Green Infrastructure Champions Program

This program is partially funded by the Rutgers New Jersey Agricultural Experiment Station, The Geraldine R. Dodge Foundation, NJ Sea Grant Consortium, The William Penn Foundation and is a collaboration of the Rutgers Cooperative Extension Water Resources Program and the Green Infrastructure Subcommittee of Jersey Water Works.

RUTGERS
New Jersey Agricultural Experiment Station

Sea Grant
NJ Sea Grant Consortium

Please enter your full name and affiliation in the chat. This is how will take attendance.

The Geraldine R. DODGE FOUNDATION
IMAGINE A BETTER NEW JERSEY

JERSEY WATER WORKS
Smart infrastructure. Strong communities.

WILLIAM PENN FOUNDATION

Green Infrastructure Champion Training: Part 10

"Using Green Infrastructure to Promote Climate Resiliency"

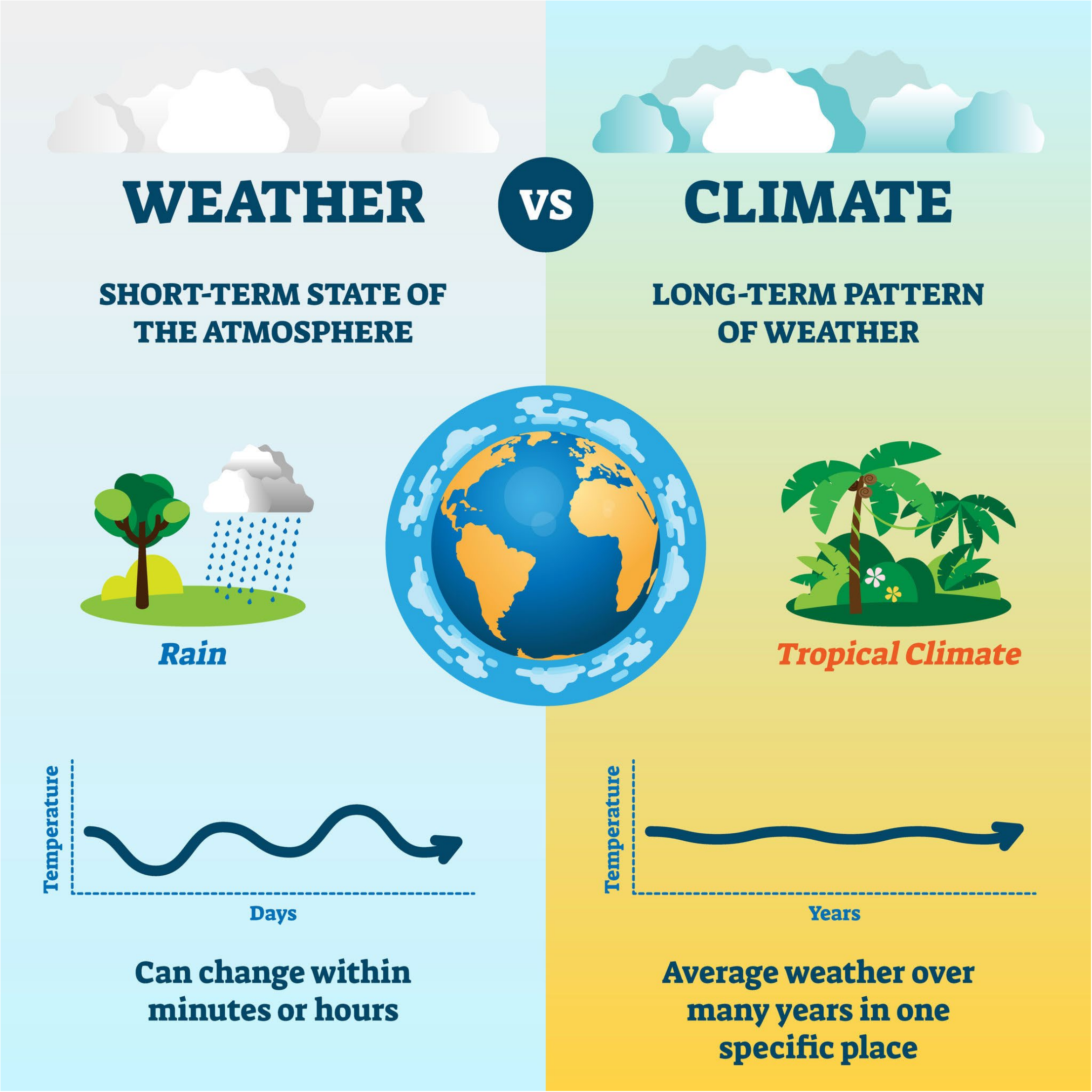
May 20, 2022
Virtual Class

Rutgers Cooperative Extension Water Resources Program
Cody Obropta, P.E.

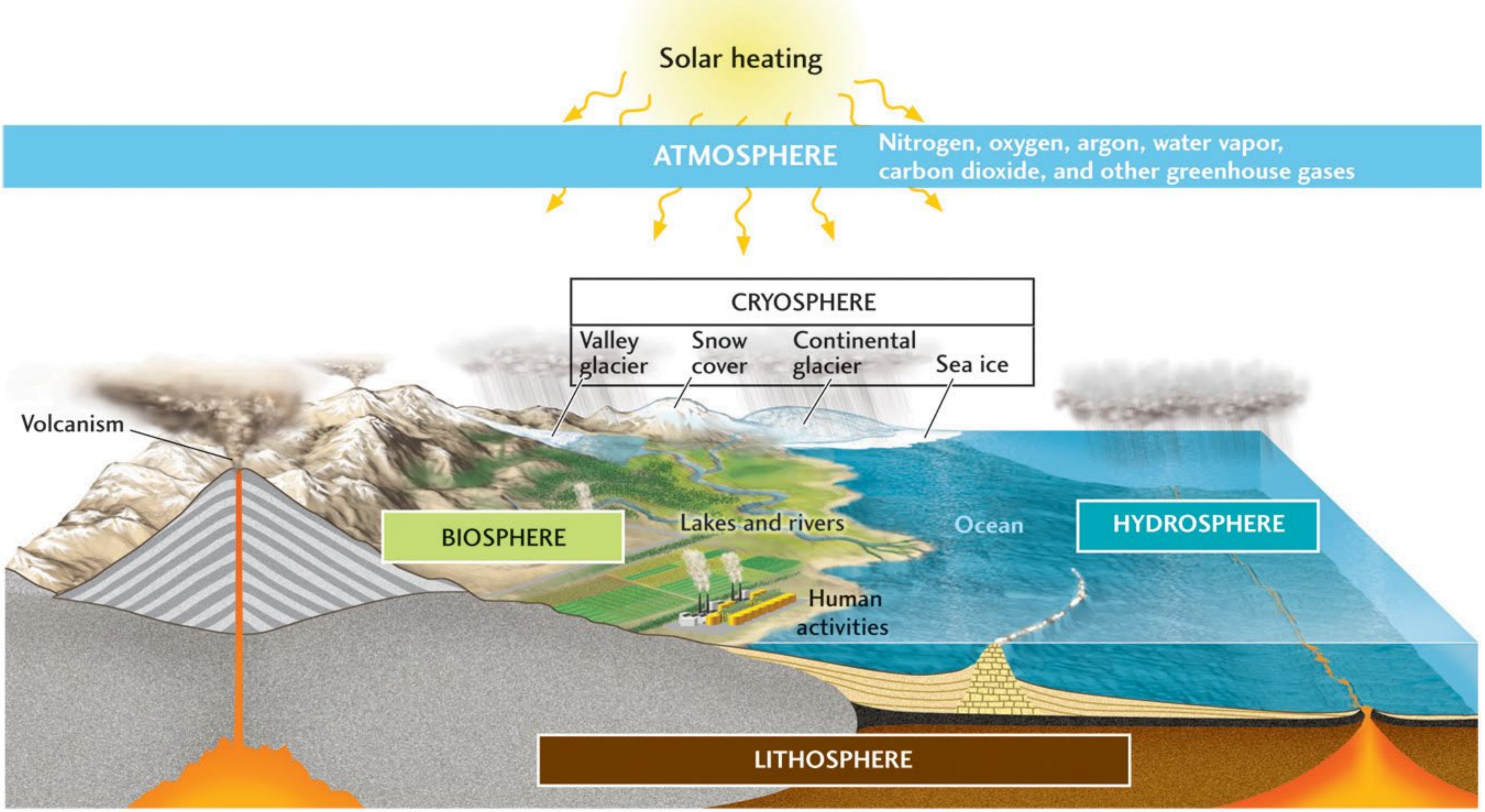
RUTGERS
New Jersey Agricultural Experiment Station

Part I: What is Climate?

The difference between weather and climate:



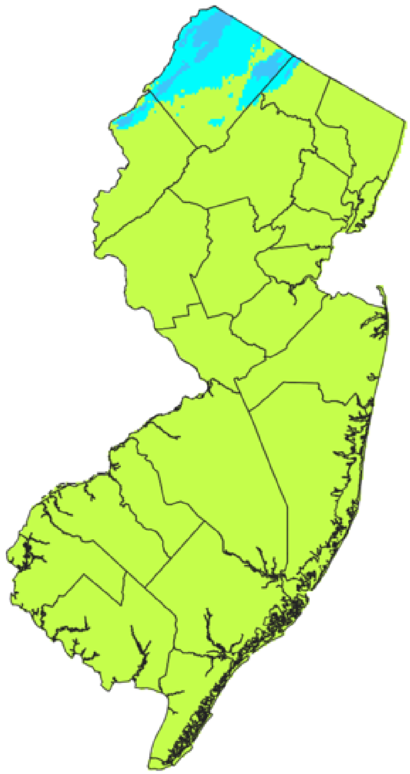
The Earth's Climate



- The climate includes many components of the Earth's system and interactions between them.

New Jersey's Climate

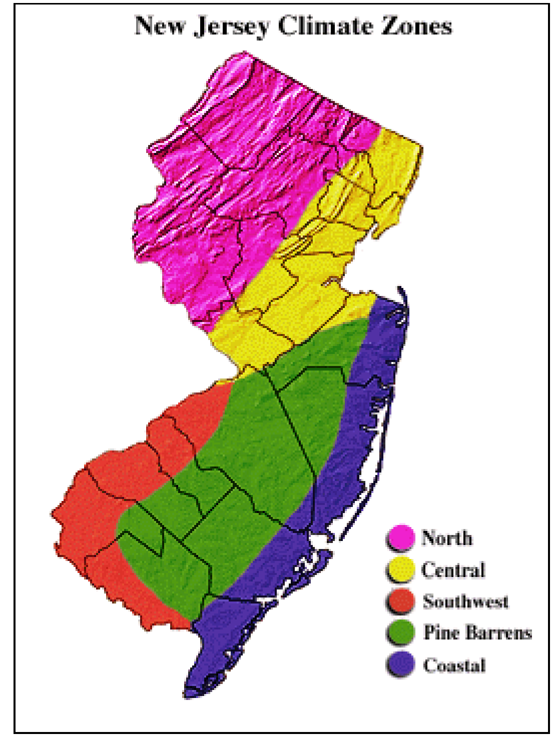
Köppen Climate Types of New Jersey



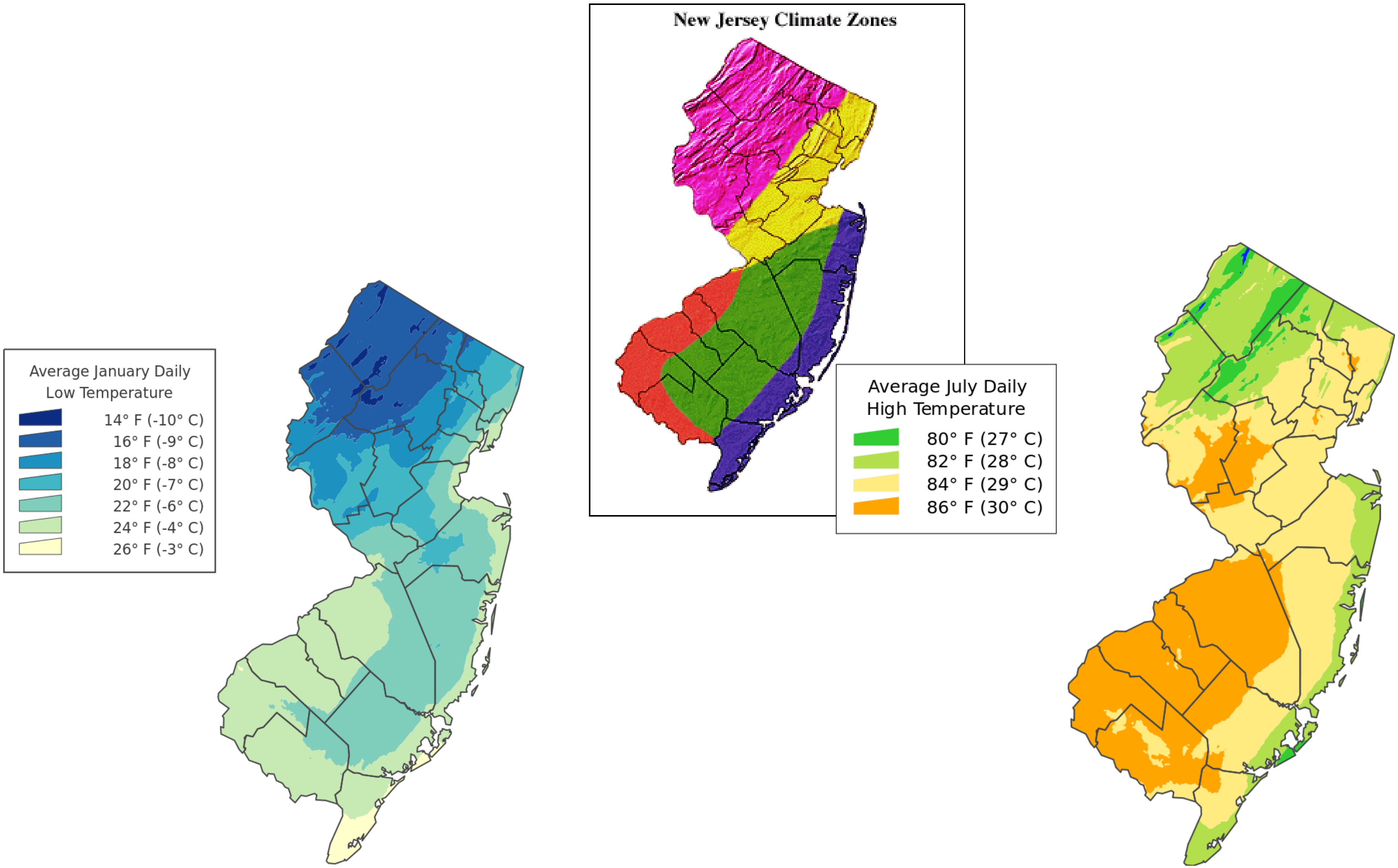
Köppen Climate Type

- Cfa (Humid subtropical)
- Dfb (Warm-summer humid continental)
- Dfa (Hot-summer humid continental)

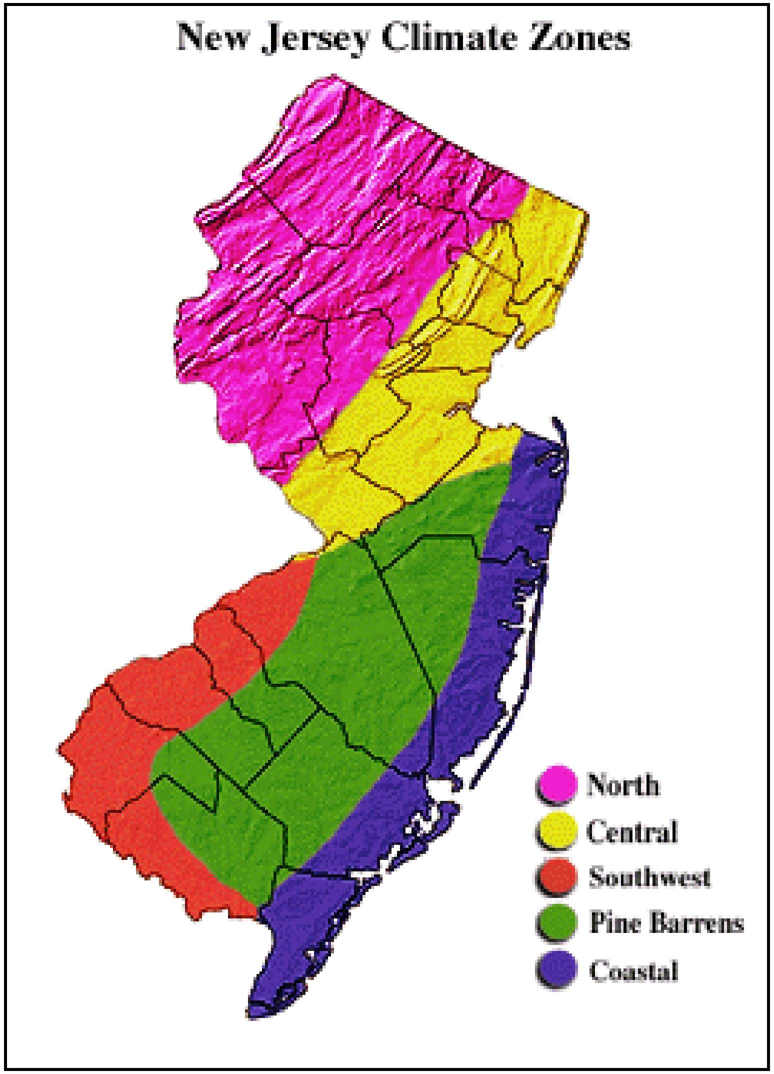
Data sources: 1991-2020 climate normals from PRISM Climate Group, Oregon State University, https://prism.oregonstate.edu; Outline map from US Census Bureau



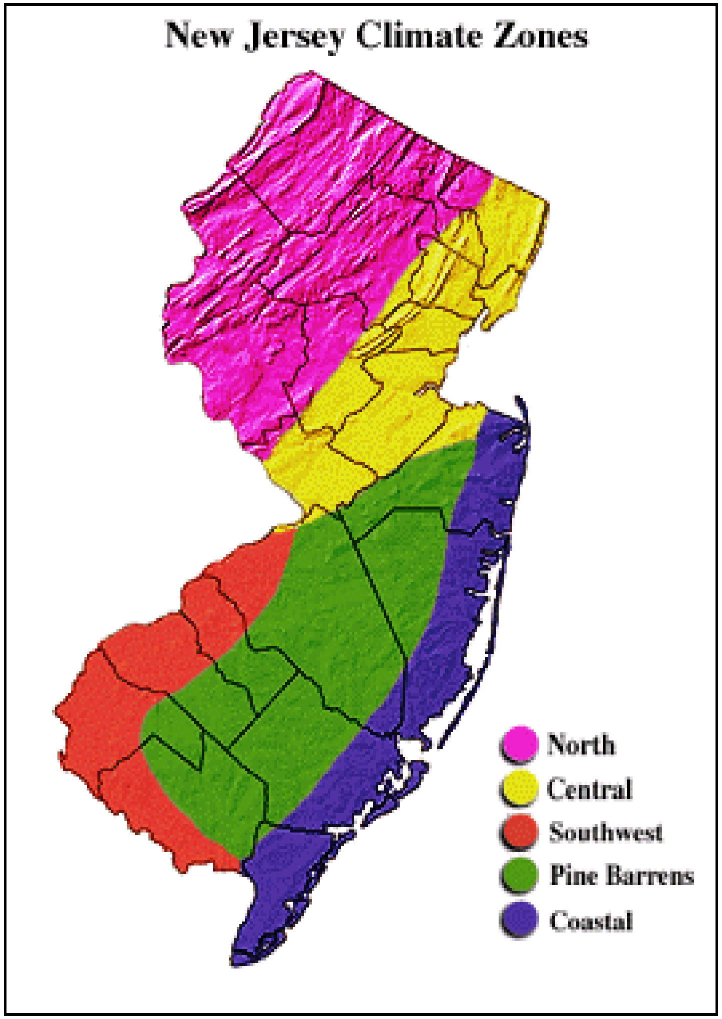
Average Daily Temperatures in NJ

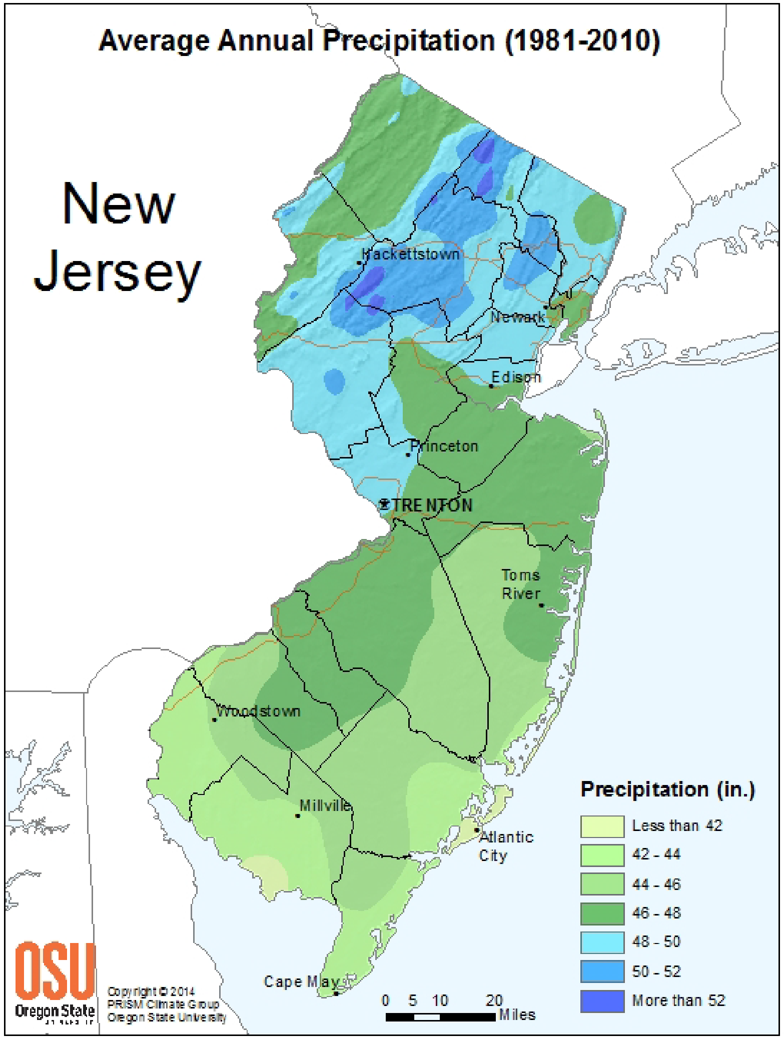


Plant Hardiness Zone Map



NJ Average Precipitation





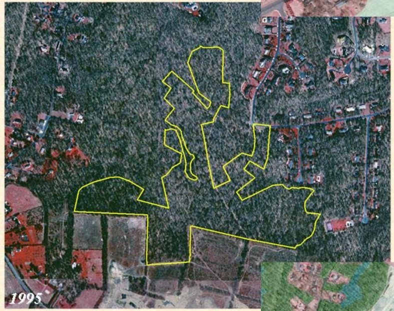
New Jersey

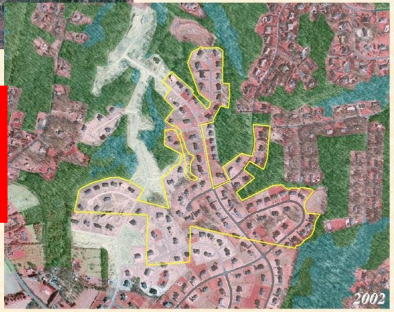
Land Use / Land Cover 1995 - 2002 Change Analysis

Agriculture

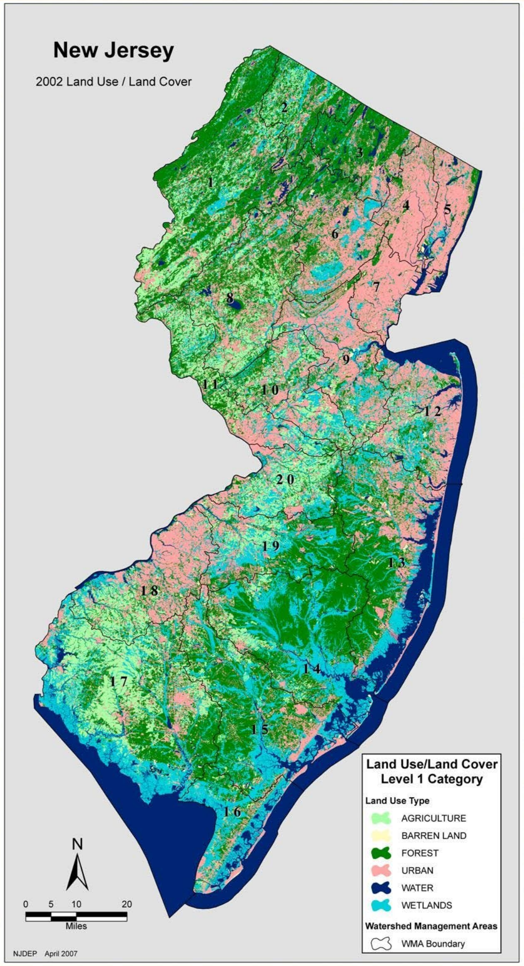
More than 21,000 acres of Agricultural Land were converted to Residential Urban Land.

Forests

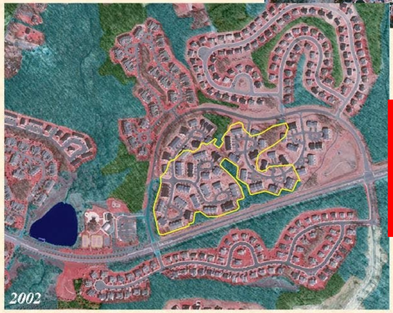




More than 38,000 acres of Forest Land were converted to Residential Urban Land



Wetlands



Almost 6,000 acres of previously mapped Forested Wetland are now in Residential Urban Land.

Land Use/Land Cover Level 1 Change Analysis

2002 Statewide Land Use/Land Cover Statistics (in acres)

Land Use Type	Revised 1995	2002	Net Change 1995-02	Net % Change 1995/97-2002	Annual Rate of Change (7 years) 1995/97-2002 (ac/yr)
Agriculture	652,334	596,804	-55,530	-9.30%	-7,933
Barren Land	57,562	61,352	3,789	6.18%	541
Forest	1,616,683	1,575,220	-41,463	-2.63%	-5,923
Urban Land	1,334,476	1,440,464	105,988	7.36%	15,141
Water	800,610	800,572	-38	0.00%	-5
Wetlands	1,022,291	1,009,544	-12,747	-1.26%	-1,821
Total	**5,483,955**	**5,483,955**			

Source: NJDEP Land Use/Land Cover Level 1 Data Analysis, 1995/97 - 2002

1995 Statewide Land Use/Land Cover Statistics (in acres)

Land Use Type	1986	1995	Net Change 1986-95	Net % Change 1986-1995/97	Annual Rate of Change (9 years) 1986-1995/97 (ac/yr)
Agriculture	744,382	659,017	-85,365	-12.95%	-9,485
Barren Land	57,223	57,971	748	1.29%	83
Forest	1,641,279	1,602,578	-38,701	-2.41%	-4,300
Urban Land	1,208,553	1,342,525	133,972	9.98%	14,886
Water	285,498	290,643	5,143	1.77%	571
Wetlands	1,049,269	1,033,471	-15,798	-1.53%	-1,755
Total	**4,986,204**	**4,986,205**			

Source: NJDEP Land Use/Land Cover Level 1 Data Analysis, 1986 - 1995/97

Note: The Values for the 1995/97 interpretation were revised during the 2002 update. The values shown for "Water" now include lakes, ponds, reservoirs, major watercourses, enclosed tidal bays (eg, Barnegat Bay), and the tidal and non-tidal portions of the Delaware River. The "Water" values also now include any open water areas of Delaware Bay, Raritan Bay or the Atlantic Ocean out to the boundaries of the WMA. The 1986/1995 "Water" values do not include any open water areas of the Delaware Bay, Raritan Bay or the Atlantic Ocean, even though the boundaries of some WMAs do extend into these water bodies.

1995 - 2002 Change Analysis by Watershed Management Area
Land Use Type - Level 1 Category (acres)

Land Use Type	WMA 1	WMA 2	WMA 3	WMA 4	WMA 5	WMA 6	WMA 7	WMA 8	WMA 9	WMA 10
Agriculture	-7,031	-2,172	37	-45	-28	-698	-7	-7,384	-3,038	-8,749
Barren Land	738	5	260	68	339	71	796	-19	-338	242
Forest	-1,497	-276	-1,938	-1,123	-925	-3,637	-1,170	-2,538	-2,662	-894
Urban Land	8,186	2,586	1,932	1,366	720	4,815	614	10,448	8,119	10,411
Water	-453	154	11	-15	370	-64	-7	9	1	59
Wetlands	56	-296	-303	-250	-475	-488	-226	-515	-2,081	-1,070

Land Use Type	WMA 11	WMA 12	WMA 13	WMA 14	WMA 15	WMA 16	WMA 17	WMA 18	WMA 19	WMA 20
Agriculture	-4,751	-3,995	-727	-1,110	-868	-695	-3,226	-4,739	-2,696	-3,608
Barren Land	311	1,147	-268	135	280	-292	61	-747	294	706
Forest	278	-2,713	-9,423	-1,352	-4,957	-569	-2,108	-1,220	-1,831	-749
Urban Land	4,779	7,738	11,548	2,420	5,705	1,795	5,798	7,649	5,051	4,219
Water	38	-492	-292	-391	-180	596	411	158	-81	130
Wetlands	-656	-1,685	-839	299	19	-835	-937	-1,101	-737	-697

In January 2007, the New Jersey Department of Environmental Protection released the Land Use/Land Cover 2002 Update data sets. This is the third in a series of land use/land cover layers that the NJDEP first began producing in 1988 utilizing a modified Anderson Classification System.

The first land use layer NJDEP produced was based on aerial photography captured in the spring of 1986 with a minimum mapping unit of 2.5 acres. Freshwater wetlands were mapped under the New Jersey Freshwater Wetlands Mapping Program and were incorporated into the 1986 land use data sets. The second iteration of the land use data was based on photography captured in 1995/97 with a minimum mapping unit of 1 acre. These first two mapping efforts provided NJDEP with the data to begin Land Use Change Analysis.

This latest series is based on photography captured in the spring of 2002. As with both previous layers, the 2002 data was produced by visually interpreting color infrared photography, however, the 1 foot pixel resolution of the 2002 imagery improved the ability of the interpreters to identify features. Through this process, photo-interpreters examine each image, and based on their knowledge of photo signatures, classify the image into well defined land use/land cover codes as well as determining the percent Impervious Surface. The 84 land use classification codes are grouped into 6 - Level 1 categories to produce this land use/land cover type map.

All three land use/land cover data sets contain important land use data used in a wide variety of environmental analyses. Every effort has been made to insure that all land use data sets are as accurate as possible. However, LULC data are not intended to substitute for on the ground jurisdictional boundaries. Users of all data sets should understand the mapping process, appropriate uses and limitations of the data.

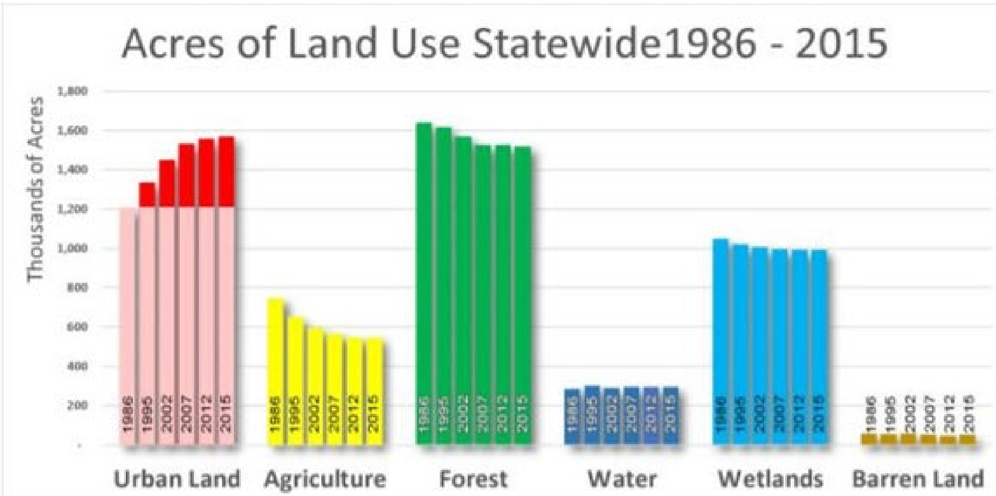
Aerial Information Systems, Inc. (AIS), Redlands, California developed the 2002 Statewide Land Use/Land Cover (LU/LC) and Hydrography Update data sets for the New Jersey Department of Environmental Protection (NJDEP). AIS has assisted NJDEP in the past with the development of the 1986 Integrated Terrain Unit Mapping (ITUM) project and the 1995/97 LU/LC Update.

Funding for this project was provided by a The NJ Department of Transportation, The NJ Department of Environmental Protection and through a grant from the National Oceanographic and Atmospheric Administration (NOAA).

