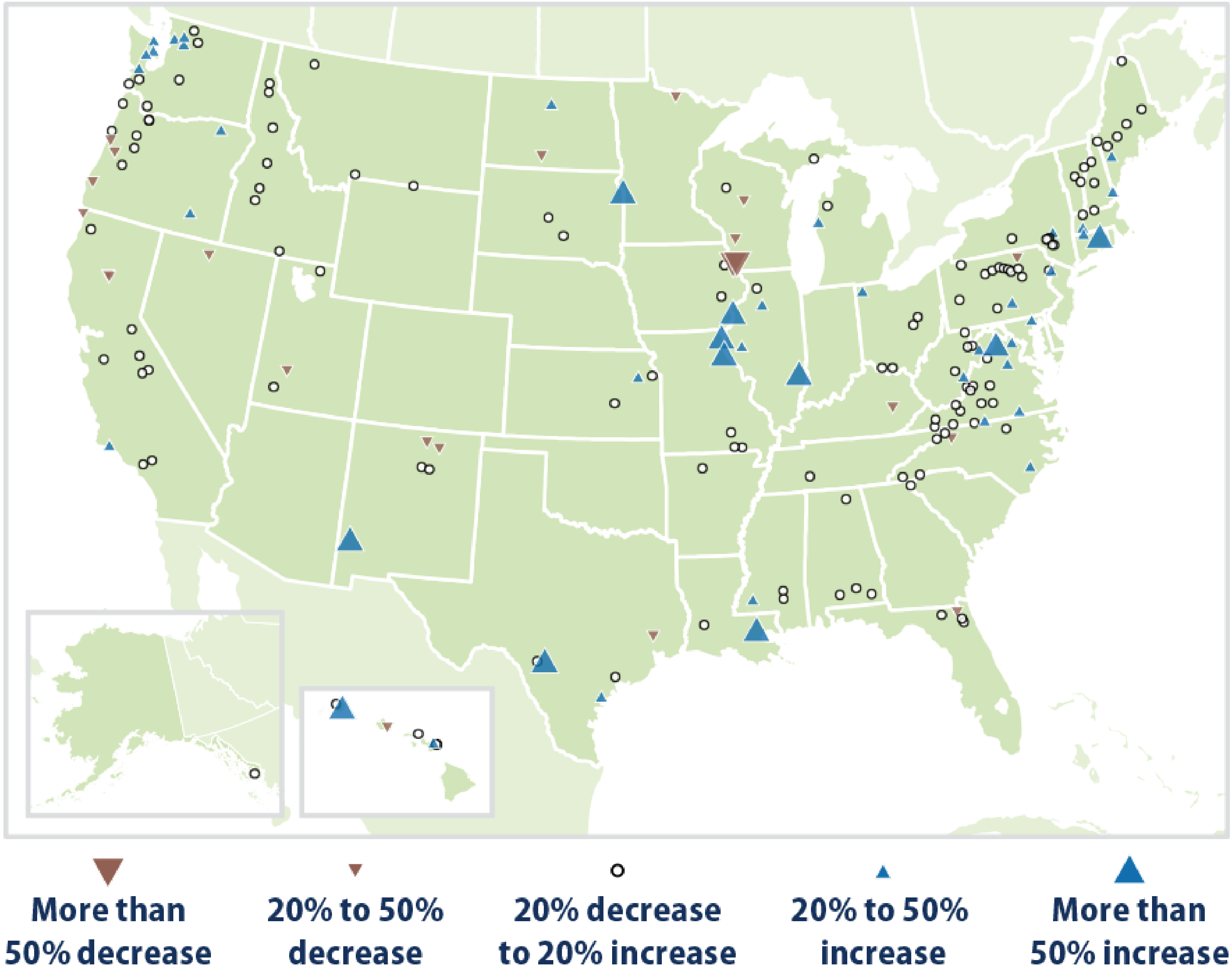


More than 50% decrease | 20% to 50% decrease | 20% decrease to 20% increase | 20% to 50% increase | More than 50% increase

Data source: USGS (U.S. Geological Survey). 2016. Analysis of data from the National Water Information System. Accessed May 2016.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

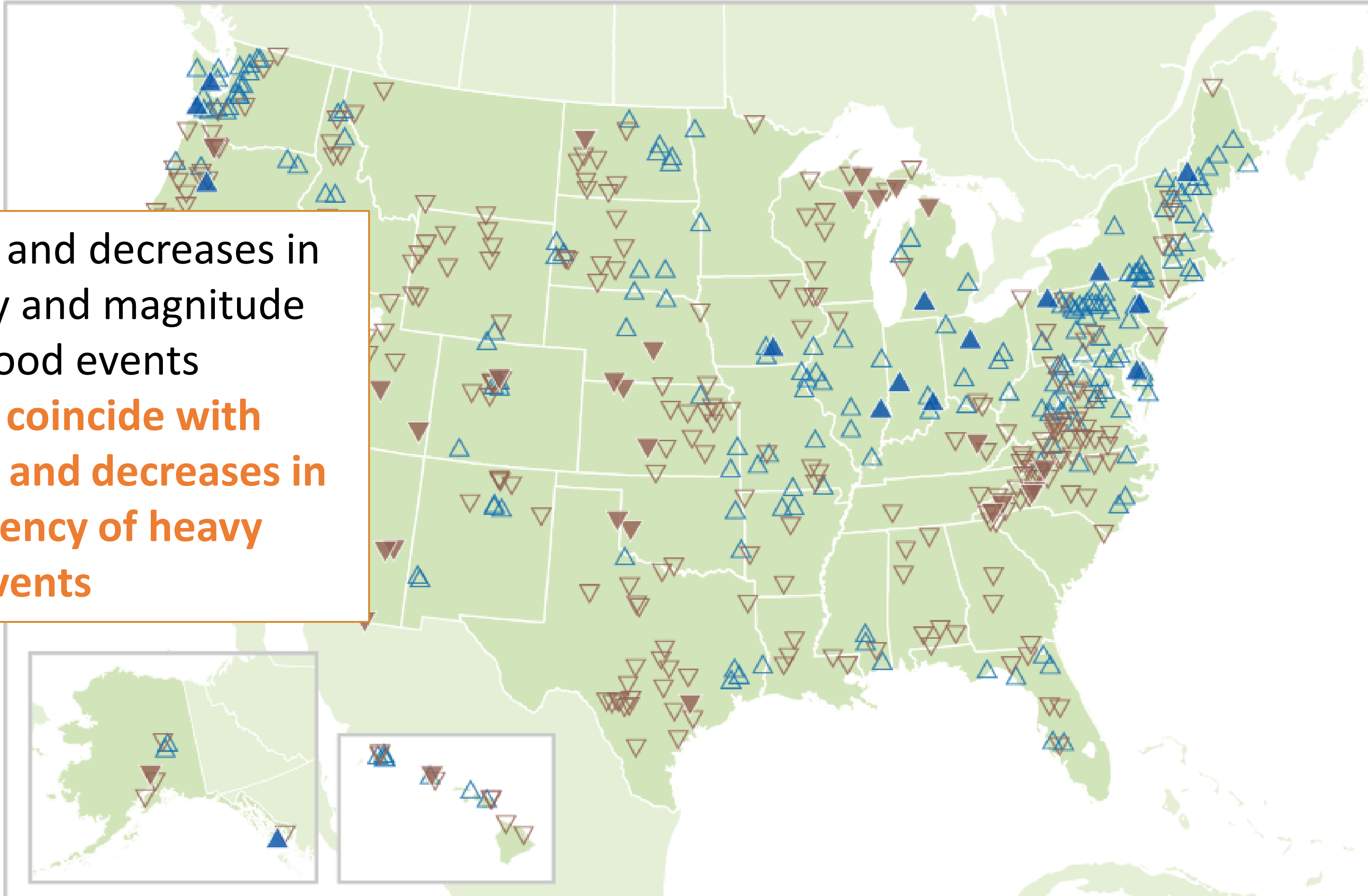
Three-Day High Streamflows in the United States, 1940–2014



Data source: USGS (U.S. Geological Survey). 2016. Analysis of data from the National Water Information System. Accessed May 2016.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Change in the Magnitude of River Flooding in the United States, 1965–2015



Increases and decreases in frequency and magnitude of river flood events **generally coincide with increases and decreases in the frequency of heavy rainfall events**

