NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Withstanding Climate Change—Resilient & Flexible Pavement

October 12, 2022

11:00 AM – 1:30 PM

NOVEMBER 2022 UPDATE

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Beth Ewoldsen at Bewoldsen@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP
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AICP Credit Information

1.5 American Institute of Certified Planners Certification Maintenance Credits

You must attend the entire webinar

Log into the American Planning Association website to claim your credits

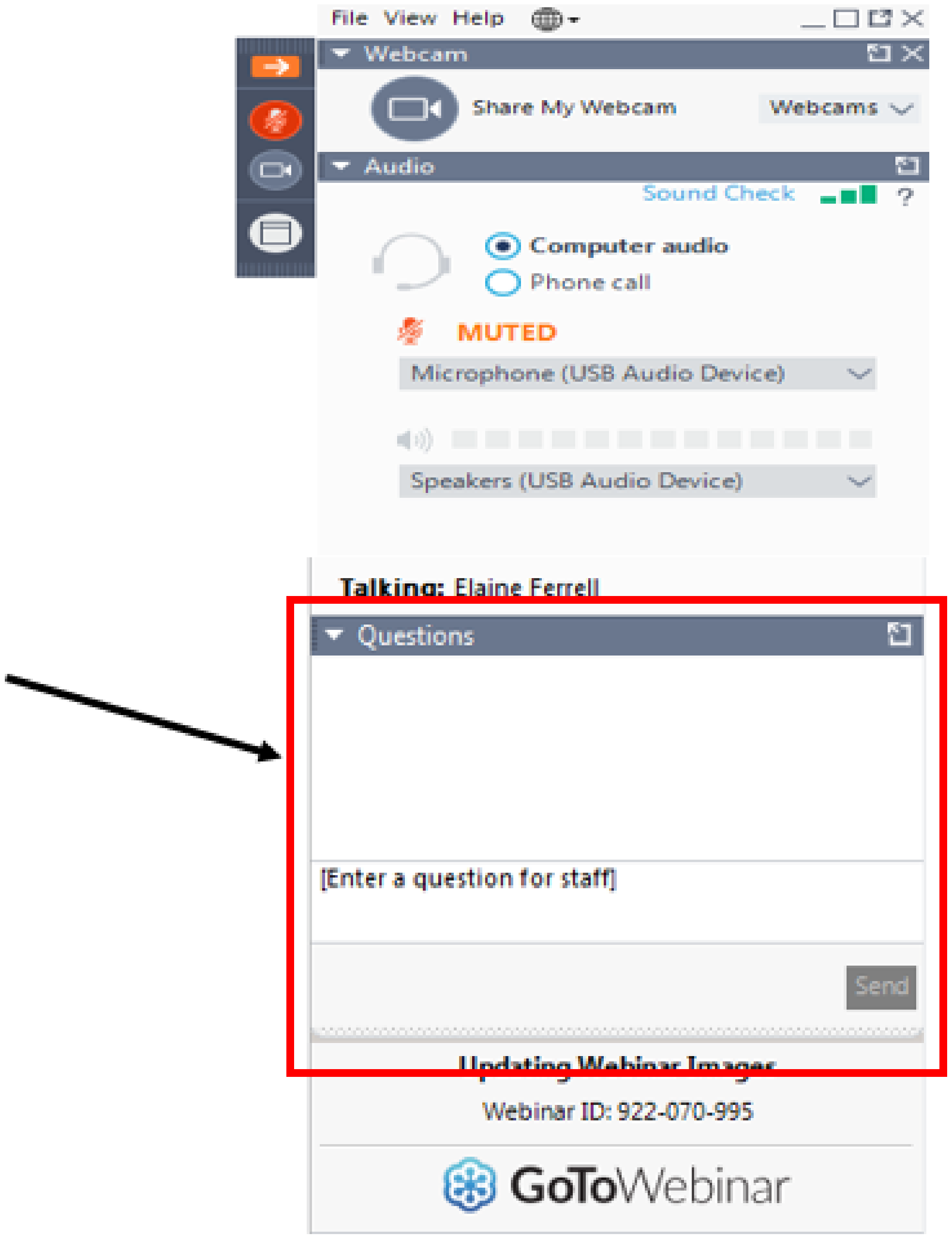
Contact AICP, not TRB, with questions

Learning Objectives

- Identify key factors to enhance resiliency of asphalts pavements, specifically, materials and methods used in the design, production, and construction of flexible pavements
- Implement proposed practices to enhance resiliency, durability and performance of asphalt pavements

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Louay Mohammad
Louaym@lsu.edu
LSU
LOUISIANA STATE UNIVERSITY