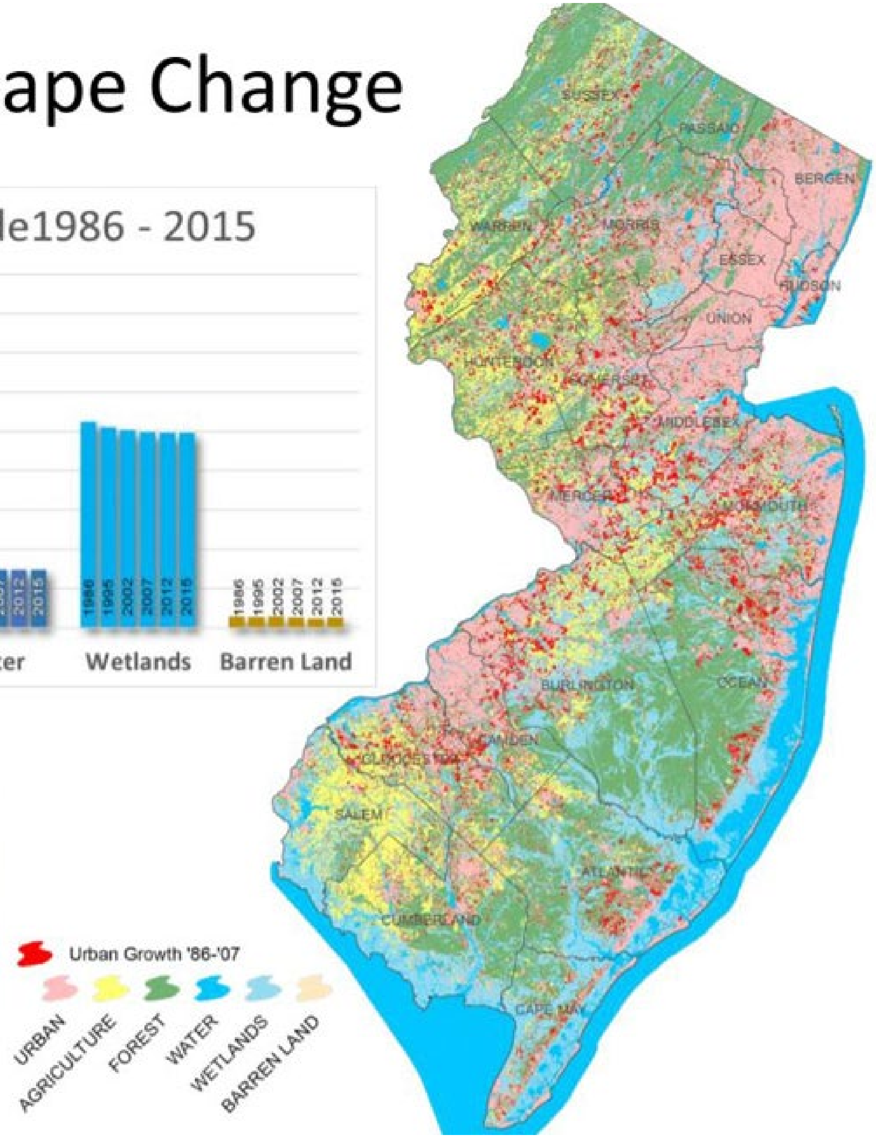
Project Team: Craig Coutros, John Tyrawski, Lawrence Thornton

Map Composition by Craig Coutros, GIS Specialist
NJ Department of Environmental Protection, Office of Information Resources Management, Bureau of Geographic Information Systems, April 2007.

Dynamic Landscape Change

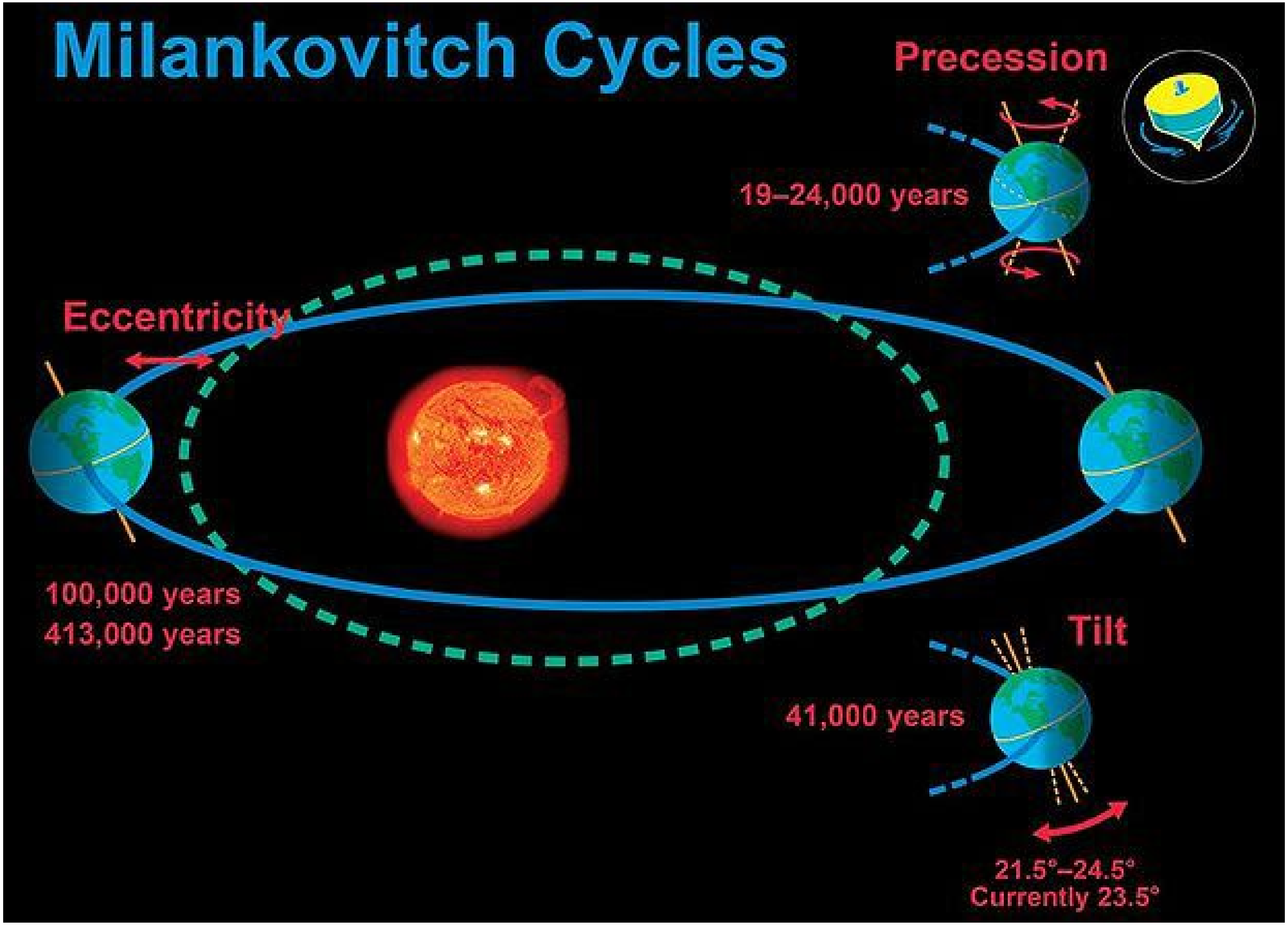


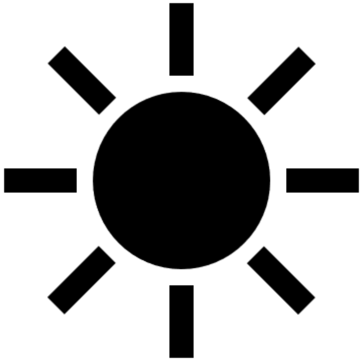
	2012-2015	1986-2015
Urban Growth	10,404 Acres	360,376 Acres
Farmland Loss	(2,087) Acres	(200,876) Acres
Forest Loss	(9,494) Acres	(122,569) Acres
Wetlands Loss	(2,295) Acres	(57,166) Acres



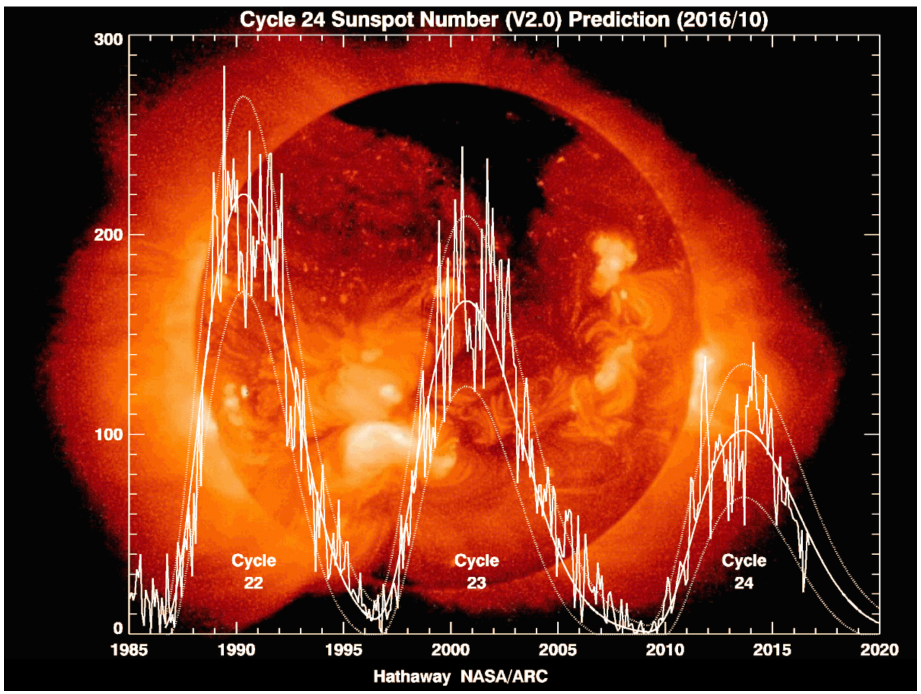
Part II: Causes of Climate Change

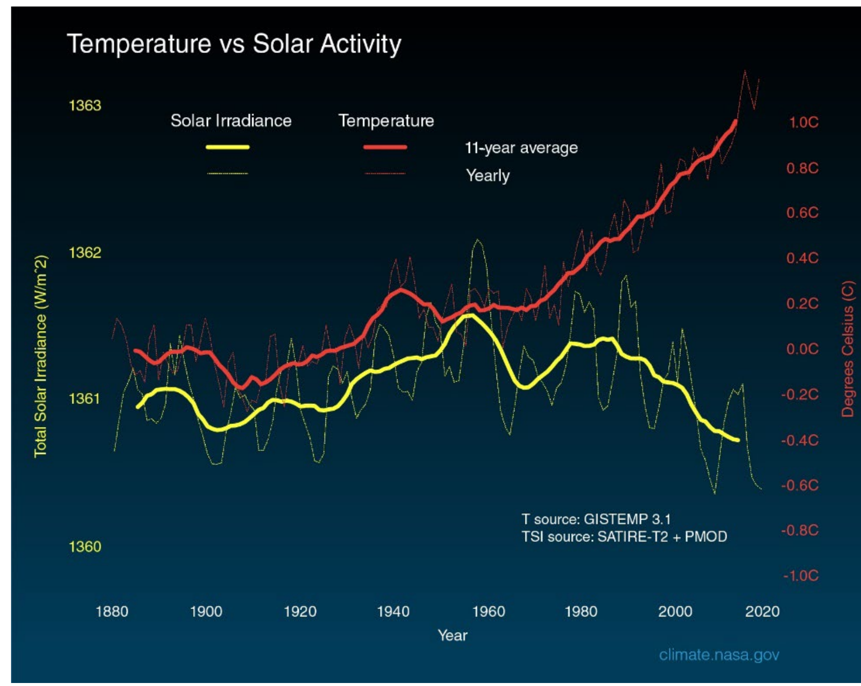
Natural Climate Change



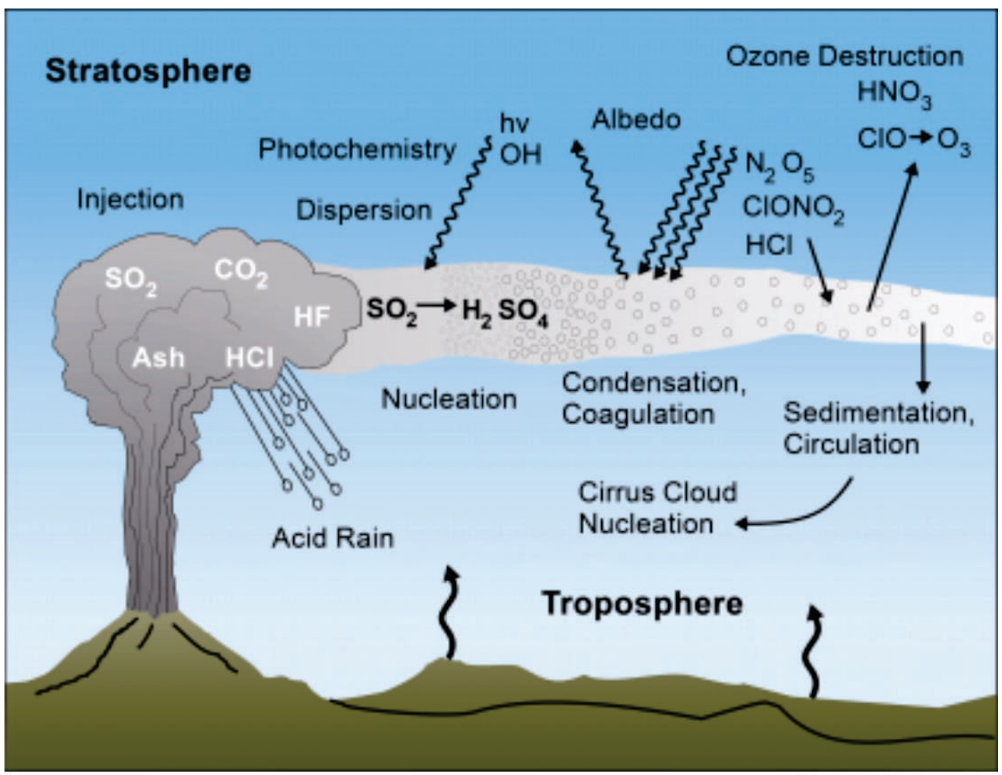


The Sun (obviously)

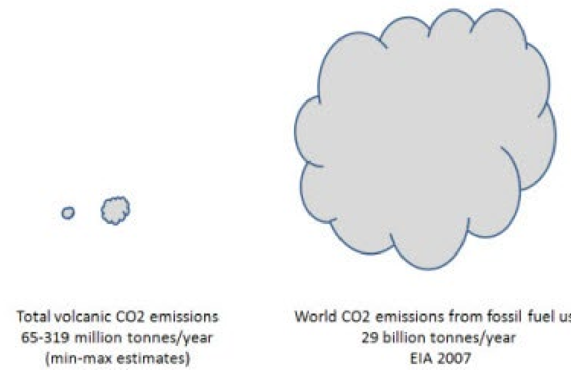


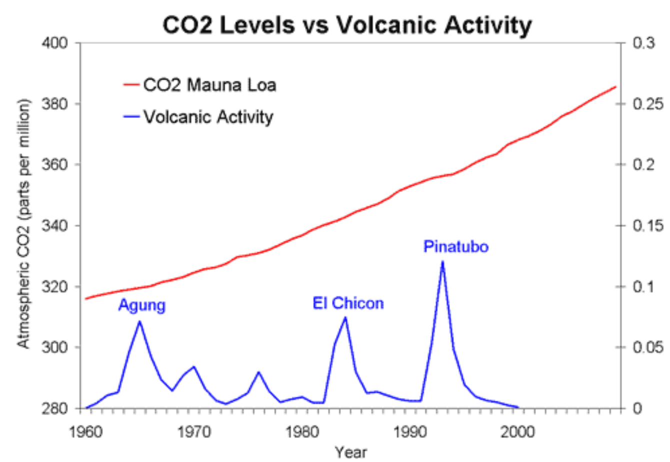


Volcanoes



This cartoon, from the USGS, illustrates the dispersal of aerosols and some of the photochemical interactions in the stratosphere. Circulation of an aerosol cloud in is eventually terminated when the particles succumb to gravity, gradually sinking to the lower atmosphere and earth's surface.





Anthropogenic Factors

Dictionary

Definitions from Oxford Languages · Learn more

Search for a word

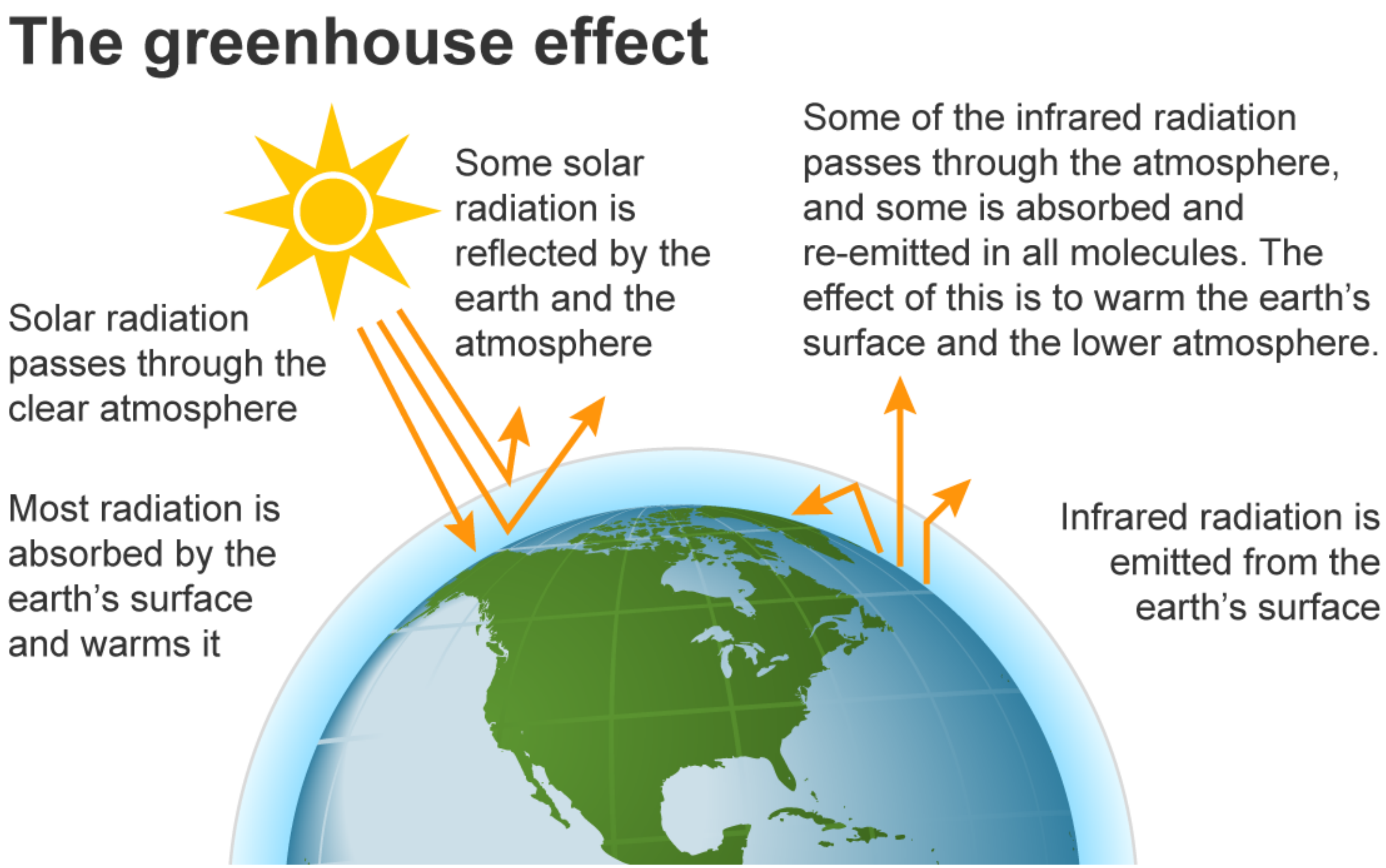
an·thro·po·gen·ic

/ˌanTHrəpōˈjenik/

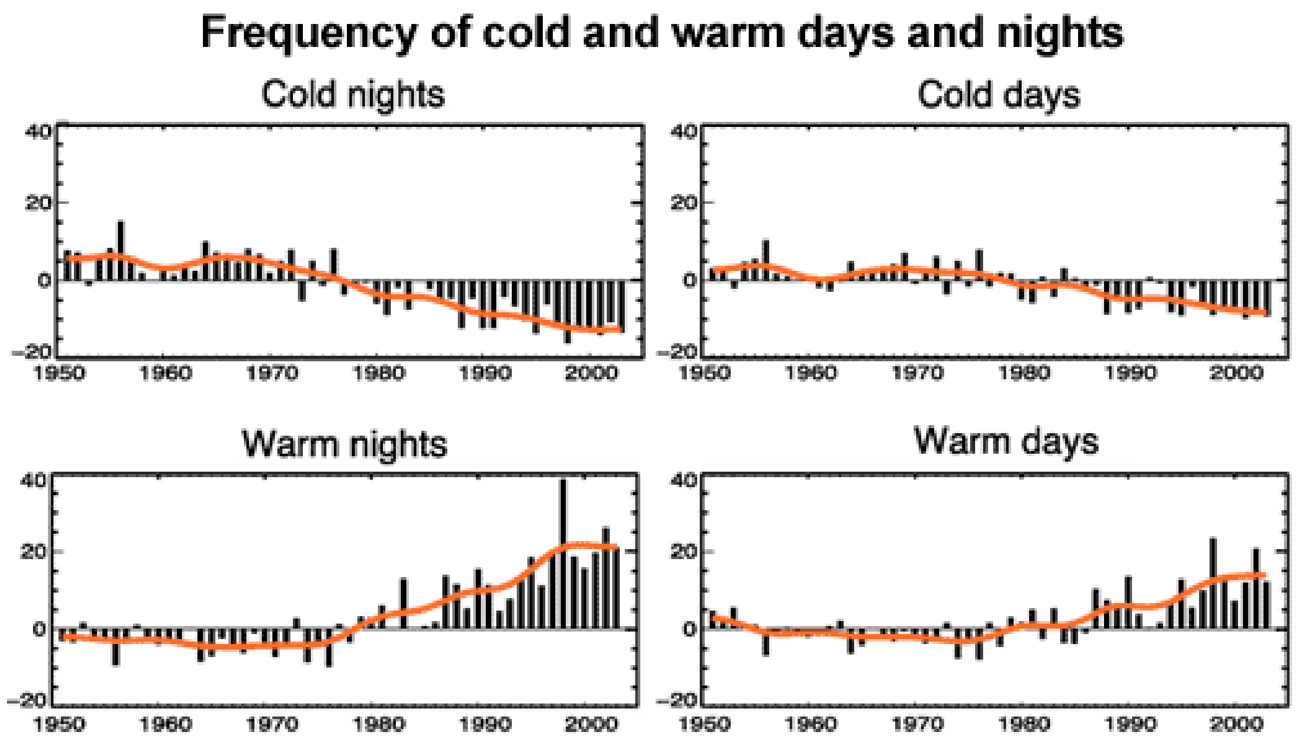
adjective

(chiefly of environmental pollution and pollutants) originating in human activity.
"anthropogenic emissions of sulfur dioxide"

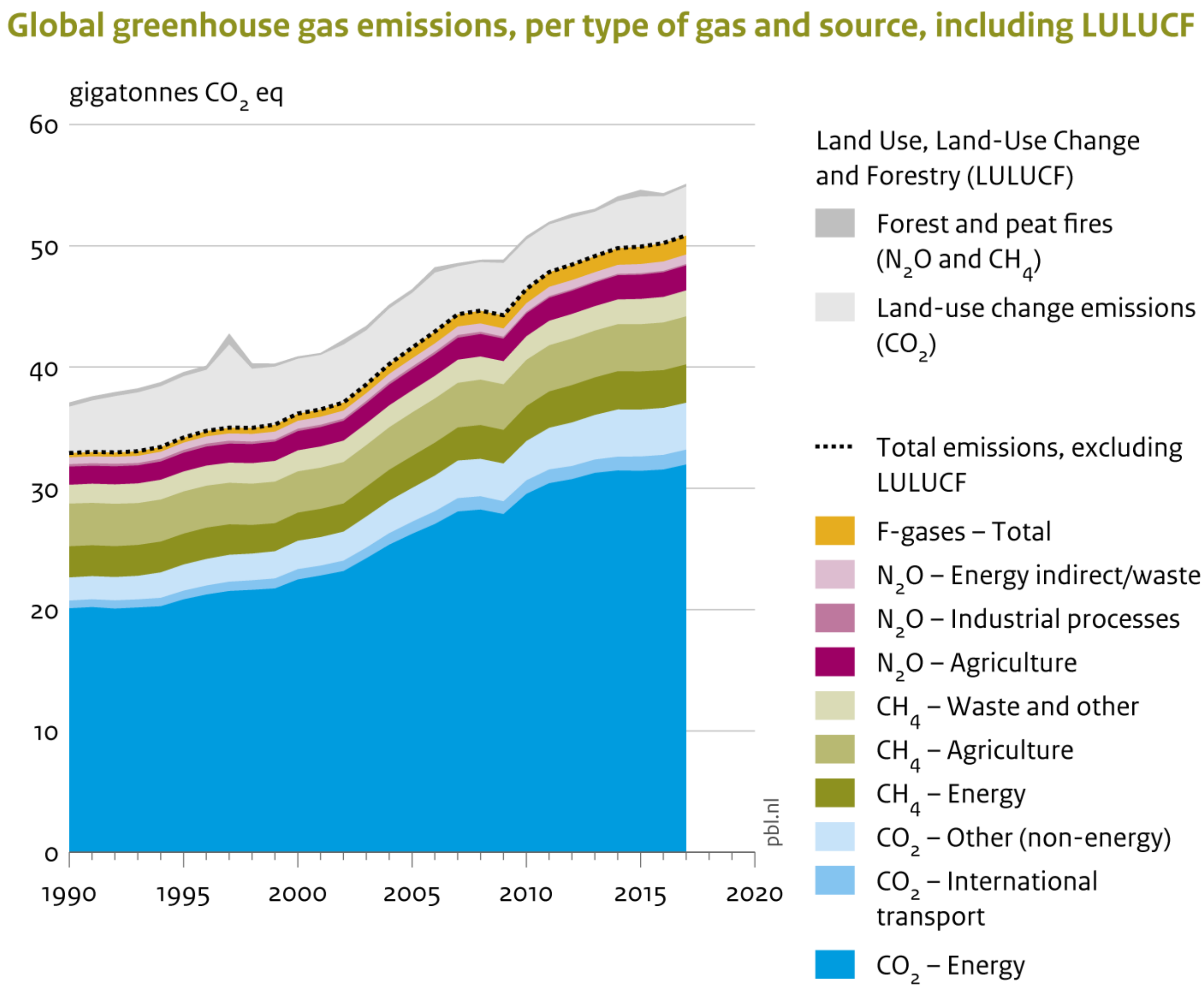
The Greenhouse Effect



Greenhouse Effect

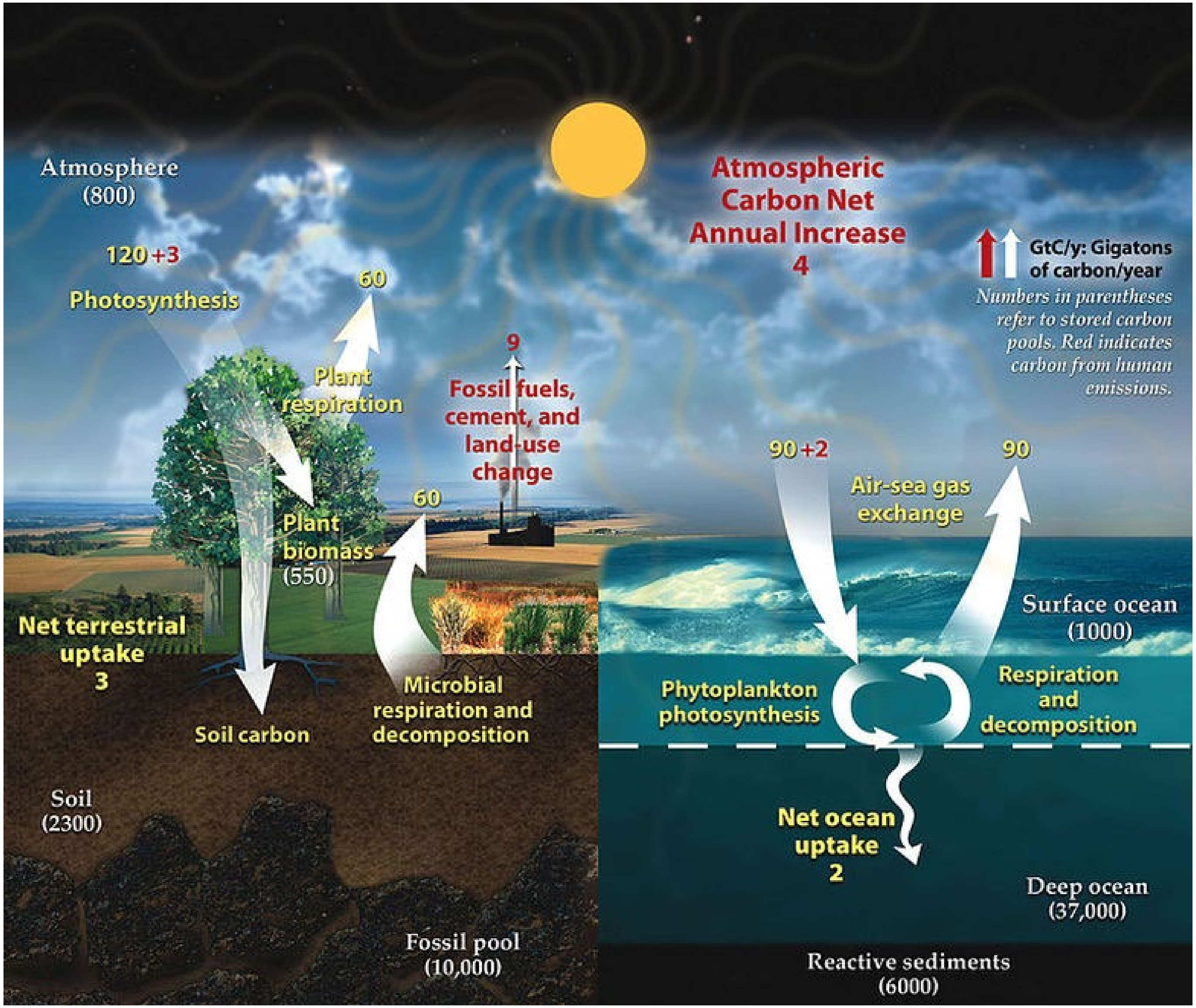


Greenhouse Gas Emissions

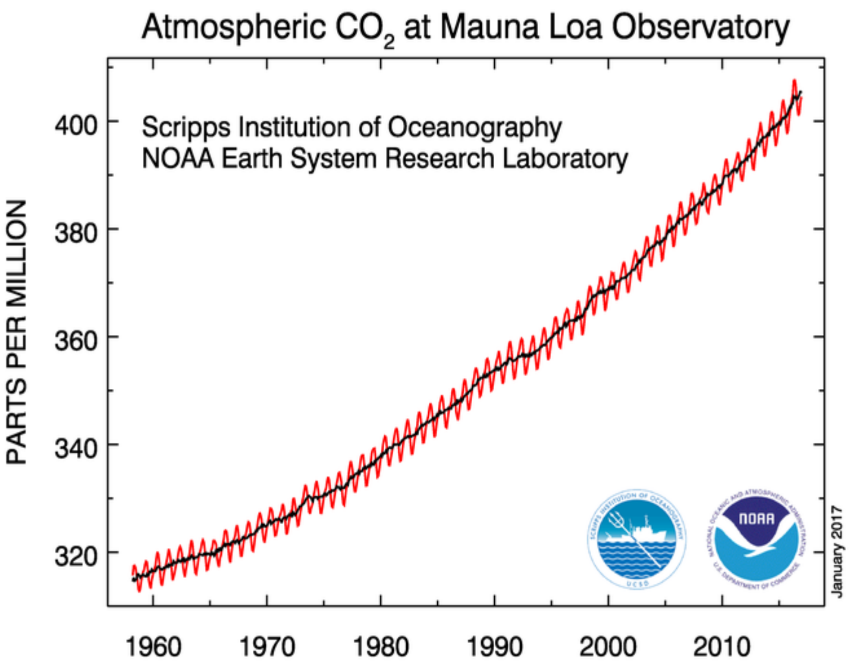


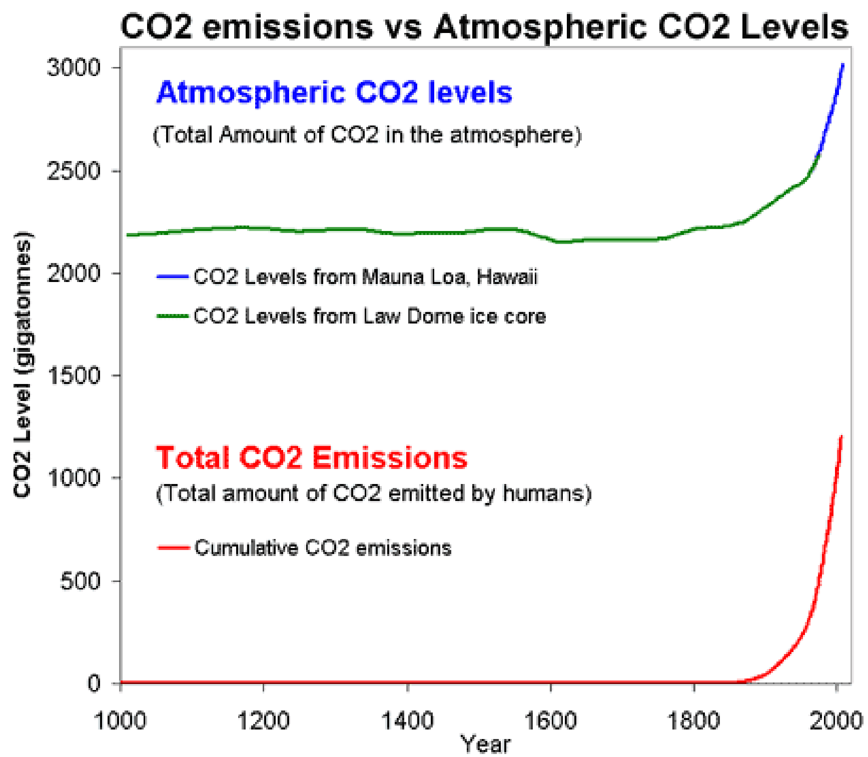
Source: EDGAR v5.0/v4.3.2 FT 2017 (EC-JRC/PBL, 2018); Houghton and Nassikas (2017)