Significant decrease | Insignificant decrease | Insignificant increase | Significant increase

Data source: Slater, L., and G. Villarini. 2016 update and expansion to data originally published in: Mallakpour, I., G. Villarini. 2015. The changing nature of flooding across the central United States. Nature Climate Change 5:250–254.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Climate change and flooding

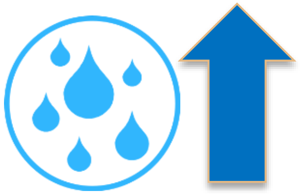
A changing climate… *Non stationary conditions*

- Warming temperatures
  - Earlier snowmelt in the spring
  - Storm systems generate more rain because warm air holds more moisture than cold air.
- Seasonal floods are expected to arrive earlier in the spring
- More heavy summer rainfall events

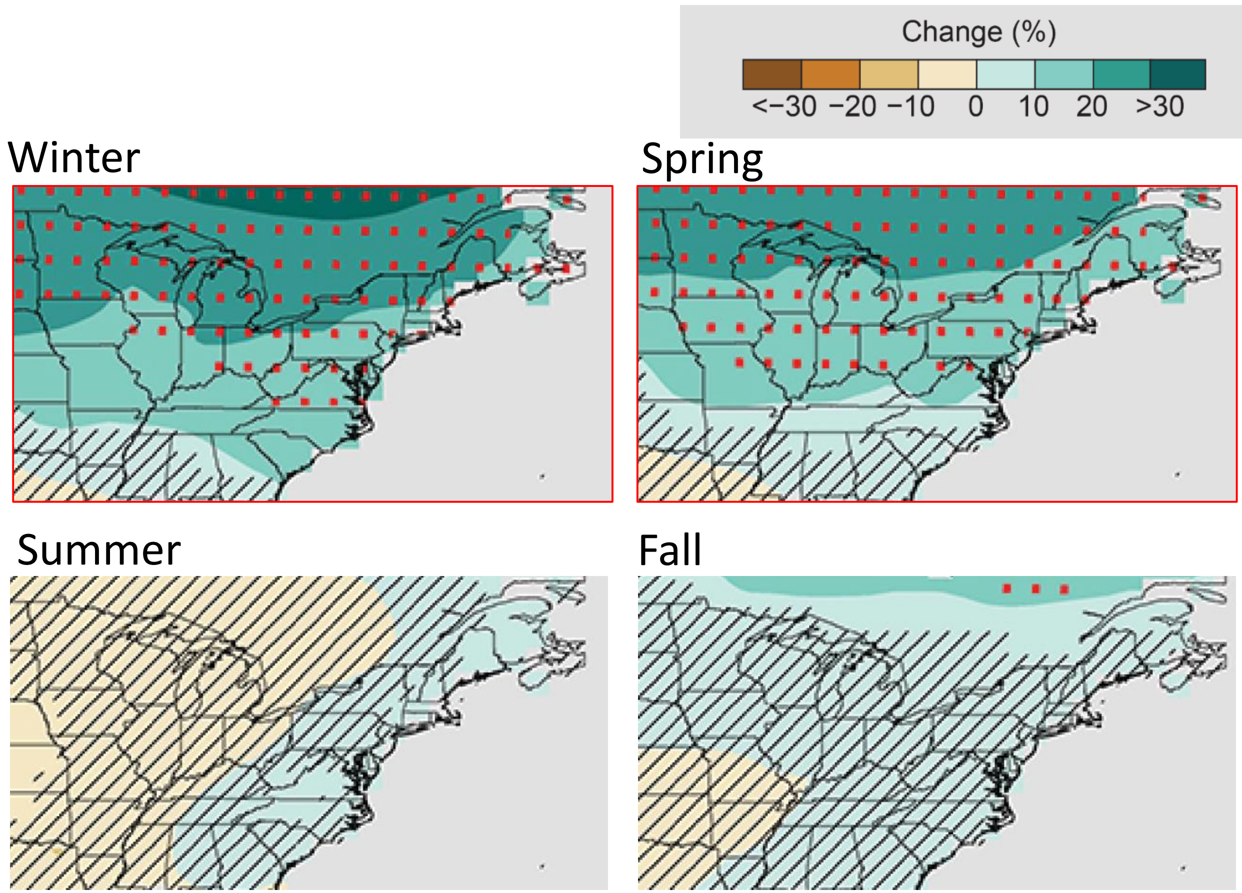
While no single storm or flood can be attributed directly to global warming, changing climate conditions are at least partly responsible for past trends and the increasing frequency of major flood events.

Take home Message: Reimagine “normal” storms, and “normal” flows.

Future Climate: Precipitation



More rain in winter and spring



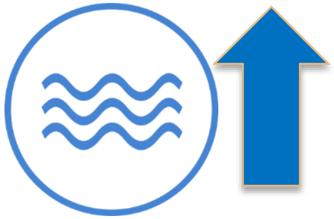
2070-2099 percent change relative to the 1976–2005 average. RCP8.5.
Stippling indicates that changes are assessed to be large compared to natural variations

High Certainty:

- More rainfall annually & some seasons
- Potential for more frequent & intense heavy rains
- Reduced snowpack, earlier melting

USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I* https://science2017.globalchange.gov/chapter/7/

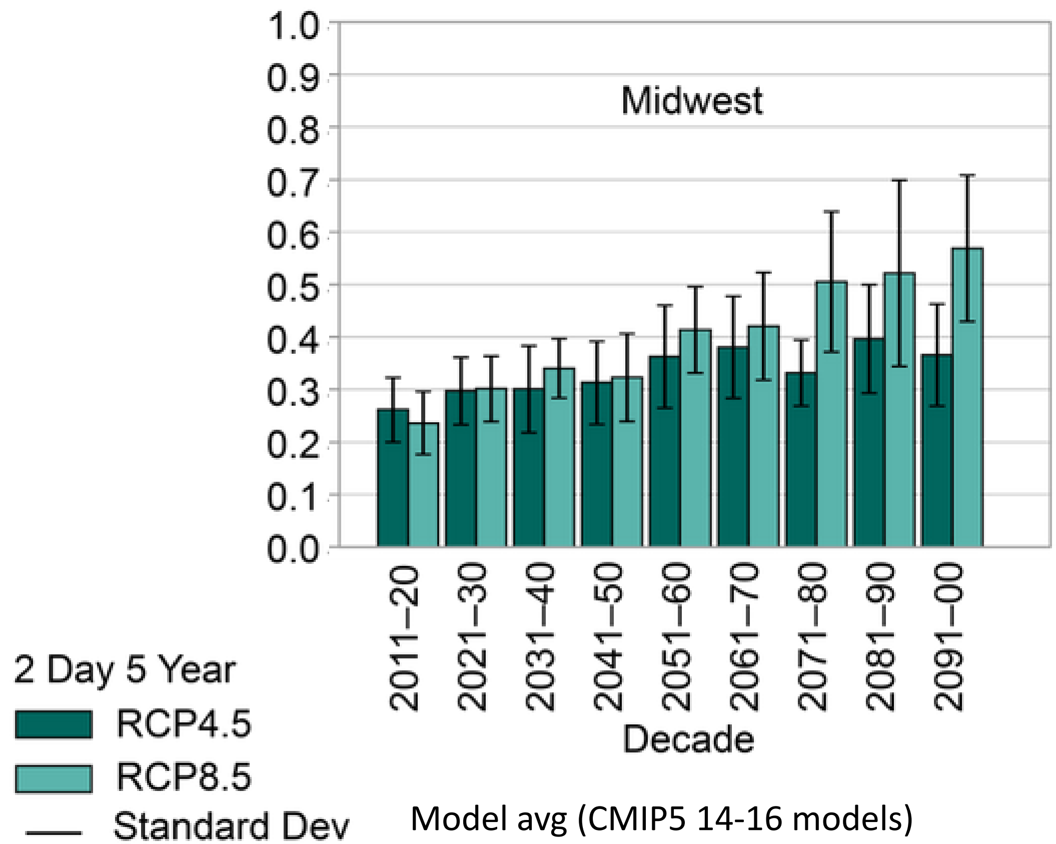
Future Climate: Increases in extreme events



Frequency of regional extreme precipitation events

- Sight increase in the very lightest precipitation days
- Large increase in the heaviest days
- "Uncertainty for each specific duration grows as the **return period increases**, specifically for short-duration storms." - **Sarhadi and Soulis, 2017). doi.org/10.1002/2016GL072201**

