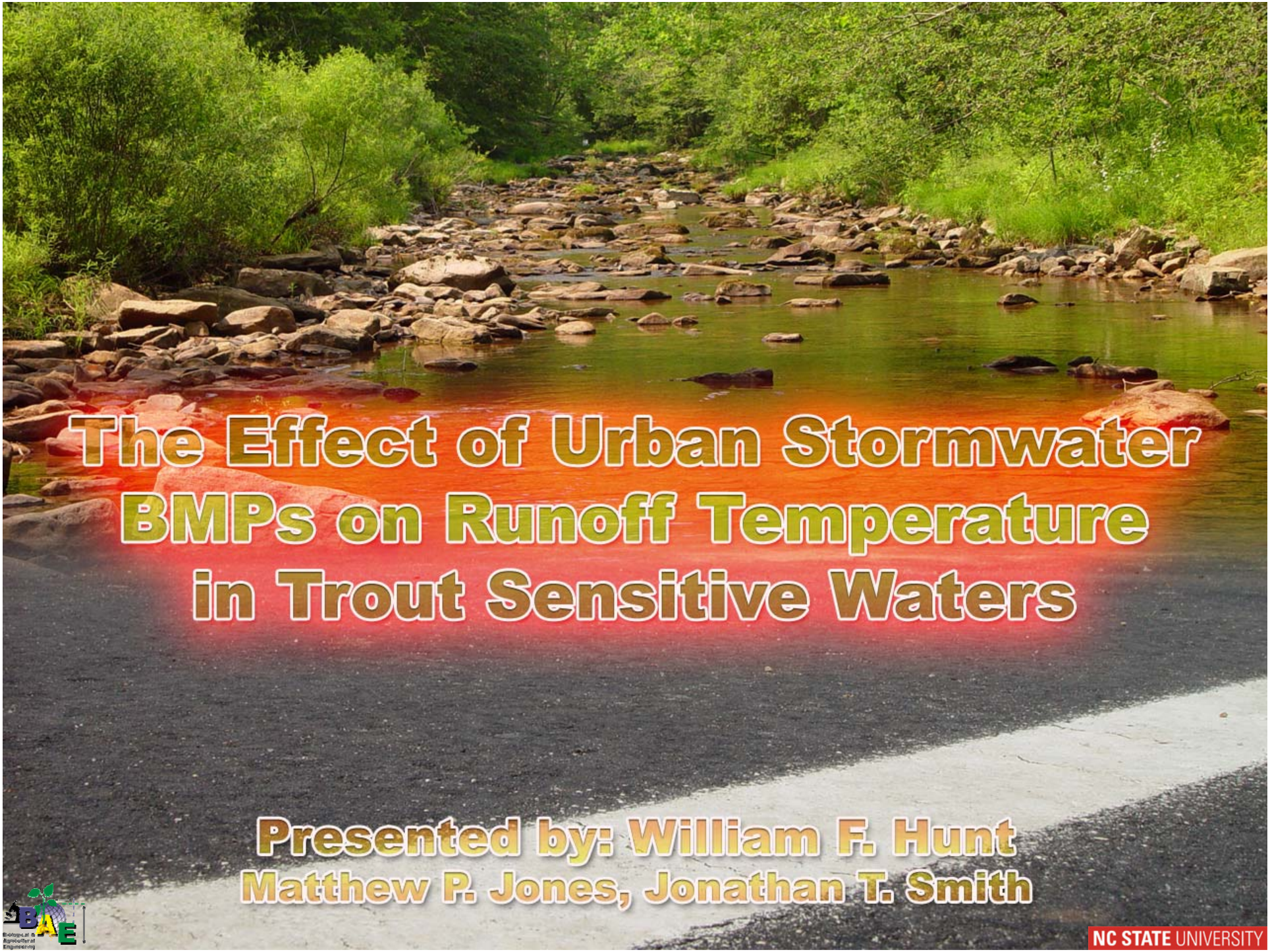
The Effect of Urban Stormwater BMPs on Runoff Temperature in Trout Sensitive Waters
Presented by: William F. Hunt
Matthew P. Jones, Jonathan T. Smith
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Thermal Enrichment

- Heated pavement surfaces transfer thermal energy to stormwater runoff
- Typical impact is short term temperature spikes in receiving waters
- Runoff temperatures can range from near ambient air temperatures to 43° C (110° F)

Thermal Impacts

- Trout and salmon species are among the most sensitive fish to temperature change
  - 4 – 21° C (40 – 70° F) is the preferred range
  - 32° C (90° F) short term exposure is lethal
- Economically important
  - $21.3 billion on freshwater recreational fishing
  - 7.5 million anglers fish for trout

Trout in North Carolina

- Brook Trout
  - Only trout native to North Carolina
  - Populations have diminished due to loss of habitat, over-fishing, and competition with other trout
  - Special emphasis has been placed on preserving wild brook trout populations

Trout in North Carolina

- Brown Trout
  - Originally imported from Northern Europe
  - Brown trout are known for their wariness and difficulty to catch
  - Brown trout generally prefer larger and slower streams than brook and rainbow trout

Trout in North Carolina

- Rainbow Trout
  - Introduced from the Western U.S.
  - Often the fish that is used to stock NC creeks
  - Rainbow trout are more tolerant than brook trout and dominant when their populations overlap

What Does Body Temperature Affect?

- Behavior
  - Increased feeding activity
    - Feeding doubles or triples with 10°-20°F increase
  - Increased movement
  - Disorientation

What Does Body Temperature Affect?

- Metabolism
  - Increased metabolic rate
  - Consume more energy
  - Increased oxygen demand
  - Can lead to cellular damage

- Enzymes
  - Effect on production and performance

What Does Body Temperature Affect?