The Carbon Cycle



Greenhouse Gas Emissions

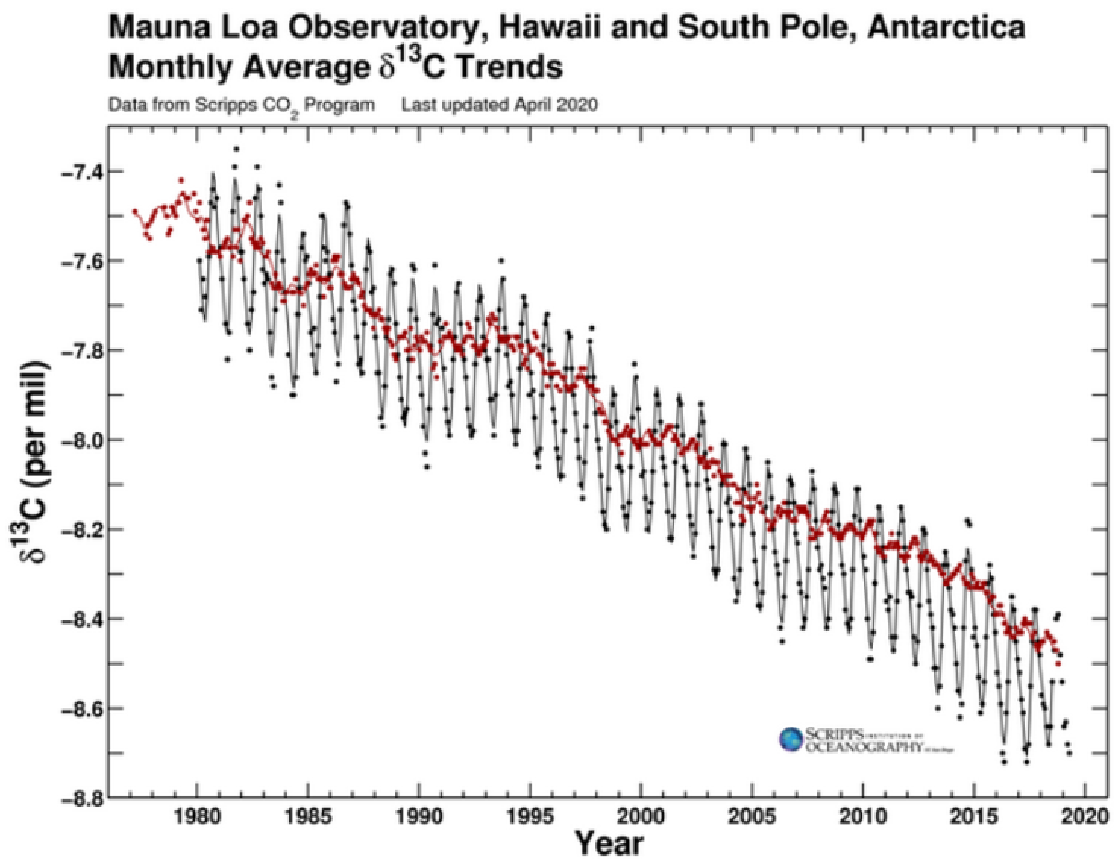


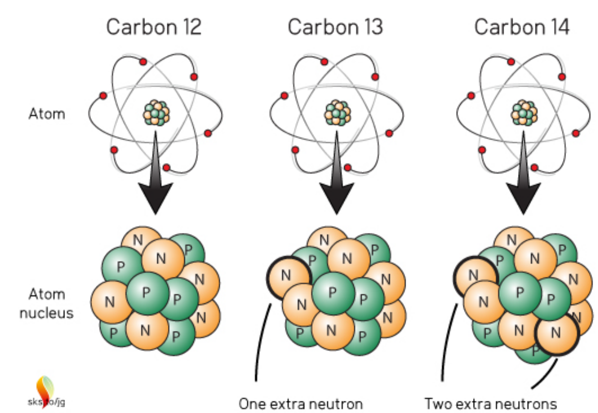


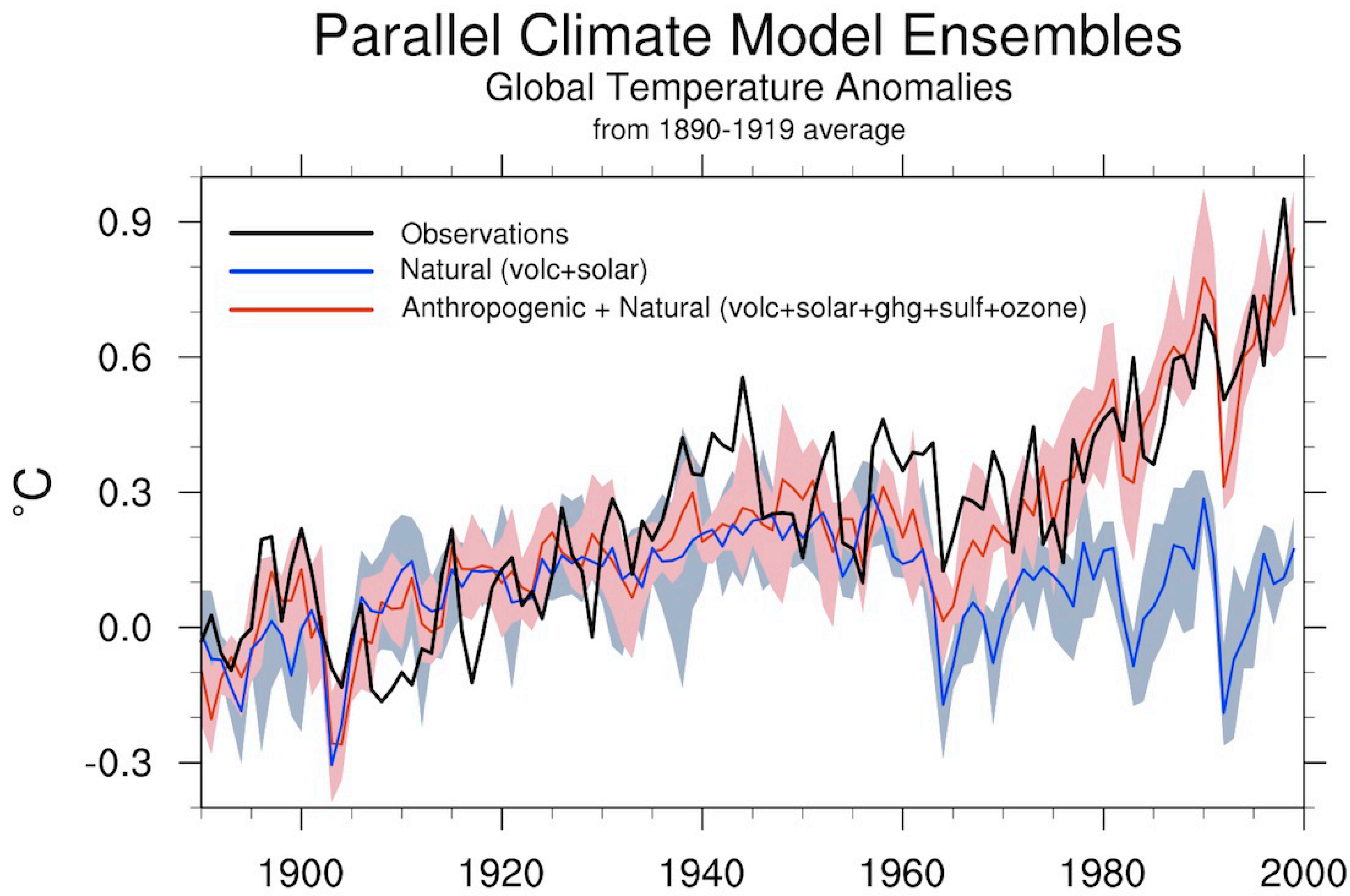
Human Footprints

Isotope fingerprints point to human sources

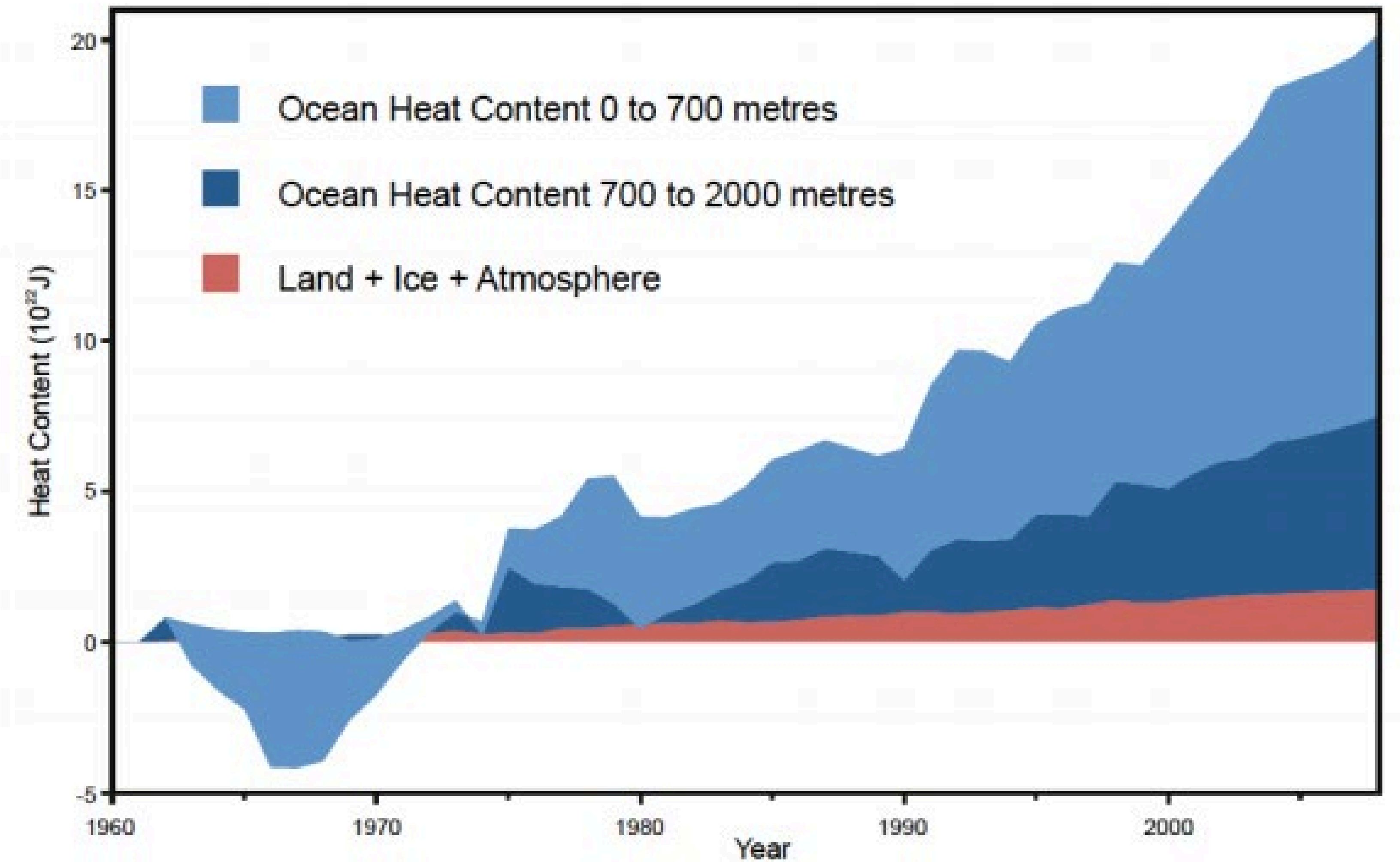
Different sources of CO_2 have their own unique isotopic fingerprints. CO_2 from the foss fuel burning doesn't have carbon 14 (^{14}C), and CO_2 from terrestrial plants has less car 13 (^{13}C) than from the ocean. Since fossil fuels are derived from ancient plants, they al have less ^{13}C isotopes. Isotope data from ice cores show that since 1800, the carbon 1 atmosphere have decreased, which means the extra CO_2 in atmosphere came from fo burning (Fig. 6).





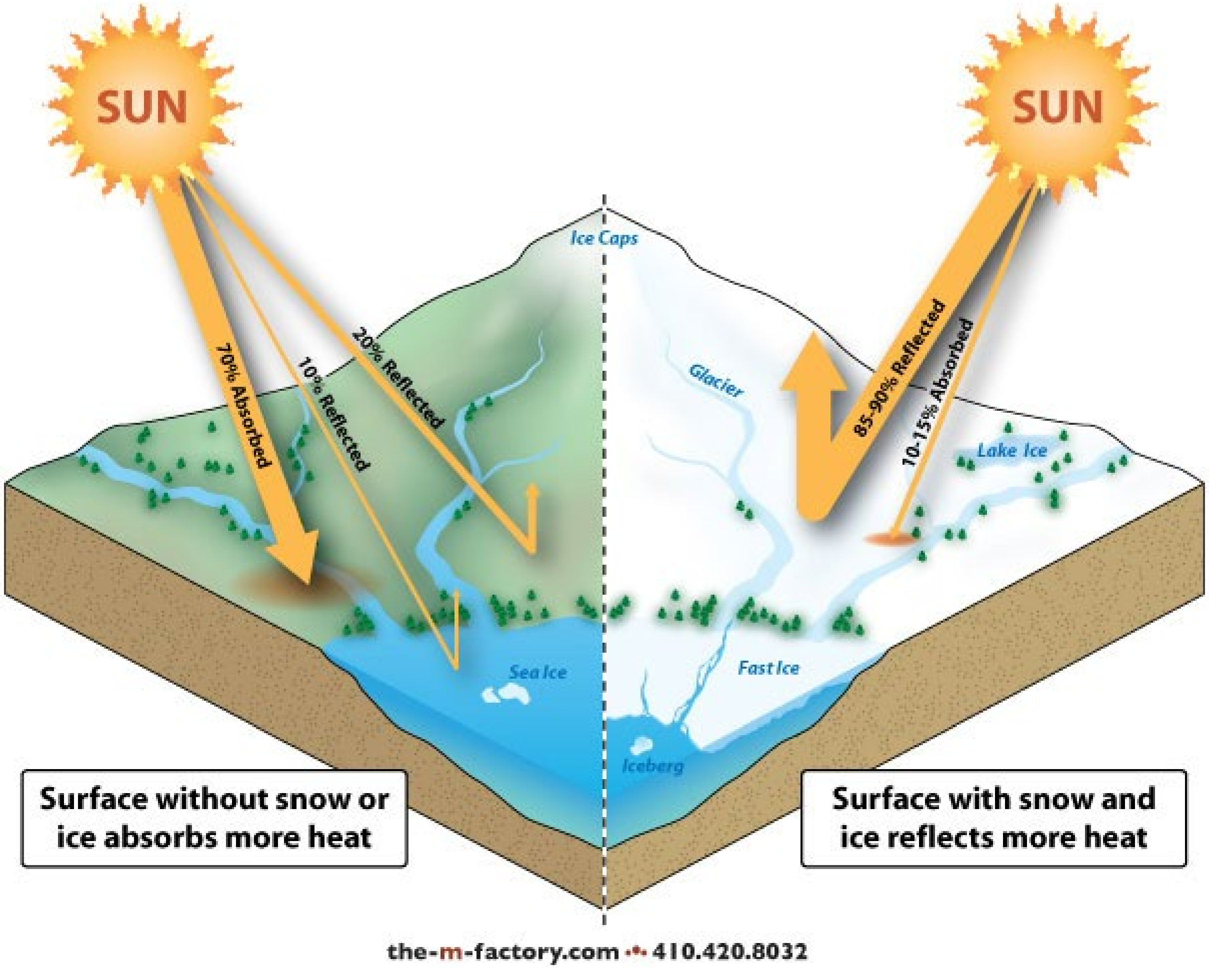

Parallel Climate Model Ensembles
Global Temperature Anomalies
from 1890-1919 average
Observations
Natural (volc+solar)
Anthropogenic + Natural (volc+solar+ghg+sulf+ozone)
°C
0.9
0.6
0.3
0.0
-0.3
1900
1920
1940
1960
1980
2000

Heat Storage



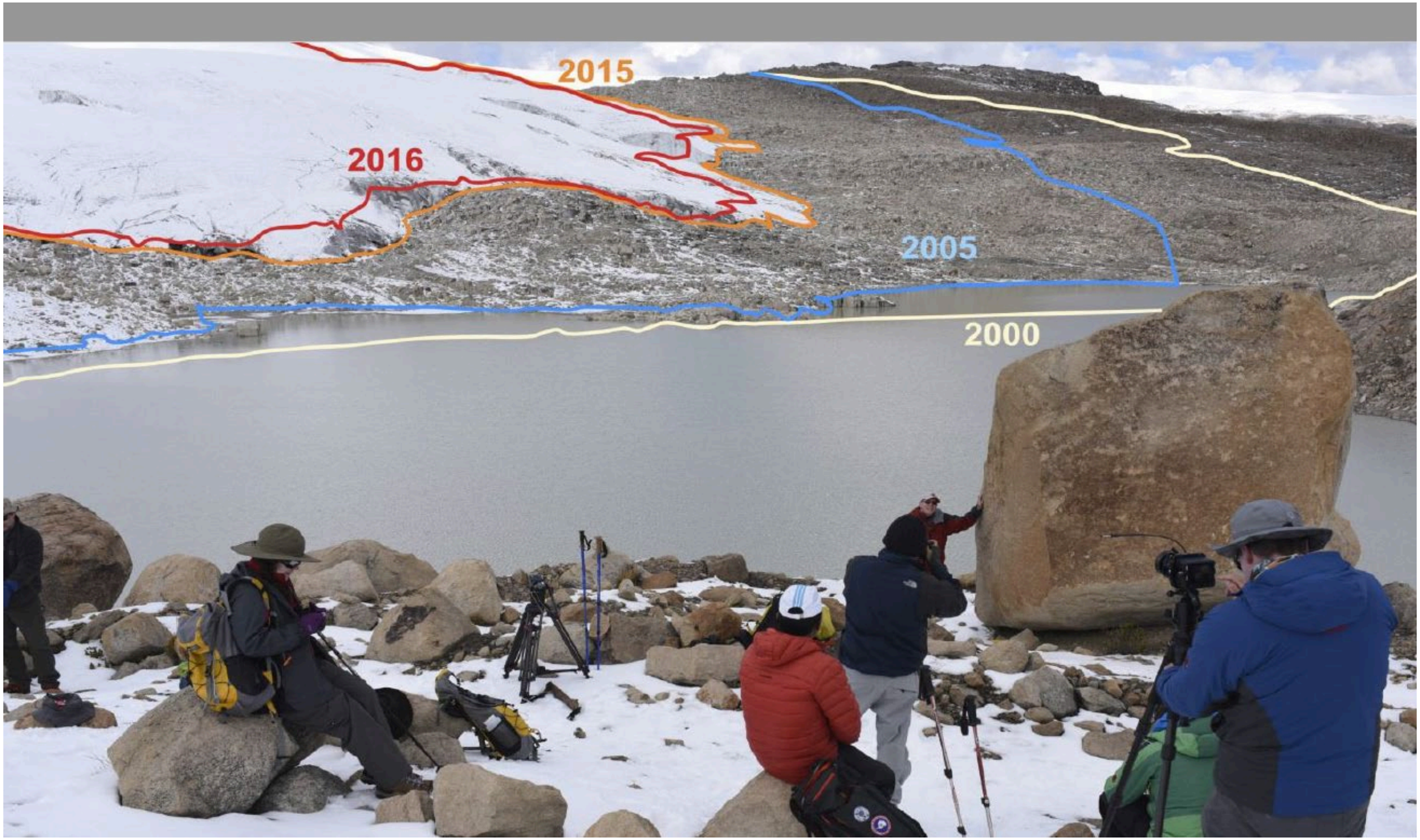
Nuccitelli et al., 2012

Feedback Loops



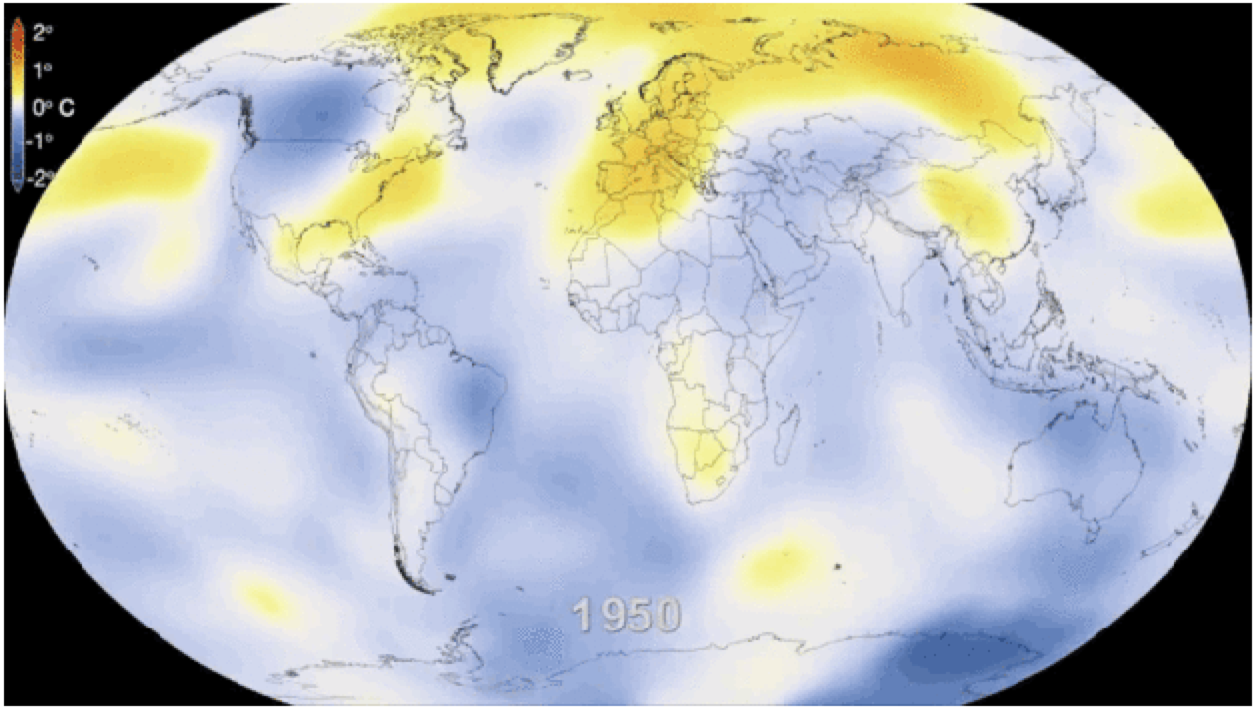
Peruvian Terminus Retreat

(Slide from a presentation created by the brilliant David Robinson)



Courtesy of L. Thompson

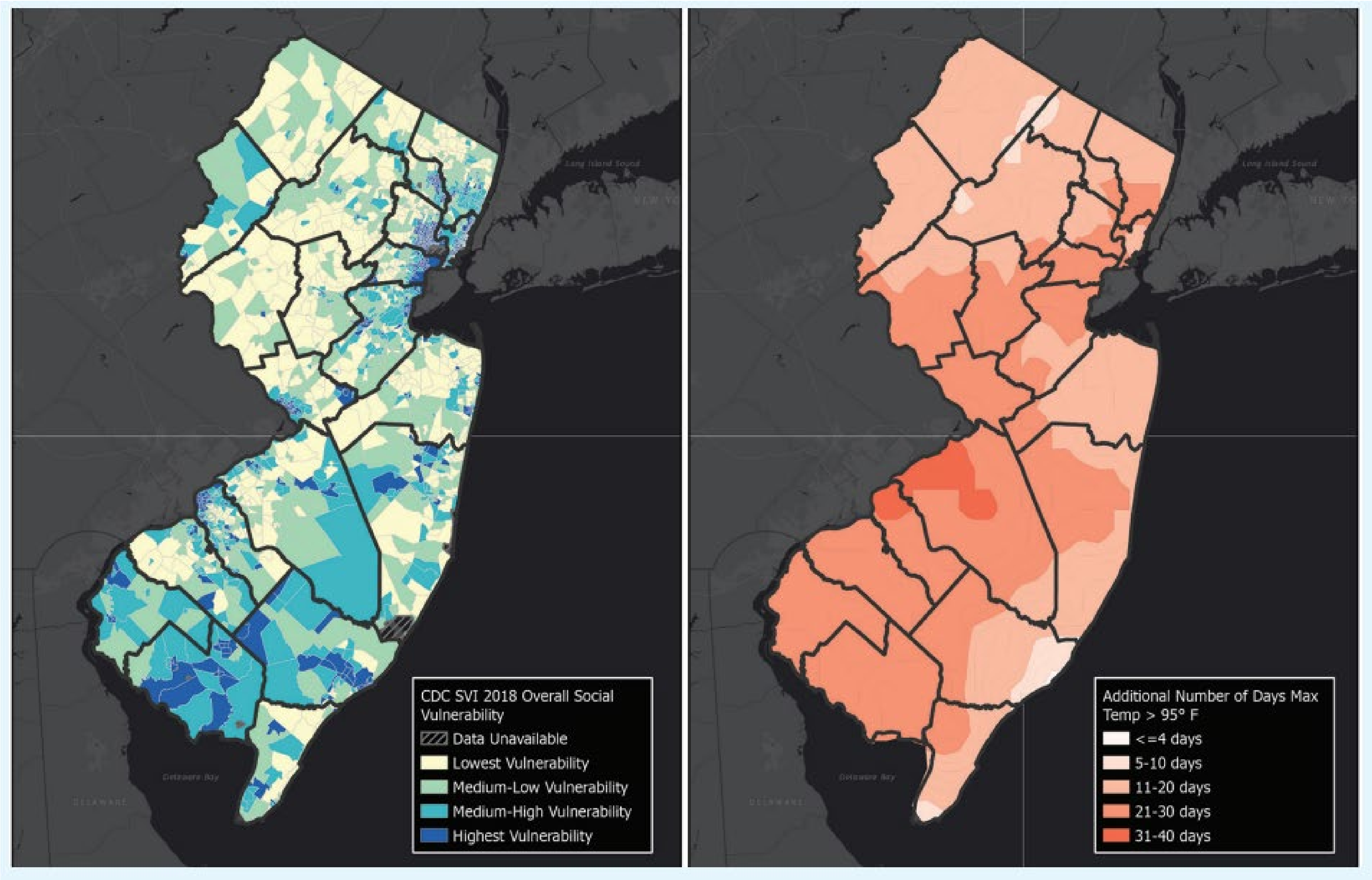
Warming Over Time



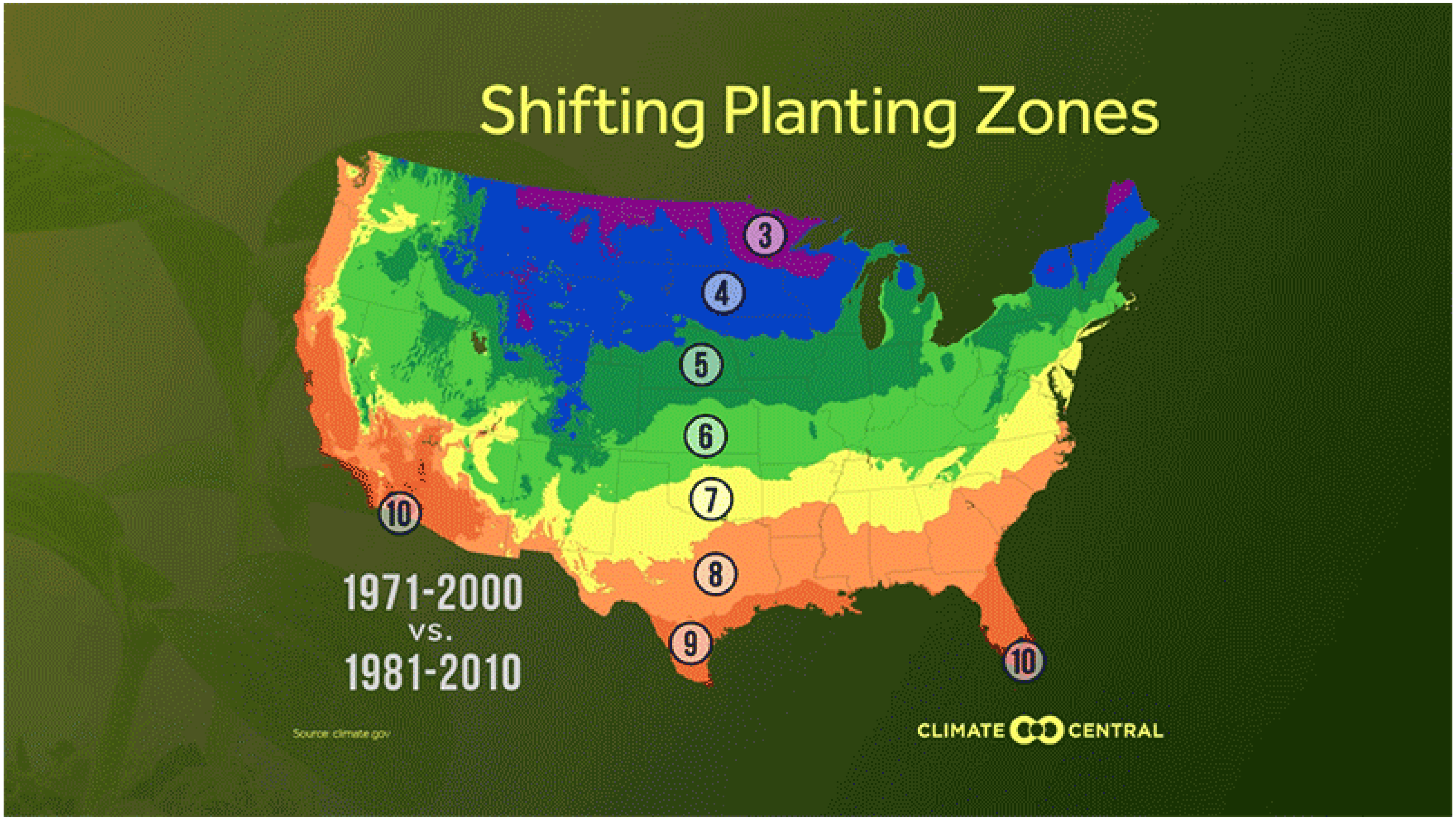
NASA Goddard Spaceflight Center

Part III:
Climate Change in New Jersey

Increasing Excessive Temperature Days



Changing Hardiness Zones



From State of the Climate – New Jersey 2021

Temperatures are climbing

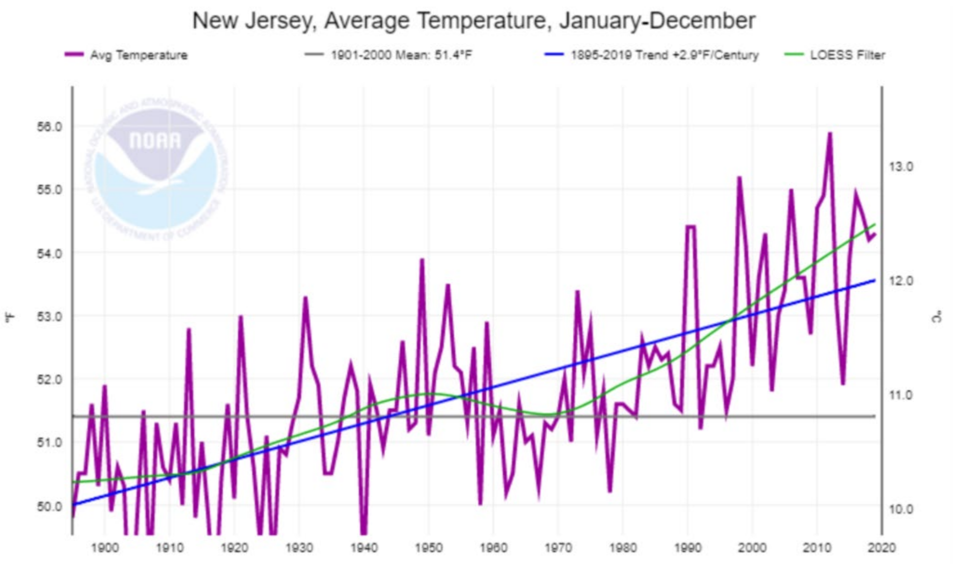
The mid-Atlantic region is one of the most rapidly warming locations in the continental U.S.

2021 was the
3rd warmest year
on record in NJ

Average annual temperatures in NJ increased nearly
4°F
since 1900, roughly twice the global average

CO_2 levels in the atmosphere are the highest in at least
800,000 years

Avg annual temperatures are projected to increase
⬆ 5–8 °F
above preindustrial levels by 2100 in a low emissions scenario
⬆ 8–14 °F
by 2100 in a high emissions scenario



National Centers for Environmental Information

From State of the Climate – New Jersey 2021

Sea-level rise is accelerating

And the trend is expected to continue well beyond the 21st century.