Heavy precipitation 2006–2100



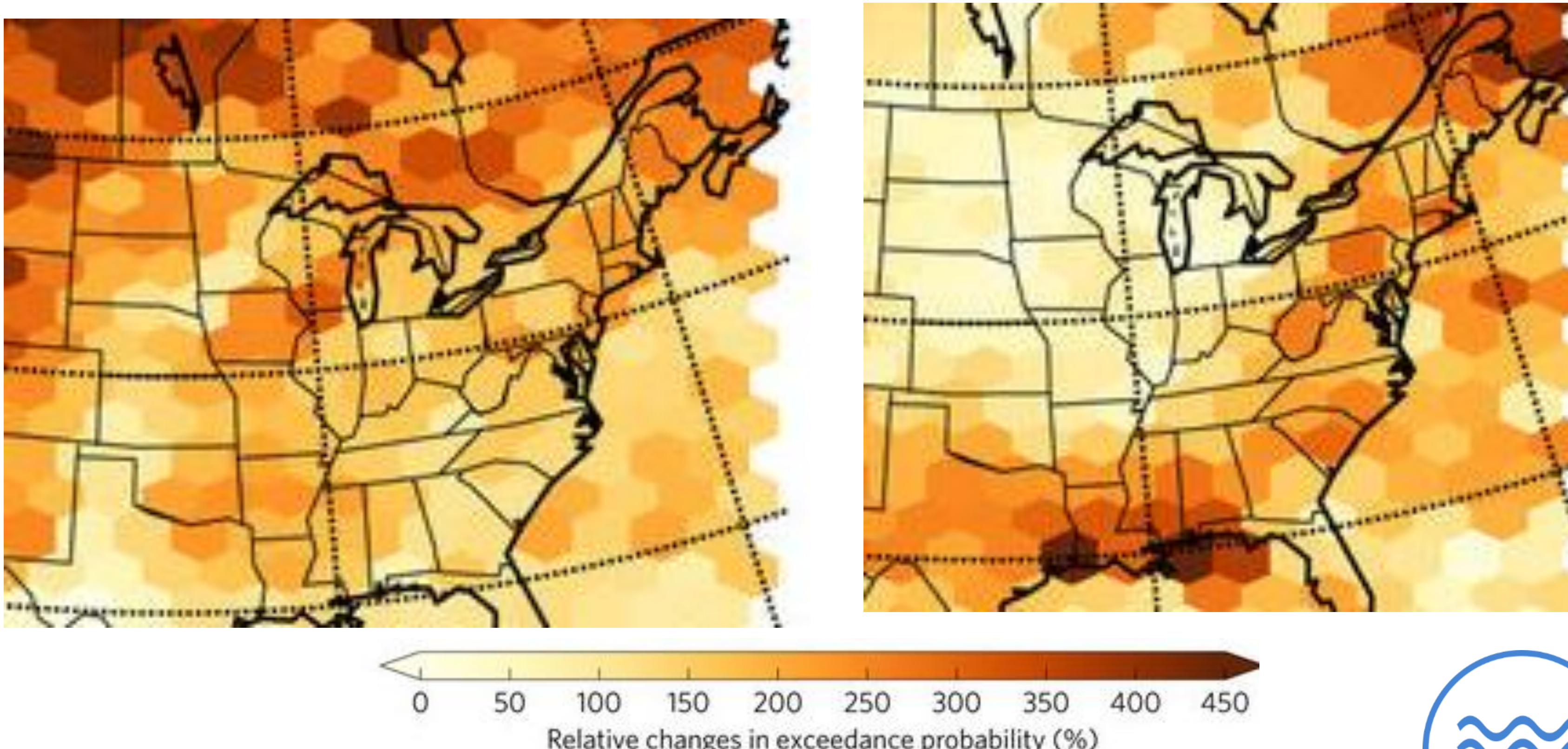
Model avg (CMIP5 14-16 models)

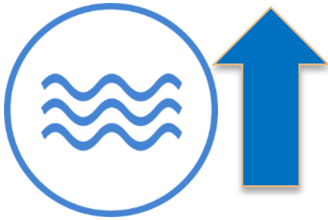
USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I* https://science2017.globalchange.gov/chapter/7/

Future Climate: Increases in extreme events

Frequency & intensity of hourly heavy precip. will increase 1-2 times

Winter (DJF) **Summer (JJA)**





Future increases in 99th% of <u>hourly</u> precipitation event intensities by 2100

Relative to January 2001 - 2013

Prein et al 2017. doi:10.1038/nclimate3168.

Streams change over time: Channel capacity

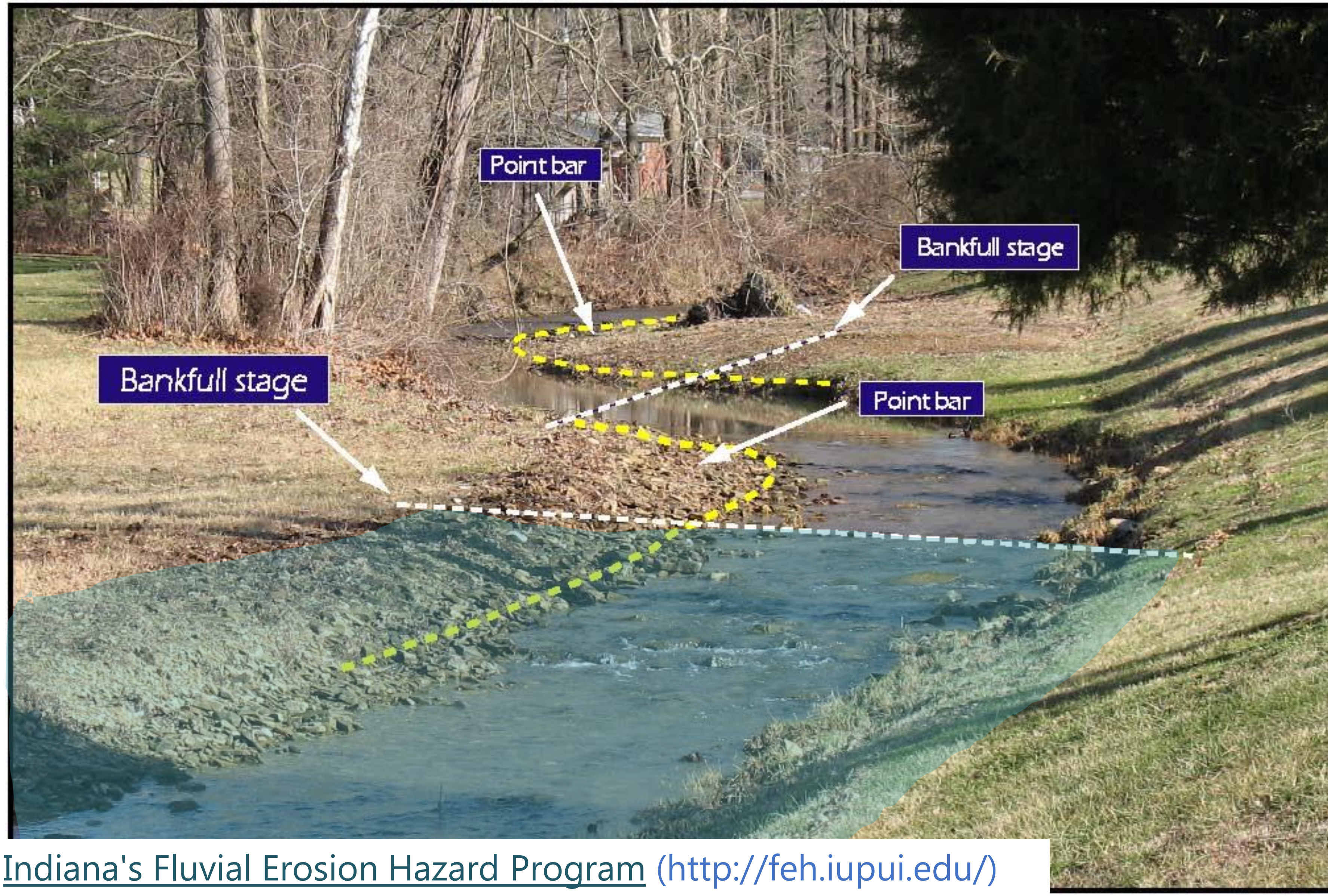
Recall Step 2: Unique Site characteristics