- Reproduction
  - Organisms don't engage in reproduction
  - Eggs can't survive high temperatures

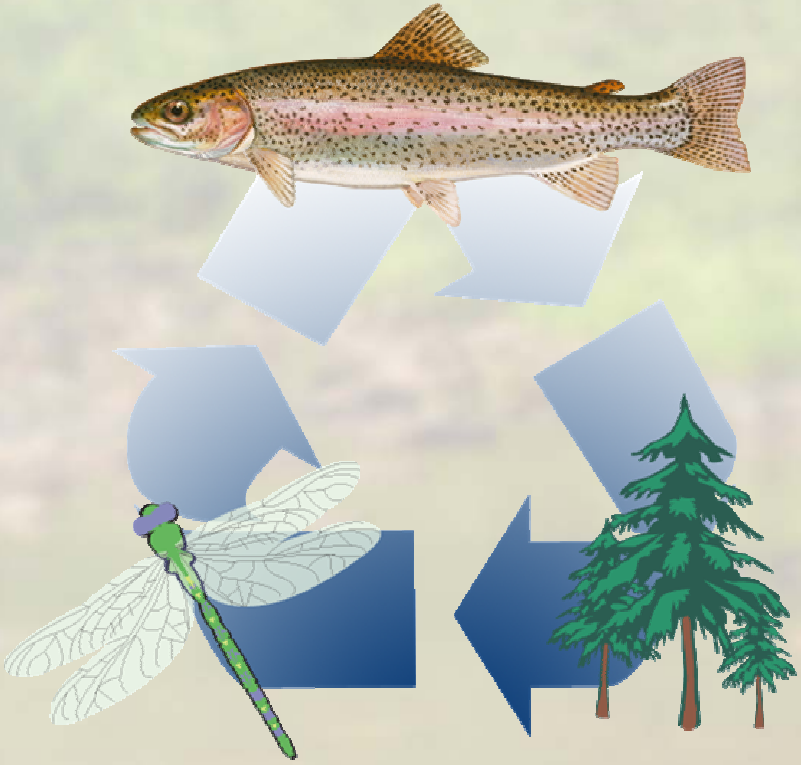
- Growth and Development
  - Smaller juveniles
  - Juveniles can't survive high temperatures

What Does Body Temperature Affect?

- Vulnerability to Disease
  - Parasites and diseases can thrive in warm water
  - Stress from heat reduces disease tolerance

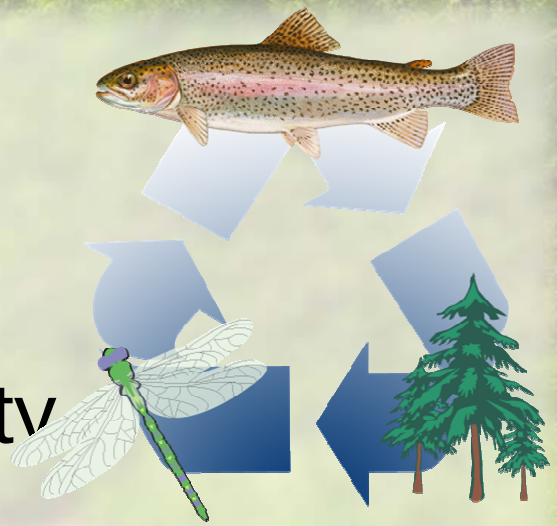
How is the Ecosystem Affected?

- Some organisms benefit, while others suffer
  - Food Source
  - Available Habitat
  - Predation
  - Disease
  - Oxygen Supply



Thermal Impacts

- Behavioral impacts
- Physiological impacts
- Macro-invertebrate community
- Lower dissolved oxygen content
- Full effect on ecosystem is unknown



Monitoring Strategy

- Temperature and flow monitoring equipment installed at 6 stormwater BMPs in Western North Carolina
  - 4 Bioretention Areas
  - 1 Stormwater Wetland
  - 1 Wet Pond
- Each monitoring site paired with a nearby BMP
- Monitoring Data Collected:
  - Temperature and flow at all BMP inlets and outlets
  - Ambient air temperature and rainfall for each pair
  - Temperature at specific depths for some sites

Objectives

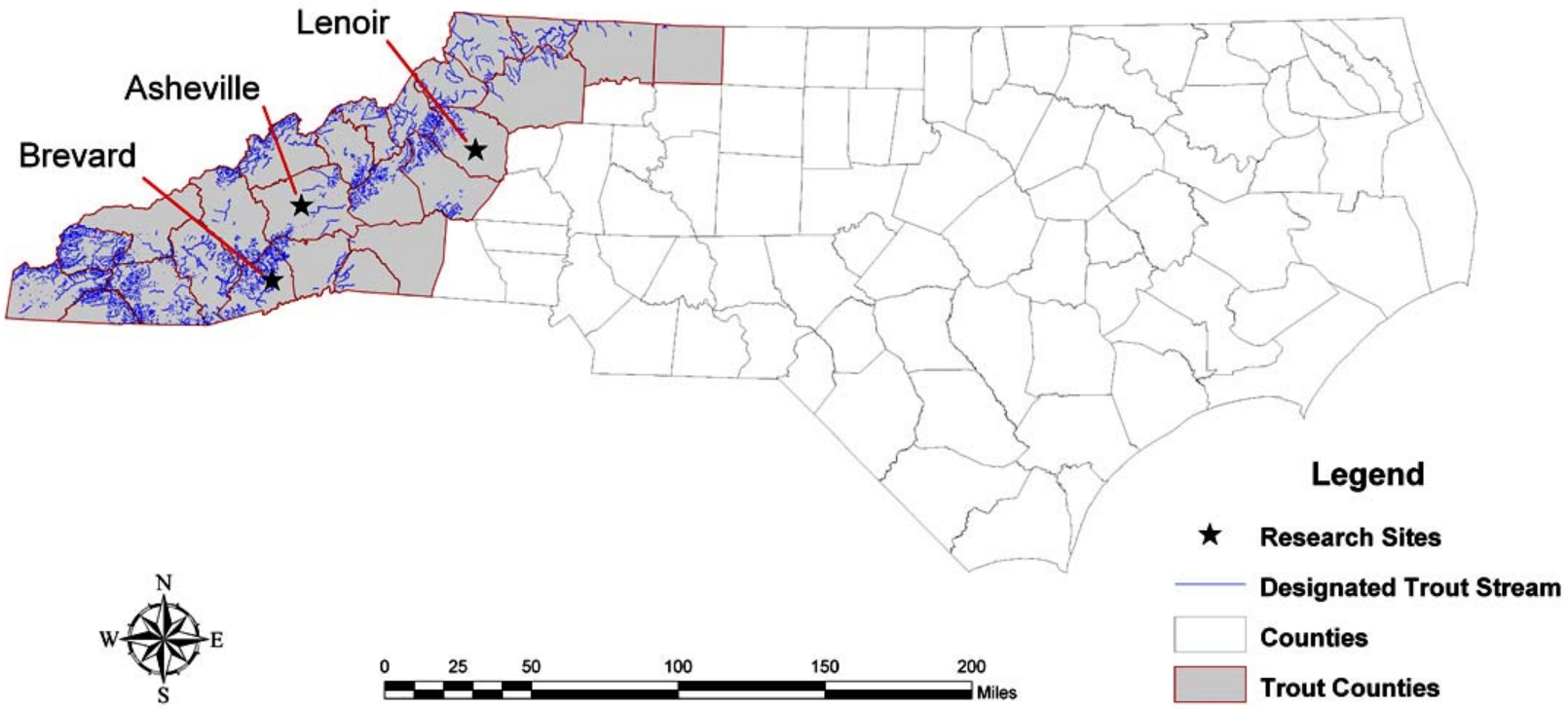
- Examine the effect of stormwater BMPs on runoff temperature