Sea level at Atlantic City rose about

18 inches

since 1911, more than double the global average

Average annual tidal flooding days in Atlantic City

	1950s:	<1
	2007-16:	8
projected	2030:	17–75
	2060:	85–315

with moderate emissions

Tidal flooding

in Atlantic City is expected to occur at least

240 days a year

with moderate emissions by 2100

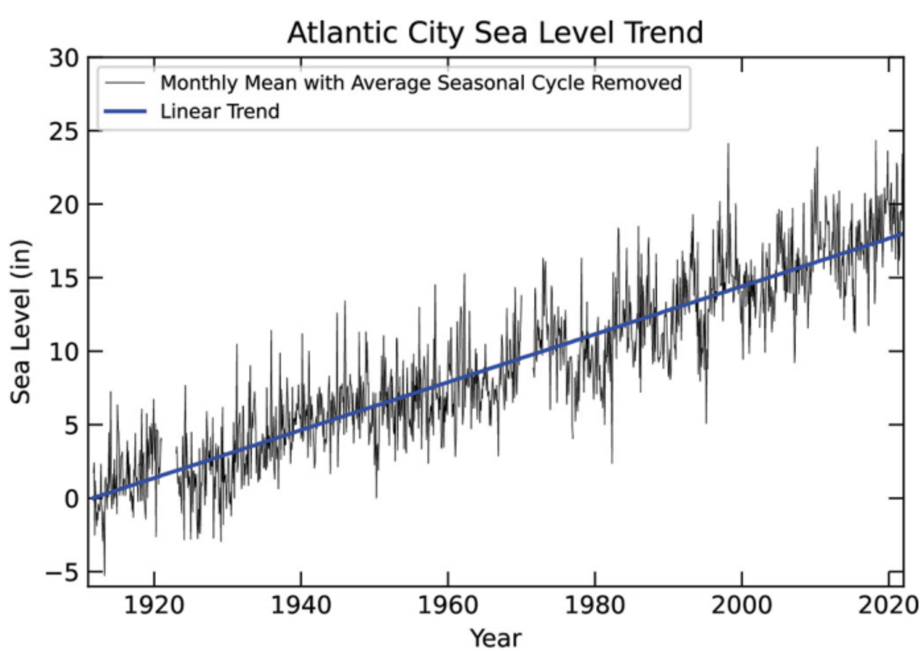
Sea level is projected to increase

0.5–1.1 ft by 2030

and

0.9–2.1 ft by 2050

relative to the year 2000



From State of the Climate – New Jersey 2021

Ida delivered catastrophic flooding (and a glimpse of the future)

Warming temperatures are driving greater variability in precipitation. New Jersey is wetter overall, and heavy rainfall is occurring more often.

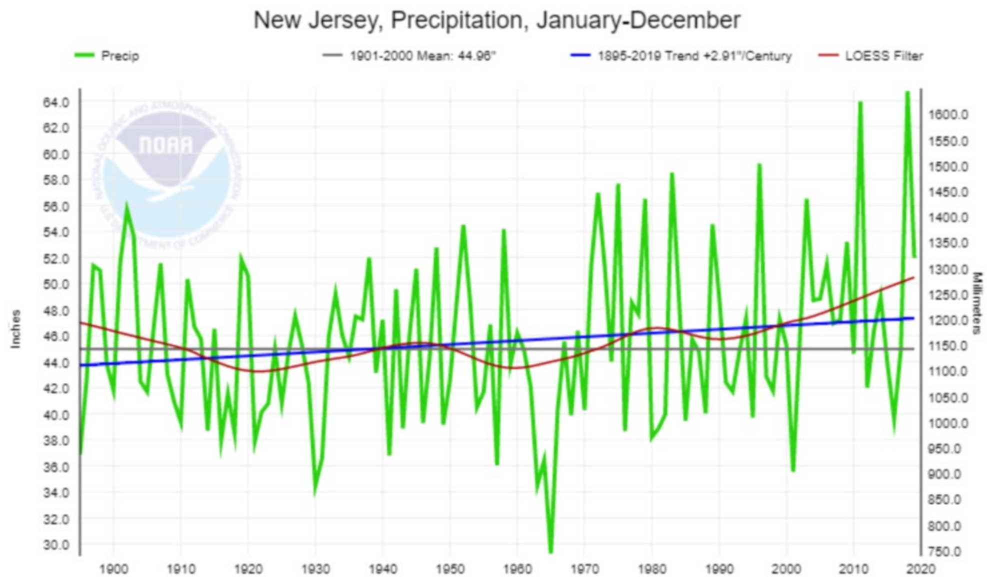
30 lives lost
2nd greatest loss of life in NJ due to a natural disaster since 1900

Estimated
$16–24B in damages
in the Northeast U.S.

>9 inches of rain
in about 6 hrs in Somerset and Hunterdon counties, 2x normal rainfall for whole month of September

By 2100, annual rainfall is expected to increase about
5–8%
relative to 2010

Extreme 24-hour rainfall is expected to increase
5–15%
relative to 1950–1999



A change in extremes?

2 crest 21.0’ (nearby Blackwells Mills: 1921-present)

6 crest 16.2’ (1 May 2014 #7 crest 15.9’)

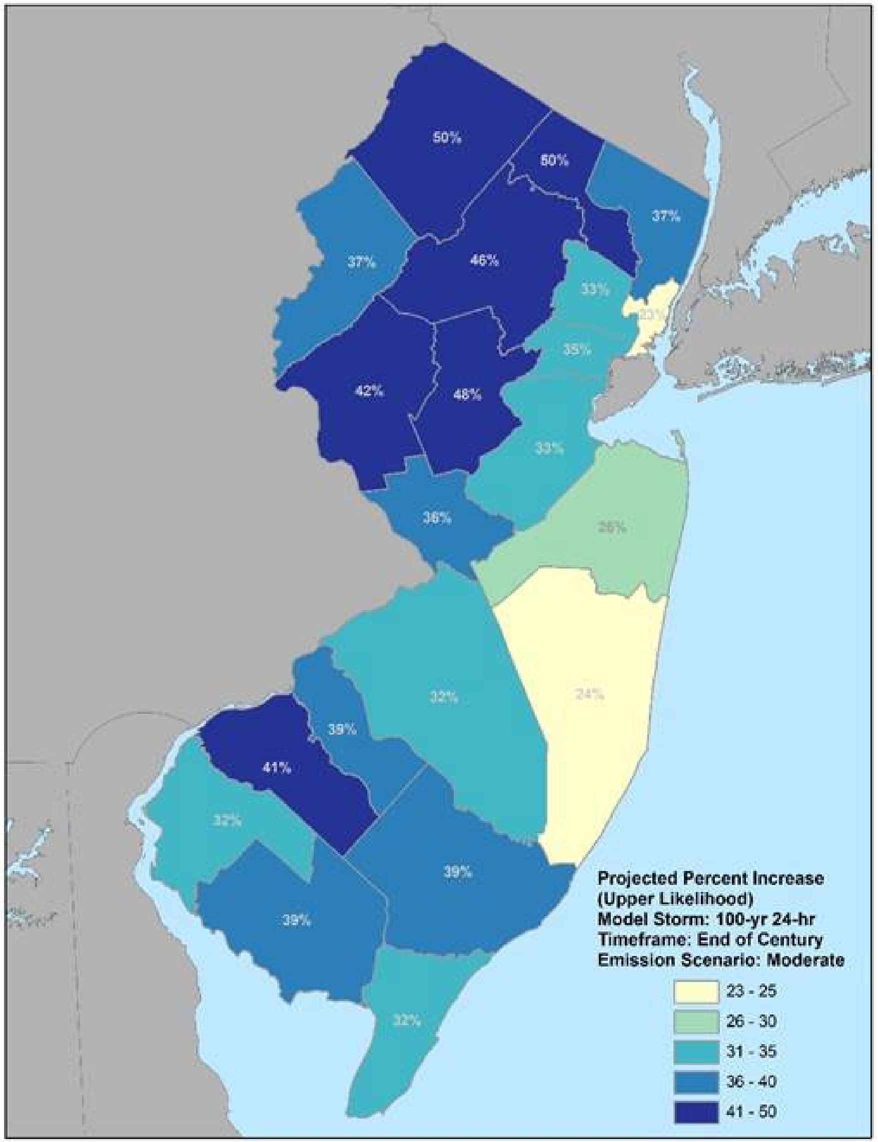
Manville

3 crest 19.2’

1 crest 21.2’

(Slide from a presentation created by the brilliant David Robinson)

Precipitation Increase

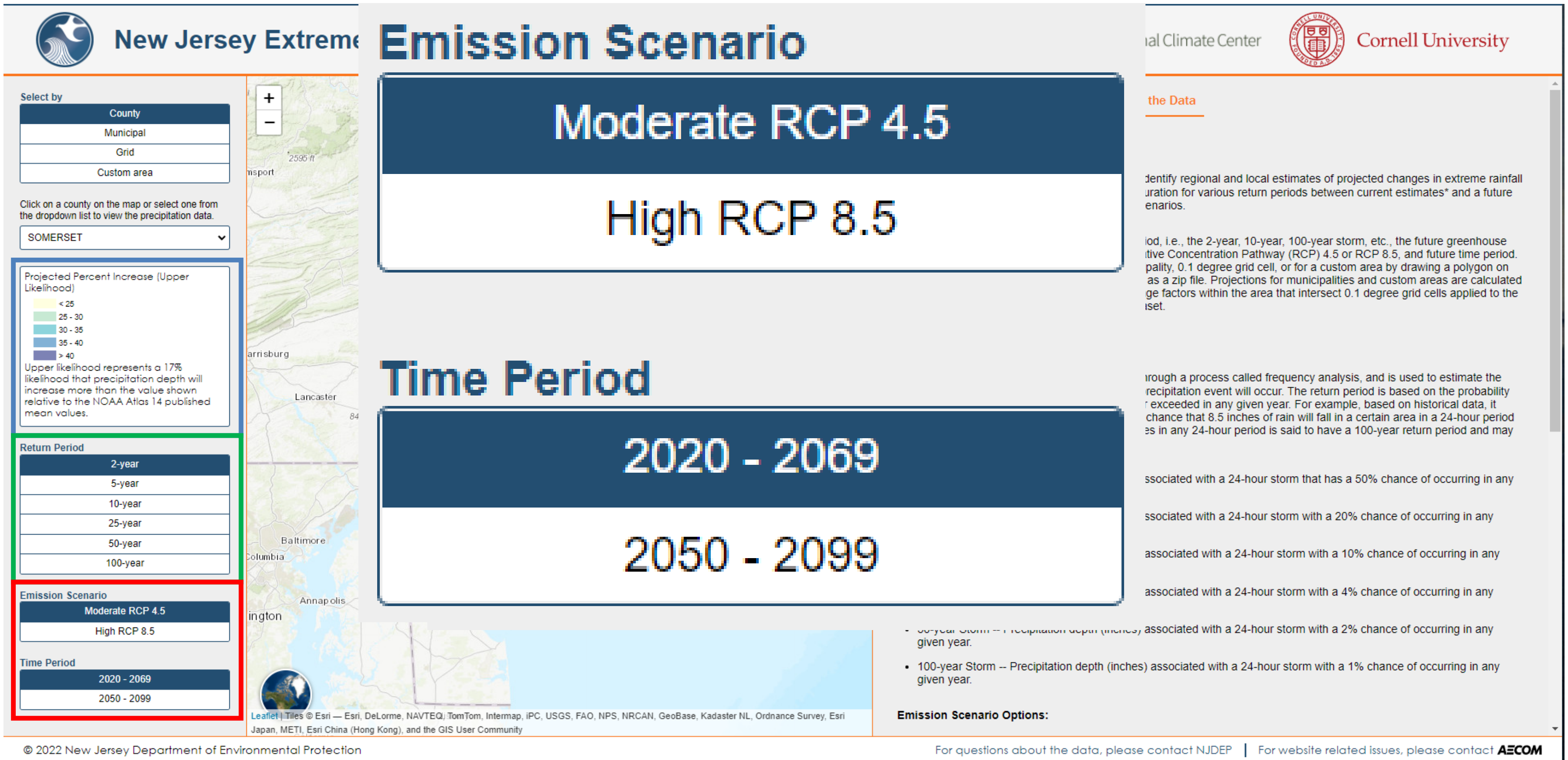


The studies show:

- **Precipitation is already 2.5% to 10% higher.** The precipitation expectations that presently guide state policy, planning and development criteria, and which rely upon data obtained through 1999, do not accurately reflect current precipitation intensity conditions. Extreme precipitation amounts are 2.5% higher now than the 1999 data suggests, and some parts of the state have seen a 10% increase above the outdated data.
- **Precipitation is likely to increase by more than 20% from the 1999 baseline by 2100,** and projected changes will be greater in the northern part of the state than in the southern and coastal areas, with projections for some northwestern counties seeing the greatest increase, some by as much as 50%.

New Jersey Extreme Precipitation Projection Tool

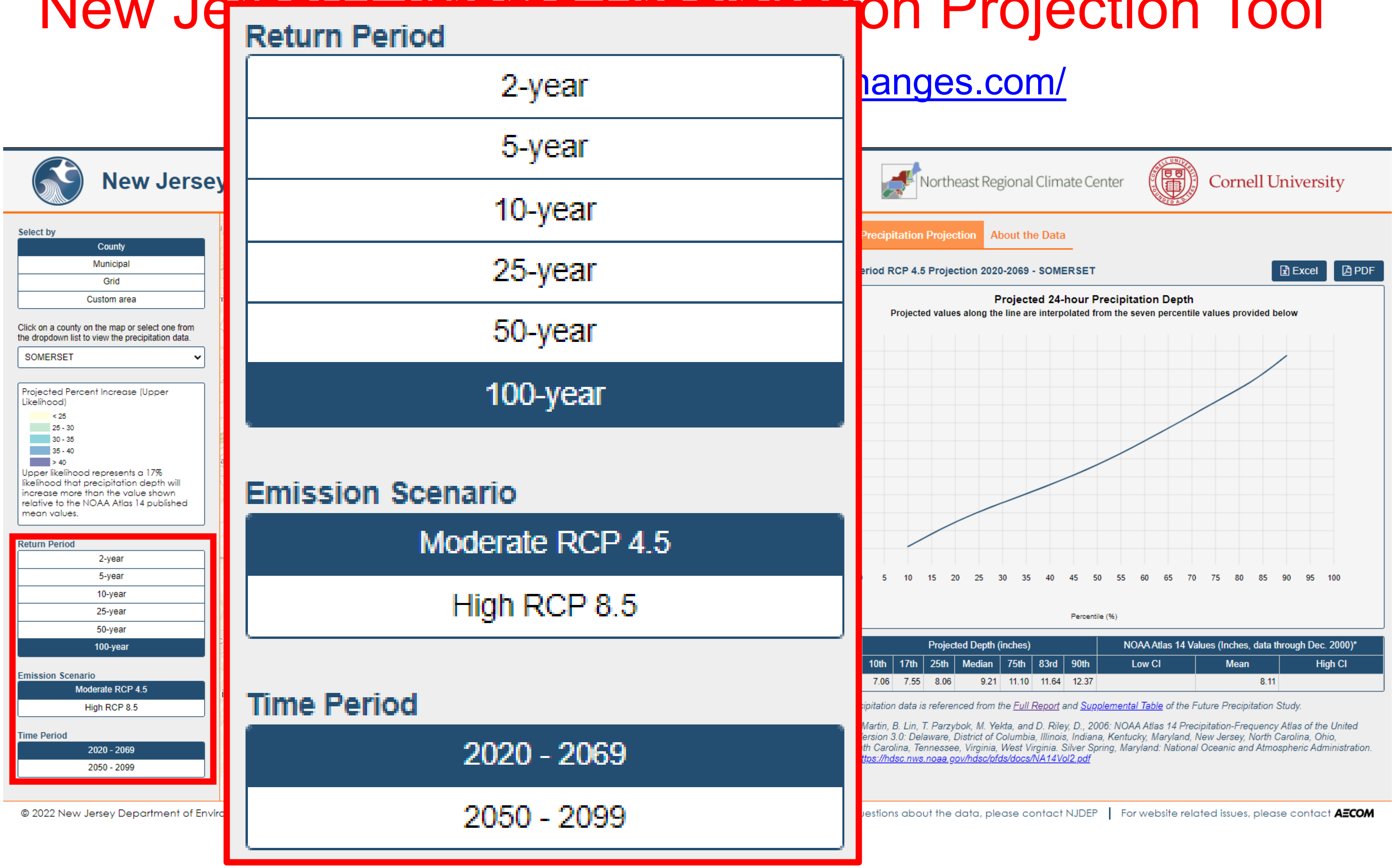
https://njprojectedprecipitationchanges.com/



Duration (hrs)	Projected Depth (inches)						
	10th	17th	25th	Median	75th	83rd	90th
24	3.09	3.20	3.30	3.51	3.75	3.86	3.97

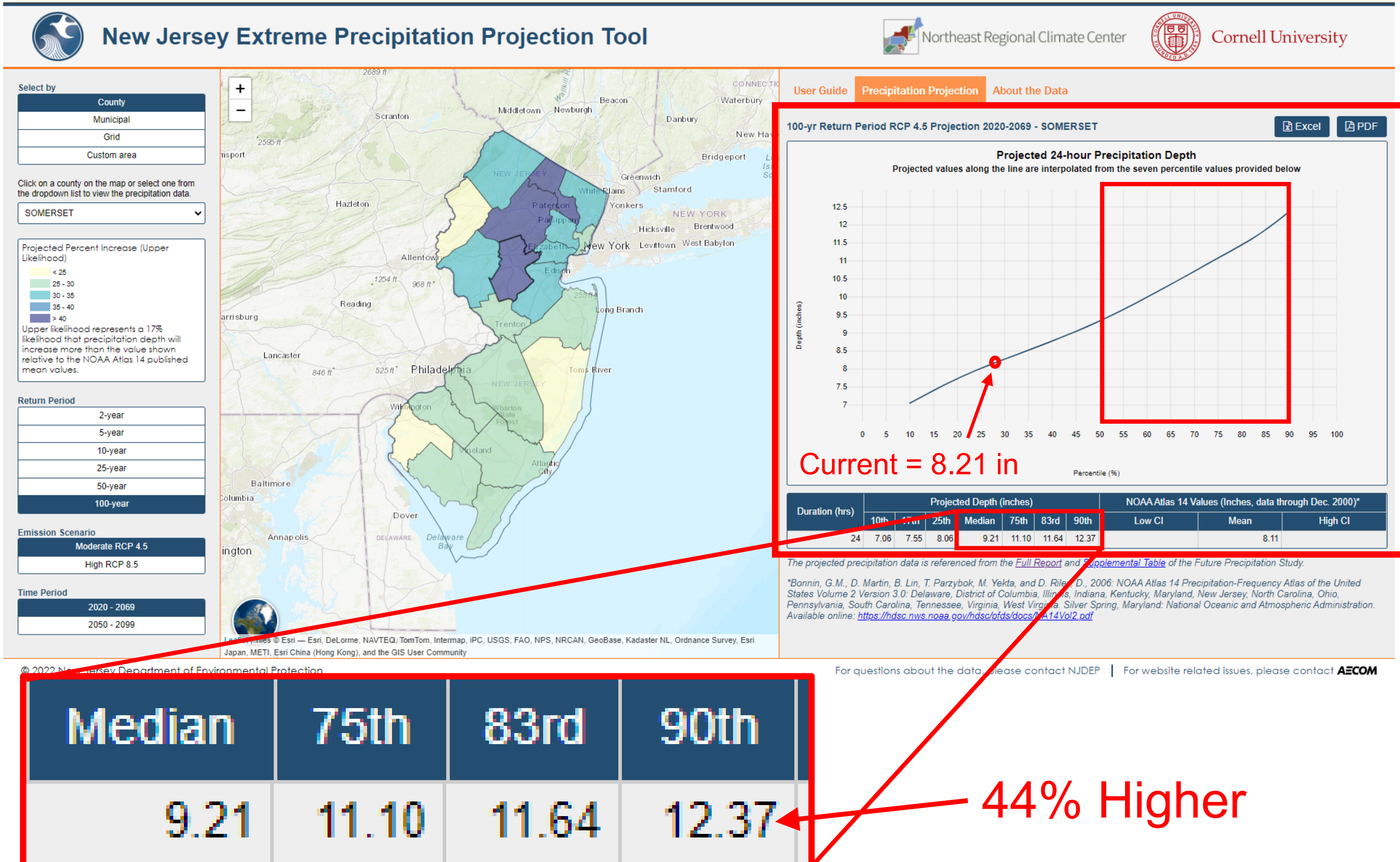
New Je … on Projection Tool

…hanges.com/



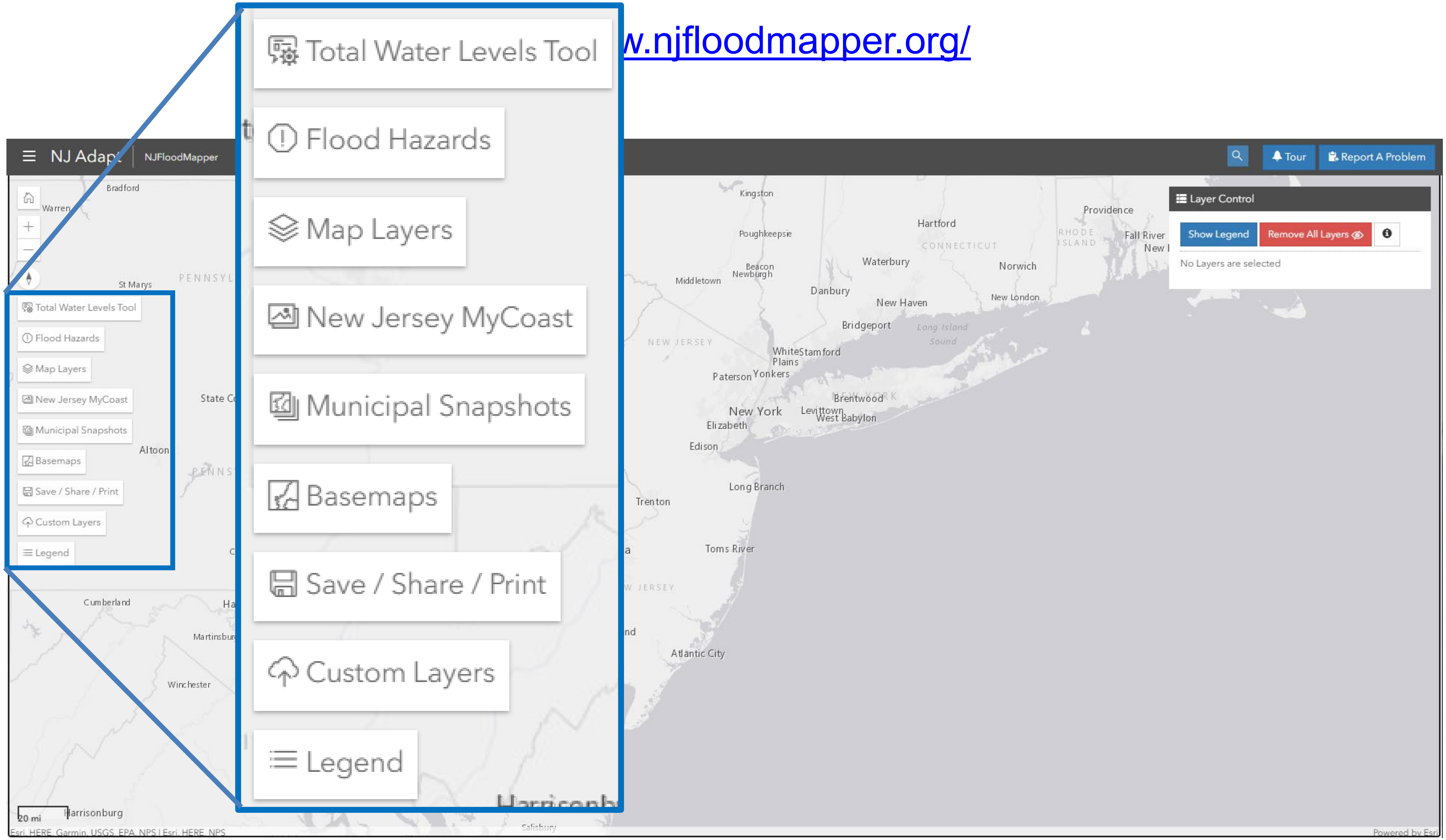
New Jersey Extreme Precipitation Projection Tool

https://njprojectedprecipitationchanges.com/



NJ Flood Mapper

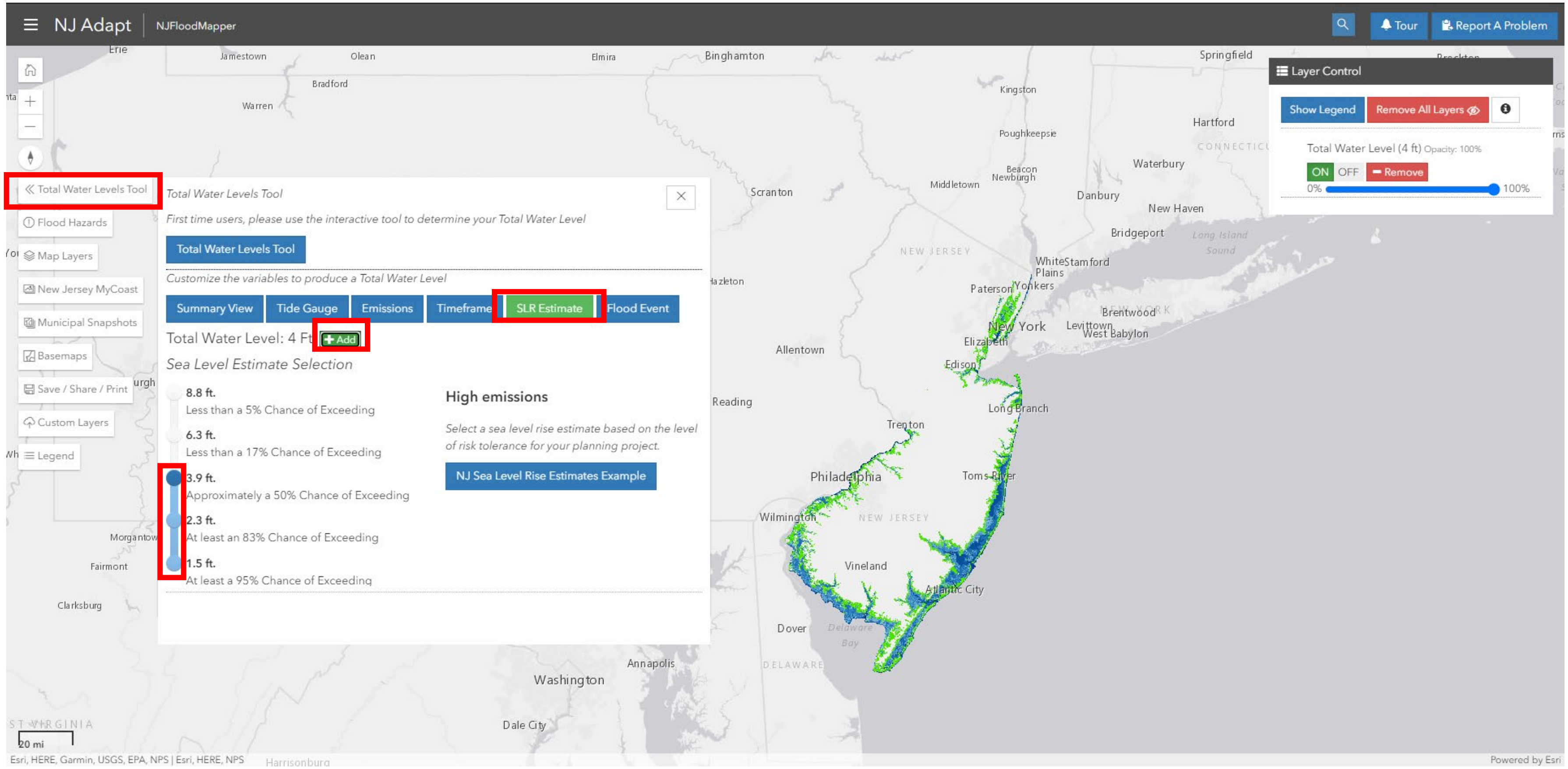
w.njfloodmapper.org/

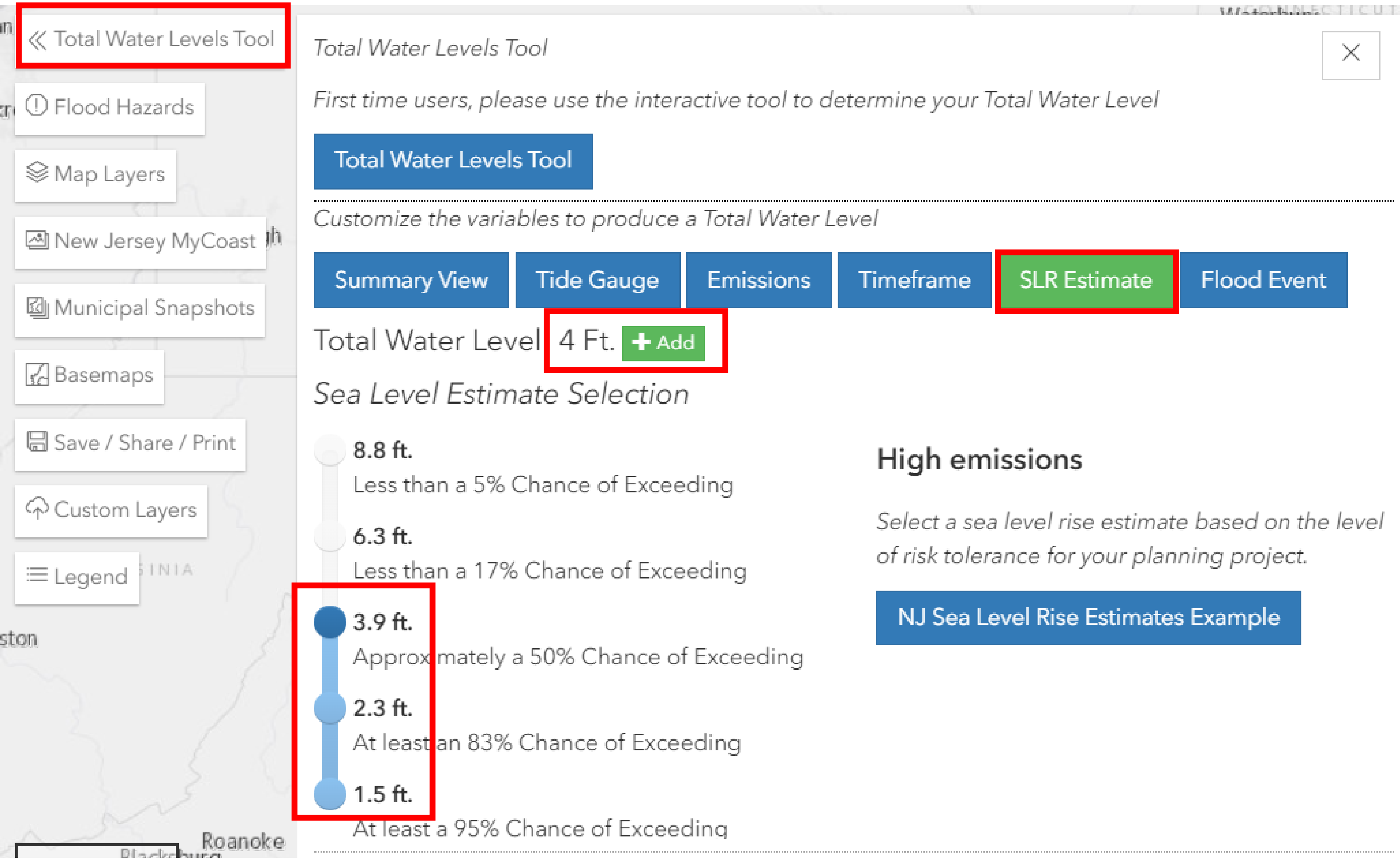


This is where you'll find the options to add data.

