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.

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

**Average January Daily Low Temperature**
- 14°F (-10°C)
- 16°F (-9°C)
- 18°F (-8°C)
- 20°F (-7°C)
- 22°F (-6°C)
- 24°F (-4°C)
- 26°F (-3°C)

**Average July Daily High Temperature**
- 80°F (27°C)
- 82°F (28°C)
- 84°F (29°C)
- 86°F (30°C)
Plant Hardiness Zone Map
NJ Average Precipitation
Dynamic Landscape Change

Acres of Land Use Statewide 1986 - 2015

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>2012-2015</th>
<th>1986-2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Growth</td>
<td>10,404 Acres</td>
<td>360,376 Acres</td>
</tr>
<tr>
<td>Farmland Loss</td>
<td>(2,087) Acres</td>
<td>(200,876) Acres</td>
</tr>
<tr>
<td>Forest Loss</td>
<td>(9,494) Acres</td>
<td>(122,569) Acres</td>
</tr>
<tr>
<td>Wetlands Loss</td>
<td>(2,295) Acres</td>
<td>(57,166) Acres</td>
</tr>
</tbody>
</table>
Part II: Causes of Climate Change
Natural Climate Change

Milankovitch Cycles

- Precession: 19–24,000 years
- Eccentricity: 100,000 years, 413,000 years
- Tilt: 41,000 years, 21.5°–24.5° Currently 23.5°
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

anthropogenic
/.anTHropˈəjenik/

adjective

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

The greenhouse effect

Solar radiation passes through the clear atmosphere

Some solar radiation is reflected by the earth and the atmosphere

Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all molecules. The effect of this is to warm the earth’s surface and the lower atmosphere.

Most radiation is absorbed by the earth’s surface and warms it

Infrared radiation is emitted from the earth’s surface
Greenhouse Effect
Greenhouse Gas Emissions

Global greenhouse gas emissions, per type of gas and source, including LULUCF

Land Use, Land-Use Change and Forestry (LULUCF)
- Forest and peat fires (N₂O and CH₄)
- Land-use change emissions (CO₂)

Total emissions, excluding LULUCF
- F-gases – Total
- N₂O – Energy indirect/waste
- N₂O – Industrial processes
- N₂O – Agriculture
- CH₄ – Waste and other
- CH₄ – Agriculture
- CH₄ – Energy
- CO₂ – Other (non-energy)
- CO₂ – International transport
- CO₂ – Energy

Source: EDGAR v5.0/v4.3.2 FT 2017 (EC-JRC/PBL, 2018); Houghton and Nassikas (2017)
The Carbon Cycle
**Isotope fingerprints point to human sources**

Different sources of CO₂ have their own unique isotopic fingerprints. CO₂ from the fossil fuel burning doesn't have carbon 14 (¹⁴C), and CO₂ from terrestrial plants has less carbon 13 (¹³C) than from the ocean. Since fossil fuels are derived from ancient plants, they all have less ¹³C isotopes. Isotope data from ice cores show that since 1800, the carbon ¹³C atmosphere have decreased, which means the extra CO₂ in atmosphere came from fossil 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)
Heat Storage

Nuccitelli et al., 2012

[Graph showing the heat storage in different layers of the ocean and the land-ice-atmosphere system over time.]
Feedback Loops

Surface without snow or ice absorbs more heat

Surface with snow and ice reflects more heat

the-m-factory.com • 410.420.8032
Warming Over Time

NASA Goddard Spaceflight Center
Part III:
Climate Change in New Jersey
Increasing Excessive Temperature Days
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

CO₂ 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
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
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.

<table>
<thead>
<tr>
<th>30 lives lost</th>
<th>Estimated $16–24B in damages</th>
<th>&gt;9 inches of rain</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd greatest loss of life in NJ due to a natural disaster since 1900</td>
<td>in the Northeast U.S.</td>
<td>in about 6 hrs in Somerset and Hunterdon counties, 2x normal rainfall for whole month of September</td>
</tr>
</tbody>
</table>

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

New Jersey, Precipitation, January-December

[Graph showing precipitation trends from 1900 to 2020]
A change in extremes?

17 September 1999
# 2 crest 21.0’ (nearby Blackwells Mills: 1921-present)

14 March 2010
# 6 crest 16.2’ (1 May 2014 #7 crest 15.9’)

Manville

16 April 2007
# 3 crest 19.2’

28 August 2011
# 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/

Emission Scenario

Moderate RCP 4.5

High RCP 8.5

Time Period

2020 - 2069

2050 - 2099

Projected Percent Increase (Upper Likelihood)

-20 to -25

-25 to -30

-30 to -35

-35 to -40

Upper Likelihood represents a 17% likelihood that precipitation depth will increase more than the value shown relative to the NOAA Atlas 14 published mean values.