- Traditional hydrological modelling **assumes that the catchment does not change…**

- Understanding the **natural capacity** of your stream can reduce risks and mitigate infrastructure losses
  - Channel geometry (width, mean, depth, cross-sectional area) and discharge
  - Future changes in streamflow are expected to alter channel morphology

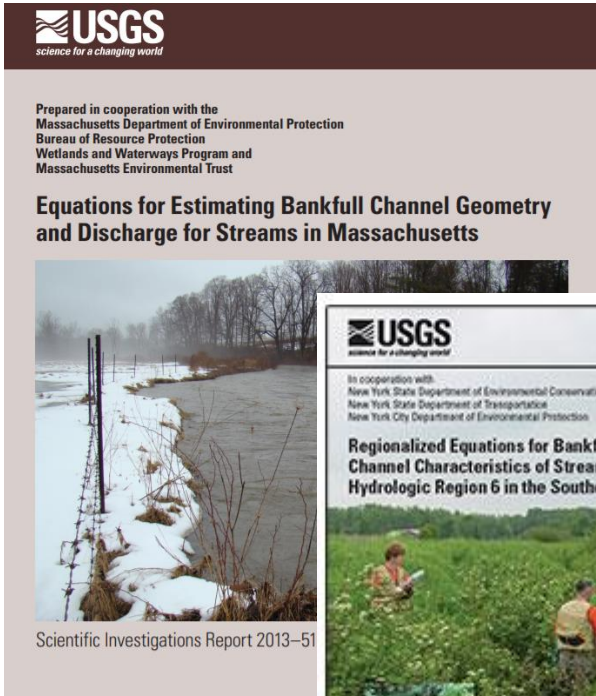
- **Bankfull discharge** is the streamflow that occurs when the stream fills its channel and any additional discharge will result in the stream overflowing its banks.
  - 1-2 year flow
  - Moves the most sediment over time and shapes the stream channel
  - "Channel forming flow"

Understanding local channel capacity can help managers recognize areas prone to natural stream-erosion



Indiana's Fluvial Erosion Hazard Program (http://feh.iupui.edu/)

Find #s based on current -


USGS
science for a changing world

Prepared in cooperation with the
Massachusetts Department of Environmental Protection
Bureau of Resource Protection
Wetlands and Waterways Program and
Massachusetts Environmental Trust

Equations for Estimating Bankfull Channel Geometry and Discharge for Streams in Massachusetts

Scientific Investigations Report 2013–51


USGS
science for a changing world

In cooperation with
New York State Department of Environmental Conservation
New York State Department of Transportation
New York City Department of Environmental Protection

Regionalized Equations for Bankfull Discharge and Channel Characteristics of Streams in New York State: Hydrologic Region 6 in the Southern Tier of New York

Chequamegon-Nicolet National Forest: Marengo and Twentymile Creek Watersheds

forestadaptation.org/cnnf-water

Find resources to help incorporate climate change into future infrastructure decisions

"If culverts built today cannot accommodate future channel conditions, then climate change could indirectly create barriers ..and consequent loss habitats"
Wilhere et al 2017

ELSEVIER

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Research paper

Incorporating climate change into culvert design in Washington State, USA

George F. Wilhere[a,*], Jane B. Atha[a], Timothy Quinn[a], Ingrid Tohver[b], Lynn Helbrecht[a]

[a] Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA, 98501, USA
[b] Climate Impacts Group, University of Washington, John Wallace Hall, 3737 Brooklyn Ave. NE, Seattle, WA, 98105, USA

https://doi.org/10.1016/j.ecoleng.2017.04.009

Hydrologic Frequency Terminology

100-Year –

Event that occurs on average every 100 years

- Average Recurrence Interval
- Commonly used term, included in NOAA Atlas 14

1% Annual Chance –

Event that has a 1% chance of being exceeded in any year

- Average Exceedance Probability (AEP)
- Common term used to delineate special flood hazard areas in federal flood insurance rate maps
- FEMA & USGS use this term

1% AEP flood: With observed or modeled data, a 1% AEP flood defines both a flow volume (E.g. 10,000 cubic feet per second) and an expected return interval or frequency for that flow volume (on average, once every 100-y)

Recurrence intervals and probabilities of occurrences

Recurrence interval, in years	Probability of occurrence in any given year	Percent chance of occurrence in any given year
100	1 in 100	1
50	1 in 50	2
25	1 in 25	4
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

Does a 100-year storm always cause a 100-year flood?

No. Several factors can independently influence the cause-and-effect relation between rainfall and streamflow.

- **Extent of rainfall in the watershed**
- **Soil saturation before the storm**
- **Watershed size and duration of the storm**

Learn more → https://water.usgs.gov/edu/100yearflood.html

Predicting future flood risks in the 100-y floodplain

Climate change impacts on flood risk and asset damages within mapped 100-year floodplains of the contiguous United States

Cameron Wobus[1], Ethan Gutmann[2], Russell Jones[1], Matthew Rissing[1], Naoki Mizukami[2], Mark Lorie[1], Hardee Mahoney[1], Andrew W. Wood[2], David Mills[1], and Jeremy Martinich[3]

[1]Abt Associates, 1881 Ninth Street, Suite 201, Boulder, CO 80302, USA
[2]National Center for Atmospheric Research, 3450 Mitchell Lane, Boulder, CO 80301, USA
[3]US Environmental Protection Agency, Climate Change Division, 1200 Pennsylvania Ave NW, Washington, DC 20460, USA

- Used National Flood Insurance Program (NFIP) – geospatial data on 100yr floodplains - "regulatory floodplain" that requires flood insurance

Modeling approach:

- Modeled both the **frequency**, and **magnitude** of high flow events with a 1% annual exceedance probability (AEP) threshold by 2100
- Quantify damages from "100-year" (1% annual exceedance probability, or AEP) floods nationwide
  - Only modeled 100-yr – yet, larger floods will be more damaging
- 1,000 model runs for high emissions (RCP 8.5), low (RCP 4.5) to develop trends