NJ Flood Mapper

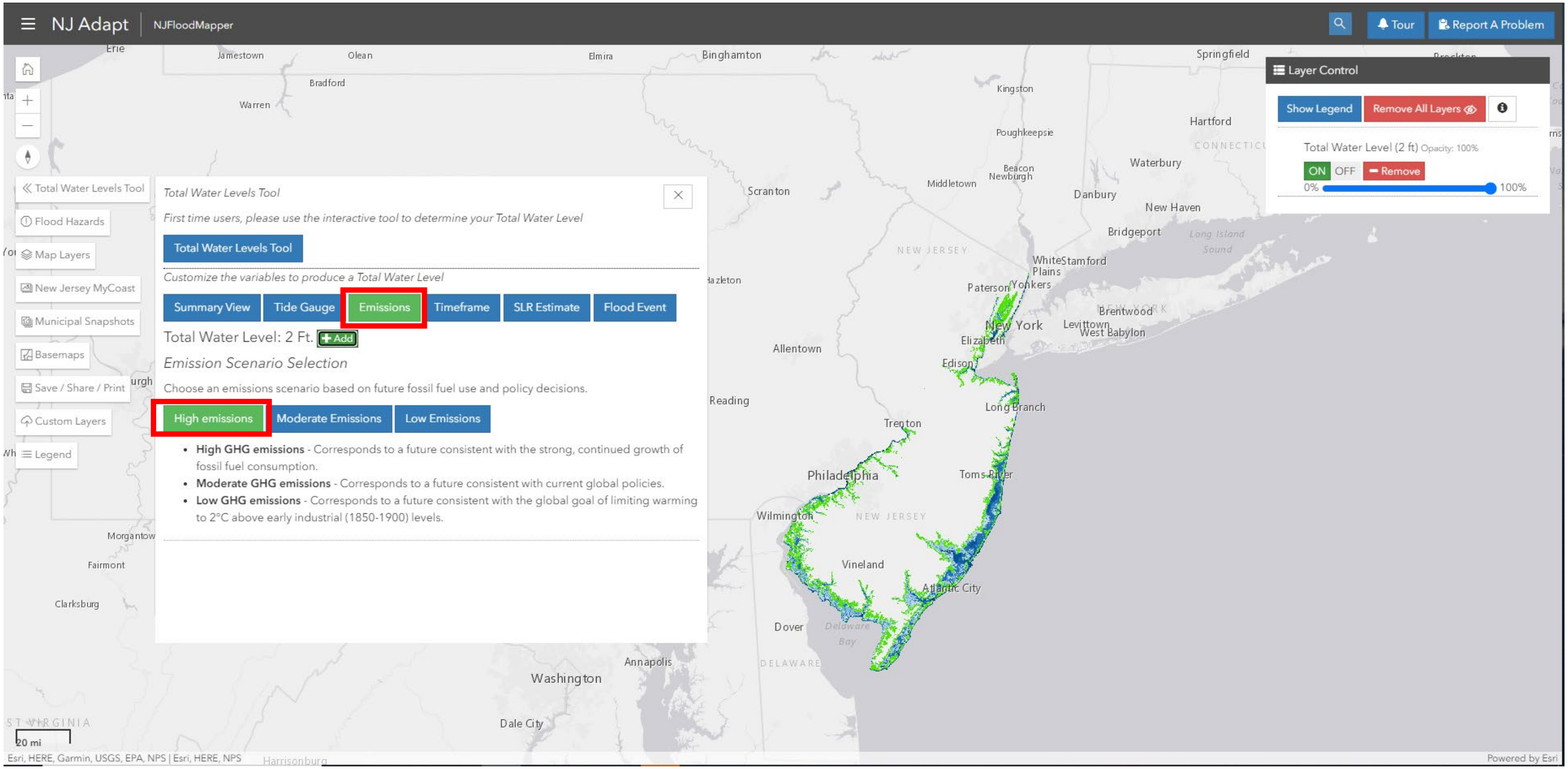
https://www.njfloodmapper.org/

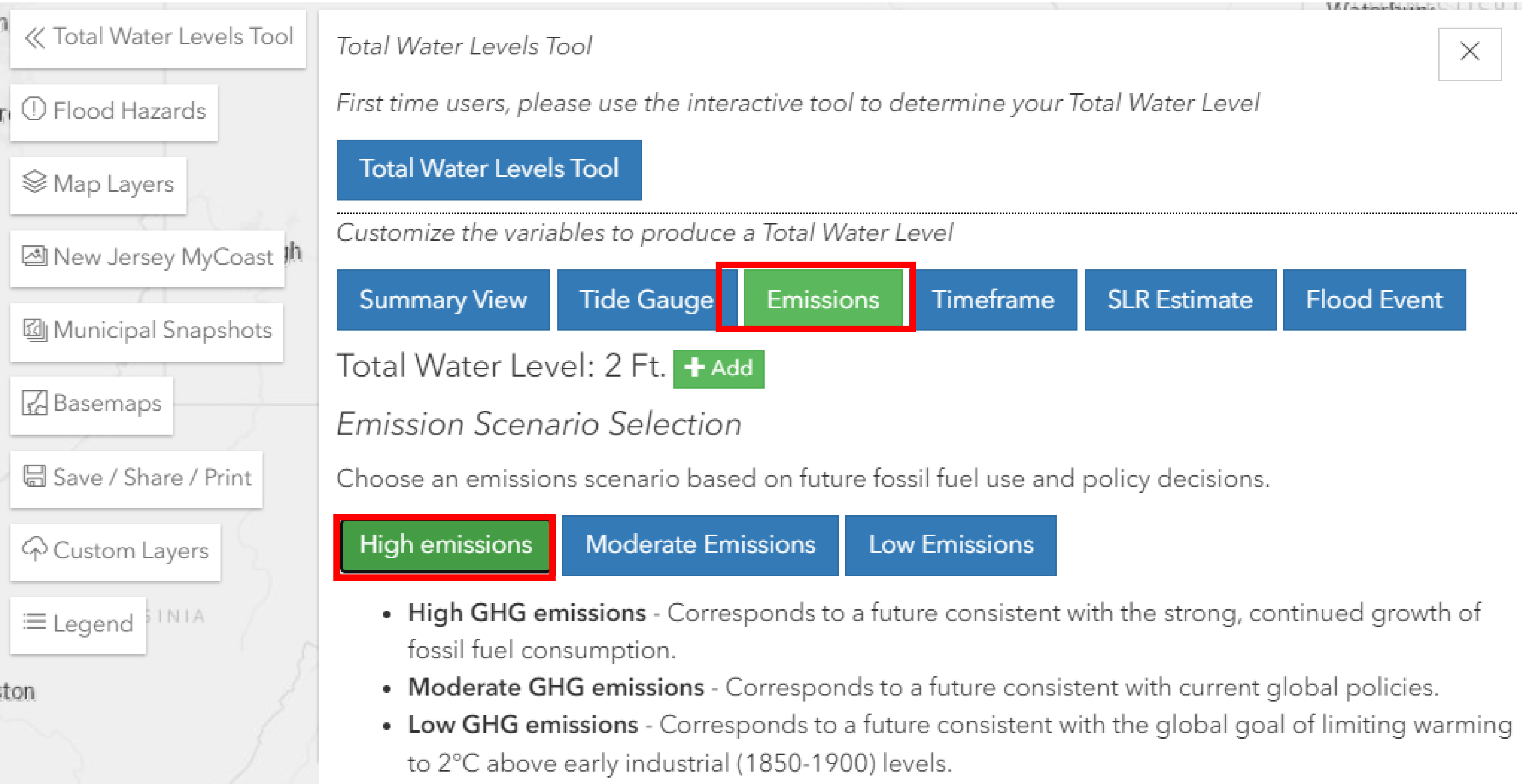



Total Water Levels Tool
Flood Hazards
Map Layers
New Jersey MyCoast
Municipal Snapshots
Basemaps
Save / Share / Print
Custom Layers
Legend
Roanoke
Total Water Levels Tool
First time users, please use the interactive tool to determine your Total Water Level
Total Water Levels Tool
Customize the variables to produce a Total Water Level
Summary View
Tide Gauge
Emissions
Timeframe
SLR Estimate
Flood Event
Total Water Level 4 Ft.
+ Add
Sea Level Estimate Selection
8.8 ft.
Less than a 5% Chance of Exceeding
6.3 ft.
Less than a 17% Chance of Exceeding
3.9 ft.
Approximately a 50% Chance of Exceeding
2.3 ft.
At least an 83% Chance of Exceeding
1.5 ft.
At least a 95% Chance of Exceeding
High emissions
Select a sea level rise estimate based on the level of risk tolerance for your planning project.
NJ Sea Level Rise Estimates Example

NJ Flood Mapper

https://www.njfloodmapper.org/





Total Water Levels Tool
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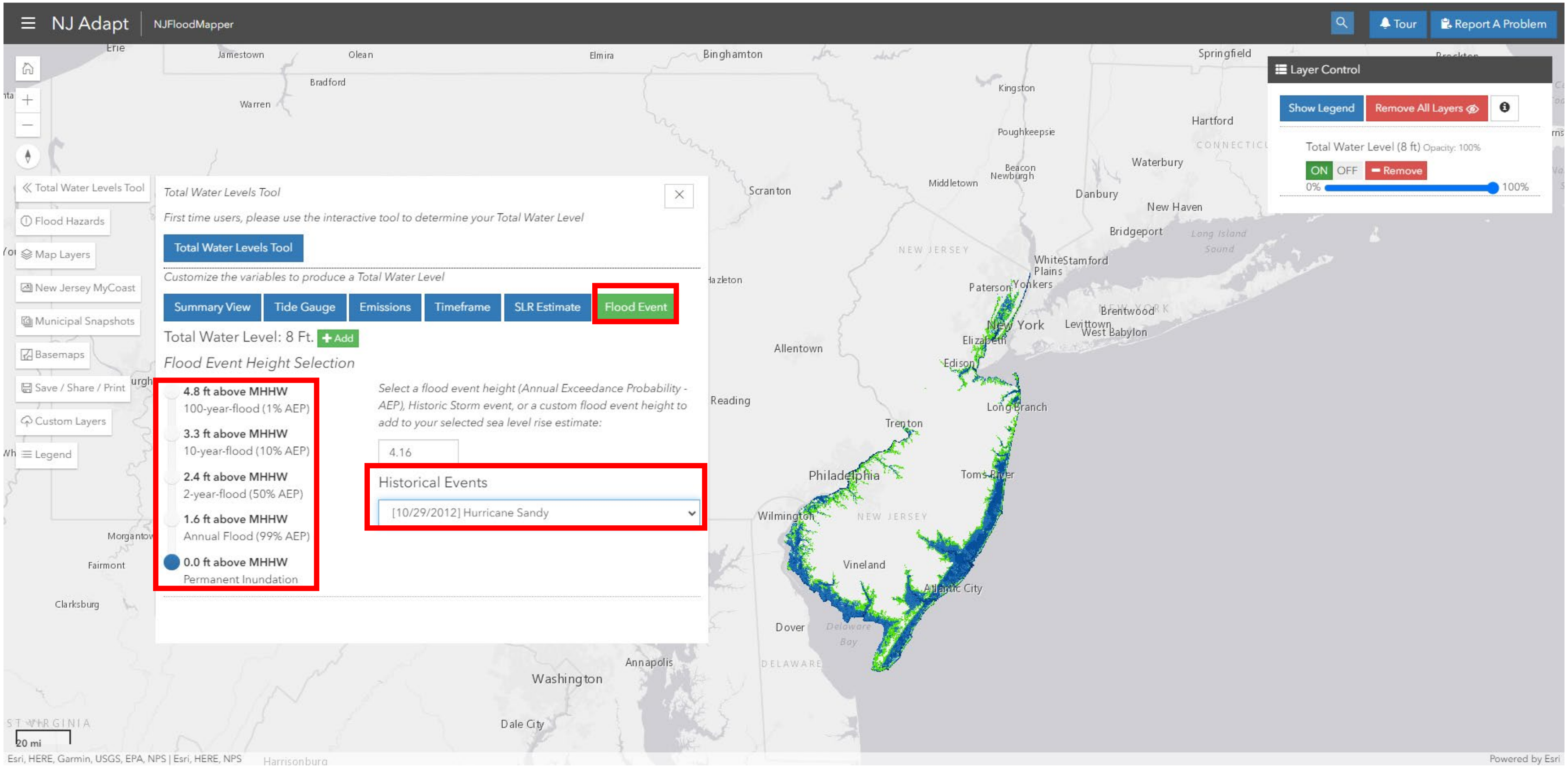
Total Water Levels Tool
Customize the variables to produce a Total Water Level
Summary View
Tide Gauge
Emissions
Timeframe
SLR Estimate
Flood Event
Total Water Level: 2 Ft.
Add
Emission Scenario Selection
Choose an emissions scenario based on future fossil fuel use and policy decisions.
High emissions
Moderate Emissions
Low Emissions
High GHG emissions - Corresponds to a future consistent with the strong, continued growth of fossil fuel consumption.
Moderate GHG emissions - Corresponds to a future consistent with current global policies.
Low GHG emissions - Corresponds to a future consistent with the global goal of limiting warming to 2°C above early industrial (1850-1900) levels.

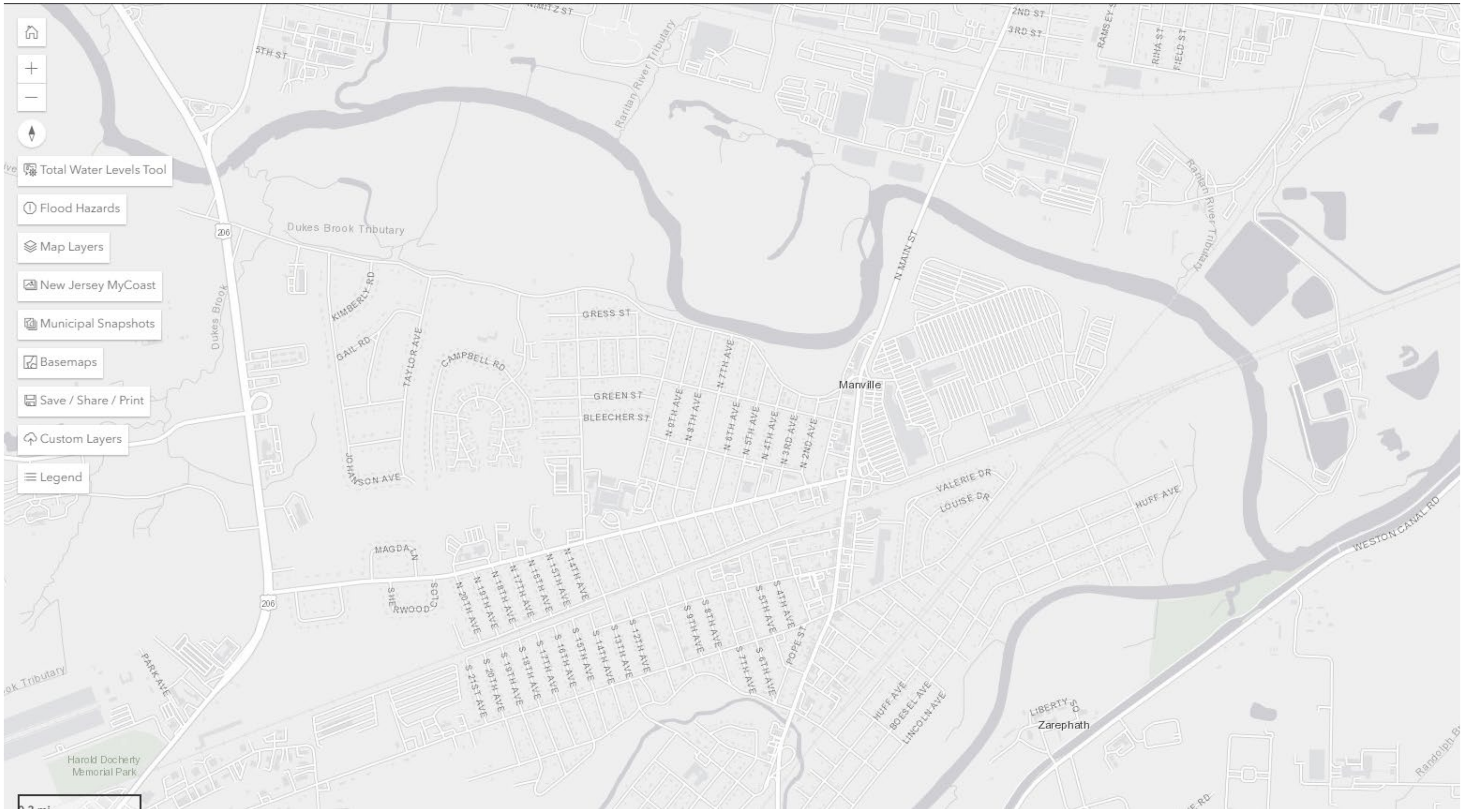
NJ Flood Mapper

https://www.njfloodmapper.org/



Manville Example

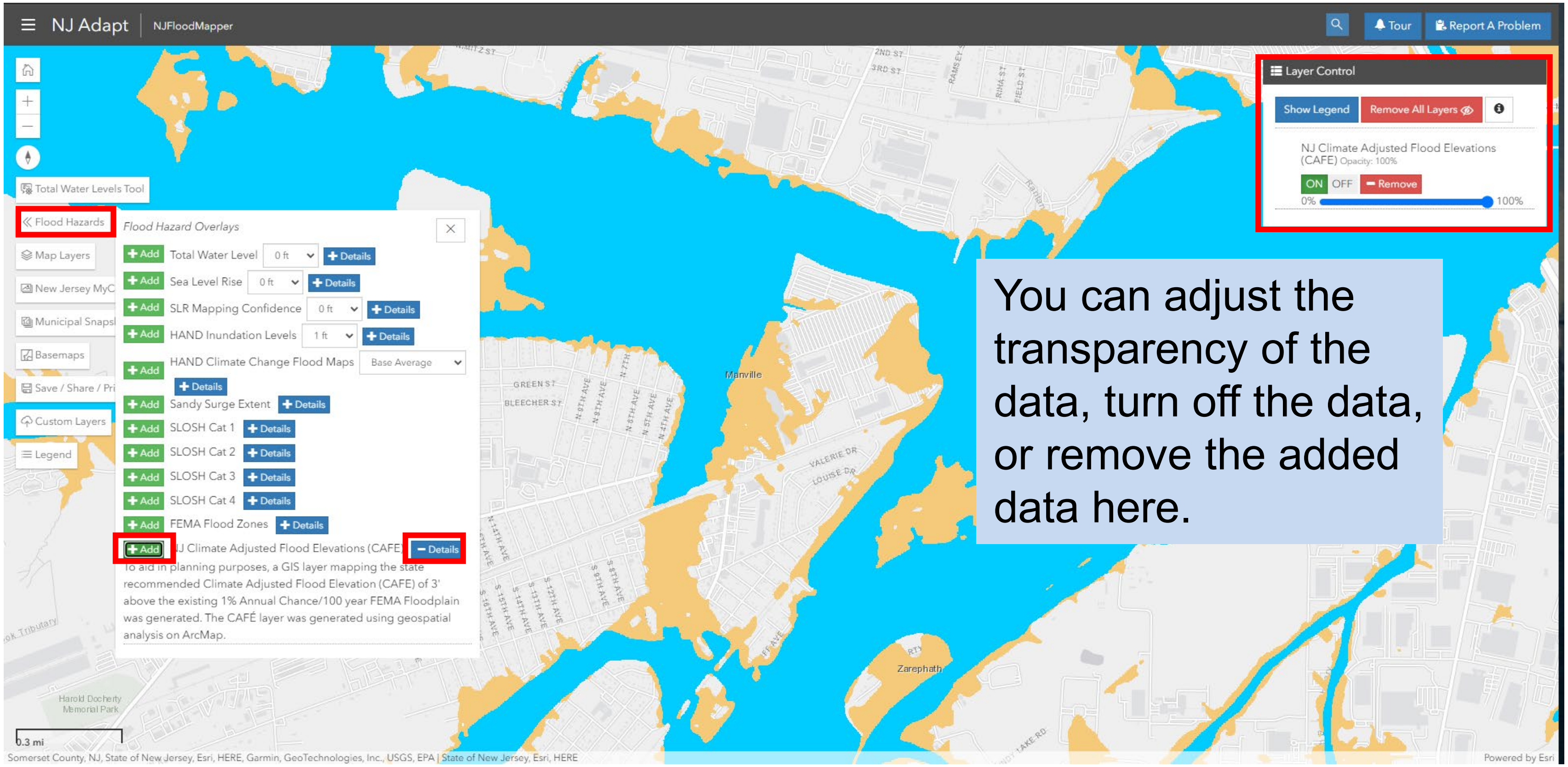
https://www.njfloodmapper.org/



Step one: Select an area of study.
You can zoom in and out using the mouse wheel.
Click and hold the left mouse button to drag the map view.

Manville Example

https://www.njfloodmapper.org/



Step two: select data from the boxes on the left panel.
Note: hitting the + Details box gives additional information about the data.

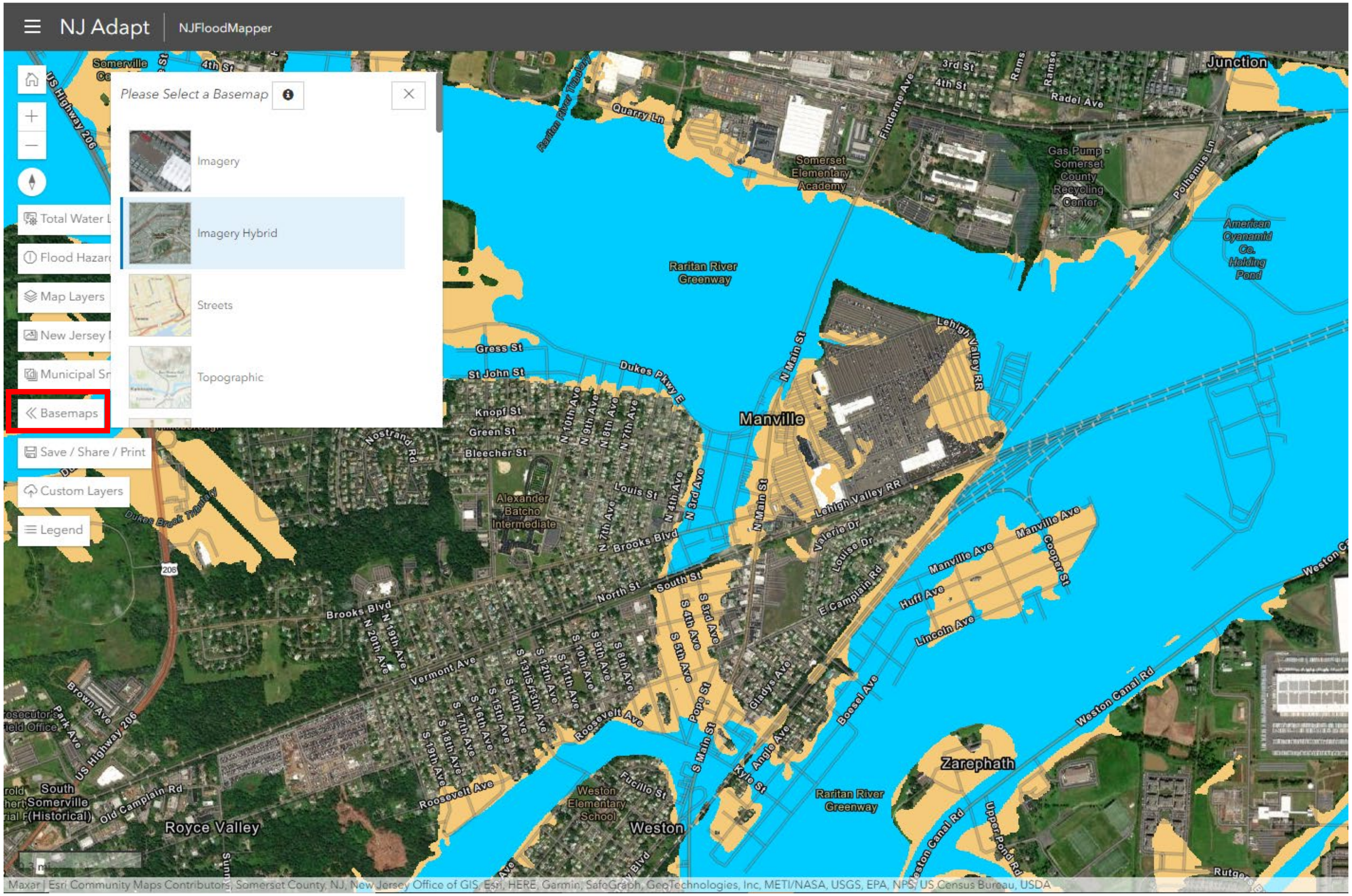
Manville Example

https://www.njfloodmapper.org/

Step three: Click the Legend on the side panel to reveal the meaning of the data.

Manville Example

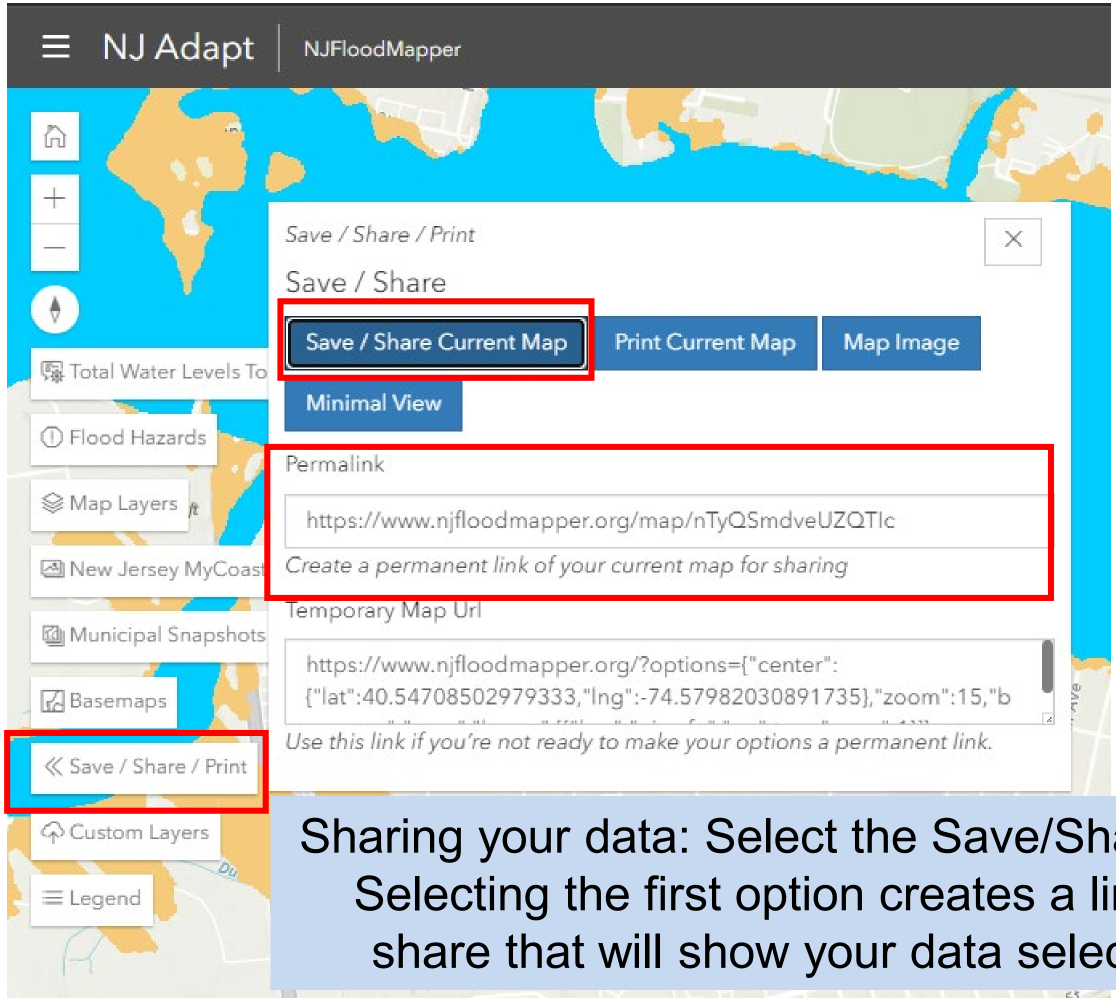
https://www.njfloodmapper.org/



Additional feature: Adding a Basemap.

Manville Example

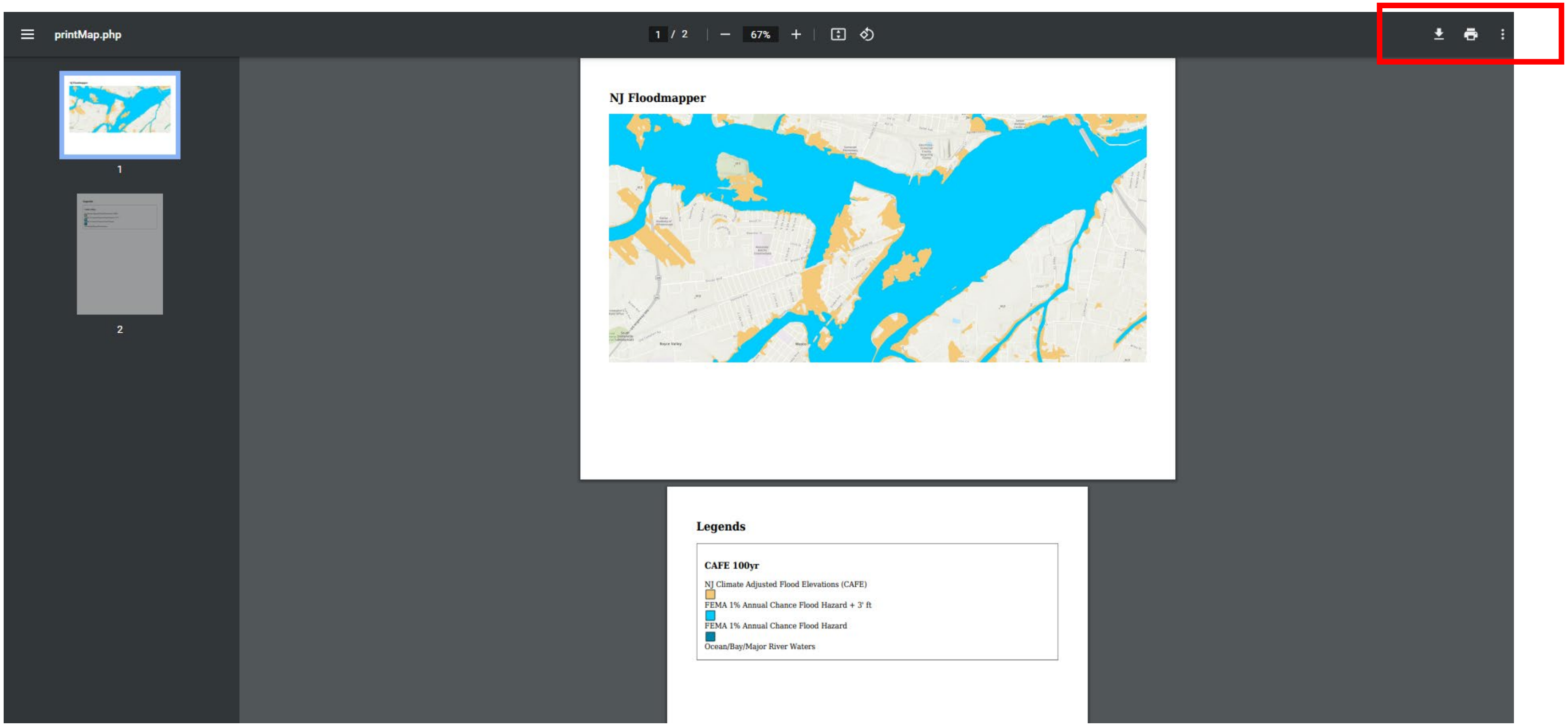
https://www.njfloodmapper.org/



Sharing your data: Select the Save/Share/Print box. Selecting the first option creates a link you can share that will show your data selection/view.

Manville Example

https://www.njfloodmapper.org/



If you select the "Print" option, it will download a view of the map with the data. It will also print the legend on a separate page. From there you can download as a PDF or send it to a printer.

Part IV: Strategies for Adaptation and Mitigation

IPCC Annual Report 6 Working Group II

- **<u>“Green Infrastructure” is mentioned 155 times in the report.</u>**

- “As green infrastructure is increasingly being used for stormwater absorption in cities (McPhillips et al., 2020), rain gardens, wetlands, or engineered infiltration ponds and bioswales are the nature-based solutions most likely to promote recharge, reduce evapotranspiration, and contribute to water provisioning.” – 6.3.4.5 Riverine Flood Impact Reduction (Pg. 1137)

- “Urban green infrastructure including urban gardens, can bring benefits to social cohesion, mental health and wellbeing and reduce the health impacts of heatwaves by decreasing temperatures, thus reducing inequities in exposure to heat stress for low income, marginalized groups (Hoffman et al., 2020) – 7.4.6.6 Adopting Mitigation Policies and Technologies that have Significant Health Co-benefits (Pg. 1408)

IPCC Annual Report 6 Working Group II

Diverse feasible climate responses and adaptation options exist to respond to Representative Key Risks of climate change, with varying synergies with mitigation

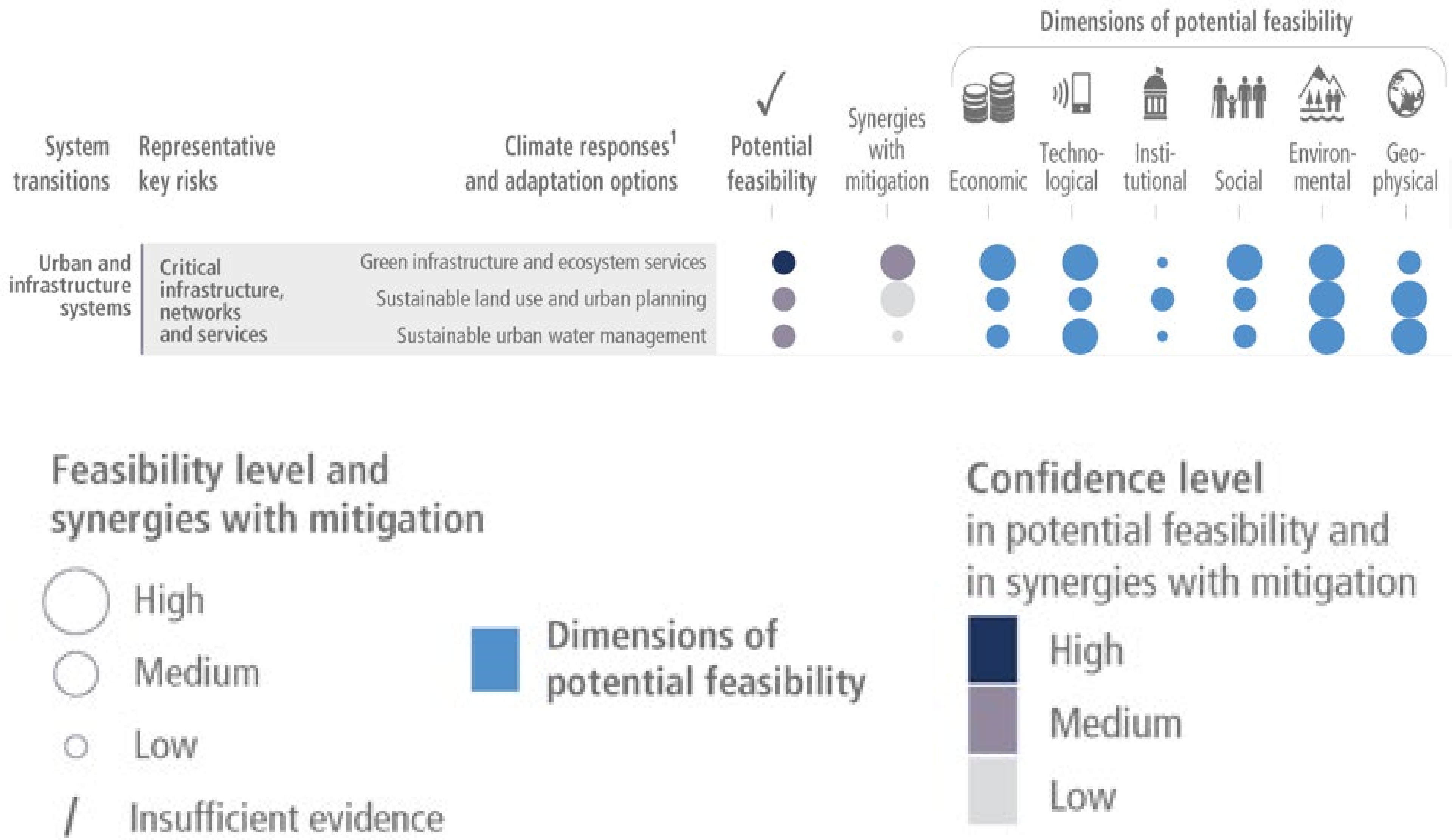
Multidimensional feasibility and synergies with mitigation of climate responses and adaptation options relevant in the near-term, at global scale and up to 1.5°C of global warming

Footnotes:

[1] The term response is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation.