- Determine which BMPs effectively reduce runoff temperature

- Develop design criteria for effective temperature reduction

- Develop a computer model to assist designers in assessing BMP thermal impacts

Site Locations




Asheville Wetland
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Asheville Bioretention

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Brevard East Bioretention
Beltone
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Brevard West Bioretention
NC STATE UNIVERSITY


Lenoir Wet Pond
NC STATE UNIVERSITY


Lenoir Bioretention
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Monitoring Results

General Findings

- Runoff temperature warmer than 21°C at all sites for the months of June through August
- Lowest runoff temperatures observed at parking lot covered with light-colored chip seal
- Runoff temperatures decreased with extended rainfall
- Increase in stream temperature observed during rainfall events

Brevard, North Carolina

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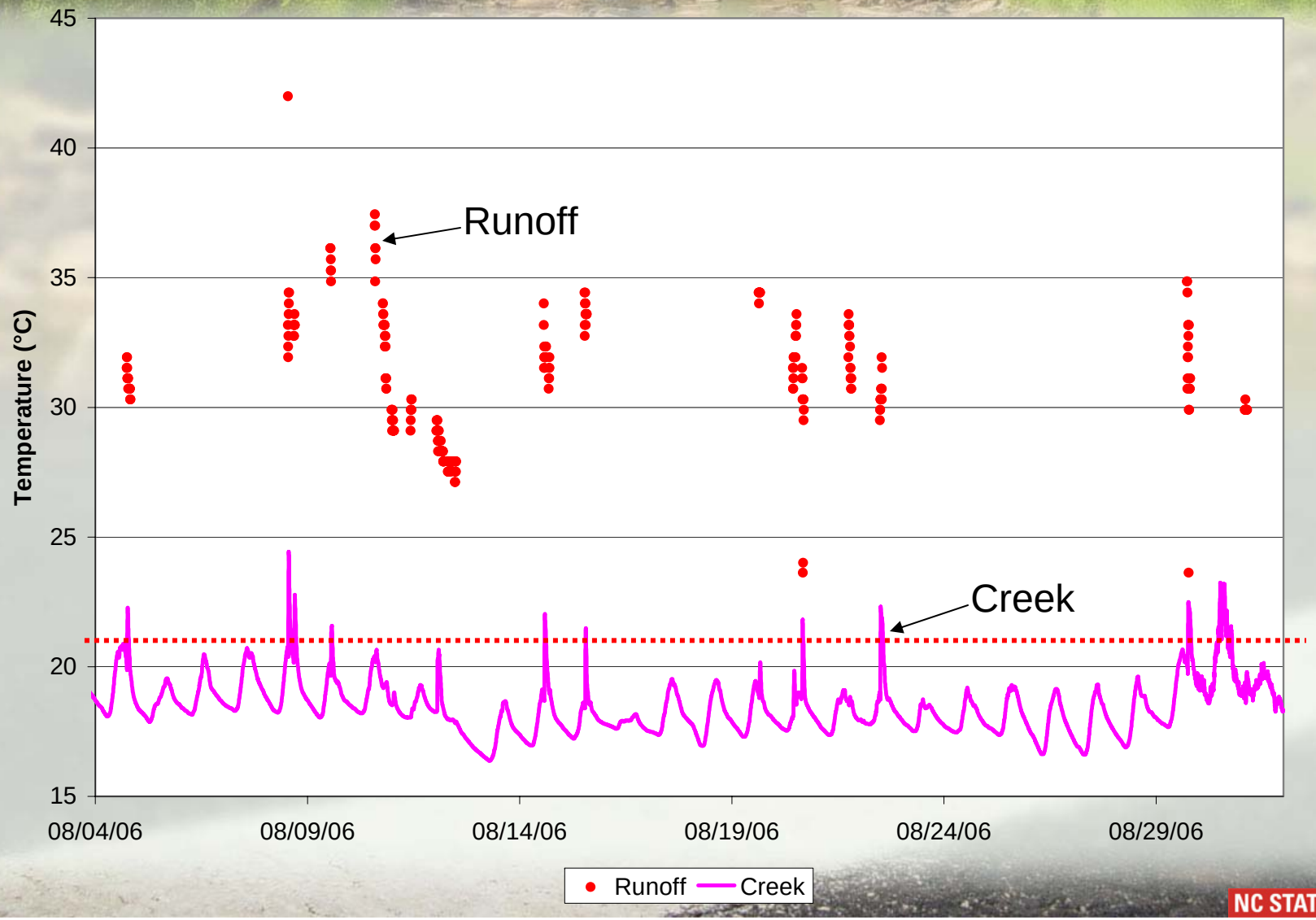
Monitoring Results