Return Period

2-year

5-year

10-year

25-year

50-year

100-year

Emission Scenario

Moderate RCP 4.5

High RCP 8.5

Time Period

2020 - 2069

2050 - 2099

Identify regional and local estimates of projected changes in extreme rainfall in New Jersey for various return periods between current estimates* and a future scenario, i.e., the 2-year, 10-year, 100-year storm, etc., and the future greenhouse gas concentration pathway (RCP) 4.5 or RCP 8.5, and future time period. For example, based on historical data, the chance that 8.5 inches of rain will fall in a certain area in a 24-hour period in any 24-hour period is said to have a 100-year return period and may be associated with a 24-hour storm that has a 50% chance of occurring in any 24-hour period in any given year.

* For questions about the data, please contact NJDEP | For website related issues, please contact AECOM
<table>
<thead>
<tr>
<th>Duration (hrs)</th>
<th>Projected Depth (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10th</td>
</tr>
<tr>
<td>24</td>
<td>3.09</td>
</tr>
</tbody>
</table>
New Jersey Extreme Precipitation Projection Tool

### Return Period
- 2-year
- 5-year
- 10-year
- 25-year
- 50-year
- 100-year

### Emission Scenario
- Moderate RCP 4.5
- High RCP 8.5

### Time Period
- 2020 - 2069
- 2050 - 2099

Projected 24-hour Precipitation Depth
Projected values along the y-axis are interpolated from the seven percentile values provided below.
New Jersey Extreme Precipitation Projection Tool

https://njprojectedprecipitationchanges.com/

Projected 24-hour Precipitation Depth

Projected values along the line are interpolated from the seven percentile values provided below:

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Projected Depth (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th</td>
<td>7.06</td>
</tr>
<tr>
<td>25th</td>
<td>7.55</td>
</tr>
<tr>
<td>Median</td>
<td>8.11</td>
</tr>
<tr>
<td>75th</td>
<td>8.92</td>
</tr>
<tr>
<td>83rd</td>
<td>9.21</td>
</tr>
<tr>
<td>90th</td>
<td>11.00</td>
</tr>
<tr>
<td>95th</td>
<td>11.64</td>
</tr>
<tr>
<td>99th</td>
<td>12.37</td>
</tr>
</tbody>
</table>

Current = 8.21 in

44% Higher
This is where you’ll find the options to add data.
NJ Flood Mapper

https://www.njfloodmapper.org/
First time users, please use the interactive tool to determine your Total Water Level.

Customize the variables to produce a Total Water Level.

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

First time users, please use the interactive tool to determine your Total Water Level

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** - 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/
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.

You can adjust the transparency of the data, turn off the data, or remove the added data here.
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.
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
“Green Infrastructure” is mentioned 155 times in the report.

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)
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.

<table>
<thead>
<tr>
<th>System transitions</th>
<th>Representative key risks</th>
<th>Climate responses and adaptation options</th>
<th>Synergies with mitigation</th>
<th>Potential feasibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal socio-ecological systems</td>
<td>Coastal defence and hardening, Integrated coastal zone management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terrestrial and ocean ecosystem services</td>
<td>Forest-based adaptation, Sustainable aquaculture and fisheries, Agroforestry, Biodiversity management and ecosystem connectivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water security</td>
<td>Water use efficiency and water resource management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food security</td>
<td>Improved cropland management, Efficient livestock systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban and infrastructure systems</td>
<td>Critical infrastructure, networks and services</td>
<td>Sustainable land use and urban planning, Sustainable urban water management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water security</td>
<td>Improve water use efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy systems</td>
<td>Critical infrastructure, networks and services</td>
<td>Resilient power systems, Energy reliability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human health</td>
<td>Health and health systems adaptation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living standards and equity</td>
<td>Livelihood diversification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peace and human mobility</td>
<td>Planned relocation and resettlement, Human migration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other cross-cutting risks</td>
<td>Disaster risk management, Climate services, including Early Warning Systems, Social safety nets, Risk spreading and sharing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
Feasibility level and synergies with mitigation

- High
- Medium
- Low
- Insufficient evidence

Dimensions of potential feasibility

- High
- Medium
- Low
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.