Amir Golalipour
amir.golalipour@dot.gov

Ben Bowers
bfbowers@auburn.edu
AUBURN
UNIVERSITY

Joseph Shacat
jshacat@asphaltpavement.org
NAPA
NATIONAL ASPHALT
PAVEMENT ASSOCIATION

Withstanding Climate Change - Resilient & Flexible Pavement

Louay N. Mohammad, Ph.D., P.E., Fellow ASCE

Department of Civil and Environmental Engineering
Louisiana Transportation Research Center
Louisiana State University

TRB Webinar: AKM40 Standing Committee on Asphalt mixture evaluation and performance
October 12, 2022

Webinar Background

- Impact of extreme weather conditions such as hurricanes and flooding on the transportation infrastructure has increased significantly Over the last few decades.
- Resilience of asphalt pavements to such extreme events has become a necessity
- Impact of climate change on the performance of flexible pavement will be discussed.
- Strategies for materials and methods used in the design, production, and construction will be offered.

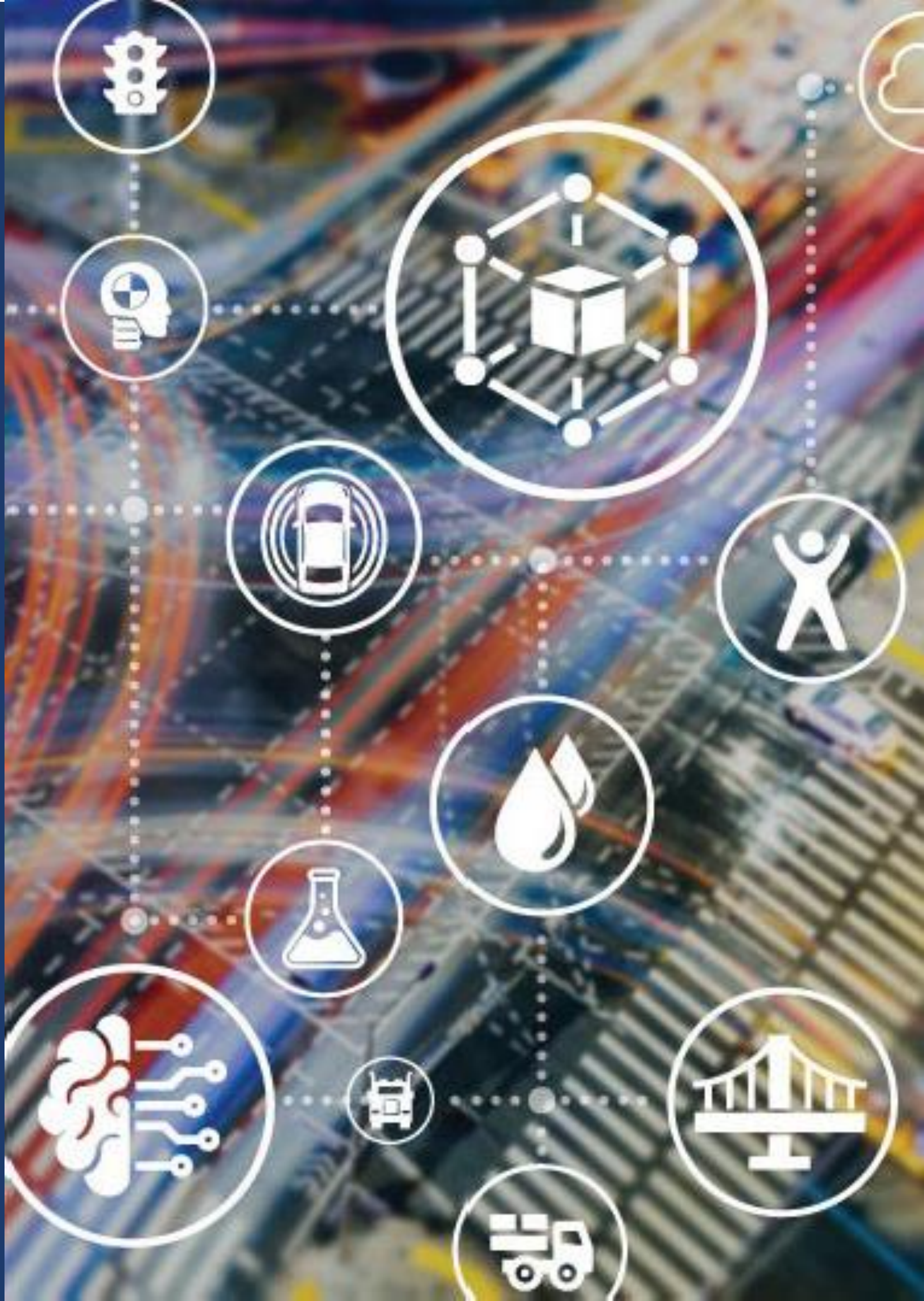
U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center