https://doi.org/10.5194/nhess-17-2199-2017

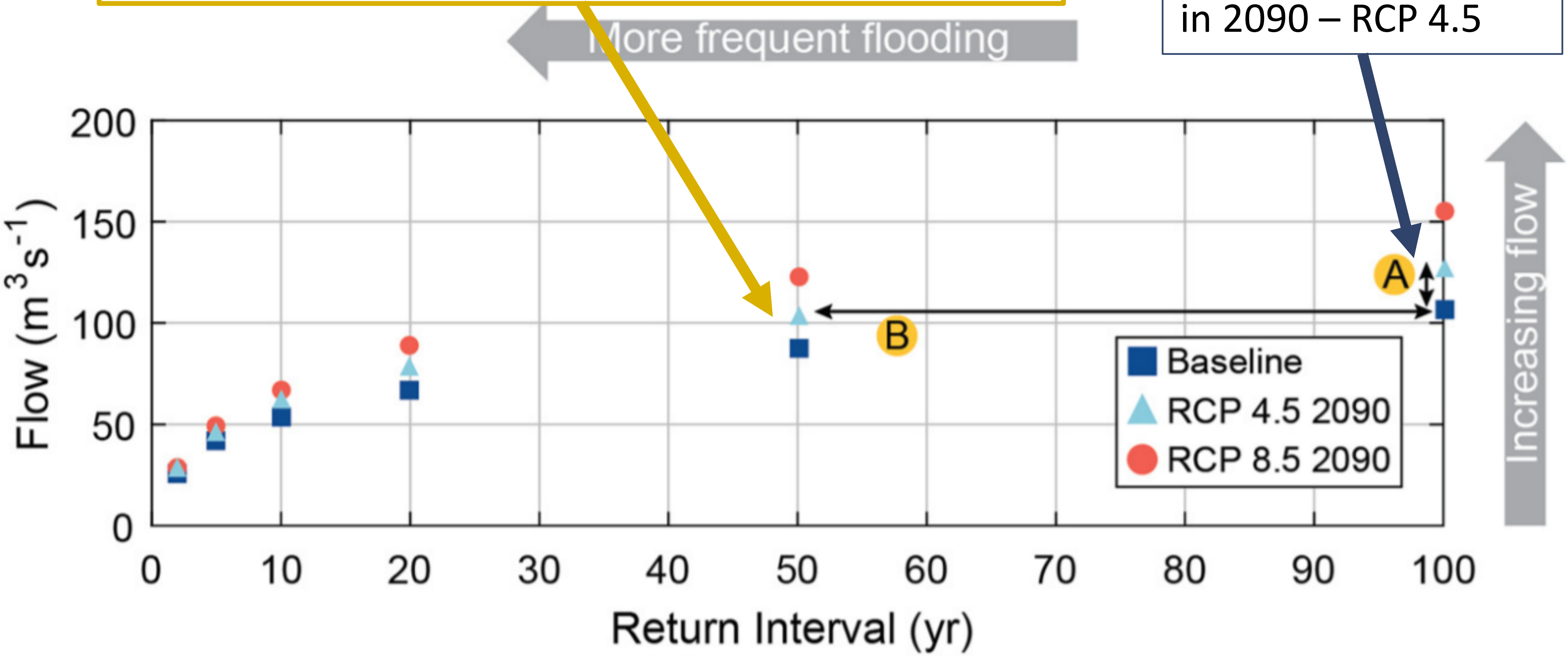
Wobus et al, 2017

Bigger flow volume for more frequent events

The 100 m3s-1 flow baseline 1% AEP flood **becomes twice** as frequent by end of century (shift from 100-y to 50-y average return interval – RCP 4.5)

Larger flow volumes

100-y return interval [1% AEP event] **becomes 25% larger** in 2090 – RCP 4.5

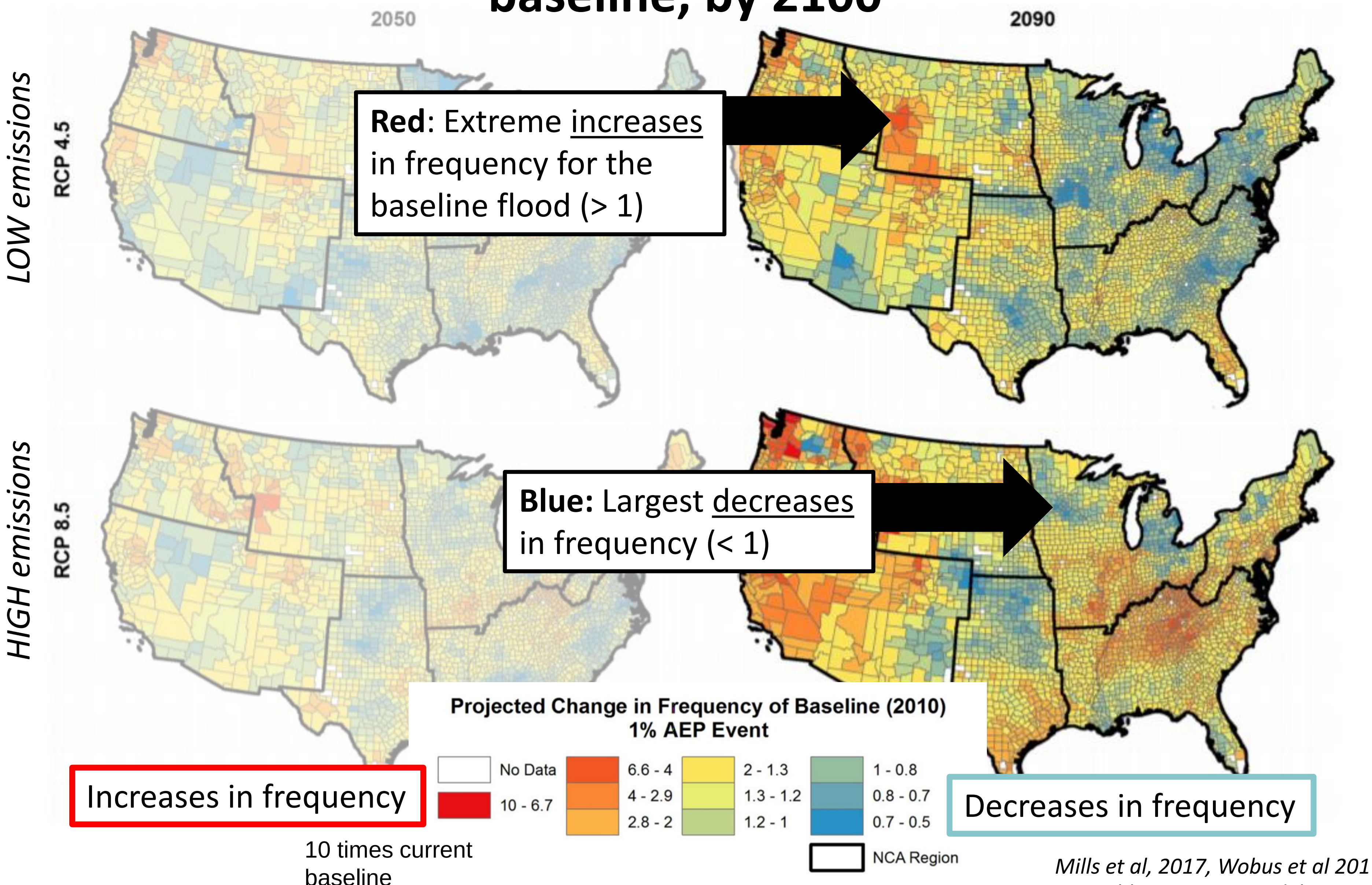


**Example of change in inland flooding for one river reach.*

- Modeled future flows
- Found flow and flood magnitude increased in some cases.

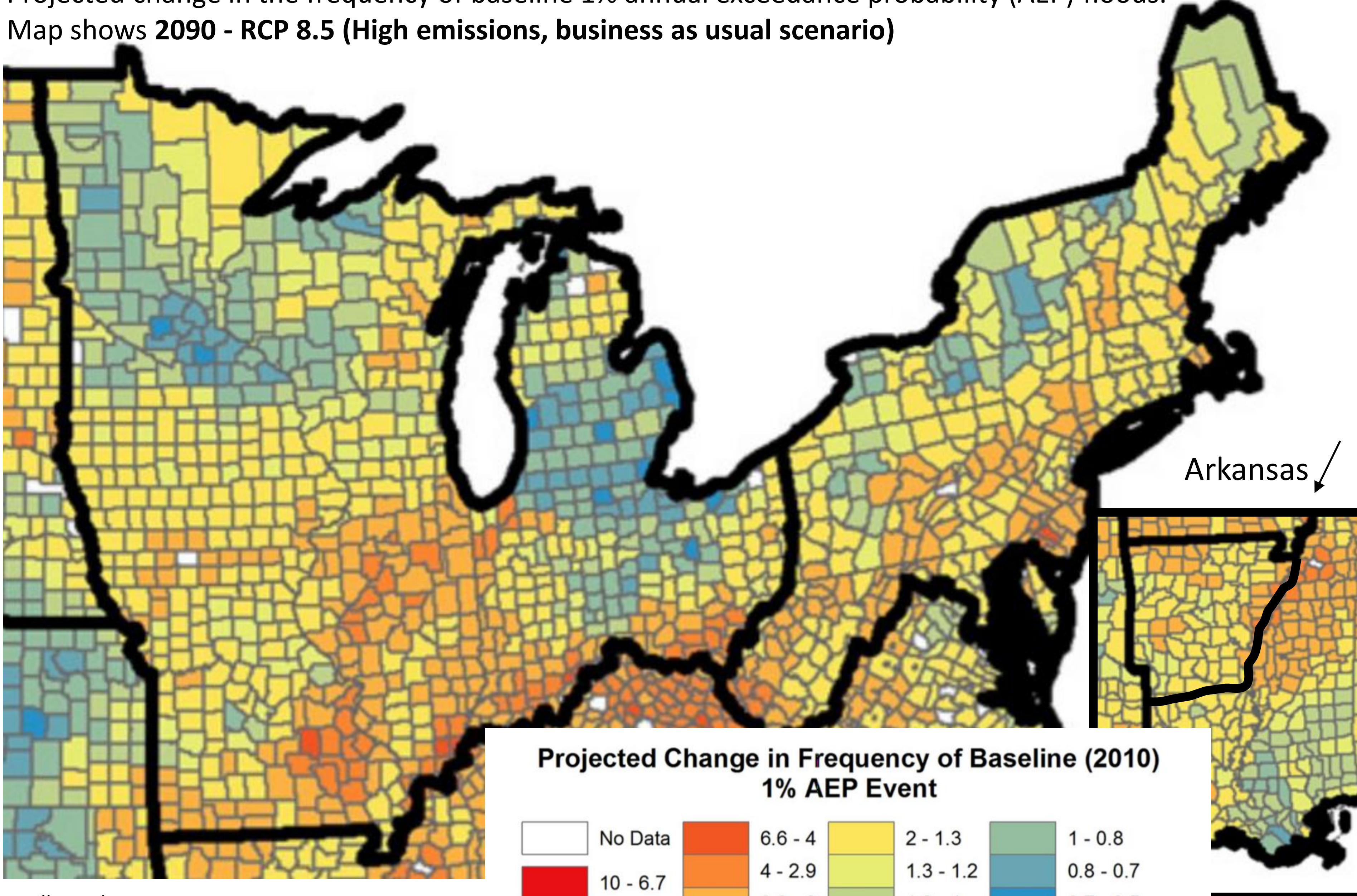
Mills et al, 2017, Wobus et al 2017
Ensemble mean, 29 models