<table>
<thead>
<tr>
<th>System transitions</th>
<th>Climate responses and adaptation options</th>
<th>Observed relation with sectors and groups at risk</th>
<th>Relation with Sustainable Development Goals&lt;sup&gt;4, 5&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ecosystems and their services</td>
<td>Ethnics groups</td>
<td>Gender equity</td>
</tr>
<tr>
<td>Coastal defence and hardening</td>
<td>+</td>
<td>/</td>
<td>+</td>
</tr>
<tr>
<td>Integrated coastal zone management</td>
<td>+</td>
<td>/</td>
<td>+</td>
</tr>
<tr>
<td>Land and ocean ecosystems</td>
<td>Forest-based adaptation&lt;sup&gt;2&lt;/sup&gt;</td>
<td>not assessed</td>
<td>+</td>
</tr>
<tr>
<td>Sustainable aquaculture and fisheries</td>
<td>+</td>
<td>/</td>
<td>+</td>
</tr>
<tr>
<td>Agroforestry</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Biodiversity management and ecosystem connectivity</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Water use efficiency and water resource management</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Improved cropland management</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Efficient livestock systems</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Urban and infrastructure systems</td>
<td>Green infrastructure and ecosystem services</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Sustainable land use and urban planning</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Sustainable urban water management</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Energy systems</td>
<td>Improve water use efficiency</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Resilient power systems</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Energy reliability</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Health and health systems adaptation</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Livelihood diversification</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Cross-sectoral</td>
<td>Planned relocation and resettlement</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Human migration&lt;sup&gt;3&lt;/sup&gt;</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Disaster risk management</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Climate services, including Early Warning Systems</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Social safety nets</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
<tr>
<td>Risk spreading and sharing</td>
<td>not assessed</td>
<td>+</td>
<td>/</td>
</tr>
</tbody>
</table>

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

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.
<table>
<thead>
<tr>
<th>System transitions and adaptation options</th>
<th>Observed relation with sectors and groups at risk</th>
<th>Relation with Sustainable Development Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban and infrastructure systems</td>
<td></td>
<td>1: No Poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: Zero Hunger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: Good Health and Well-being</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4: Quality Education</td>
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<tr>
<td></td>
<td></td>
<td>5: Gender Equality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6: Clean Water and Sanitation</td>
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<tr>
<td></td>
<td></td>
<td>7: Affordable and Clean Energy</td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>9: Industry, Innovation and Infrastructure</td>
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<td></td>
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<tr>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>16: Peace, Justice, and Strong Institutions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17: Partnerships for the Goals</td>
</tr>
</tbody>
</table>

**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**
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.

<table>
<thead>
<tr>
<th>Sectoral and system mitigation options</th>
<th>Relation with Sustainable Development Goals</th>
<th>Chapter source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind energy</td>
<td></td>
<td>Sections 6.4.2, 6.7.7</td>
</tr>
<tr>
<td>Solar energy</td>
<td></td>
<td>Sections 6.4.2, 6.7.7</td>
</tr>
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<td>Bioenergy</td>
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<td>Sections 6.4.2, 12.5, Box 6.1</td>
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<tr>
<td>Hydropower</td>
<td></td>
<td>Section 6.4.2</td>
</tr>
<tr>
<td>Geothermal energy</td>
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<td>Section 6.4.2</td>
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<td>Nuclear power</td>
<td></td>
<td>Section 6.4.2, Figure 6.18</td>
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<tr>
<td>Carbon capture and storage (CCS)</td>
<td></td>
<td>Sections 6.4.2, 6.7.7</td>
</tr>
<tr>
<td>Carbon sequestration in agriculture¹</td>
<td></td>
<td>Sections 7.3, 7.4, 7.6</td>
</tr>
<tr>
<td>Reduce CH₄ and N₂O emission in agriculture</td>
<td></td>
<td>Section 7.4</td>
</tr>
<tr>
<td>Reduced conversion of forests and other ecosystems²</td>
<td></td>
<td>Section 7.4</td>
</tr>
<tr>
<td>Ecosystem restoration, reforestation, afforestation</td>
<td></td>
<td>Section 7.4</td>
</tr>
<tr>
<td>Improved sustainable forest management</td>
<td></td>
<td>Section 7.4</td>
</tr>
<tr>
<td>Reduce food loss and food waste</td>
<td></td>
<td>Section 7.5</td>
</tr>
<tr>
<td>Shift to balanced, sustainable healthy diets</td>
<td></td>
<td>Section 7.4</td>
</tr>
<tr>
<td>Renewables supply³</td>
<td></td>
<td>Section 7.6</td>
</tr>
<tr>
<td>Urban land use and spatial planning</td>
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<td>Sections 8.2, 8.4, 8.6</td>
</tr>
<tr>
<td>Electrification of the urban energy system</td>
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<td>Sections 8.2, 8.4, 8.6</td>
</tr>
<tr>
<td>District heating and cooling networks</td>
<td></td>
<td>Sections 8.2, 8.4, 8.6</td>
</tr>
<tr>
<td>Urban green and blue infrastructure</td>
<td></td>
<td>Sections 8.2, 8.4, 8.6</td>
</tr>
<tr>
<td>Waste prevention, minimization and management</td>
<td></td>
<td>Sections 8.2, 8.4, 8.6</td>
</tr>
<tr>
<td>Integrating sectors, strategies and innovations</td>
<td></td>
<td>Sections 8.2, 8.4, 8.6</td>
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<tr>
<td>Demand-side management</td>
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<td>Section 9.8, Table 9.5</td>
</tr>
<tr>
<td>Highly energy efficient building envelope</td>
<td></td>
<td>Section 9.8, Table 9.5</td>
</tr>
<tr>
<td>Efficient heating, ventilation and air conditioning (HVAC)</td>
<td></td>
<td>Section 9.8, Table 9.5</td>
</tr>
<tr>
<td>Efficient appliances</td>
<td></td>
<td>Section 9.8, Table 9.5</td>
</tr>
<tr>
<td>Building design and performance</td>
<td></td>
<td>Section 9.8, Table 9.5</td>
</tr>
<tr>
<td>On-site and nearby production and use of renewables</td>
<td></td>
<td>Section 9.8, Table 9.5</td>
</tr>
<tr>
<td>Change in construction methods and circular economy</td>
<td></td>
<td>Sections 9.4, 9.5</td>
</tr>
<tr>
<td>Change in construction materials</td>
<td></td>
<td>Section 9.4</td>
</tr>
</tbody>
</table>