Progress Toward More Resilient Pavements

FHWA Resilience Efforts

Amir Golalipour, Ph.D., P.E.
Office of Research, Development, and Technology
Federal Highway Administration (FHWA)

TRB Webinar: Withstanding Climate Change—Resilient & Flexible Pavement
October 12th, 2022



What Is Resilience?

Resilience: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions, FHWA Order 5520 (FHWA 2014c).

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Environmental Impacts on Pavements

- Environmental factors contribute to pavement distresses, such as blowups, buckling, rutting, and thermal cracking.
- The Long-Term Pavement Performance Program studied environmental factor impacts on pavement performance (FHWA 2016b):
  - There is 36 percent of total damage for flexible pavements.
  - There is 24 percent of total damage for rigid pavements.
- Pavements are designed using climatic data; however, engineers typically assume stationarity.

Static Versus Future Climate Inputs

Stationary Climate Inputs:

- Based on historical data: Previously observed and measured.
- Grounded in well-established methods for design consideration.
- Based on the fundamental assumption: Historical data = future climate.

Future (Nonstationary) Climate Inputs:

- Generated by climate models: Partially incorporating historical inputs.
- Built on assumptions of greenhouse gas emission sources and levels.
- Based on the explicit assumption: Historical data ≠ future climate.

Future (Nonstationary) Climate Inputs

- Global climate models (GCMs)—Large-scale output, lower resolution.
- Regional climate models (RCMs)—Small-scale output, higher resolution.

We must downscale climate models to establish relationships between:

- GCM and RCM outputs (projections).
- Local variables (historical data).

Potential Consequences with Assuming Stationarity for Flexible Pavements

Higher average temperature	Increased potential for rutting and shoving, requiring more rut-resistant asphalt mixtures. Increased age hardening of asphalt binder.
Moisture changes	Increased potential for soil shrinking and swelling, particularly in times of drought, requiring stiffer pavement designs.
Increased precipitation	Reduced pavement structural capacity due to increased levels of saturation, potentially requiring base stabilization, a better understanding of foundation design, and improved mix designs.