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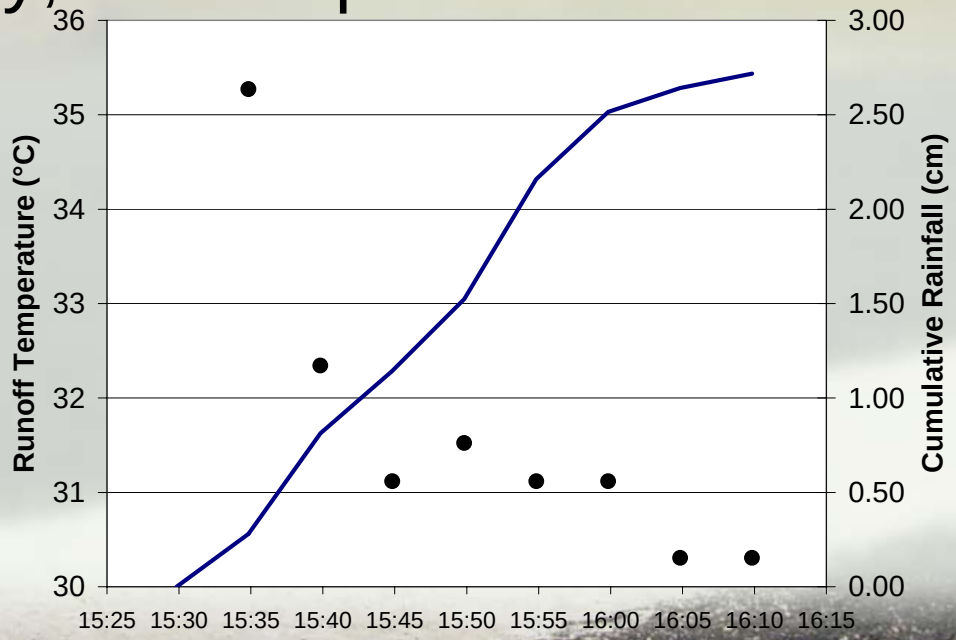
Design Guidance

First Flush

- Temperature is much more dynamic than conventional pollutants
- After 2.5 cm of rainfall, additional cooling unlikely, but still poses a concern

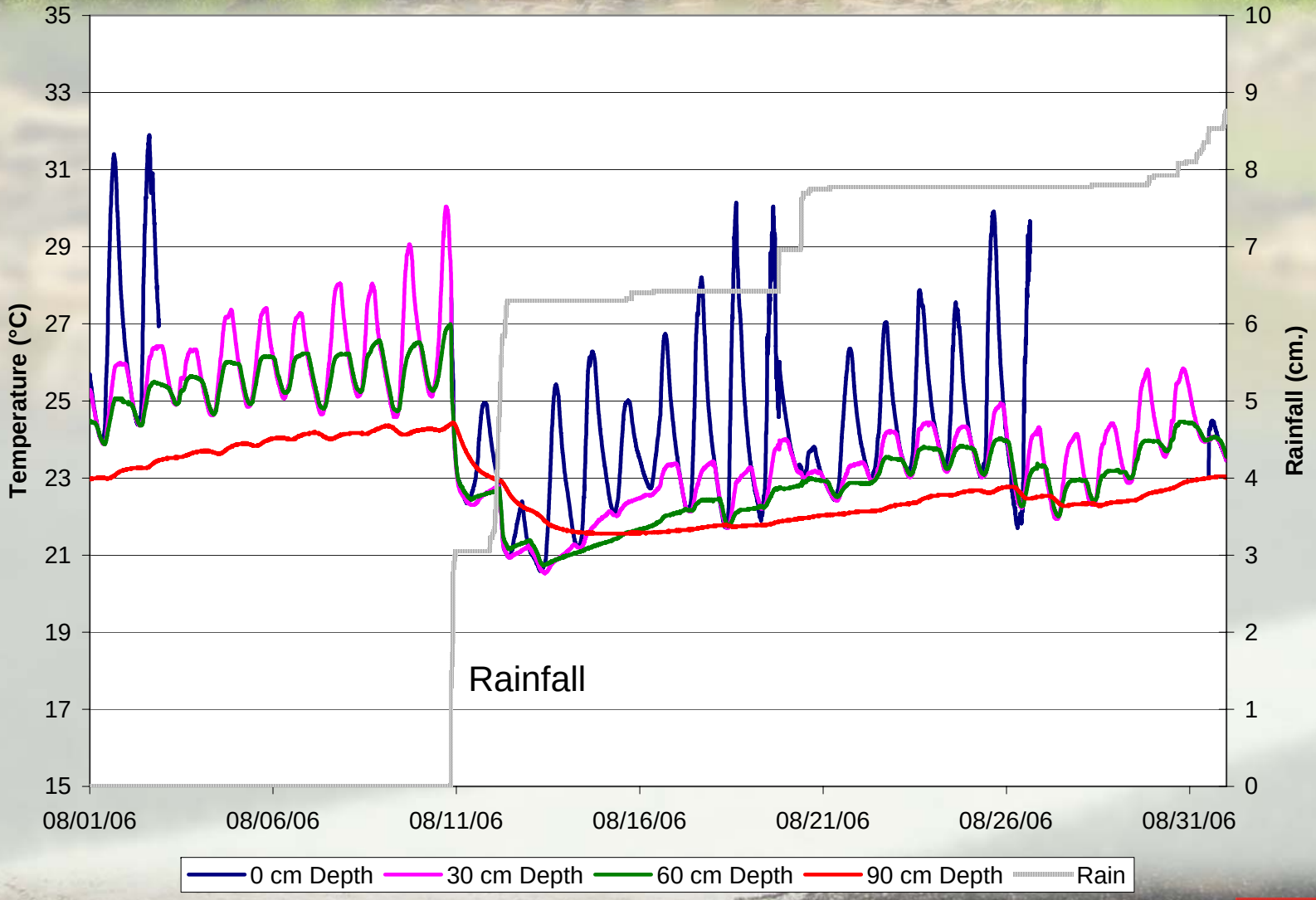


Stormwater Wetland

Stormwater Wetland

- Water temperature subject to wide variability due to the effects of the sun and storms
- Effluent temperatures decreased as storms progressed due to mixing and effects of cooler runoff
- Bottom waters significantly cooler than 21°C for the months of May, June, September, and October
- Temperature of bottom waters was not significantly different from influent temperature