Change in frequency of annual 1% (100 year) event from baseline, by 2100



Mills et al, 2017, Wobus et al 2017
Ensemble mean, 29 models

Projected change in the frequency of baseline 1% annual exceedance probability (AEP) floods.
Map shows **2090 - RCP 8.5 (High emissions, business as usual scenario)**



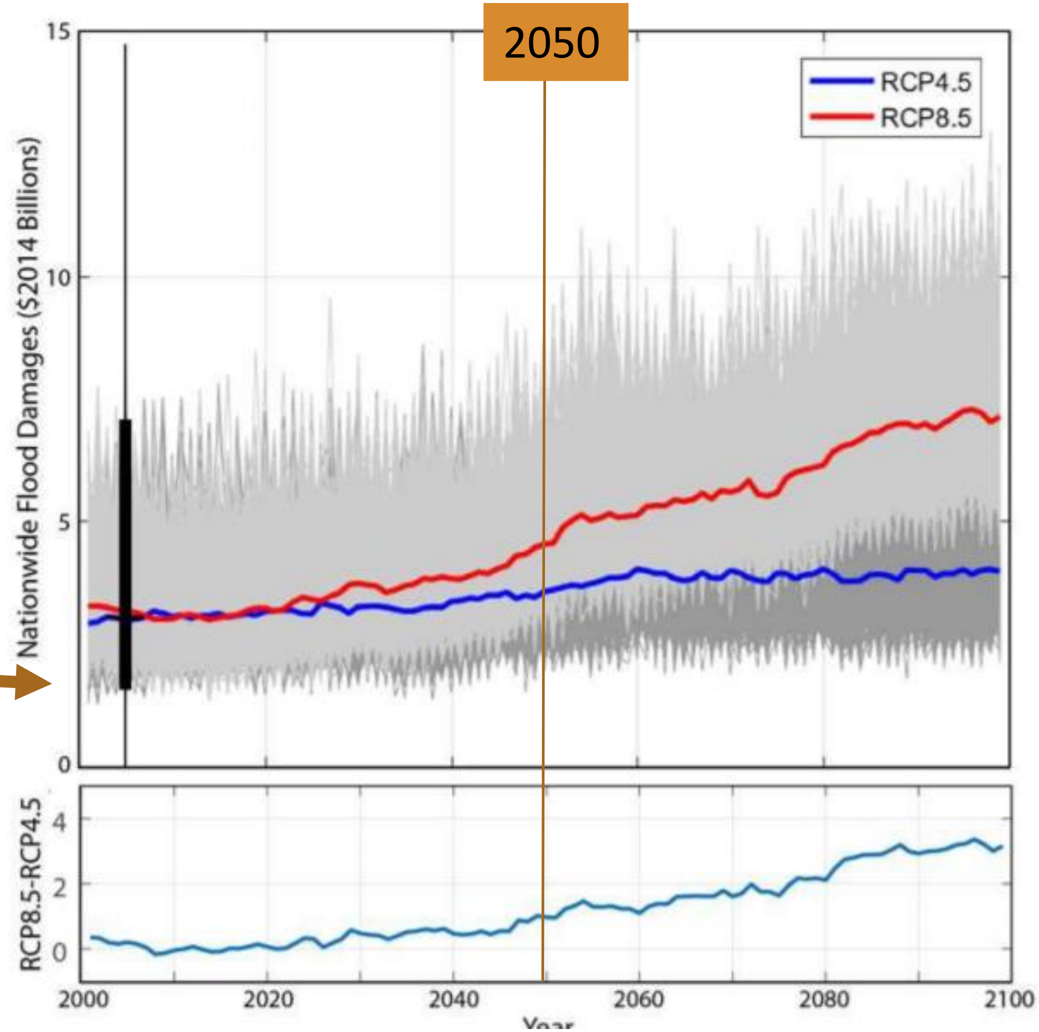
Mills et al, 2017,
Wobus et al 2017
Ensemble mean,
29 models

Increases in frequency (>1) ↔ Decreases in frequency (<1)

Projected Flood damages ($ cost)

(Wobus et al, 2017)

- <u>High emissions:</u> Flood damages exceed low emissions by ~$3B/year in 2100
- Gray lines show results from 1,000 simulations for RCP 4.5 and RCP 8.5
- Emissions scenarios diverge primarily after 2050



**in 2014 dollars*

Wobus et al, 2017

Stream channels are dynamic, and change over time…

Recall Step 2: Unique Site characteristics

- Any changes in a river channel's capacity (i.e., the depth, width, and roughness) may significantly **alter the frequency of local flooding above set flood levels** (even in the absence of any changes in discharge) (Slater et al, 2015)
  - Stream channels evolve, aggrade, degrade, narrow, widen.

- Particularly in locations that have experienced major changes in channel capacity due to urbanization or water regulation

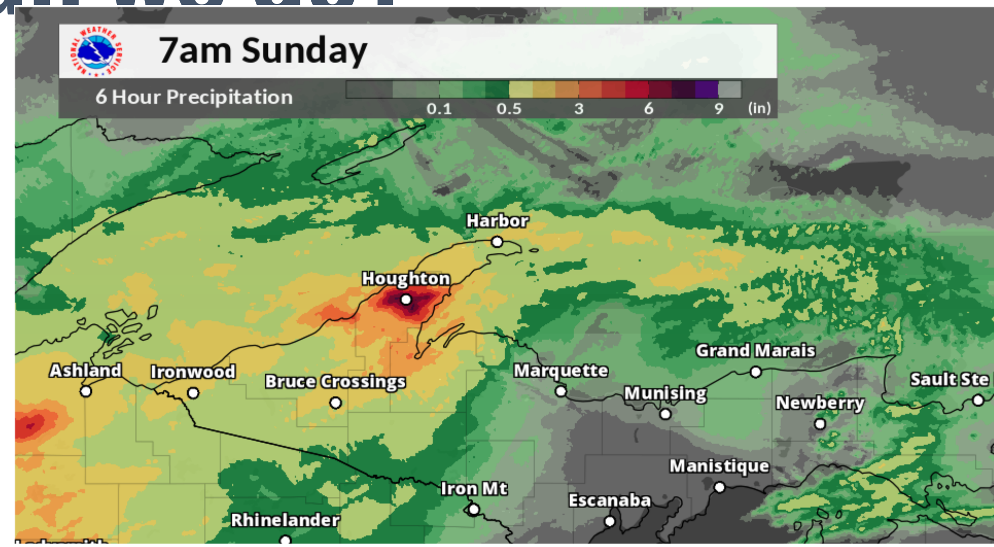
Image: Cuyahoga Soil & Water Conservation District

Read more on this concept:
Slater, L. J., M. B. Singer, and J. W. Kirchner (2015), Hydrologic versus geomorphic drivers of trends in flood hazard, Geophys. Res. Lett., 42, 370–376, doi:10.1002/2014GL062482.

What can we do?