(FHWA 2015)

Data Sources for Future Climate Projections (Including Sea-Level Rise (SLR))

Resource	Description
Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (DCHP) database (U.S. Federal Government 2021)	A database that contains publicly available, downloadable, downscaled climate projection data for temperature and precipitation in the contiguous United States.
USGS Geo Data Portal (U.S. Geological Survey 2022)	A web portal that provides access to a suite of climate datasets for temperature and precipitation, including climate projections using different downscaling techniques.
U.S. DOT CMIP Climate Data Processing Tool 2.0 (FHWA 2021a)	An Excel®-based tool to process data from the DCHP database to provide temperature and precipitation projections for climate variables relevant to transportation planners. The updated version uses the localized constructed analog dataset and incorporates several new variables.
U.S. Army Corps of Engineers Sea- Level Change Curve Calculator (U.S. Army Corps of Engineers 2021)	A web-based tool that accepts user input to produce a table and graph of the projected sea-level changes at the project site, including vertical land movement.
National Oceanic and Atmospheric Administration's (NOAA's) SLR Viewer (NOAA 2022)	A web mapping tool to visualize community-level impacts from coastal flooding or SLR that contains downloadable SLR data for many locations.

CMIP = Coupled Model Intercomparison Project; USGS = U.S. Geological Survey; DOT = department of transportation.

FHWA Resilience

Application to Pavements

U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center

Adaptation Strategies: 1. Monitor Trends

Most predicted changes to environmental variables are projected to occur relatively slowly in relation to a typical infrastructure lifecycle (FHWA 2015).

Key pavement indicators to monitor for climate change impacts.

Asphalt Pavement Indicators	Concrete Pavement Indicators
Rutting of asphalt surface	Blow-ups (JPCP)
Low temperature (transverse) cracking	Slab cracking
Block cracking	Punch-outs (CRCP)
Raveling	Joint spalling
Fatigue cracking and pot holes	Freeze-thaw durability
Rutting of subgrade and unbound base	Faulting, pumping, and corner breaks
Stripping	Slab warping
	Punch-outs (CRCP)

Source: FHWA.
(FHWA forthcoming b.)

CRCP = continuously reinforced concrete pavement; JPCP = jointed plain concrete pavement.

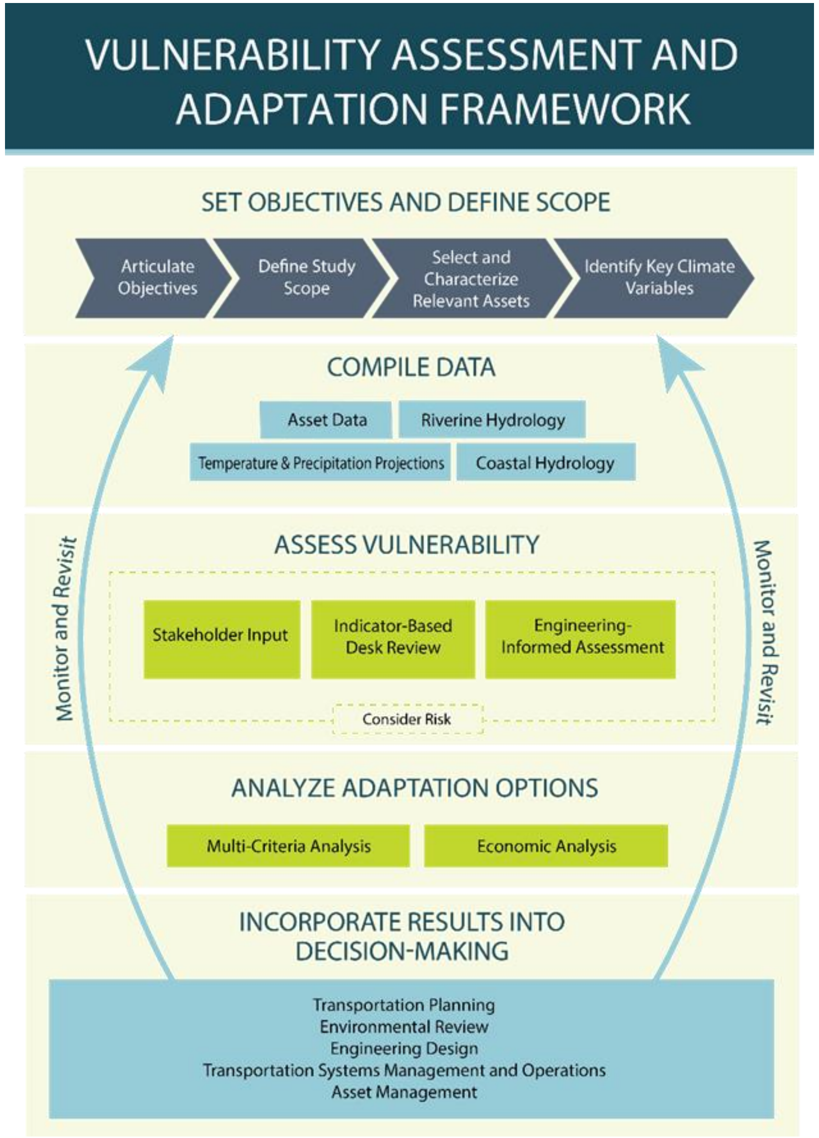
2. When Trends Differ, Evaluate Vulnerability