Stormwater Wetland



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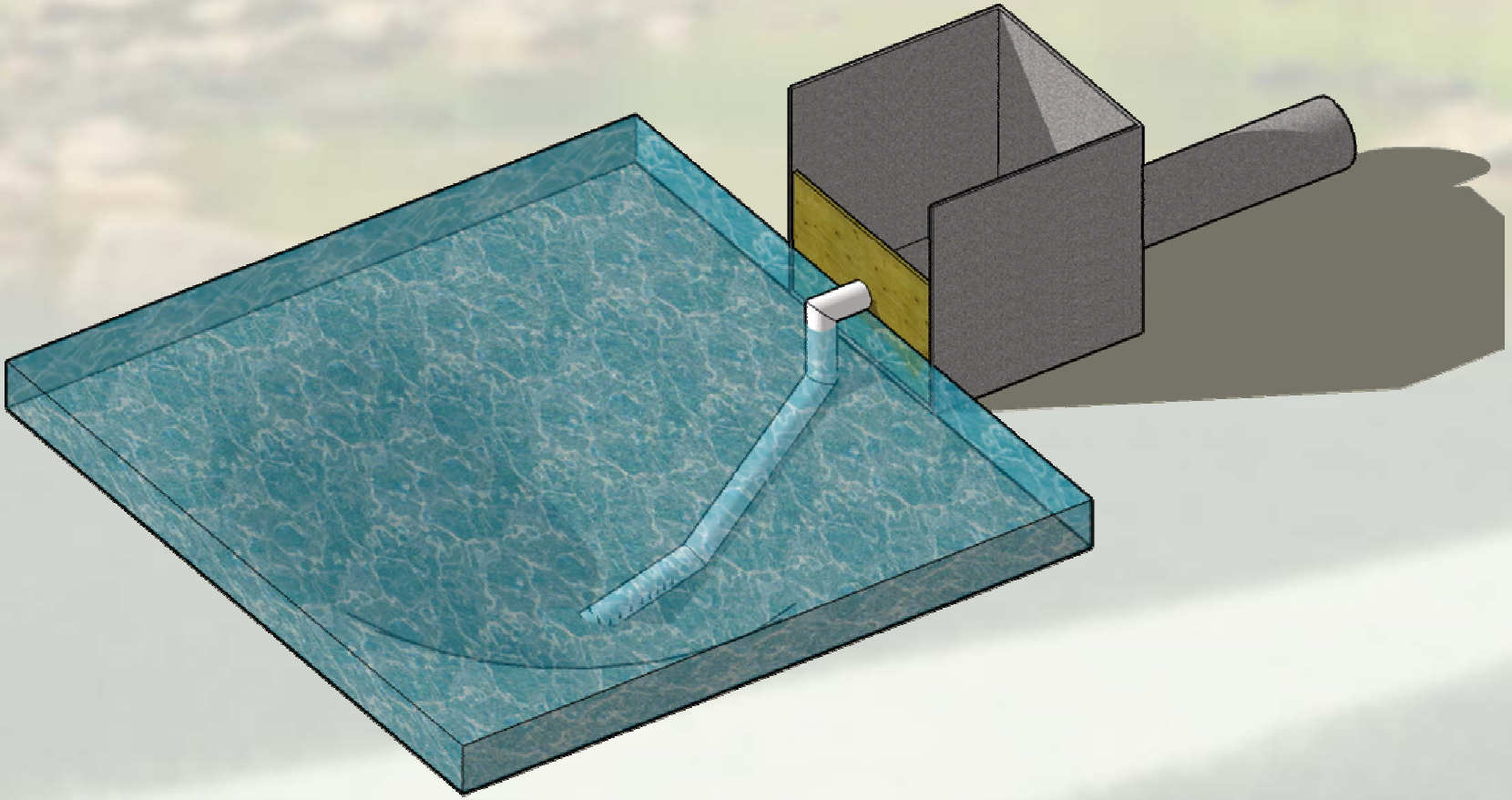
Stormwater Wetland



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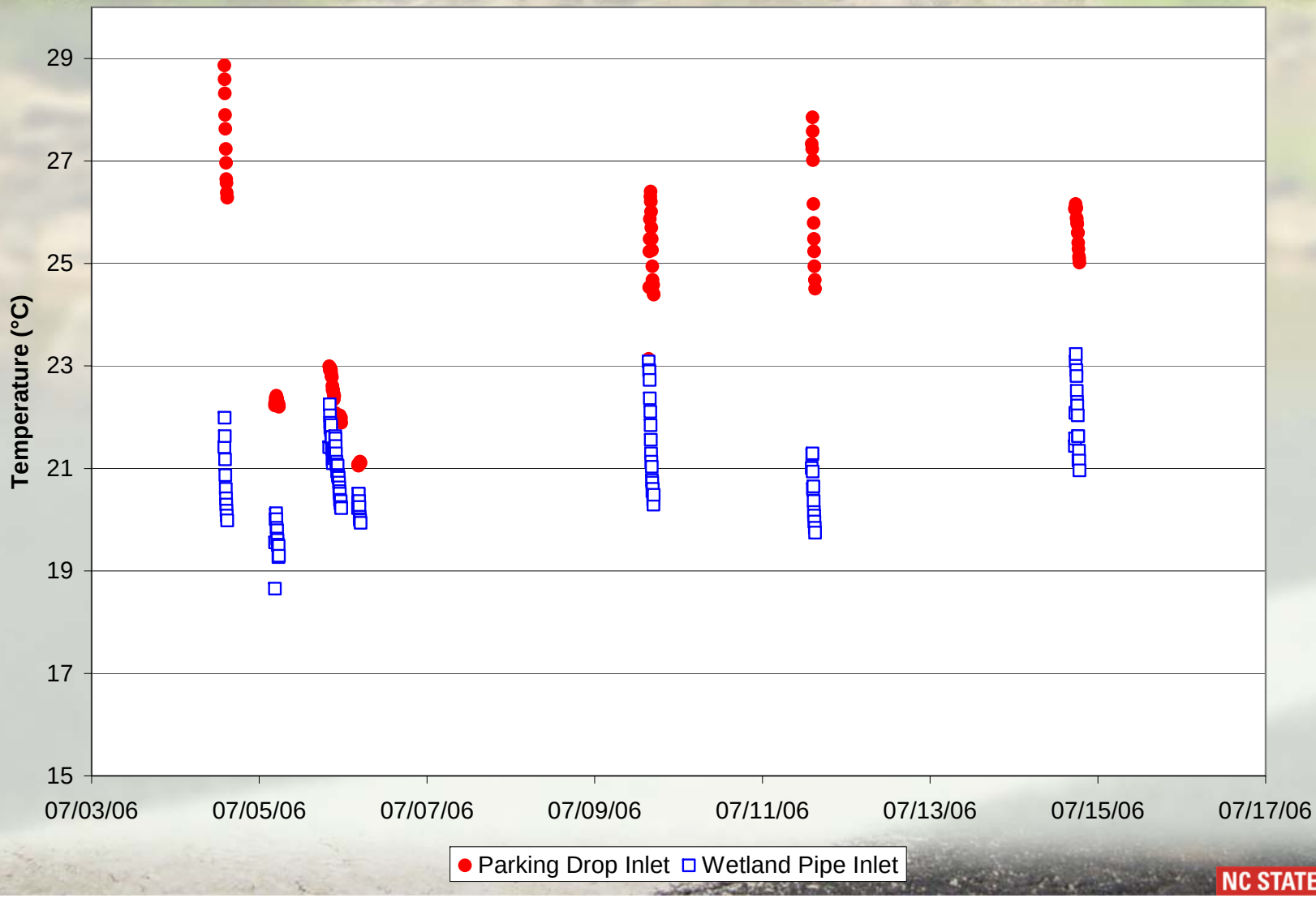
Stormwater Wetland