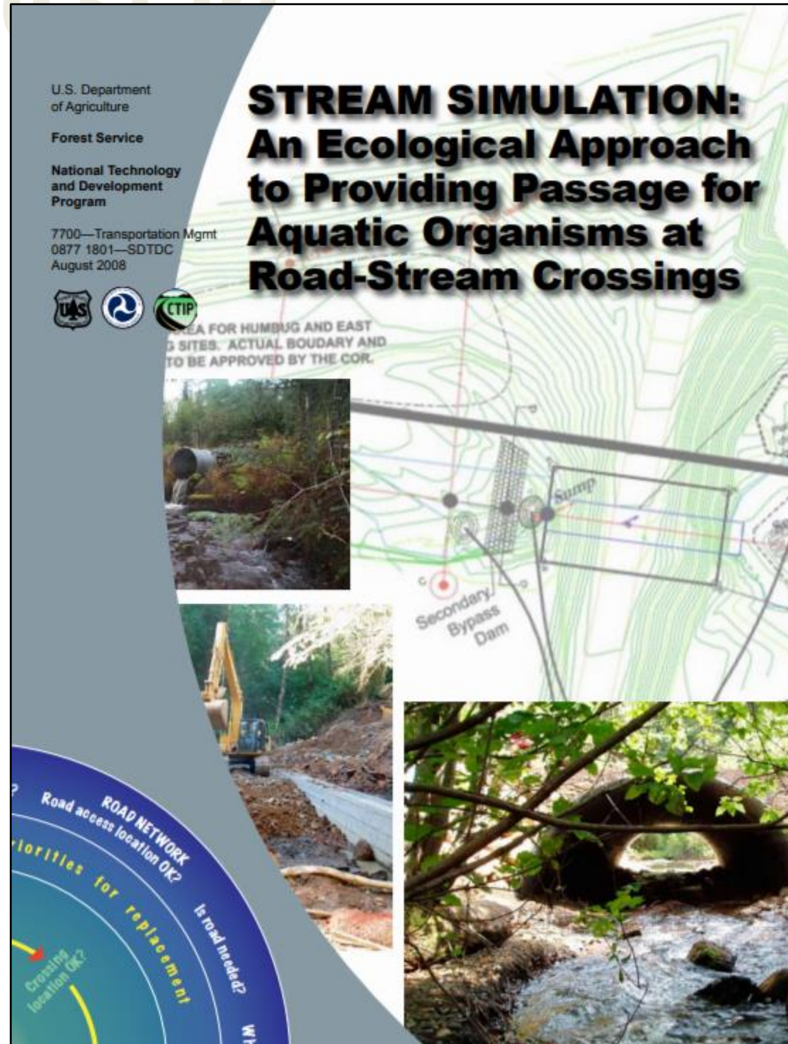
- ~~Leave?~~
- ~~Pretend it's not happening?~~
- Embrace uncertainty

- Reframe our idea of "future conditions"
- Get out in front and address the problem in planning… now



Where to start

- Understand the channel capacity at your site
- Learn how to incorporate ecological considerations into road-stream crossing designs to accommodate changing hydrology

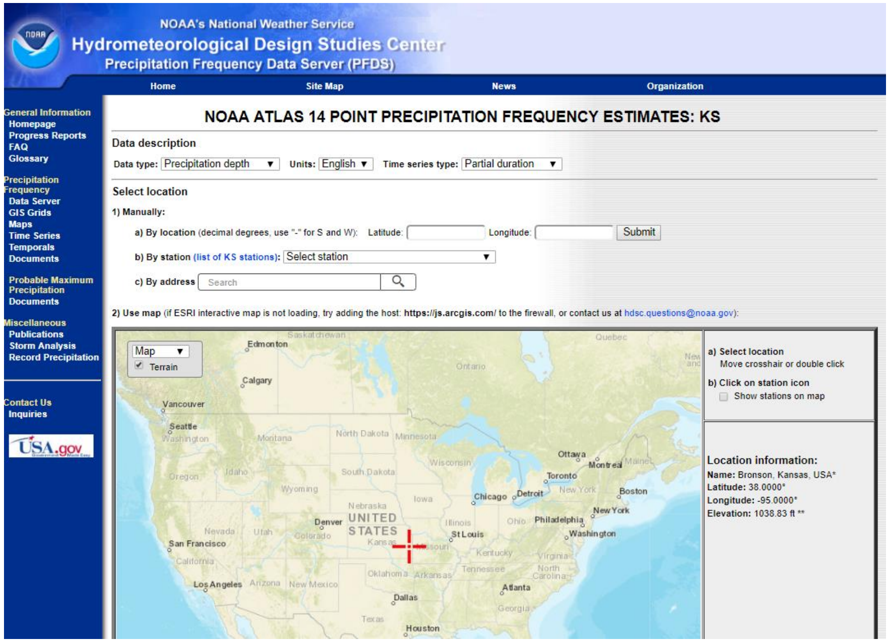


USDA FS Stream Simulation tool

https://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/hi_res/%20FullDoc.pdf

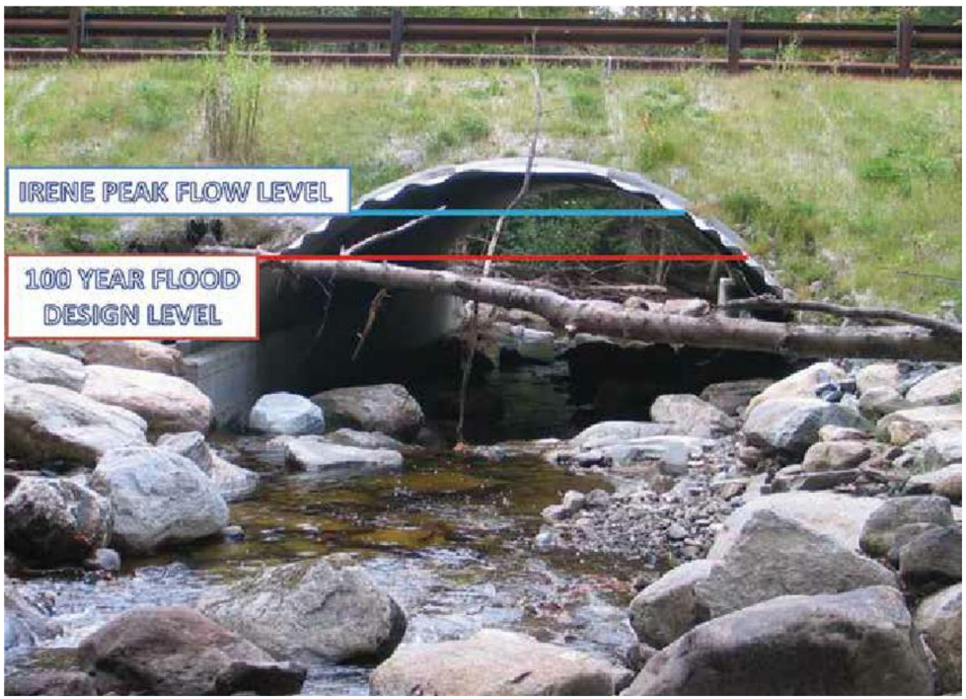
Where to start: Evaluate storm frequency – tool: NOAA Atlas 14

- NOAA has updated precipitation frequency (PF) estimates for the U.S *(Pmin, Pmax, Pavg)*
- <u>Updates are noteworthy</u>:
    - **Atlas 14 includes most recent 30 years of precipitation data**
    - **And includes more weather stations than previous efforts.**
- Gridded precipitation-frequency estimates at 30 arc-seconds resolution
- Provides estimates of 500-yr and 1000-yr events



<u>http://hdsc.nws.noaa.gov/hdsc/pfds/</u>

Where to start: Evaluate storm frequency - NOAA Atlas 14



- **Atlas 14 can replace older technical reports when making infrastructure sizing** and **design decisions for conveyance and detention.**

- Likely - Precipitation Frequency estimates used for stormwater management **do not accurately reflect the depths falling during precipitation events –**

  - Climate change projections indicate rainfall volumes will continue to increase over the next 50 years

  - Start with Atlas 14, incorporate other considerations.

http://hdsc.nws.noaa.gov/hdsc/pfds/

Expected "normal" rainfall amount

Case study: Ann Arbor, MI
(Older technical report vs. Atlas 14)

Bulletin 71/Atlas 14
[% change]