**Type of relations:**
- Synergies
- Trade-offs
- Both synergies and trade-offs

**Related Sustainable Development Goals:**
1. No poverty
2. Zero hunger
3. Good health and wellbeing
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. Reduced inequalities
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. Partnership for the goals

¹ Soil carbon management in crop lands and grasslands
² Agriculture, forestry and other land-use
³ High confidence
⁴ Medium confidence
⁵ Low confidence
⁶ Both synergies and trade-offs
⁷ Not assessed due to limited literature
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:

<table>
<thead>
<tr>
<th>Type of Organization</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-profit organization</td>
<td>25.2%</td>
</tr>
<tr>
<td>Regional/county/municipal government</td>
<td>20.0%</td>
</tr>
<tr>
<td>Business</td>
<td>15.5%</td>
</tr>
<tr>
<td>University/college</td>
<td>12.3%</td>
</tr>
<tr>
<td>State agency</td>
<td>11.0%</td>
</tr>
<tr>
<td>Other</td>
<td>10.3%</td>
</tr>
<tr>
<td>Federal agency</td>
<td>5.8%</td>
</tr>
</tbody>
</table>
**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...
New Jersey Global Warming Response Act
80x50 Report

Table 7.5 Carbon Sequestration Programmatic Recommendations

<table>
<thead>
<tr>
<th>Actions</th>
<th>Entity</th>
<th>Timeframe</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Update the Municipal Land Use Law to encourage and facilitate green</td>
<td></td>
<td>Near-term</td>
<td></td>
</tr>
<tr>
<td>infrastructure including green streets. Prioritization should be given</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to infrastructure that accommodates trees.</td>
<td>DCA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Images:**
- **Native Plants:** A stormwater planter is planted with a variety of grasses, wildflowers, and woody plants that are adapted to soil, precipitation, climate, and other site conditions.
- **Curb Cut:** This curb cut and concrete flow path are designed to help reduce stormwater runoff to the rain garden system and out of the storm drain.
- **Concrete Wall:** Concrete walls are installed to match the existing curb. These walls create the framework for the stormwater planter and continue to function as a curb.
- **Subgrade:** Stormwater planter systems are unique because of their subgrade structure. This structure is layered with infiltration media, crushed stone, compacted aggregate, and a separation fabric.
- **Inlet:** This is the area where stormwater enters. The inlet is often lined with stone to slow water flow and prevent erosion.
- **Pervious Concrete:** Pervious concrete is installed to act as an additional storage system to increase the stormwater capacity treated by the system.
- **Asphalt:** This system is often designed with conventional asphalt in areas of high traffic to prevent any damage to the system.

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 Improves Resilience to Climate Change

- **CORAL REEFS** can reduce 97% of incoming wave energy, which helps reduce erosion and storm-surges.