Objectives:

- Identify whether an asset is more vulnerable than other system assets.
- Prioritize potential vulnerabilities for the system.

Approach:

- Use the Vulnerability Assessment Scoring Tool (FHWA 2017e).
- Input local asset data.
- Output the relative vulnerability scores per asset.



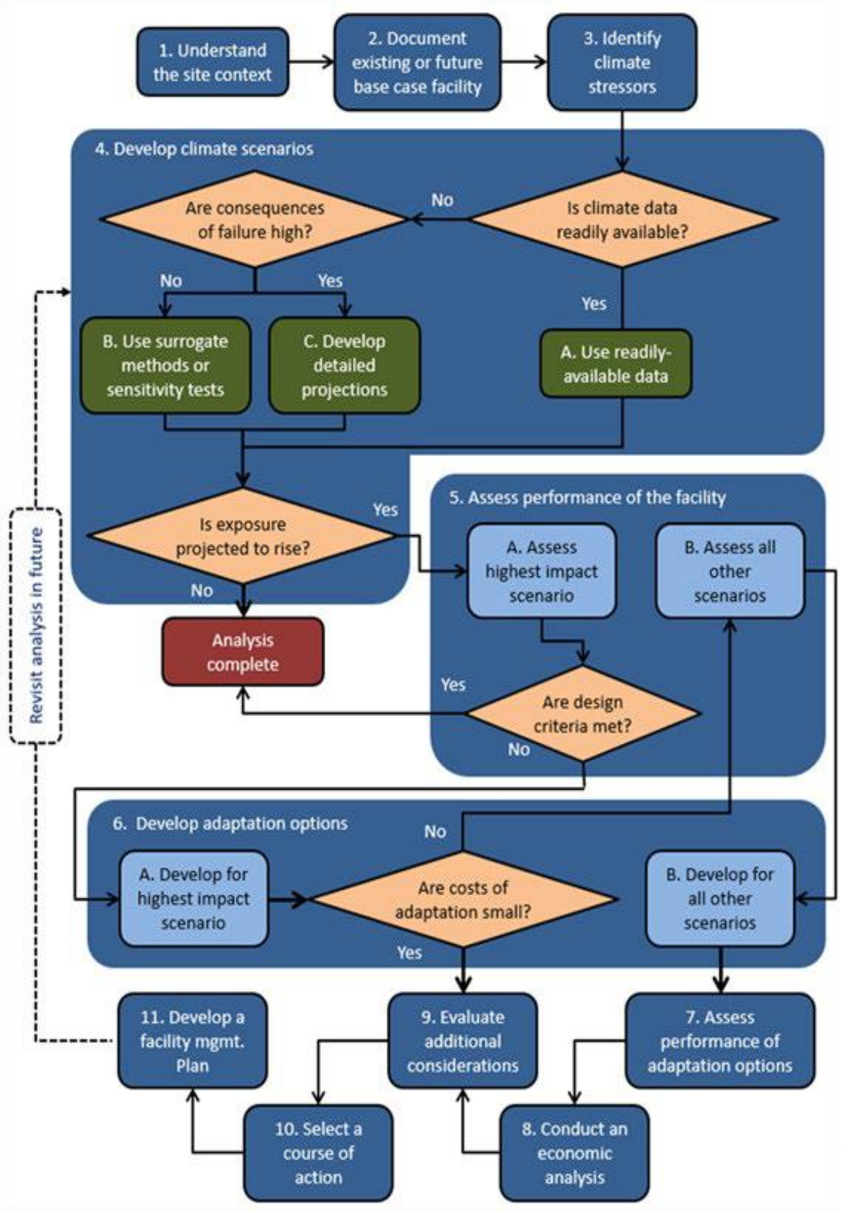
Source: FHWA.