	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
1-hr	0.88/0.969 [10%]	1.06/1.14 [8%]	1.29/1.44 [12%]	1.47/1.70 [16%]	1.69/2.07 [22%]	1.87/2.38 [27%]	2.05/2.69 [31%]
12-hr	1.63/1.82 [12%]	1.97/2.06 [5%]	2.39/2.50 [5%]	2.72/2.90 [7%]	3.13/3.54 [13%]	3.46/4.09 [18%]	3.79/4.68 [23%]
24-hr	1.87/2.09 [12%]	2.26/2.35 [4%]	2.75/2.83 [3%]	3.13/3.26 [9%]	3.60/3.93 [9%]	3.98/4.50 [13%]	4.36/5.11 [17%]

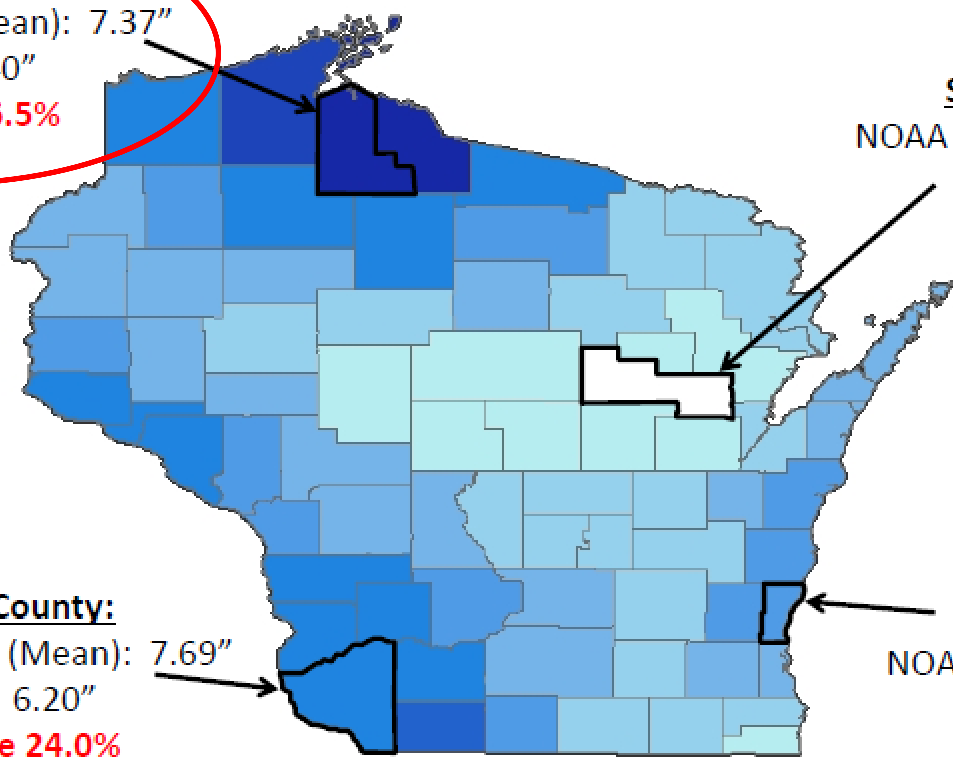
Atlas 14 prediction: Changes storm estimates

Huron River Watershed – Stormwater Guide
https://www.hrwc.org/wp-content/uploads/2016/02/Stormwater-and-Climate-Guide-1.pdf

NRCS NOAA Atlas 14 Versus TP40 Precipitation Depths

100-Yr, 24-Hr Precipitation Depths
Percent Change From TP40 to NOAA Atlas 14 (Mean)

Ashland County:
NOAA Atlas 14 (Mean): 7.37"
TP40: 5.40"
Increase 36.5%



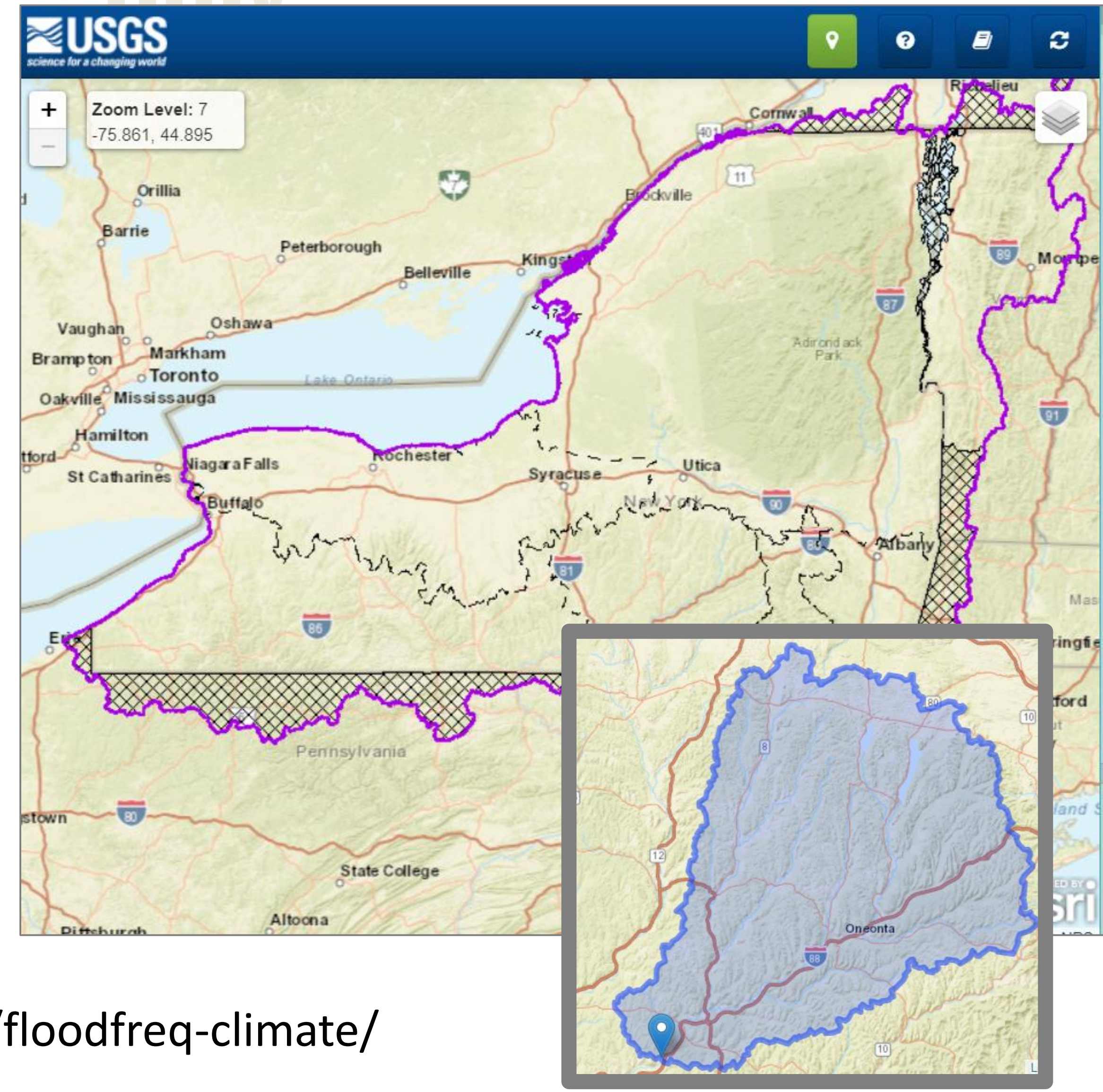
Shawano County:
NOAA Atlas 14 (Mean): 5.40"
TP40: 5.40"
No Change

Grant County:
NOAA Atlas 14 (Mean): 7.69"
TP40: 6.20"
Increase 24.0%

Ozaukee County:
NOAA Atlas 14 (Mean): 6.38"
TP40: 5.40"
Increase 18.1%

Tool: USGS Future Flow – NY state only

- Get future flow predictions for your watershed
- Flood regressions and climate change scenarios – future peak flows
- Estimate flows (cfs, and % change)



https://ny.water.usgs.gov/maps/floodfreq-climate/

To-do list for next week:

- Complete **Step 5:** Monitor and evaluate effectiveness
- Complete the **Homework** section after Step 5
- Recommended readings:
  - Roman et al. 2017
  - Janowiak et al. 2017
- Come to Session 6 (Tuesday, December 11) ready to discuss your monitoring!

Thanks everyone!

Troubleshooting? Stay on the line.