- Increased water temperature significantly from June through September
- Effluent temperatures decreased as storms progressed
- Substantial cooling occurred as water traveled through a buried metal corrugated pipe
- Effect of cooling was negligible due to warm water within the wetland

Stormwater Wetland



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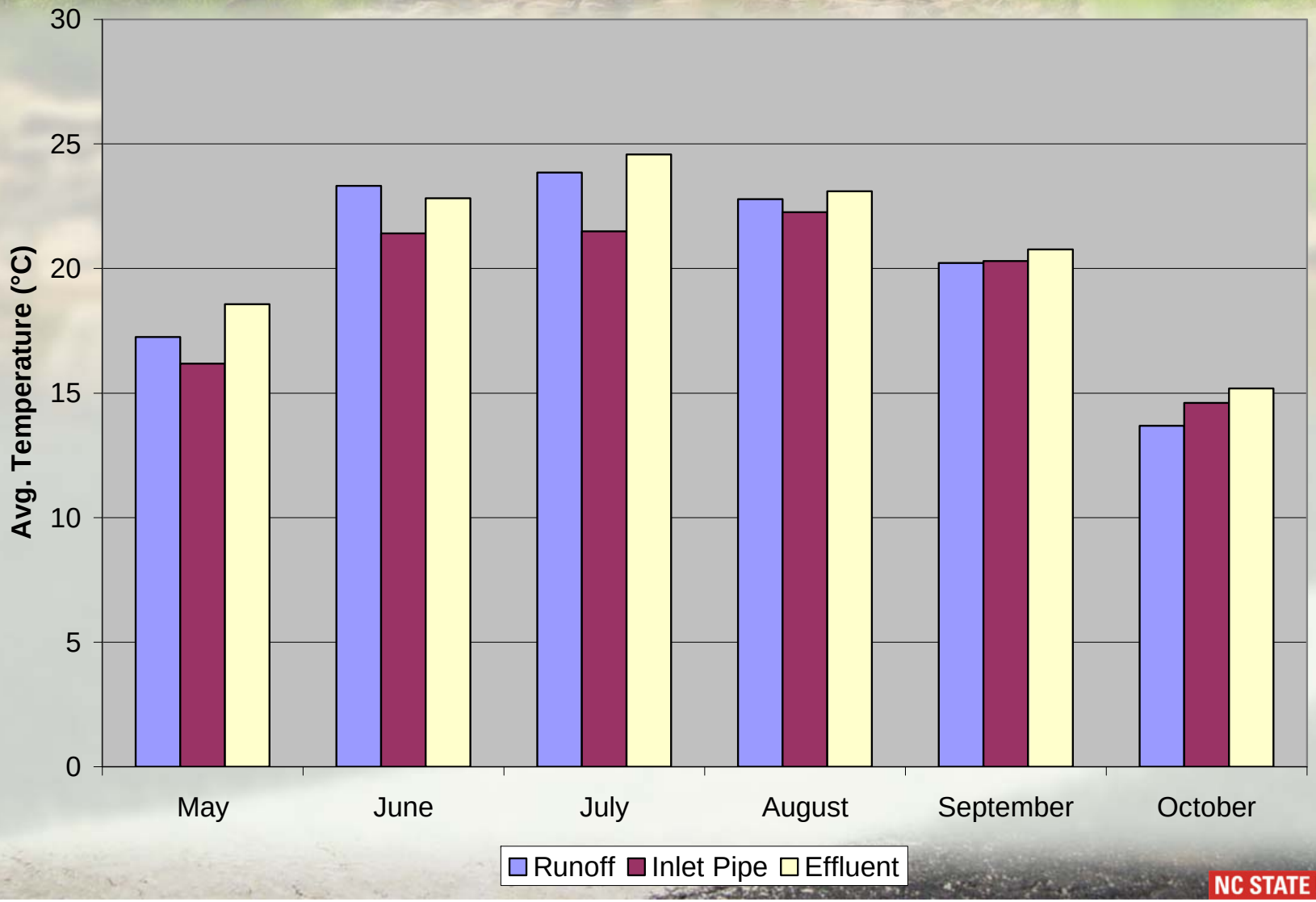
Stormwater Wetland