(FHWA 2019)

3. Plan and Design Pavements to Meet Future Conditions:

- Use the adaptation decisionmaking assessment process (ADAP).
- Use a risk-based approach for planners, designers, or engineers.
- Tailor to each State.
- Aid decisionmakers in determining which project alternative is best (lifecycle costs, resilience, and regulatory and political settings) (FHWA 2021b).

Decision Tree of the ADAP Steps



Source: FHWA.
(FHWA 2016a)

Possible Solutions for Pavement Vulnerabilities

Climate Change Stressors	Strategies
More Extreme Rainfall	Apply high-friction surface treatments. Use porous pavements or open-graded friction courses.
Higher Average Precipitation	Reduce moisture susceptibility of unbound base/subgrade materials through stabilization. Ensure asphalt mixtures' resistance to moisture susceptibility.
Wetter Winters and Drier Summers	Incorporate soil modification/stabilization into design. Use stiffer/improved pavement designs that are less susceptible to changes in subgrade properties. Ensure concrete freeze-thaw resistance. Ensure concrete in joint design remains below critical saturation.
Low Summer Humidity	Add asphalt binder antiaging additives. Pavement preservation to address binder aging. Reduce drying shrinkage of concrete mixes by decreasing paste volume. Consider concrete drying shrinkage in design by reducing slab length.
Higher Average Temperature	Raise asphalt binder grade or consider polymer modified binders. Exercise greater consideration of concrete coefficient of thermal expansion and drying shrinkage. Incorporate design elements to reduce damage from thermal effects in concrete pavements, including shorter joint spacing, thicker slabs, less rigid support, and enhanced load transfer.
Higher Extreme Maximum Temperature	Consider polymer-modified binders. Use shorter joint spacing in concrete designs. Keep joints clean and, in extreme cases, install expansion joints in existing pavements.
More Freeze-Thaw Events in Some Locations	Increase consideration of the thermal fatigue characteristics of asphalt binder.

FHWA Resilience

Ongoing Efforts

U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center

Assessing Flooded Pavements Project

- Project objectives:
  - Develop methods to assess flooded pavements.
  - Assess the capacity to carry traffic during/after flooding.
  - Evaluate emergency or heavy equipment.
  - Evaluate normal traffic.
  - Determine the tradeoff between the user costs of road closure (and detours) versus the costs of increased road damage.
  - Develop a decision support tool.
- Project deliverables: A report is in publication (FHWA forthcoming a).

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National Oceanic and Atmospheric Administration Project: Effects of Sea Level Rise

- Joint project with the National Centers for Coastal Ocean Science.
- Project goal details: Facilitate informed adaptation planning and coastal management decisions through a multidisciplinary research program that results in integrated models and tools of dynamic physical and biological processes capable of evaluating vulnerability and resilience under multiple SLR, inundation, and management scenarios.