[2] Including sustainable forest management, forest conservation and restoration, reforestation and afforestation.

[3] Migration, when voluntary, safe and orderly, allows reduction of risks to climatic and non-climatic stressors.



Dimensions of potential feasibility
System transitions
Representative key risks
Climate responses[1] and adaptation options
Potential feasibility
Synergies with mitigation
Economic
Techno-logical
Insti-tutional
Social
Environ-mental
Geo-physical
Urban and infrastructure systems
Critical infrastructure, networks and services
Green infrastructure and ecosystem services
Sustainable land use and urban planning
Sustainable urban water management
Feasibility level and synergies with mitigation
High
Medium
Low
Insufficient evidence
Dimensions of potential feasibility
Confidence level in potential feasibility and in synergies with mitigation
High
Medium
Low

IPCC Annual Report 6 Working Group II

Climate responses and adaptation options have benefits for ecosystems, ethnic groups, gender equity, low-income groups and the Sustainable Development Goals

Relations of sectors and groups at risk (as observed) and the SDGs (relevant in the near-term, at global scale and up to 1.5°C of global warming) with climate responses and adaptation options

Footnotes: [1] The term response is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation. [2] Including sustainable forest management, forest conservation and restoration, reforestation and afforestation. [3] Migration, when voluntary, safe and orderly, allows reduction of risks to climatic and non-climatic stressors. [4] The Sustainable Development Goals (SDGs) are integrated and indivisible, and efforts to achieve any goal in isolation may trigger synergies or trade-offs with other SDGs. [5] Relevant in the near-term, at global scale and up to 1.5°C of global warming.

System transitions	Climate responses[1] and adaptation options	Observed relation with sectors and groups at risk: Ecosystems and their	Ethnic groups	Gender equity	Low-income	SDG 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Urban and infrastructure systems	Green infrastructure and ecosystem services	+ (High)	/	+ (Low)	+ (Medium)			+			+		+	+	+	+	+	■				
	Sustainable land use and urban planning	+ (Medium)	• (Medium)	• (Medium)	• (Medium)			+			+		+	+	+	+		■				
	Sustainable urban water management	not assessed						+			+		+	+	+	+		■				

Relation with Sustainable Development Goals[4, 5]

Types of relation

- + With benefits
- – With dis-benefits
- • Not clear or mixed
- / Insufficient evidence

Confidence level
in type of relation with sectors and groups at risk

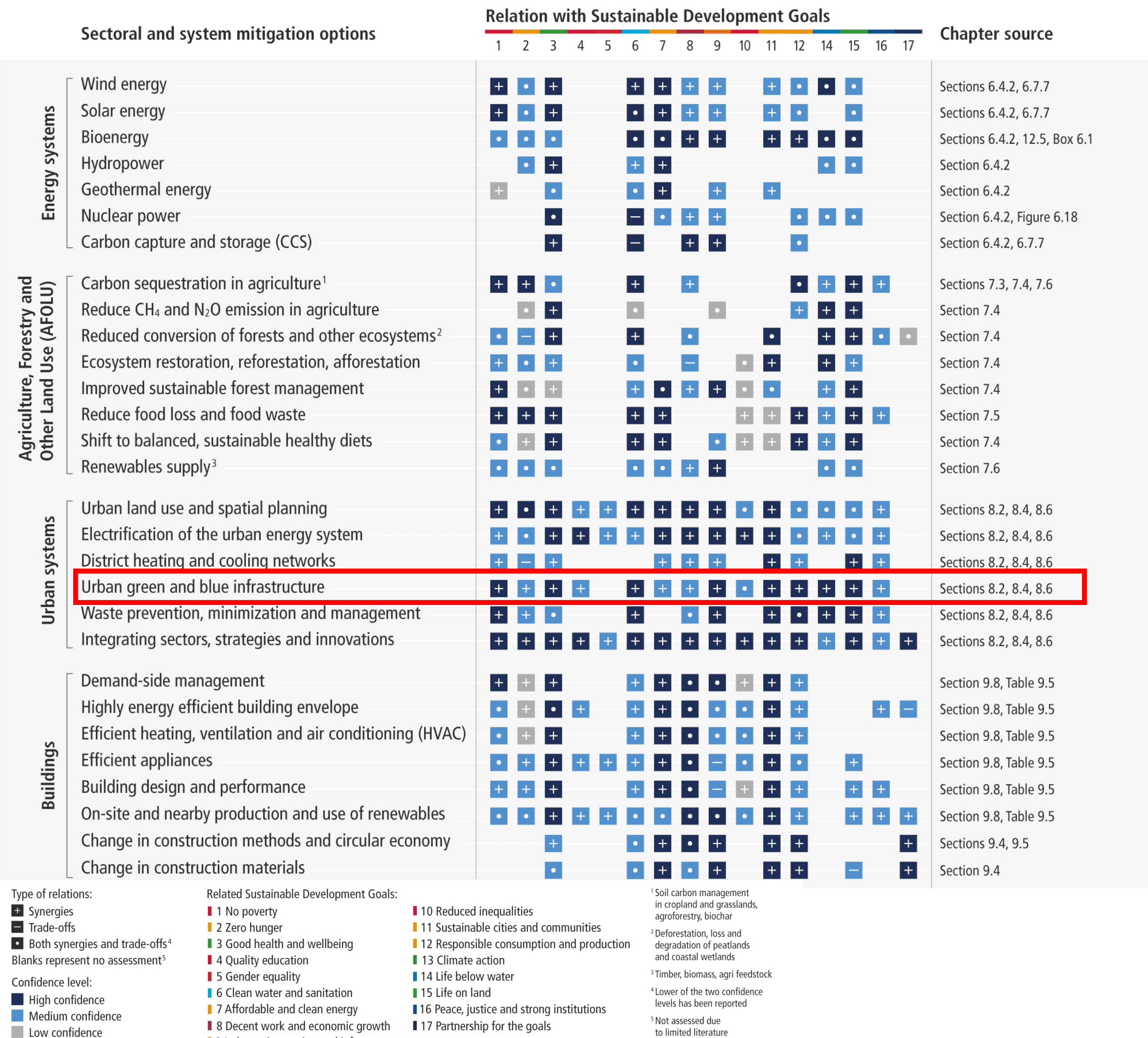
- High
- Medium
- Low

Related Sustainable Development Goals

1: No Poverty
2: Zero Hunger
3: Good Health and Well-being
4: Quality Education
5: Gender Equality
6: Clean Water and Sanitation
7: Affordable and Clean Energy
8: Decent Work and Economic Growth
9: Industry, Innovation and Infrastructure
10: Reducing Inequality
11: Sustainable Cities and Communities
12: Responsible Consumption and Production
13: Climate Action
14: Life Below Water
15: Life On Land
16: Peace, Justice, and Strong Institutions
17: Partnerships for the Goals

IPCC Annual Report 6 Working Group III

Mitigation options have synergies with many Sustainable Development Goals, but some options can also have trade-offs. The synergies and trade-offs vary dependent on context and scale.



2020 CLIMATE RESILIENCE SURVEY RESULTS

Top Six Concerns regarding climate change effects as selected by participants:

1. Increasing precipitation/storms
2. Sea-level rise
3. Decreased water quality
4. Extreme temperatures
5. Ocean acidification
6. Decreased air quality

Climate Resilience Actions favored by participants to be implemented by the state:

1. Incentivize green infrastructure/nature-based solutions
2. Preserve natural lands
3. Regulate at risk buildings/development
4. Support vulnerable populations
5. Pilot innovative solutions

Coastal Resilience Strategies favored by participants to be implemented by the state:

1. Marsh restoration and migration
2. Living shorelines
3. Buyouts or managed retreat
4. Infrastructure projects
5. Beach and dune nourishment

Types of Organizations that participated:

Non-profit organization	Regional/county/ municipal government	Business	University/ college	State agency	Other	Federal agency
25.2%	20.0%	15.5%	12.3%	11.0%	10.3%	5.8%

From State of New Jersey Climate Resilience Strategy - 2021

STRATEGY 2.3:

Deploy Natural and Nature-based Solutions for Resilience

ACTIONS

2.3.1 Create a homeowner assistance program to encourage use of nature-based shoreline stabilization statewide

2.3.2 Prioritize investment in green infrastructure to augment water quality protection and stormwater management, particularly in underserved communities

2.3.3 Deploy urban and community forestry solutions for heat mitigation, stormwater retention, beautification, and air quality benefits

Rain Garden

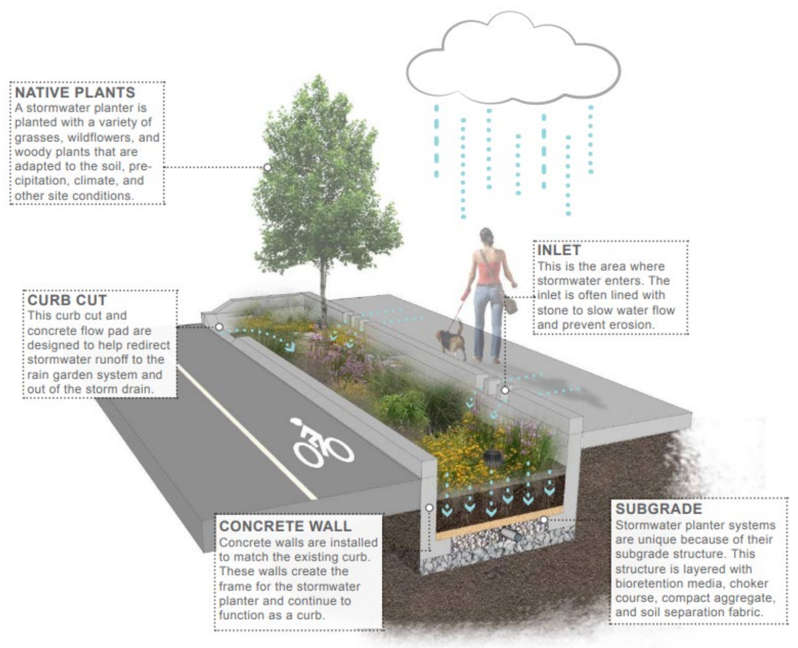
Harnessing the power of nature through natural and nature-based solutions supports multiple resilience goals. Natural and nature-based solutions are resilience interventions that utilize natural ecological processes to reduce negative environmental impacts. Some common examples include trees

From State of New Jersey Climate Resilience Strategy - 2021

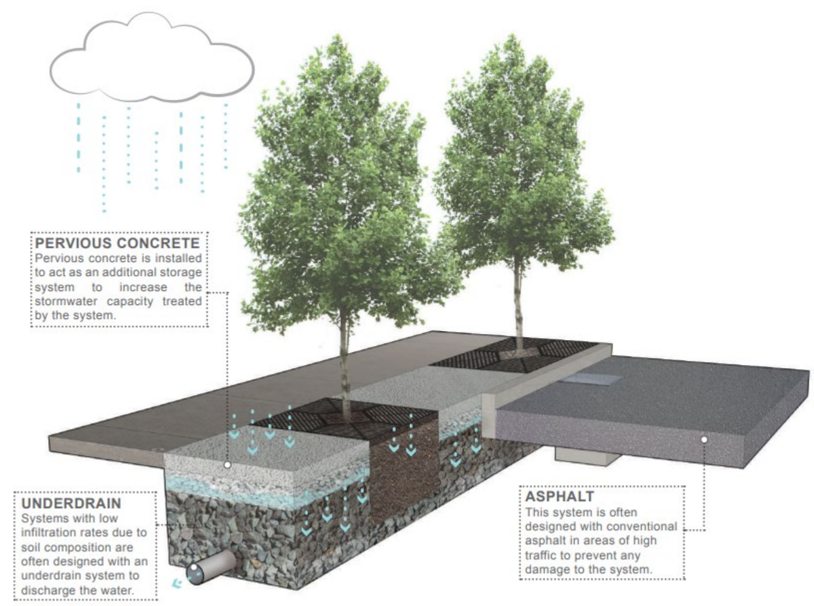
New Jersey Global Warming Response Act 80x50 Report

Table 7.5 Carbon Sequestration Programmatic Recommendations

Actions	Entity	Timeframe	Reference
Update the Municipal Land Use Law to encourage and facilitate green infrastructure including green streets. Prioritization should be given to infrastructure that accommodates trees.	DCA	Near-term	



Green Infrastructure Guidance Manual



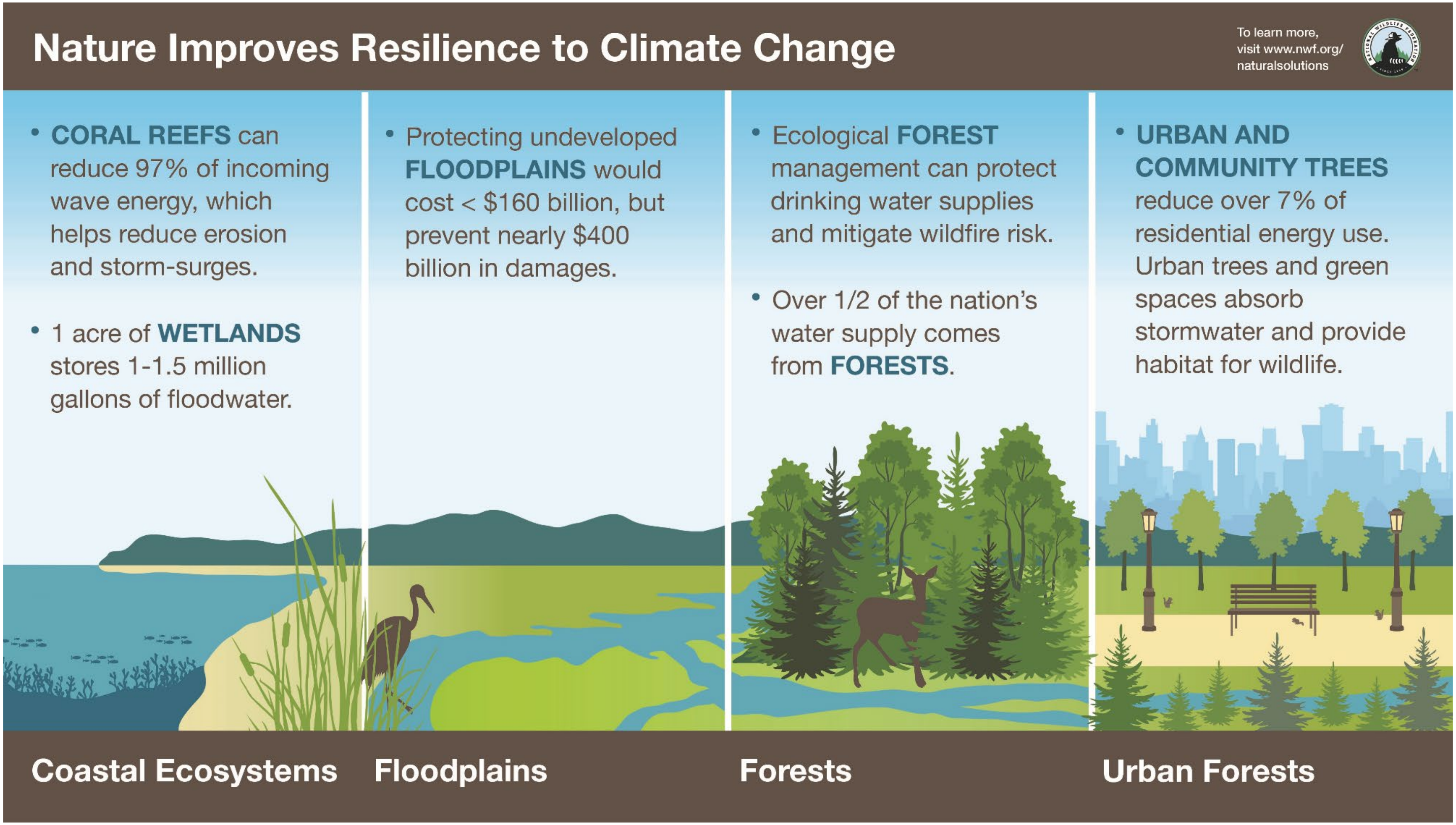
Green Infrastructure Guidance Manual

New Jersey PACT
Protecting Against Climate Threats

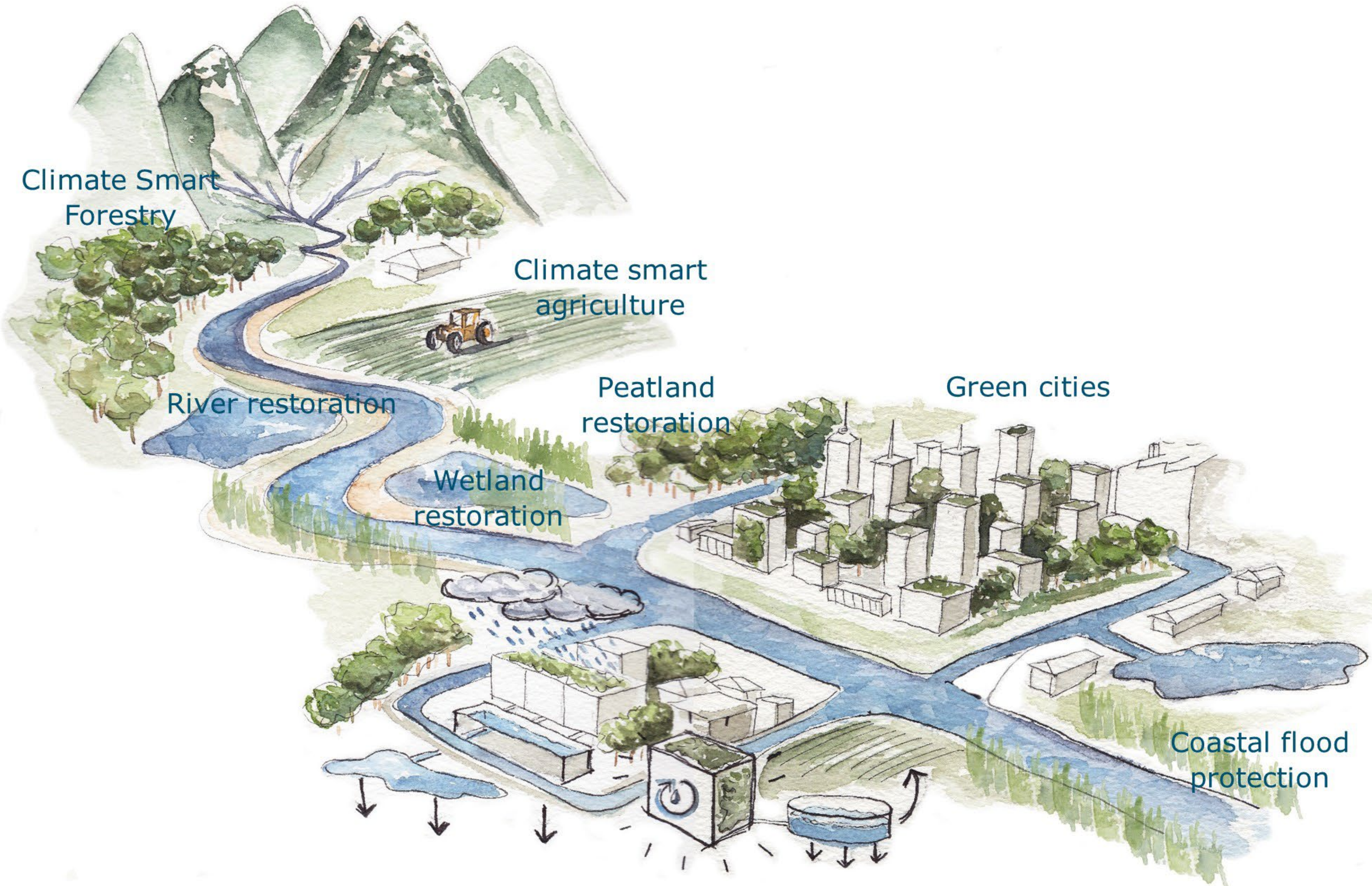
Resilient Environments and Landscapes (REAL)

Modernizing environmental land use rules to respond to climate change by considering risks such as sea level rise and chronic flooding, and to facilitate climate resilience by supporting green infrastructure and renewable energy. To learn more about the Department's rulemaking efforts pursuant to the REAL initiative.

Nature-Based Solutions



Nature Based Climate Solutions



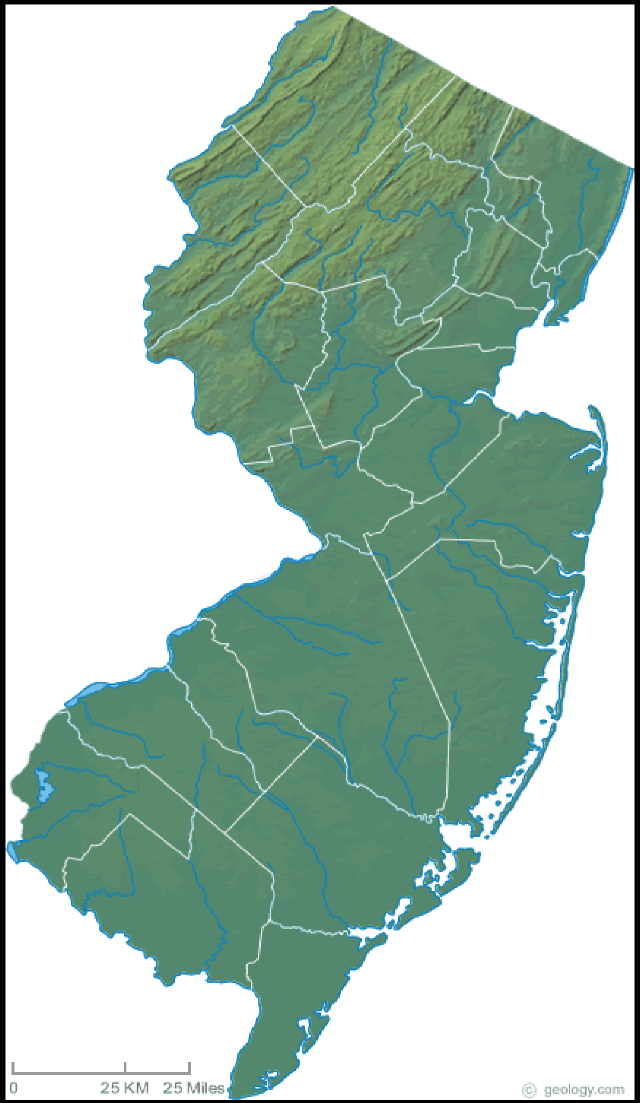
Rutgers
New Jersey Agricultural Experiment Station

So what did we learn?

Climate change …
it's real, it's
happening now,
and it's affecting
New Jersey.

Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding

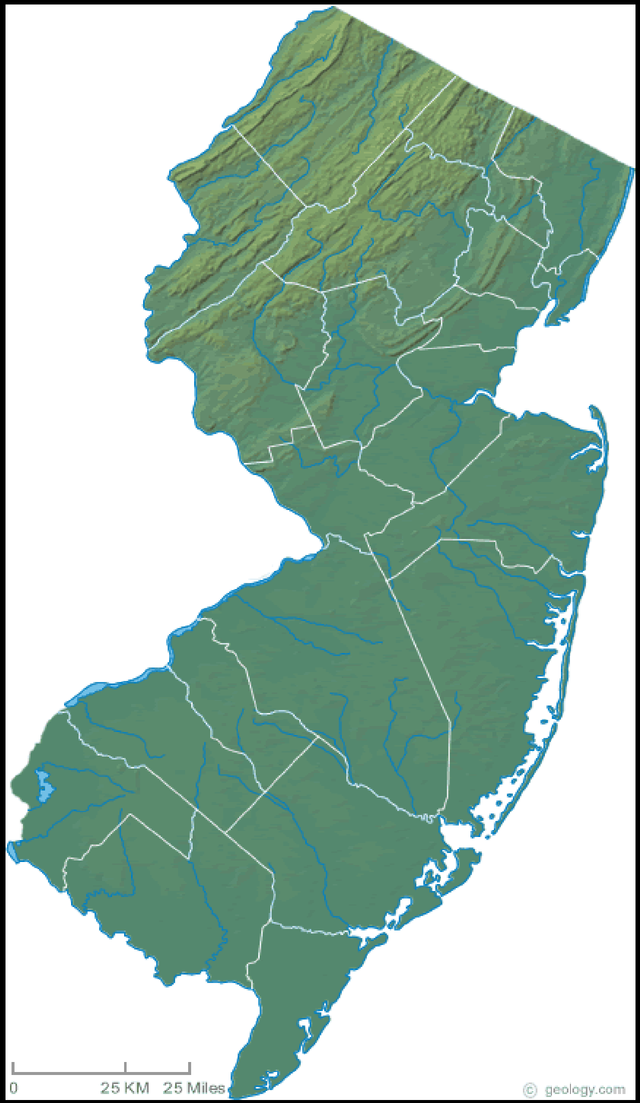


What do we do now?

- Reduce carbon emissions
- Convert to alternative sustainable fuels (solar and wind)
- Pray
- Manage stormwater runoff more effectively using sustainable practices
- Work together – only through cooperative and collaborative partnership will we be successful

Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding



Rainwater Harvesting - Functions

- Rainwater harvesting involves collecting, filtering, and storing water from roof tops and paved and unpaved areas for multiple uses.
- Harvested water can be used for nonpotable or potable purposes after testing and treatment.
- Surplus water after usage can be used for recharging groundwater.
- Systems can range in size from a simple PVC tank or cistern to a contractor designed and built tank/sump with water treatment facilities.

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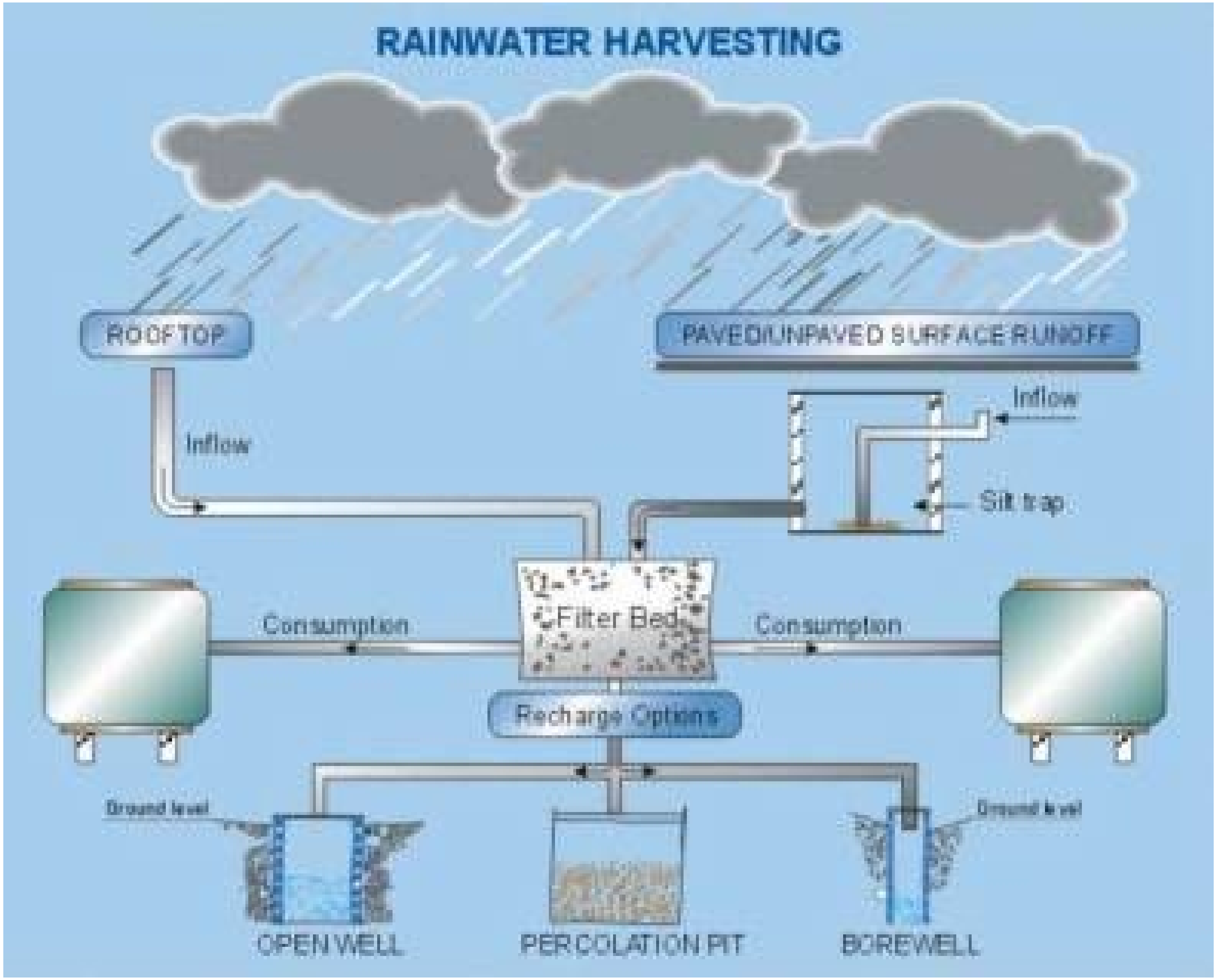
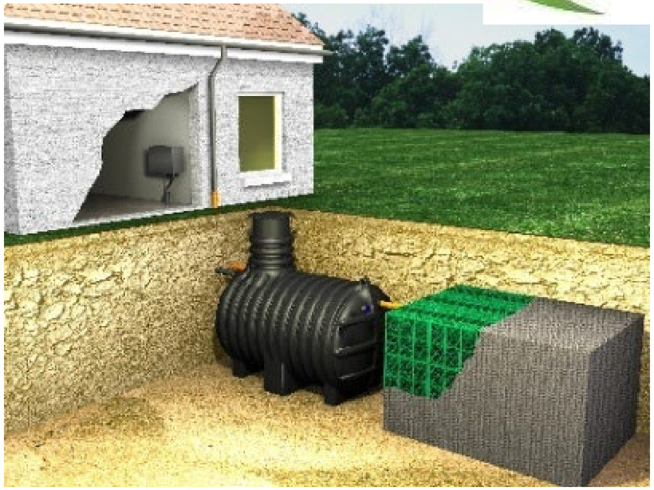
New Jersey Agricultural Experiment Station

Rainwater Harvesting – Components





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Sizing

- The rule of thumb is 600 gallons of water per inch of rain per thousand square feet of catchment area.
- Not all the rain that falls can actually be collected; efficiency is usually presumed to be 75% depending on system design and capacity.

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New Jersey Agricultural
Experiment Station

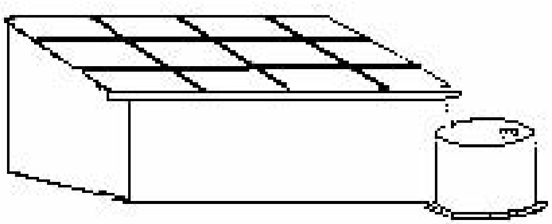
Sizing Formula

Here is the basic formula for calculating the potential amount that can be collected:

$$\frac{\textit{(Catchment area) x (inches of rain) x (600 gallons) x (.75)}}{\textit{1,000 square feet}}$$

Design Example

The sample roof shown below has a catchment area that is 40 feet wide and 30 feet long. Hence, it has a 1,200 square feet roof (40 feet wide x 30 feet long). Assume that it rains 2 inches. We can now plug this information into our general formula (see equation above).