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Wet Pond

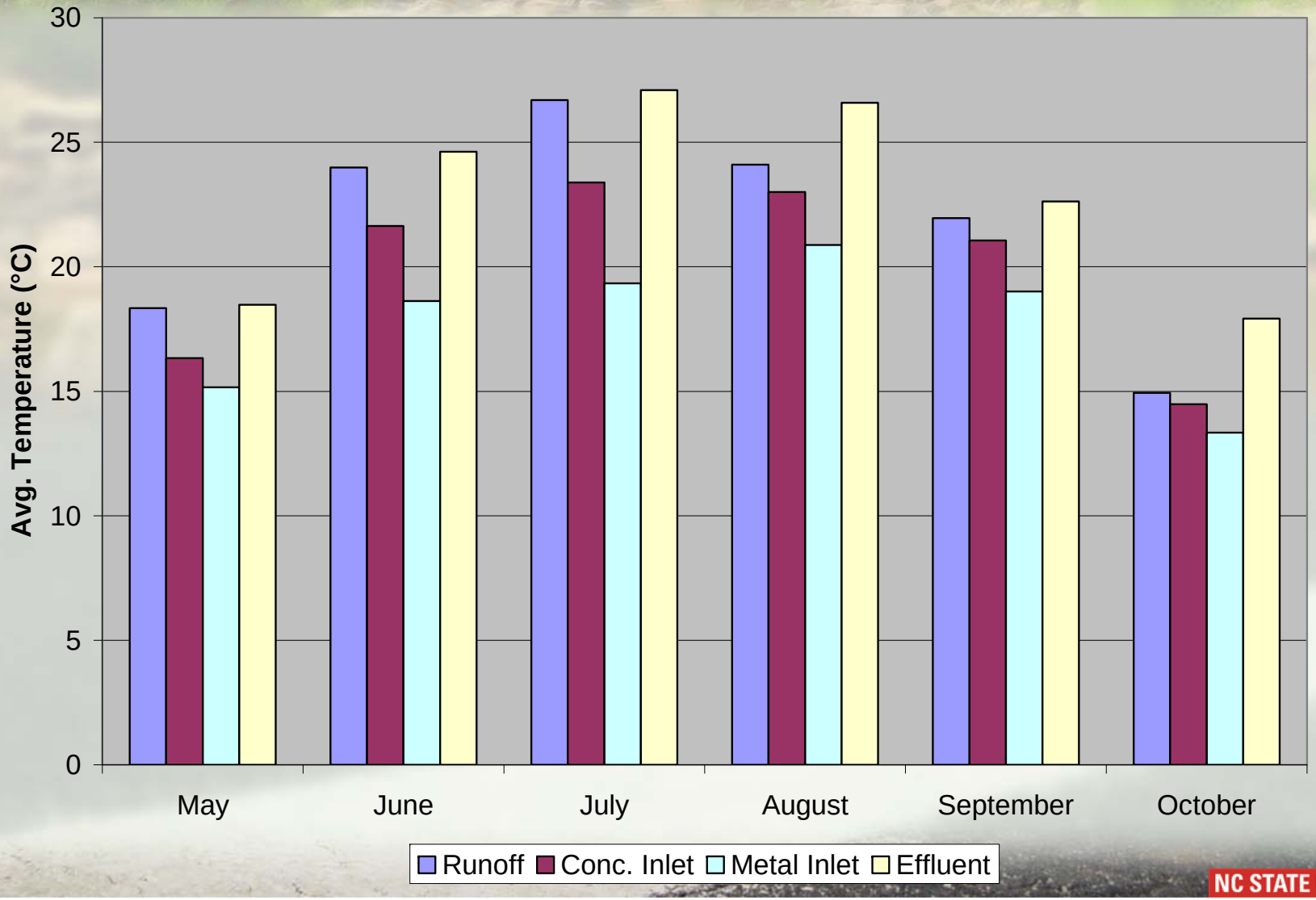
Wet Pond

- Results similar to stormwater wetland
- Effluent temperatures and water temperatures within the wet pond were warmer than wetland
- High fluctuation near surface due in part to algae and floating vegetation
- Effluent temperatures remained above 21°C from June through August

Wet Pond

- Runoff cooled in buried pipes before entering wet pond
- Bottom waters of wet pond warmer than incoming water
- Wet pond constant source of thermal pollution

Wet Pond

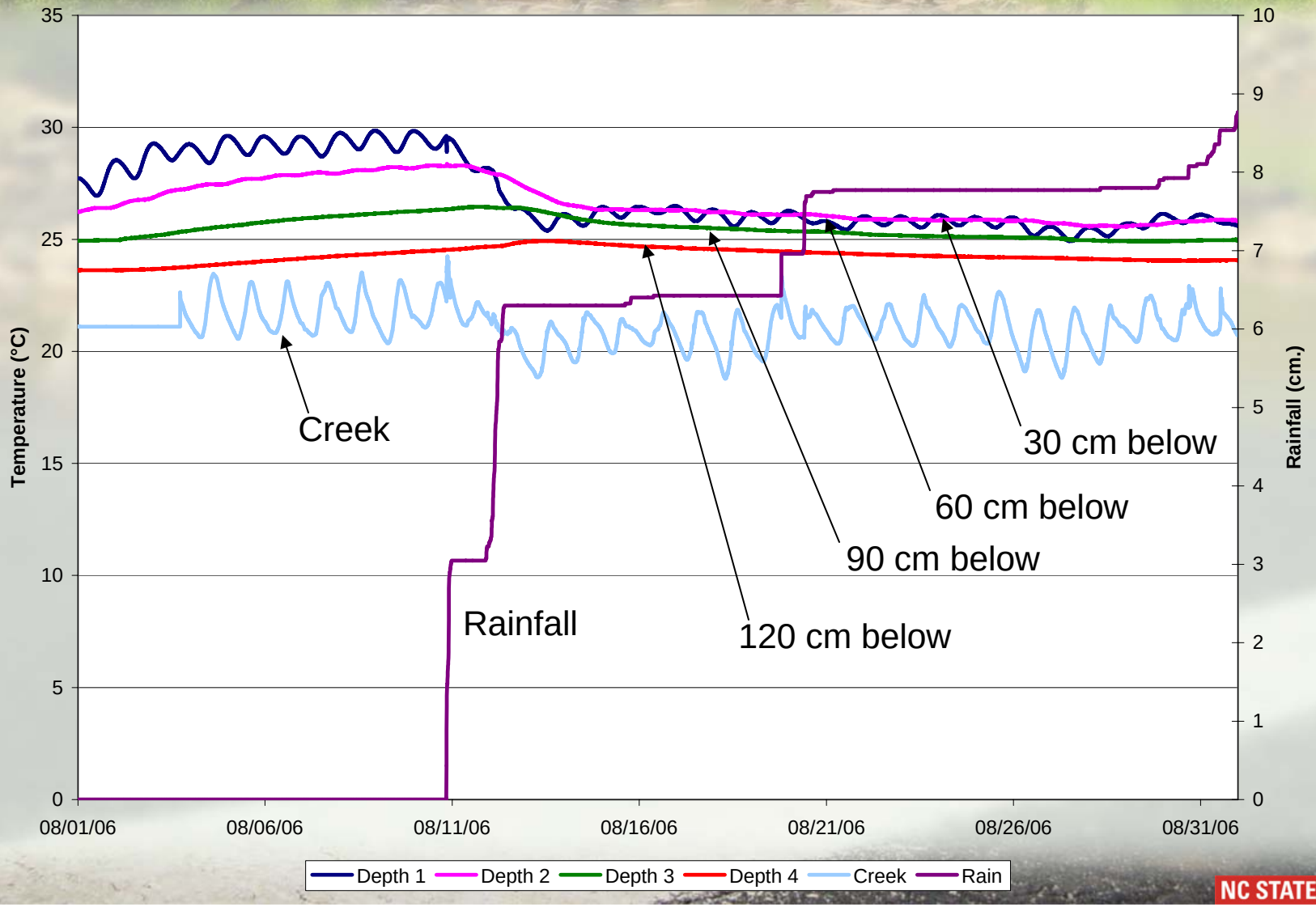

30
25
20
15
10
5
0
Avg. Temperature (°C)
May
June
July
August
September
October
Runoff
Conc. Inlet
Metal Inlet
Effluent