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NOAA Project (Continued)

Two focus areas:

- Coastal resilience.
- Surface transportation resilience:
  - Quantify the vulnerability of surface transportation systems to SLR and inundation.
  - Quantify the social, economic, and/or ecological benefits.
  - Predict the effects of SLR and inundation on surface transportation infrastructure under varying risk mitigation and management strategies.

NOAA Project (Continued)

- Surface Transportation, Sea Level Rise, and Coastal Storms: A Sustainable Path to Increased Resilience
  - Project principal investigator (PI): Ben Bowers, Ph.D., P.E.
  - Collaborating institutions include Auburn University, University of Wisconsin-Madison, and University of South Alabama.
- Coastal Communities' Pavement Resilience to Sea Level Rise Using Natural and Nature-Based Features
  - Project PI: Jo Sias, Ph.D., P.E.
  - Collaborating institutions include University of New Hampshire, University of South Alabama, and South Coast Engineers.

New Project: Impacts of Wildfires on Pavements

- Project objectives:
  - Determine the state of knowledge of wildfire impacts on pavements.
  - Define direct and indirect impacts.
  - Identify research gaps and needs.
- Project deliverables:
  - Determine the state of knowledge.
  - Identify how State DOTs deal with this issue:
    - Conduct detailed interviews.
    - Gather information on their experiences, observations, and challenges.

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New Projects/Efforts

- Holistic Framework for Project-Level Resilient Pavement Adaptation and Engineering Design—Future climate projection incorporation for resilient mechanistic-empirical pavement design.
- Dissemination of Available Knowledge on Pavement Resilience—A series of technical webinars, workshops, and a TechBrief.
- Impact of Environmental Factors on Pavement Infrastructure—Different datasets will be used for the development of deterioration models.

Resilient Pavements Roadmap

- What are the current gaps and future needs?
  - Pavement resilience peer exchange.
  - Highway resilience to wildfire events.
- What education resources are available to incorporate more resilient practices?
  - Pavement resilience technical guidelines (FHWA forthcoming b).
  - Pavement resilience website: In progress.

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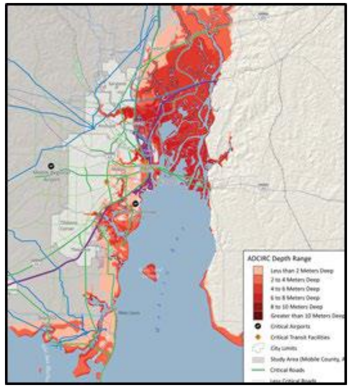
National Highway Institute (NHI) Course:
Addressing Resilience in Highway Project Development and Preliminary Design (2022)

Four 1-h web-based prerequisite courses and one 2.5-d instructor-led course (NHI 2022):

- **Content:**
  - Addressing resilience in engineering decisionmaking (pavements and geohazards, inland flooding, coastal hydraulics).
  - Accessing and using climate projections.
  - Integrating resilience into project development.
- **Audience:**
  Engineering, design, project development/environmental staff, and others.
- **Source material:**
  - *Synthesis of Approaches for Addressing Resilience in Project Development* (FHWA 2015).
  - Project assessments.
  - Hydraulic Engineering Circulars 17 and 25 (Kilgore et al. 2016; Douglass and Webb 2020).

FHWA Resilience Resources

Gulf Coast 2 Study



(FHWA 2019)

Resilience Pilots with State DOTs and MPOs

(FHWA 2021c) MPOs = metropolitan planning organizations.