Catchment Area = 1,200 square feet

Amount of Rain = 2 inches

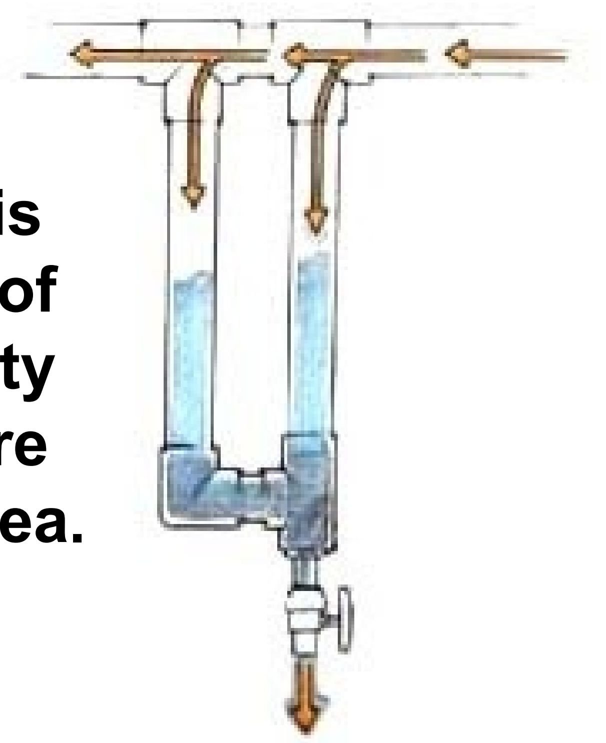
Gallons of water collected per inch of rain per 1,000 square feet = 600 gallons

Percent Efficiency = 75% or 0.75

$$\frac{\textit{(1,200 square feet) x (2 inches of rain) x (600 gallons) x (.75)}}{\textit{1,000 square feet}} = \textit{1,080 gallons}$$

First Flush Diverter or Roof Washer

The rule of thumb is one to two gallons of roof washer capacity for every 100 square feet of catchment area.



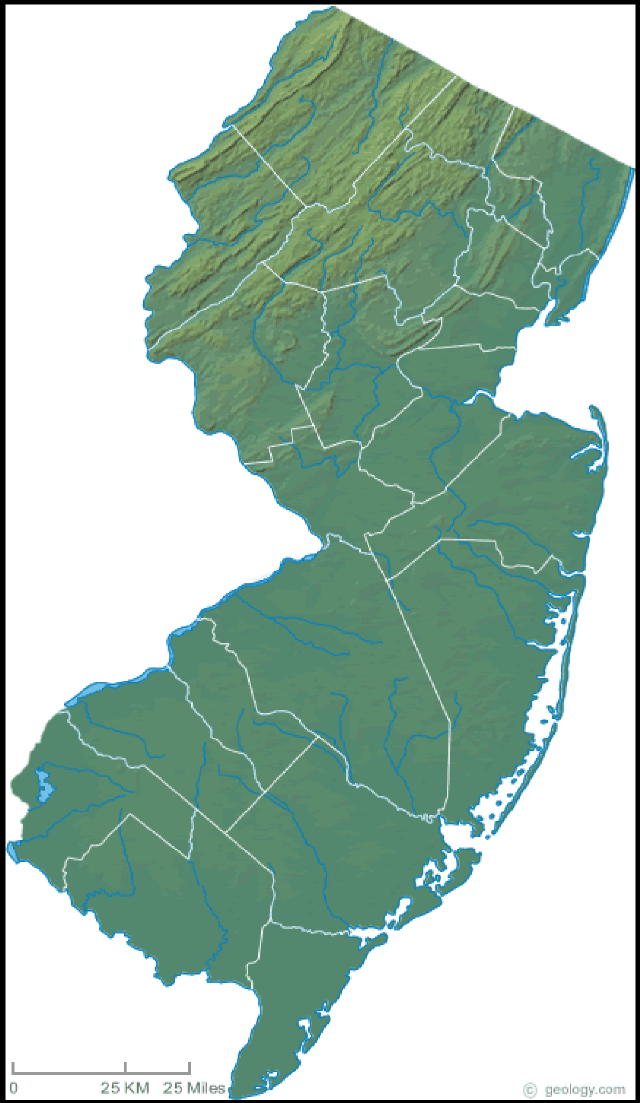
- A one foot length of 6 inch diameter PVC pipe holds 1.5 gallons.
- A one foot length of 4 inch diameter PVC pipe holds 0.66 gallons.

Construction

- The most stable place to position the cistern is against a stable wall on level ground as close to the downspout as possible.
- Gravity moves water downhill. Be sure there is available space for a downward pitch in all pipes.
- The cistern on its platform is the highest point of the garden but the lowest point of the system.
- The overflow pipe should be directed toward a rain garden not toward pathways or structures.
- The overflow pipe should flow from the cistern's highest point.
- The spigot should be at the cistern's lowest point.

Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding



KNOWN: The New Jersey Water Quality Design Storm is 1.25 inches of rain over two-hours and 90% of New Jersey rainfall events come in storms of less than 1.25 inches of rain.

UNKNOWN: If "heavy rains become more intense" due to climate change in New Jersey, how much will the New Jersey Water Quality Design Storm increase?

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The scientists just say it will be “more,” but how do we design for “more?”

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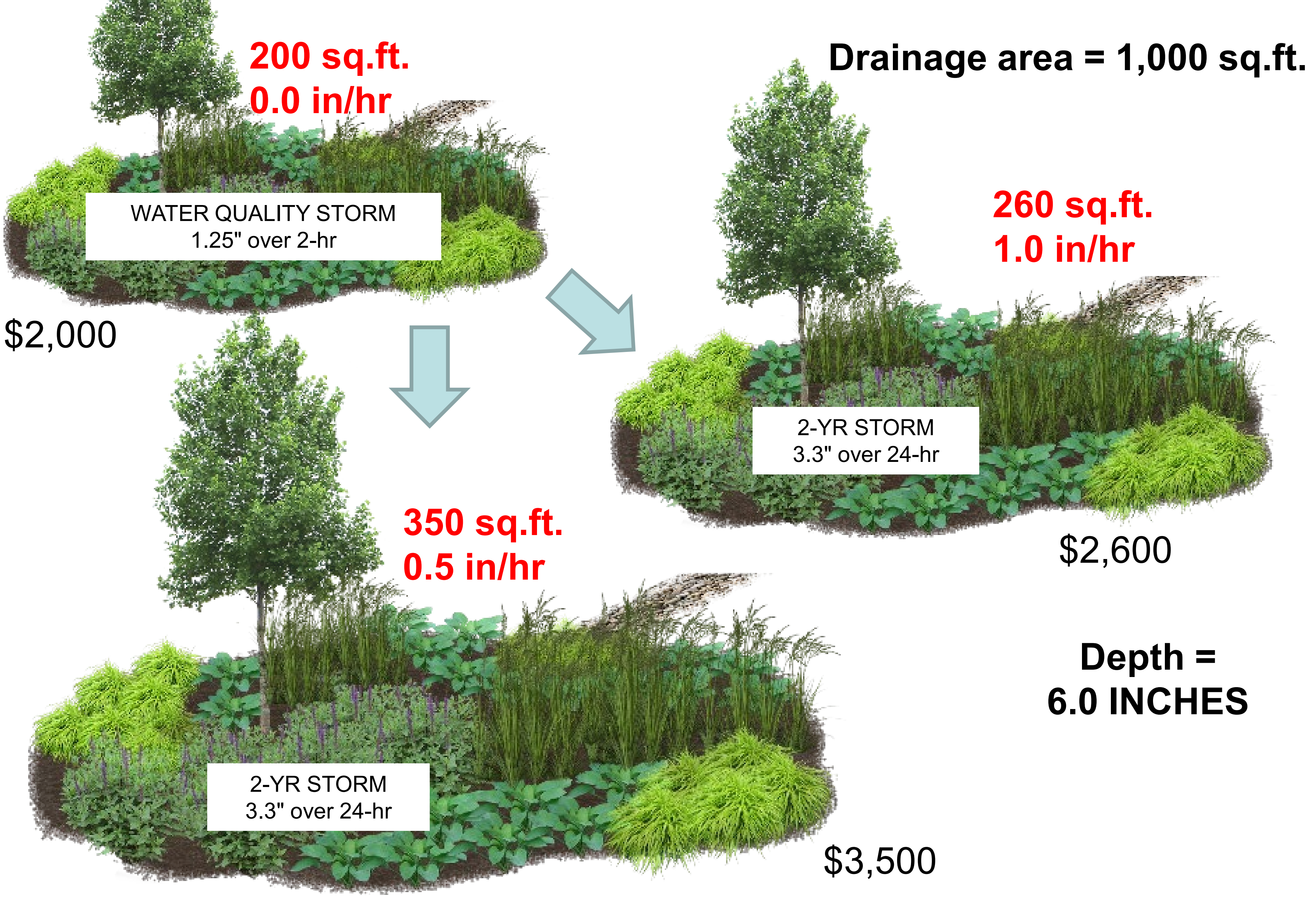
Experiment Station

What if we size our green infrastructure practices for the next higher design storm – the two-year storm (3.3 inches of rain over 24 hours)?

Parameters	Two-hour design storm	24-hour design storm
Rainfall total	1.25 inches	3.3 inches
Drainage area	1,000 sq.ft.	1,000 sq.ft.
Infiltration during the storm	None	0.5 to 1.0 in/hr
Cost basis	Surface area	Surface area

Climate Resilient Rain Garden



Climate Resilient Rain Garden

260 sq.ft.
1.0 in/hr

Depth =
6.0 INCHES

260 sq.ft.
0.5 in/hr

Depth =
9.0 INCHES

$2,600

Results

Rain Garden Surface Area (sq. ft.)	Rain Garden Depth (in.)	Rain Garden Storage Volume (cu. ft.)	Rain Garden Capacity for 2-hr Rainfall (in.)	Cost ($)
200	6	100	1.25	2,000
260	6	130	1.56	2,600
350	6	175	2.10	3,500
260	9	195	2.34	2,600

What if we combined roadside rain gardens with street trees?


Credit: Montgomery County, MD

Can green infrastructure be used to control flooding from larger storms?



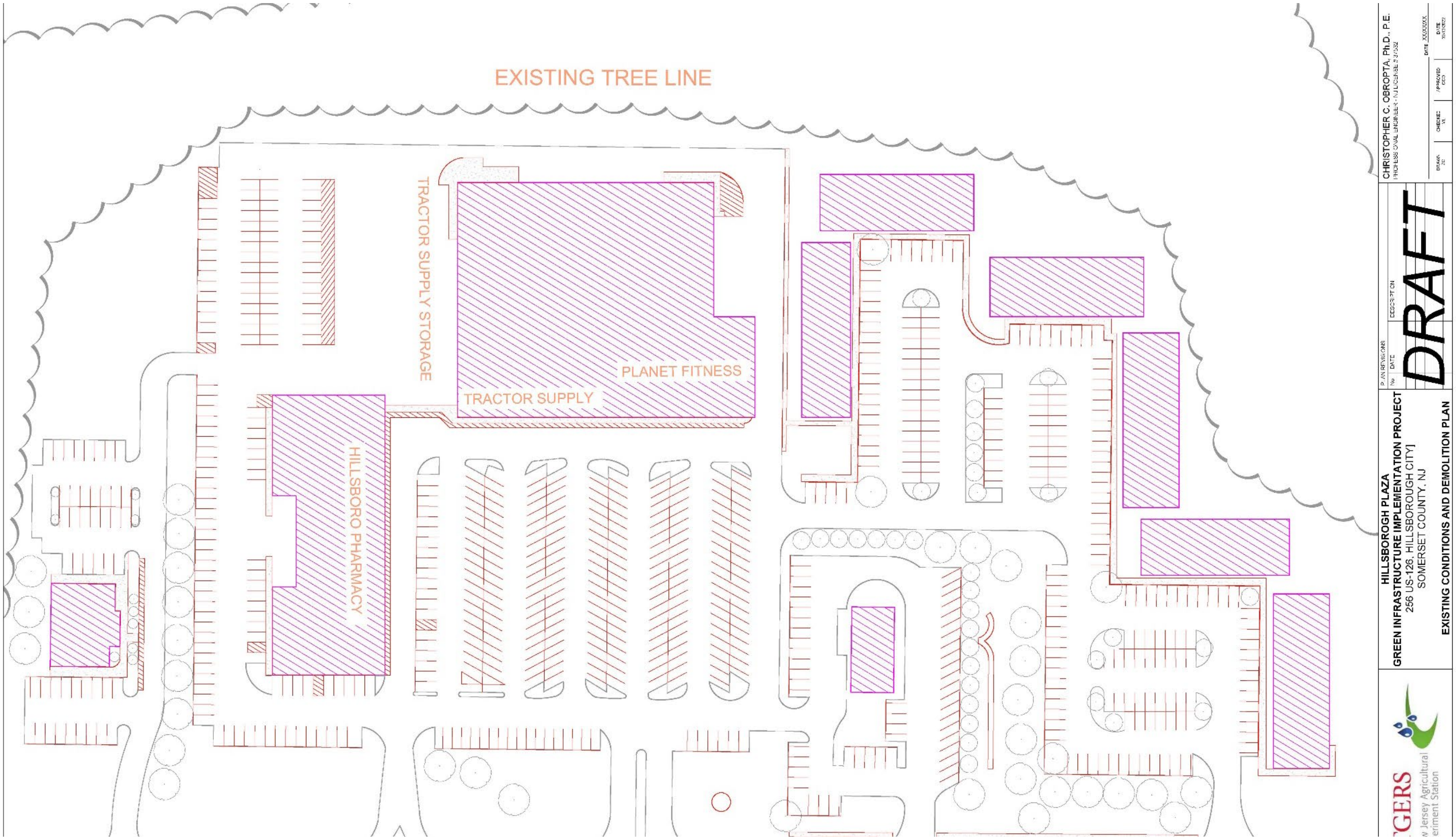
Bioretention is an option, but does it take up too much space?

Bioretention might be good for new construction but not for retrofitting existing development.

We could increase the depth from 6 inches to 42 inches to handle the 100-year storm.

What if we couple green with gray infrastructure?

Hillsborough Plaza
256 Route 206
Hillsborough, New Jersey

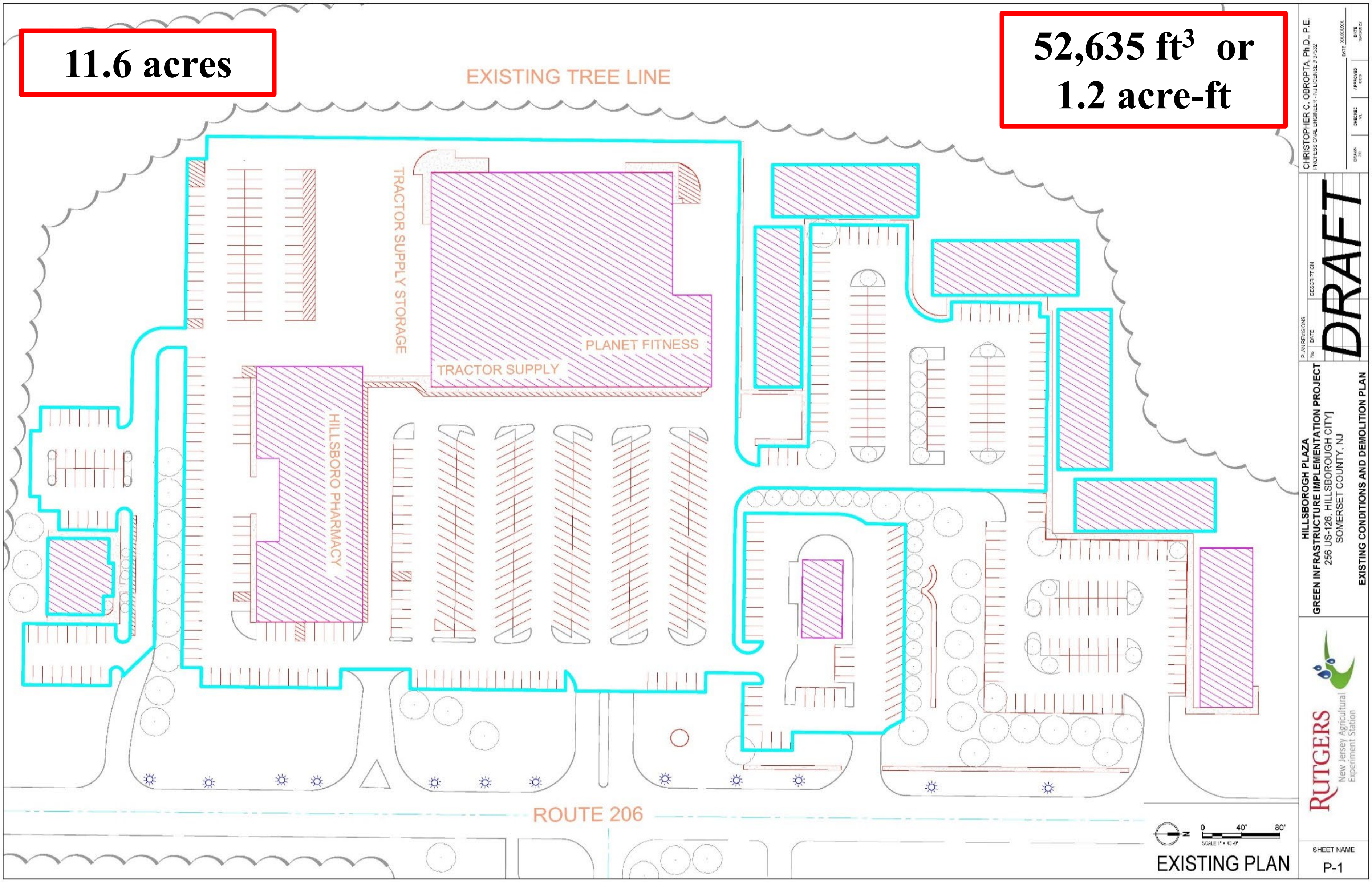


EXISTING TREE LINE
TRACTOR SUPPLY STORAGE
PLANET FITNESS
TRACTOR SUPPLY
HILLSBORO PHARMACY
CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532
DATE XX/XX/XX
PLAN REVISIONS
No. DATE DESCRIPTION
DRAFT
DRAWN
CHECKED
APPROVED
DATE
HILLSBOROGH PLAZA
GREEN INFRASTRUCTURE IMPLEMENTATION PROJECT
256 US-126, HILLSBOROUGH CITY]
SOMERSET COUNTY, NJ
EXISTING CONDITIONS AND DEMOLITION PLAN
GERS
w Jersey Agricultural
eriment Station

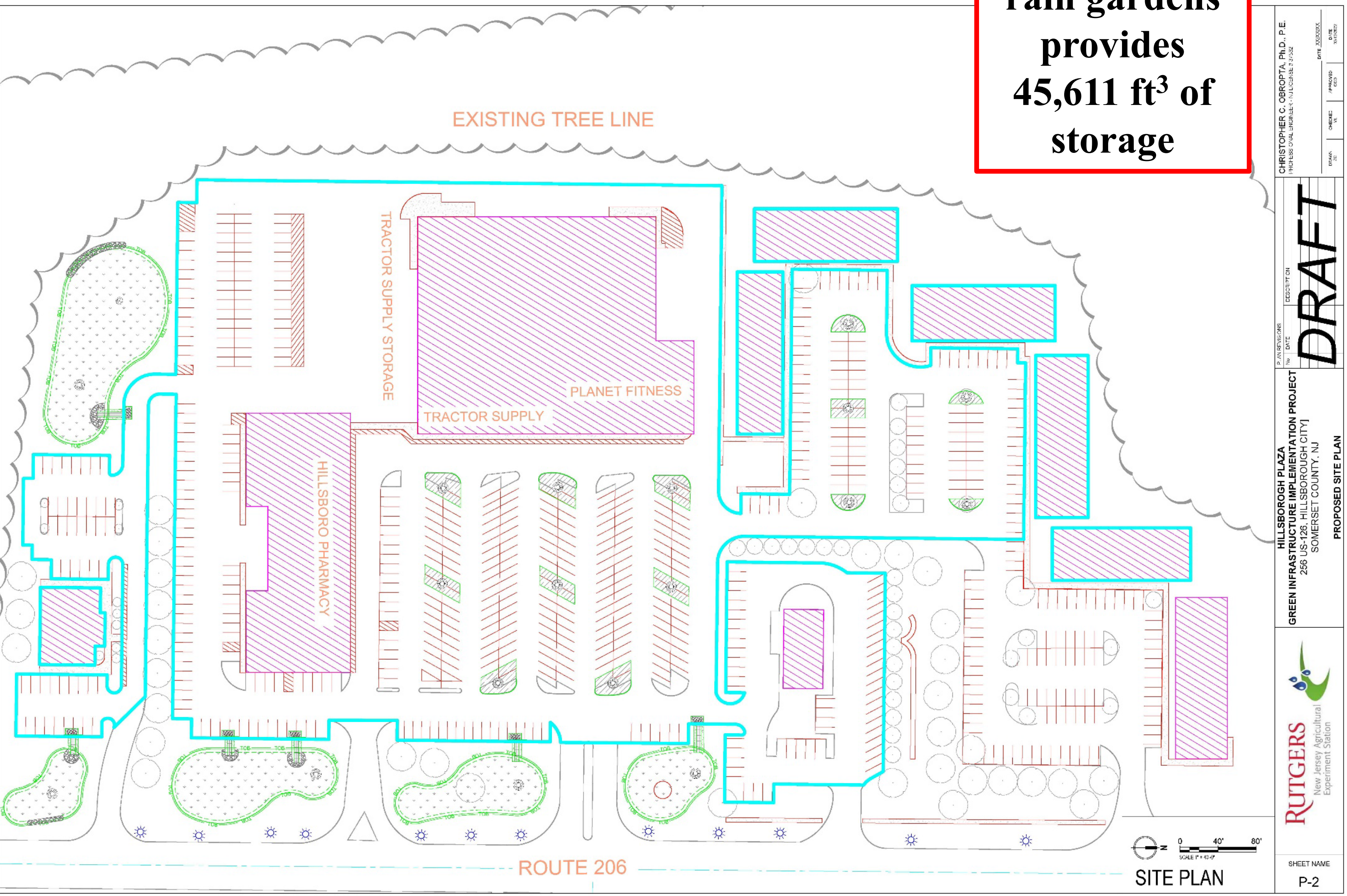
Water Quality Storm Analysis (1.25 inches)

11.6 acres

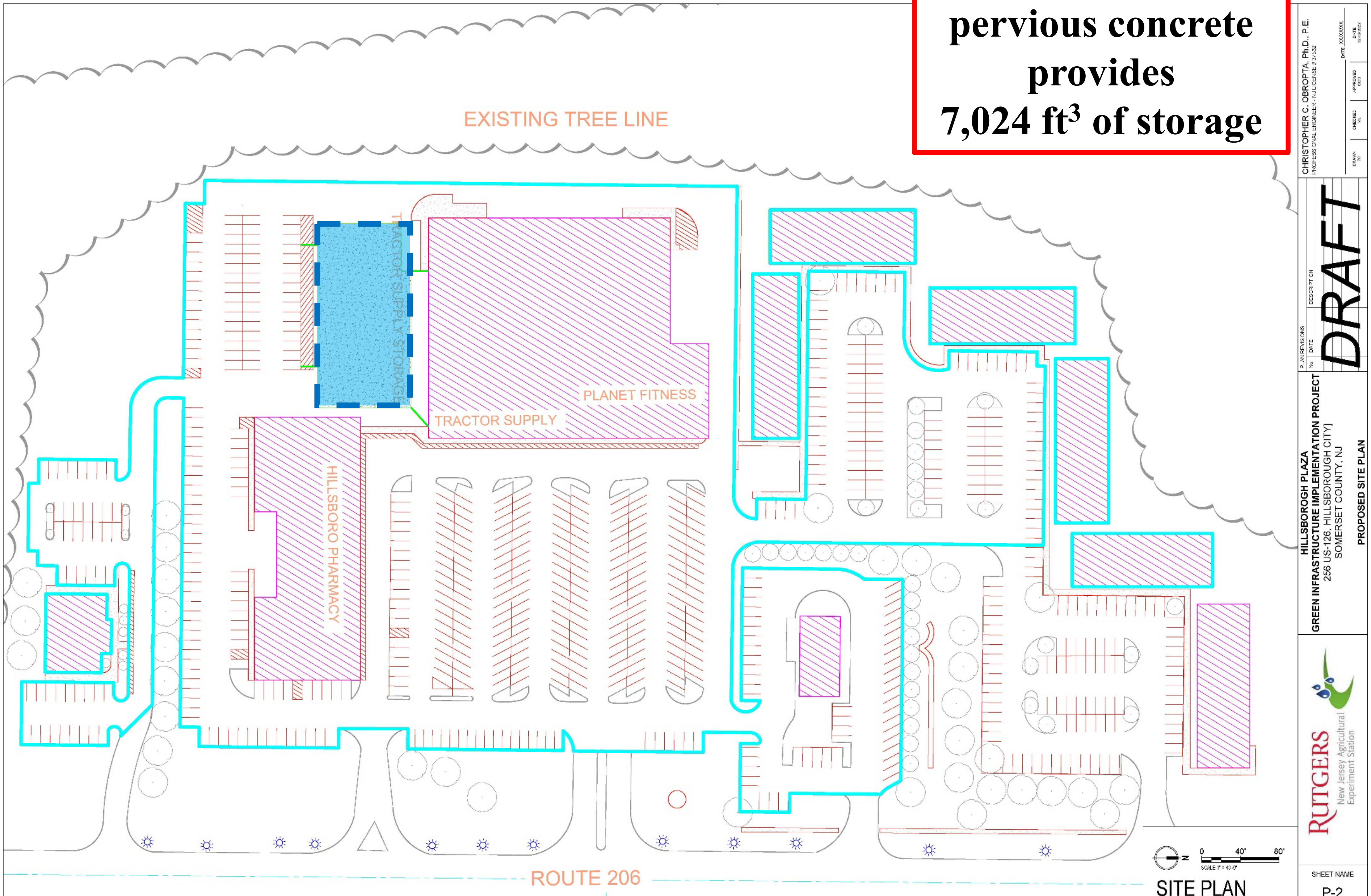
52,635 ft^3 or 1.2 acre-ft



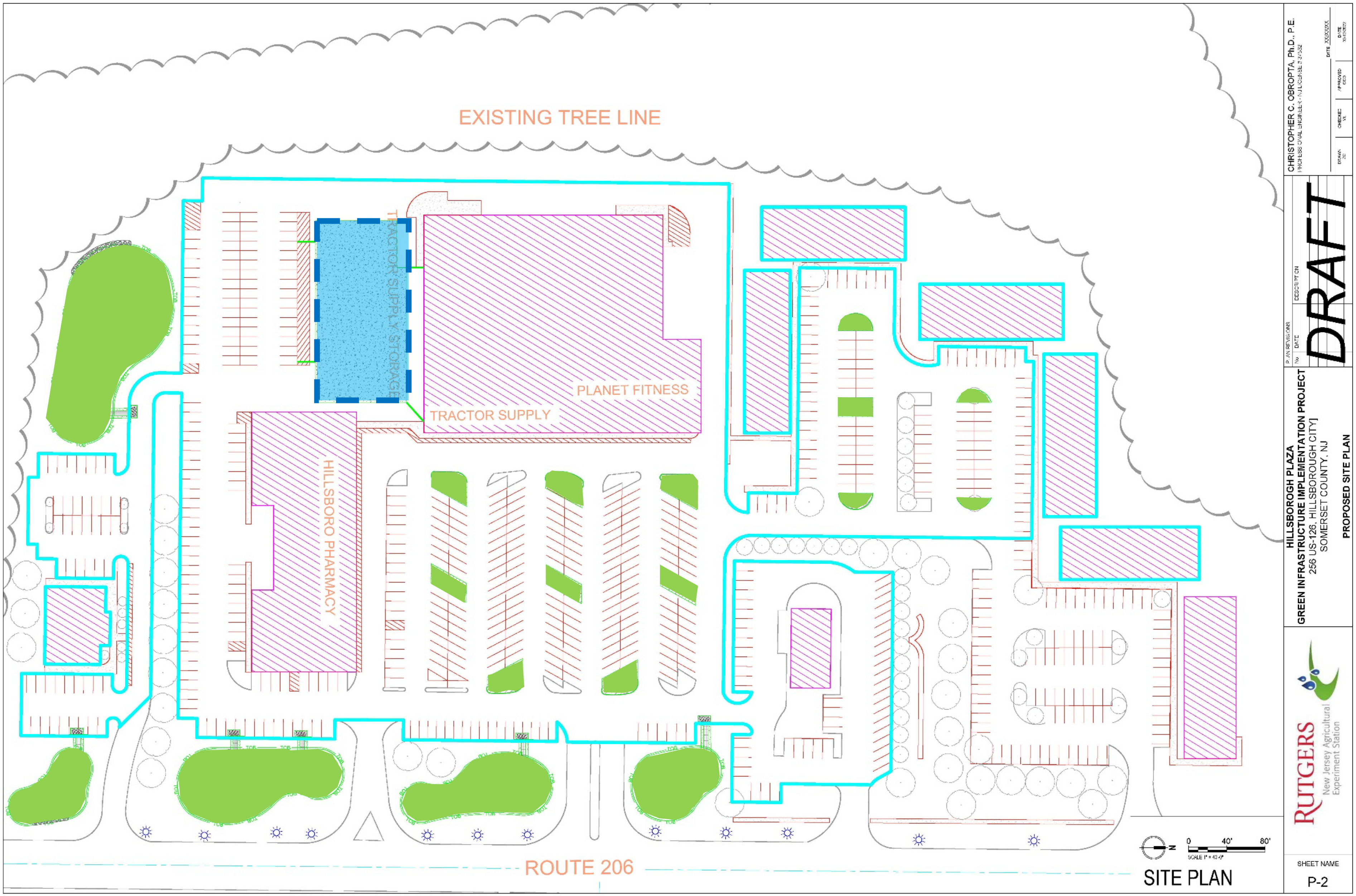
1.23 acres of rain gardens provides 45,611 ft^3 of storage



17,560 ft² of pervious concrete provides 7,024 ft³ of storage



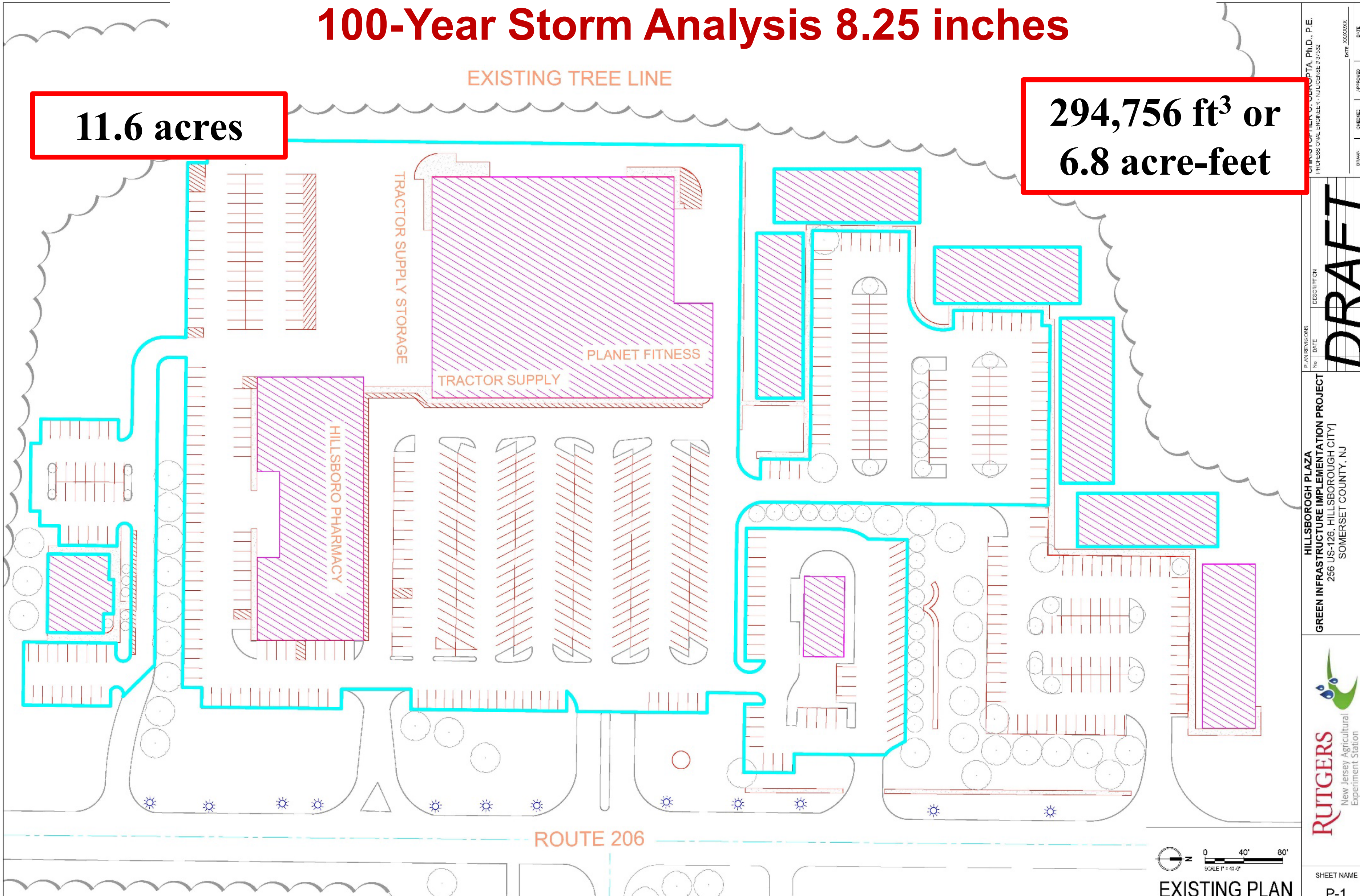
All of the Green Infrastructure Practices