Bioretention Area

Bioretention Areas

- Soil temperature at greater depths buffered from daily weather changes and storm events
- Temperatures at bottom depths warmer than 21°C for much of the monitoring period
- Bioretention areas that were smaller with respect to their watershed significantly reduced both maximum and median storm temperatures

Bioretention Area



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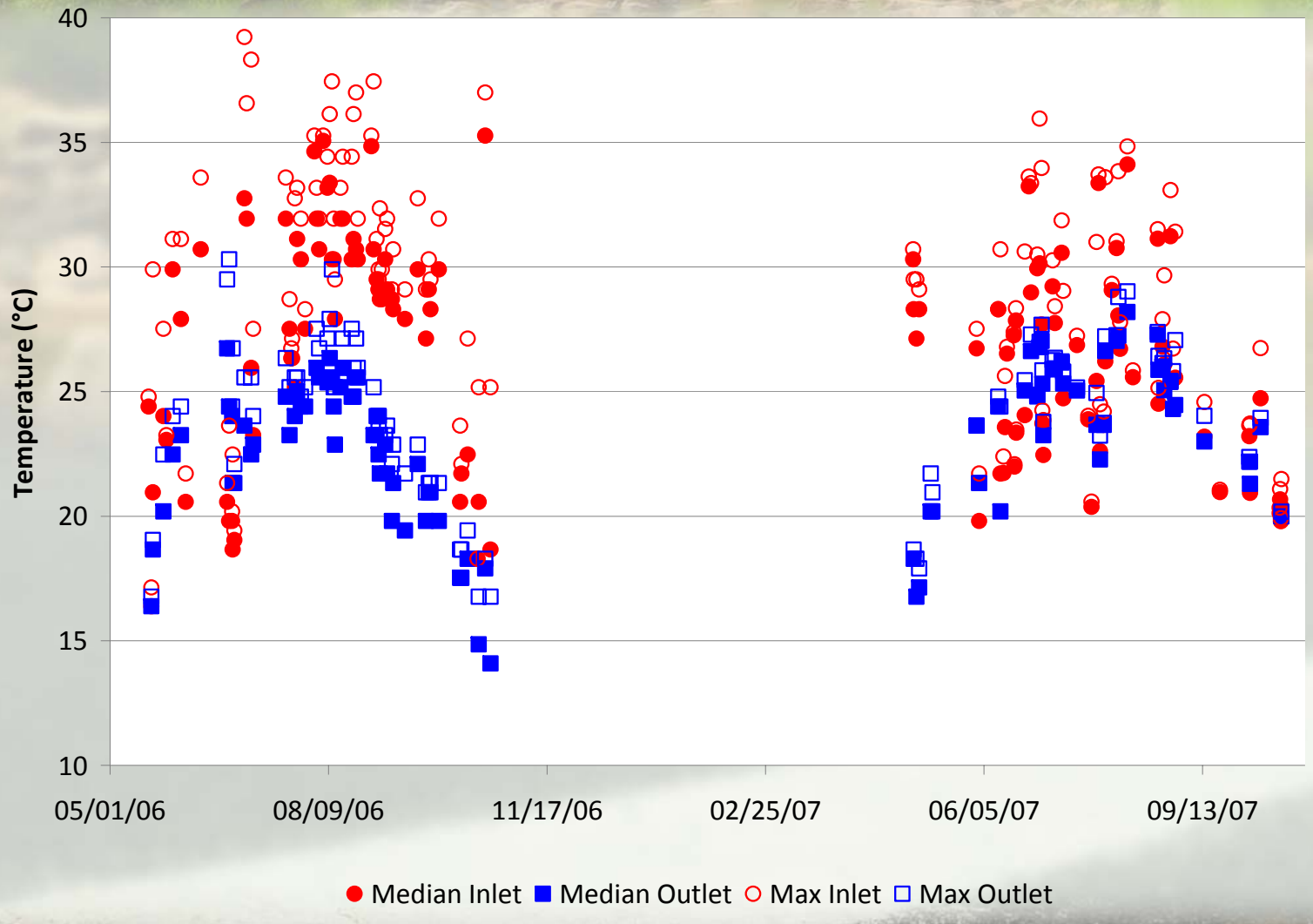
Bioretention Area

- Bioretention able to reduce the effects of temperature spikes
- Heat stored within soil may increase water temperatures late in a storm when runoff has cooled
- Effluent temperatures more predictable than stormwater wetlands and wet ponds
- At larger bioretention areas, the benefit of cooler runoff late in a storm was not realized at the outlet due to consistent soil temperatures

Bioretention Area



Bioretention Area

- Ability of bioretention to exfiltrate water leads to reductions in thermal load
- Effluent reductions were greatest for bioretention areas larger with respect to their watershed

	Percentage of Watershed Area	Events with Outflow
Asheville	16%	12%
Lenoir	4%	79%
Brevard East	7%	76%
Brevard West	11%	27%

Design Guidance

Stormwater Wetland

- Outflow temps from current design greater than influent temps
- Bottom waters cooler than 21°C during some months
- Some reductions in runoff volume

Wet Pond

- All foreseeable designs would increase outflow temperature
- Effluent temperatures consistently warmer than 21°C

Bioretention Area

- Standard design able to reduce runoff temperatures
- Soil buffering results in more predictable effluent temperatures
- Substantial reductions in runoff volume

Summary

- Without consideration for runoff temperature in design, BMPs can serve as a pollution source
- Infiltration throughout the watershed beneficial
- Conveyance in underground pipes can reduce runoff temperatures substantially
- Modified outlet structures beneficial for open water systems
- Bioretention able to reduce runoff temperature and volume

Acknowledgements

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Questions?
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