- **1 acre of WETLANDS** stores 1-1.5 million gallons of floodwater.

- Protecting undeveloped **FLOODPLAINS** would cost < $160 billion, but prevent nearly $400 billion in damages.

- Ecological **FOREST** management can protect drinking water supplies and mitigate wildfire risk.

- **URBAN AND COMMUNITY TREES** reduce over 7% of residential energy use. Urban trees and green spaces absorb stormwater and provide habitat for wildlife.

Coastal Ecosystems  Floodplains  Forests  Urban Forests
Nature Based Climate Solutions

- Climate Smart Forestry
- River restoration
- Climate smart agriculture
- Wetland restoration
- Peatland restoration
- Green cities
- Coastal flood protection
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.
Rainwater Harvesting – Components

The diagram illustrates the components of rainwater harvesting. It shows the inflow from rooftop and paved/unpaved surface runoff, which are directed to a filter bed for consumption. The filter bed is connected to recharge options including open wells, percolation pits, and borewells at ground level.
**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.
Sizing Formula

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

\[(\text{Catchment area}) \times (\text{inches of rain}) \times (600 \text{ gallons}) \times (0.75)\]

\[\frac{\text{1,000 square feet}}{}\]
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

\[
\frac{(1,200 \text{ square feet}) \times (2 \text{ inches of rain}) \times (600 \text{ gallons}) \times (0.75)}{1,000 \text{ square feet}} = 1,080 \text{ gallons}
\]
First Flush Diverter or Roof Washer

- 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.

The rule of thumb is one to two gallons of roof washer capacity for every 100 square feet of catchment area.
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?
1.25" becomes what?
1.50"?
1.75"?
2.00"?
The scientists just say it will be “more,” but how do we design for “more?”
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)?
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Two-hour design storm</th>
<th>24-hour design storm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall total</td>
<td>1.25 inches</td>
<td>3.3 inches</td>
</tr>
<tr>
<td>Drainage area</td>
<td>1,000 sq.ft.</td>
<td>1,000 sq.ft.</td>
</tr>
<tr>
<td>Infiltration during the storm</td>
<td>None</td>
<td>0.5 to 1.0 in/hr</td>
</tr>
<tr>
<td>Cost basis</td>
<td>Surface area</td>
<td>Surface area</td>
</tr>
</tbody>
</table>
Climate Resilient Rain Garden

200 sq.ft. 0.0 in/hr

Drainage area = 1,000 sq.ft.

260 sq.ft. 1.0 in/hr

WATER QUALITY STORM 1.25” over 2-hr

2-YR STORM 3.3” over 24-hr

$2,000

350 sq.ft. 0.5 in/hr

$2,600

$3,500

Depth = 6.0 INCHES
Climate Resilient Rain Garden

260 sq.ft.
1.0 in/hr

Depth = 6.0 INCHES

2-YR STORM
3.3" over 24-hr

260 sq.ft.
0.5 in/hr

Depth = 9.0 INCHES

2-YR STORM
3.3" over 24-hr

$2,600
## Results

<table>
<thead>
<tr>
<th>Rain Garden Surface Area (sq. ft.)</th>
<th>Rain Garden Depth (in.)</th>
<th>Rain Garden Storage Volume (cu. ft.)</th>
<th>Rain Garden Capacity for 2-hr Rainfall (in.)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>6</td>
<td>100</td>
<td>1.25</td>
<td>2,000</td>
</tr>
<tr>
<td>260</td>
<td>6</td>
<td>130</td>
<td>1.56</td>
<td>2,600</td>
</tr>
<tr>
<td>350</td>
<td>6</td>
<td>175</td>
<td>2.10</td>
<td>3,500</td>
</tr>
<tr>
<td>260</td>
<td>9</td>
<td>195</td>
<td>2.34</td>
<td>2,600</td>
</tr>
</tbody>
</table>
What if we combined roadside rain gardens with street trees?
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
Water Quality Storm Analysis (1.25 inches)

11.6 acres

52,635 ft³ or 1.2 acre-ft
1.23 acres of rain gardens provides 45,611 ft³ 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 ft³ 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

EXISTING TREE LINE
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

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
Figure 9-2: Examples of Management Measures across Coastal Landscape
Design Guidelines for Porous Asphalt with Subsurface Infiltration

- **Riverjacks** open into recharge bed
- **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
Together we can do it!

Thanks, Cody!
WE ARE DONE!
Congratulations!

Christopher C. Obropta, Ph.D., P.E.
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Rutgers Cooperative Extension

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