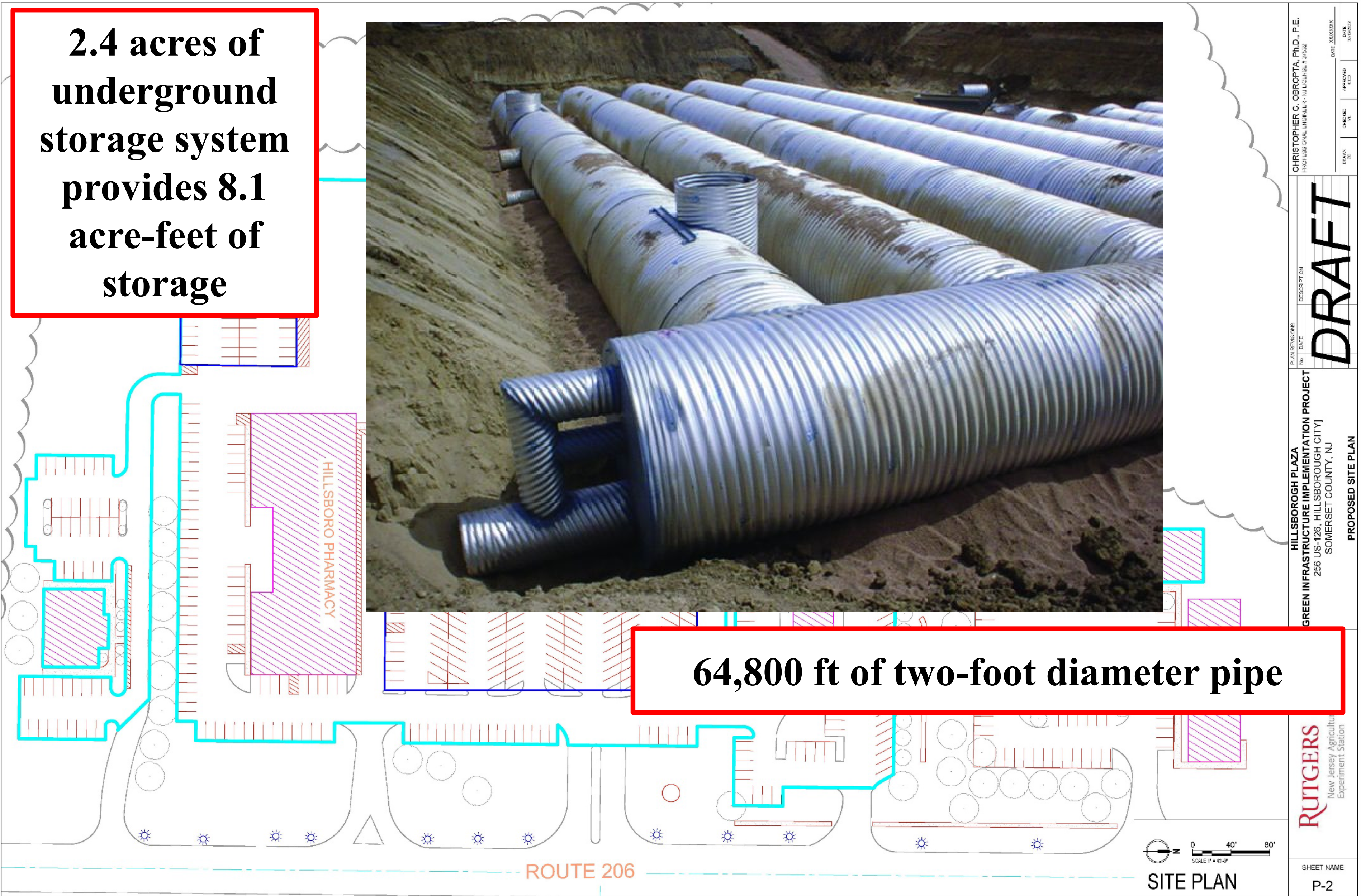
100-Year Storm Analysis 8.25 inches

11.6 acres

294,756 ft^3 or 6.8 acre-feet

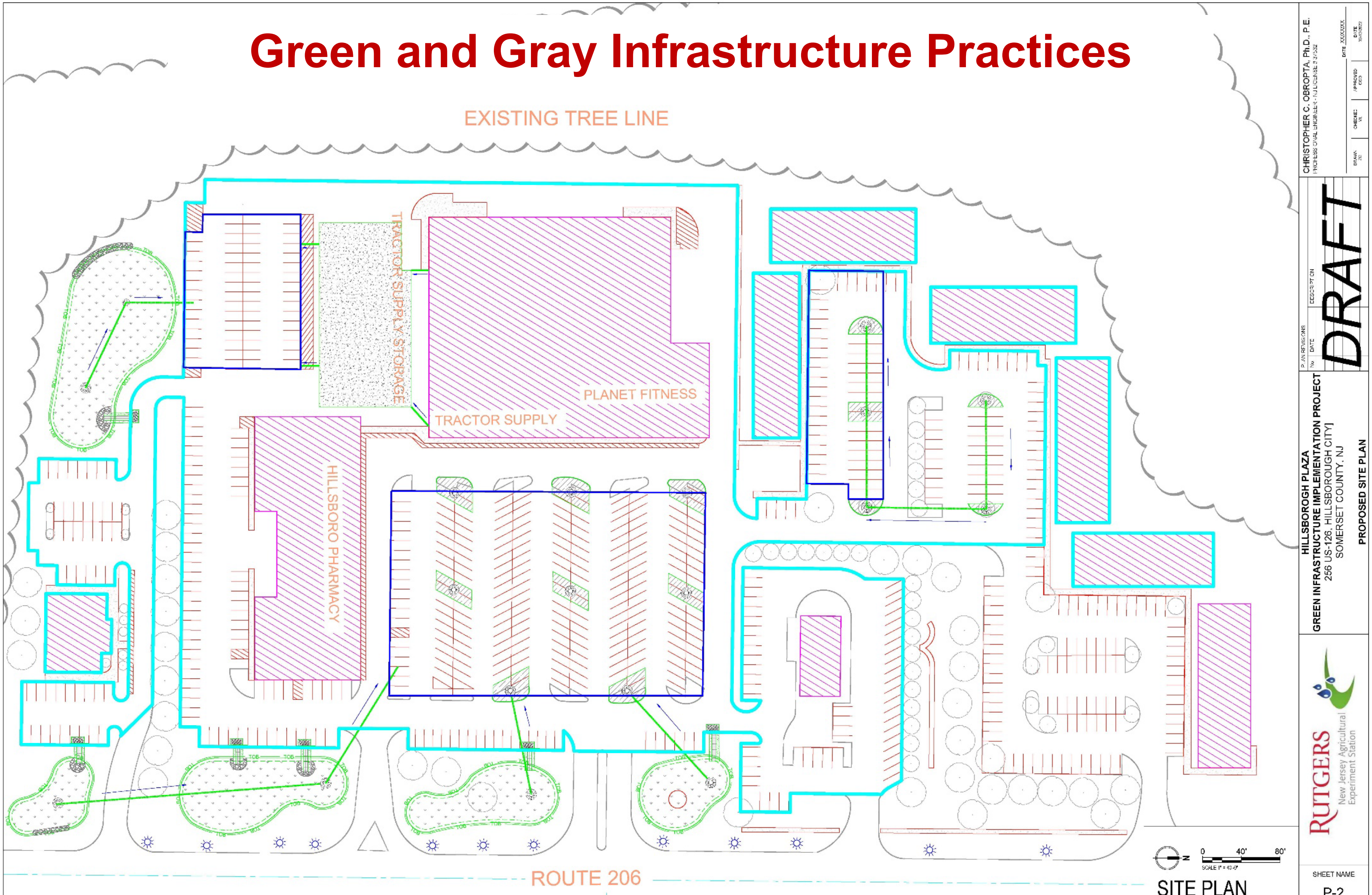


2.4 acres of underground storage system provides 8.1 acre-feet of storage



64,800 ft of two-foot diameter pipe

Green and Gray Infrastructure Practices

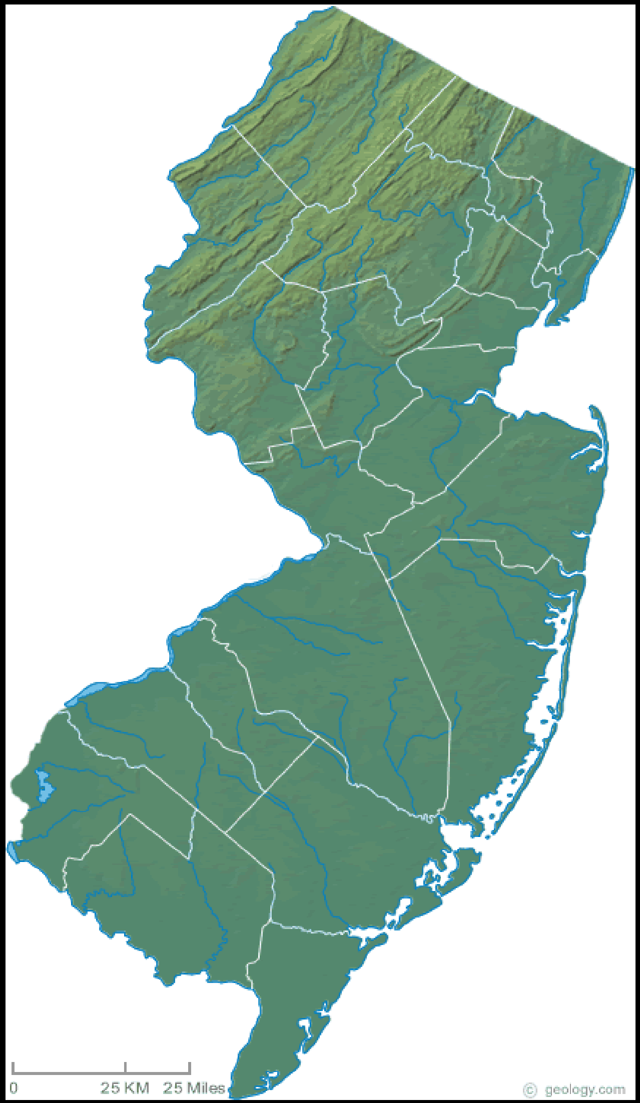


Remaining Questions

1. Is it possible to route all the stormwater runoff for the 1.25-inch storm to the green infrastructure practices?
2. Is it possible to bypass the larger storms to the underground storage system?
3. How long do we hold the larger storms before we can safely release the stormwater?
4. If we over-design the system, can we get stormwater flows from nearby areas to this location for storage?
5. How many developed areas must get this treatment to reduce flooding downstream?
6. What is the cost?

Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding



NEW JERSEY BACK BAYS COASTAL STORM RISK MANAGEMENT INTERIM FEASIBILITY STUDY AND ENVIRONMENTAL SCOPING DOCUMENT

1 March 2019

U.S. Army Corps of Engineers
Philadelphia District

NJBB
NEW JERSEY BACK BAYS STUDY

NJDEP

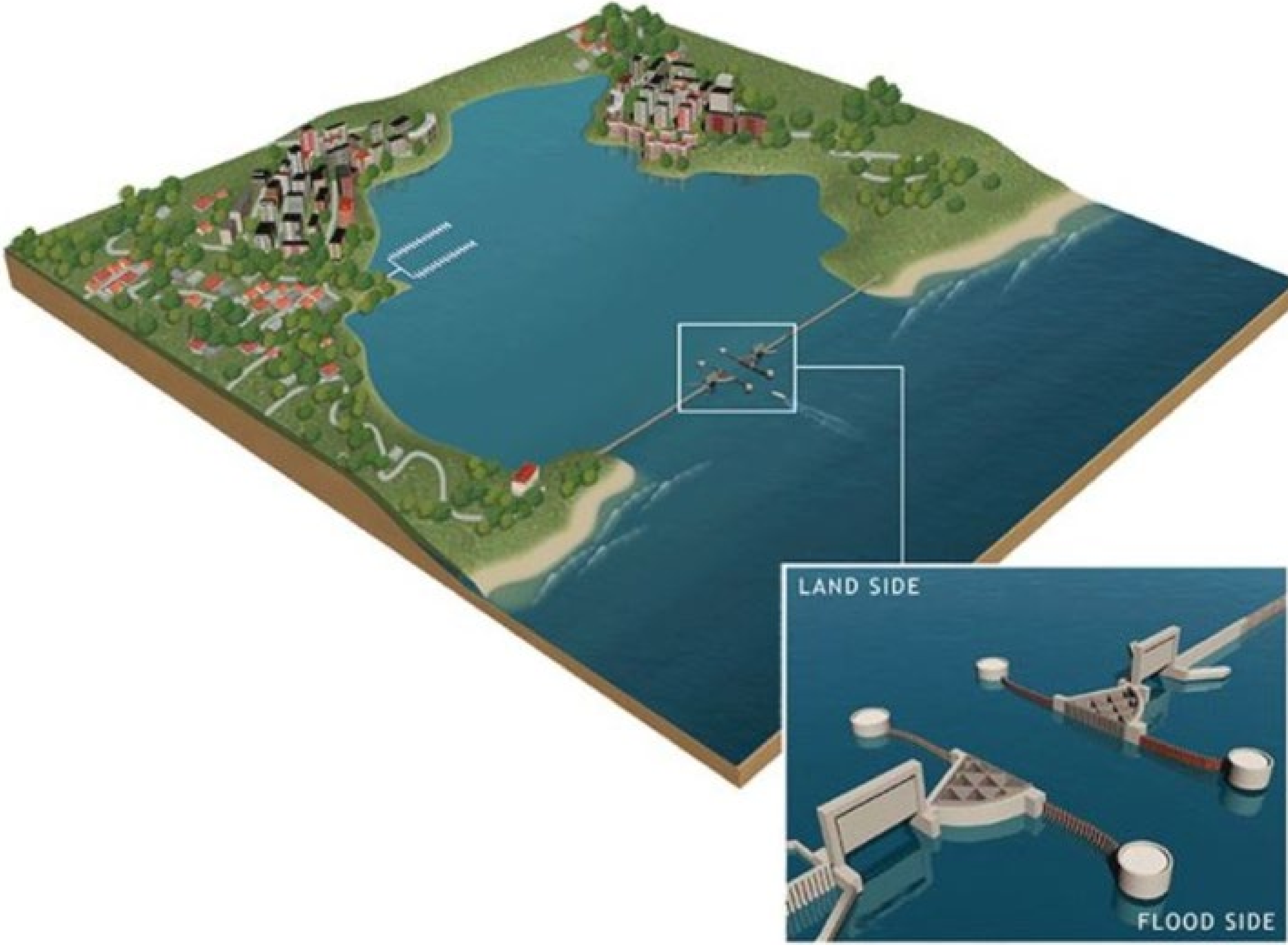
Examples of Measures Under Consideration

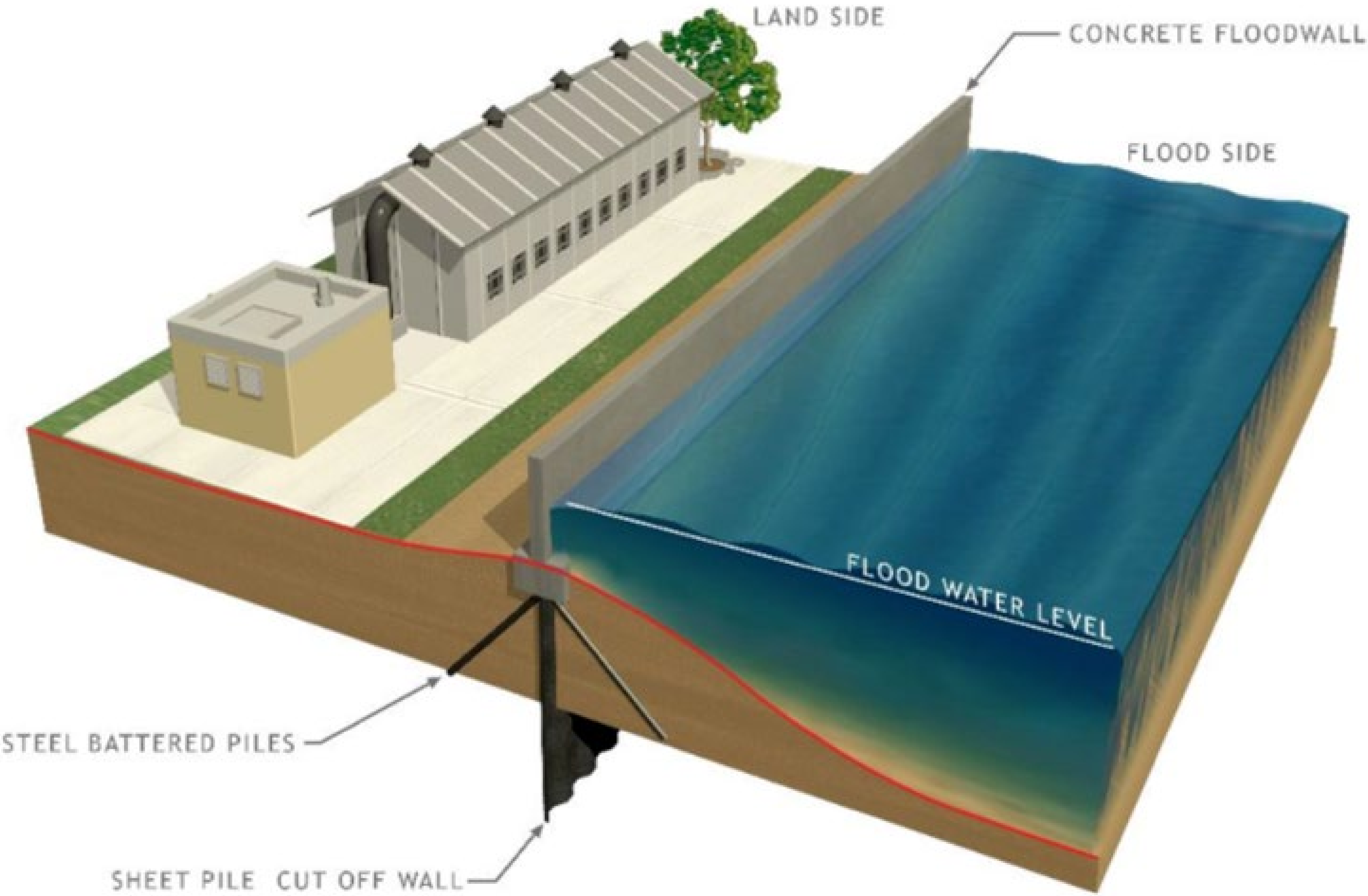
Structural Measures

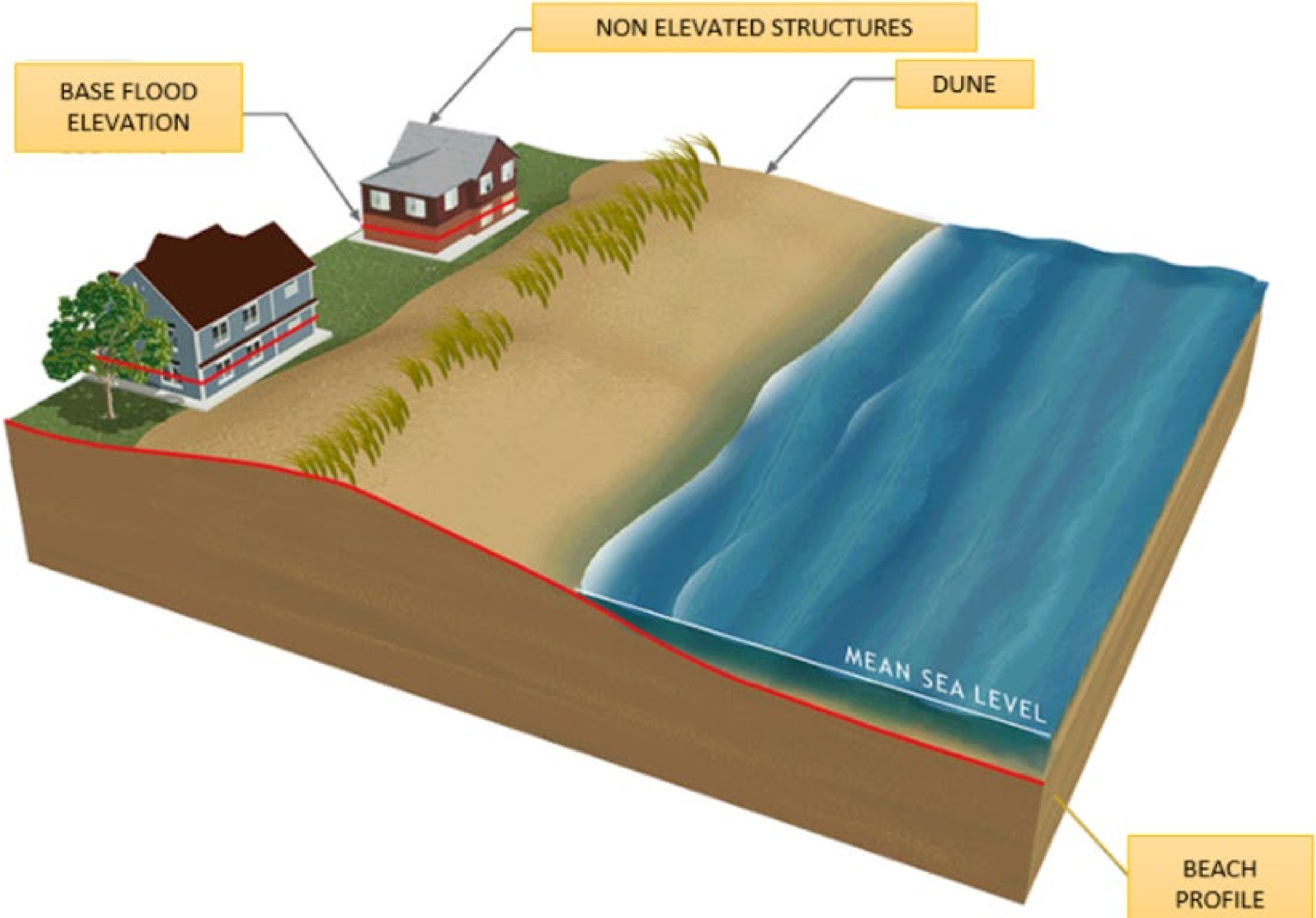
- Inlet Storm Surge Barriers
- Interior Bay Closures
- Raised Roads and Rails
- Levees
- Floodwalls (Permanent)
- Deployable Floodwalls
- Crown Walls
- Beach Restoration/Groins/Breakwaters
- Bulkheads
- Seawalls
- Revetments
- Stormwater System Drainage Improvements

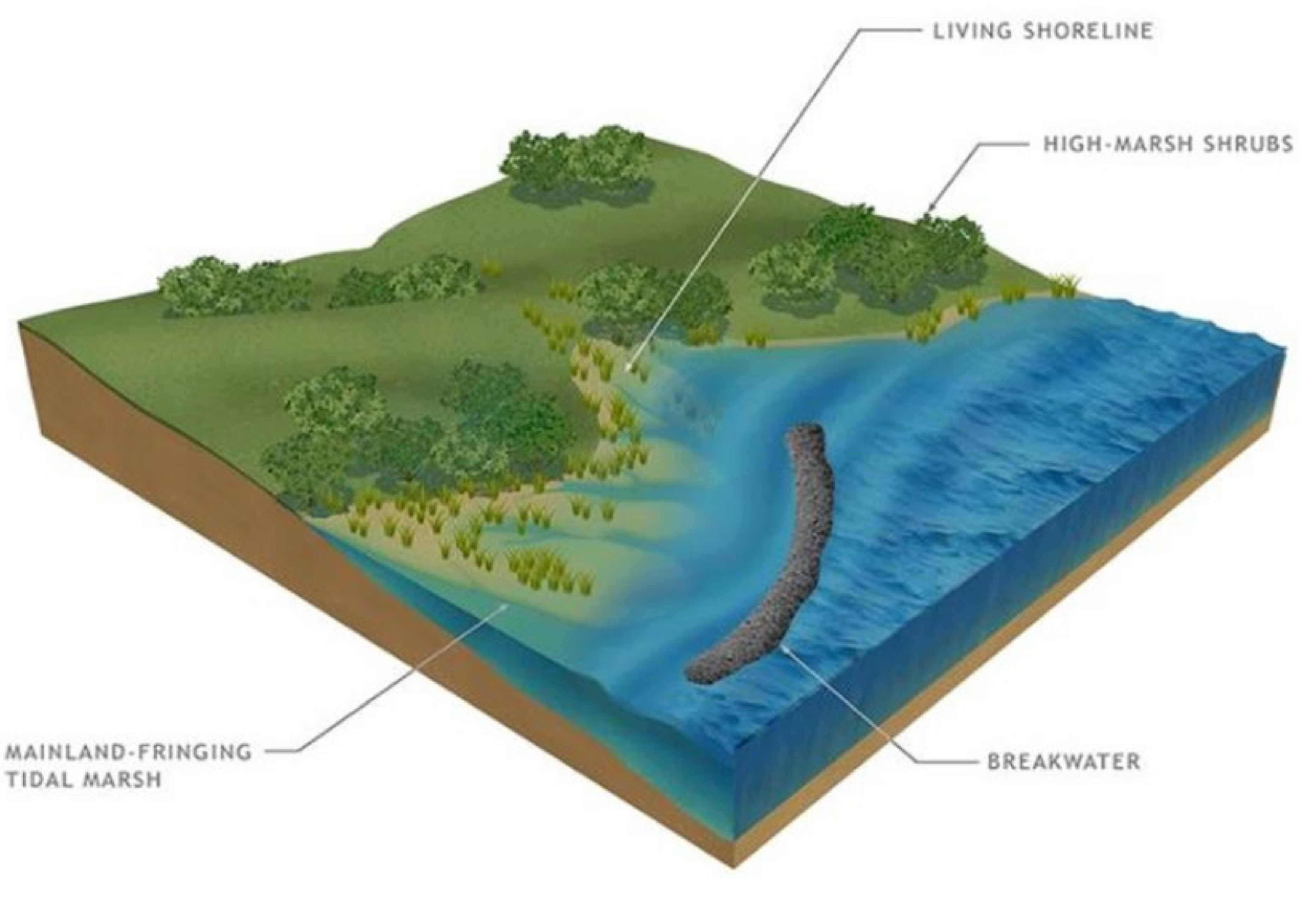
Natural and Nature-Based Features

- Living Shorelines
- Reefs
- Wetland Restoration
- Submerged Aquatic Vegetation (SAV) Restoration
- **Green Stormwater Management**


LAND SIDE
FLOOD SIDE


LAND SIDE
CONCRETE FLOODWALL
FLOOD SIDE
FLOOD WATER LEVEL
STEEL BATTERED PILES
SHEET PILE CUT OFF WALL


NON ELEVATED STRUCTURES
BASE FLOOD ELEVATION
DUNE
MEAN SEA LEVEL
BEACH PROFILE


LIVING SHORELINE
HIGH-MARSH SHRUBS
MAINLAND-FRINGING
TIDAL MARSH
BREAKWATER

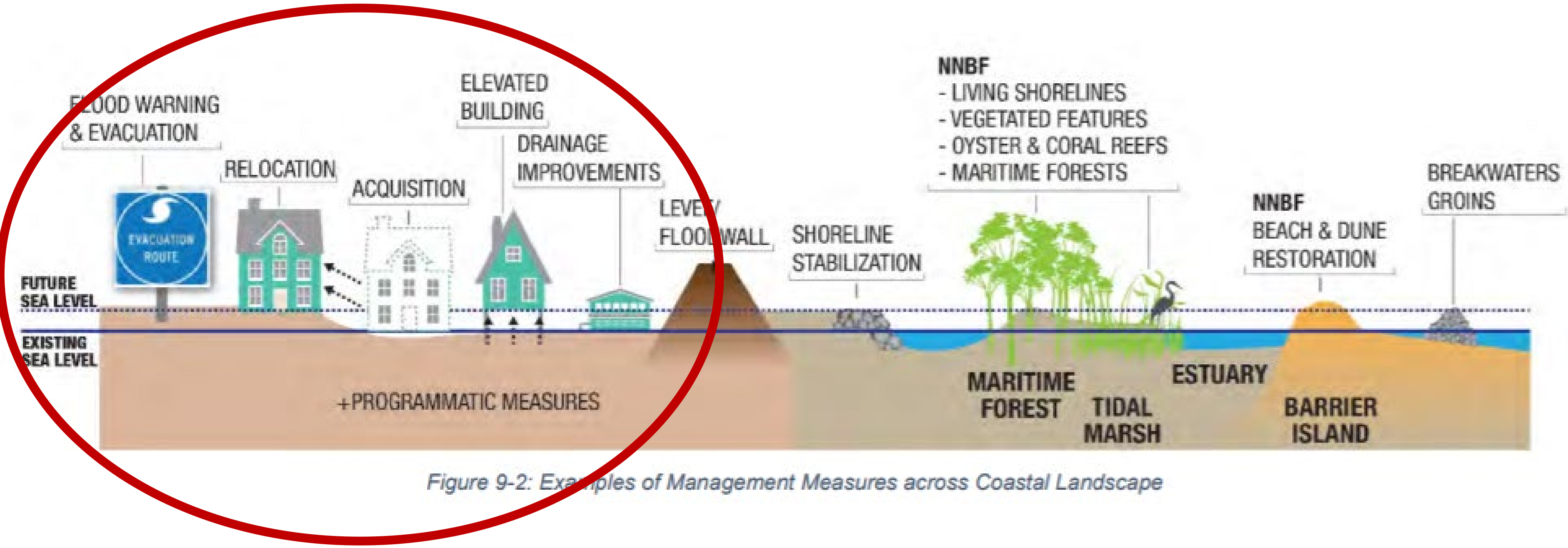
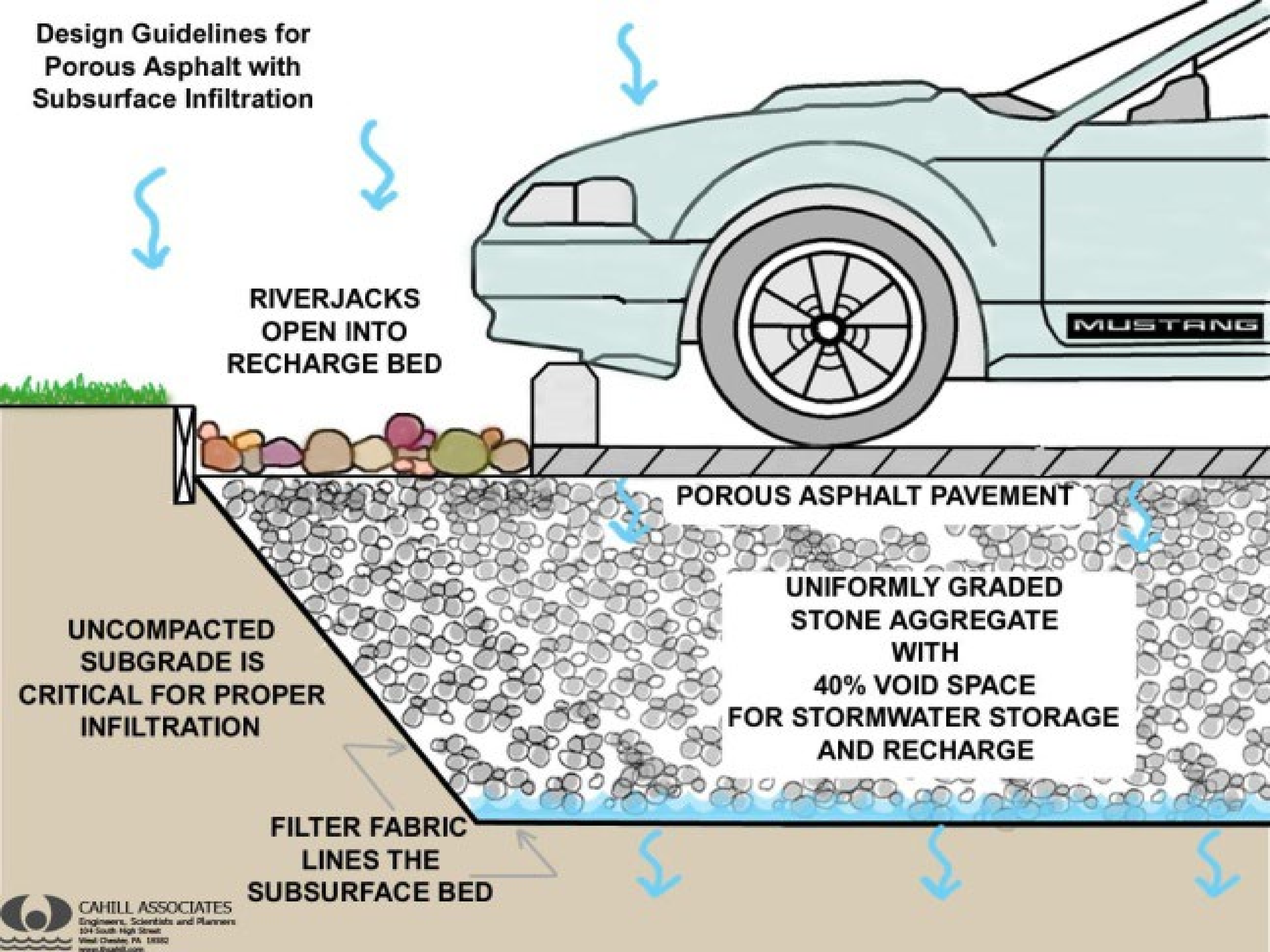


Figure 9-2: Examples of Management Measures across Coastal Landscape


Design Guidelines for
Porous Asphalt with
Subsurface Infiltration
RIVERJACKS
OPEN INTO
RECHARGE BED
MUSTANG
POROUS ASPHALT PAVEMENT
UNIFORMLY GRADED
STONE AGGREGATE
WITH
40% VOID SPACE
FOR STORMWATER STORAGE
AND RECHARGE
UNCOMPACTED
SUBGRADE IS
CRITICAL FOR PROPER
INFILTRATION
FILTER FABRIC
LINES THE
SUBSURFACE BED
CAHILL ASSOCIATES
Engineers, Scientists and Planners

Together we can do it!

Thanks, Cody!

WE ARE DONE! Congratulations!

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