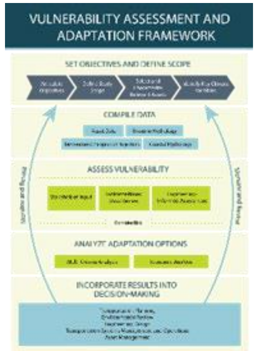
Hurricane Sandy Project

(FHWA 2017c)

Engineering Assessments

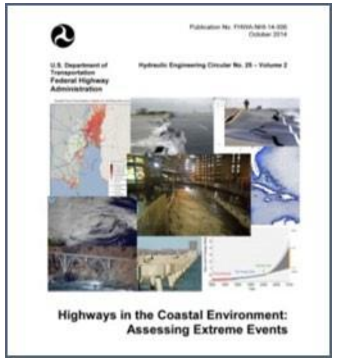
(FHWA 2017d)

Vulnerability and Adaptation Framework



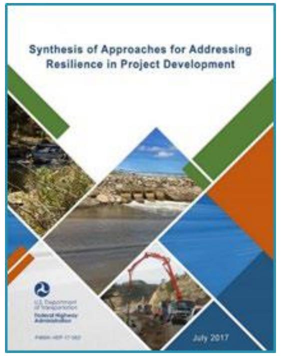
(FHWA 2019)

Engineering Guidance (HEC-25 & 17)



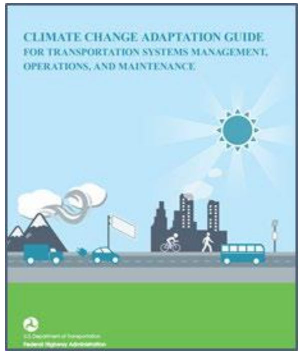
(FHWA 2014a)

Project Development



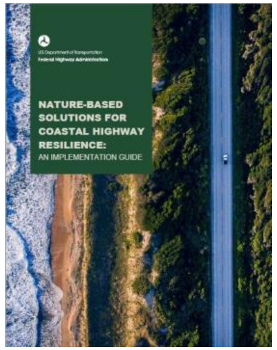
(FHWA 2015)

Operations and Maintenance



(FHWA 2017a)

Nature-Based Solutions



(Buckingham and Torossian 2021)

All photos source: FHWA.

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Contact

Amir Golalipour, Ph.D., P.E.

amir.golalipour@dot.gov

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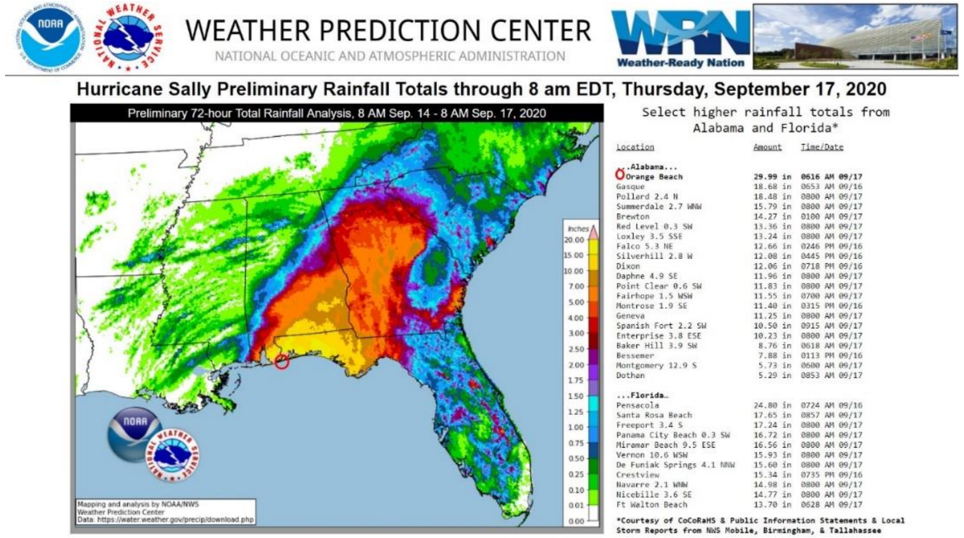
Withstanding Climate Change

Resilient and Flexible Pavement

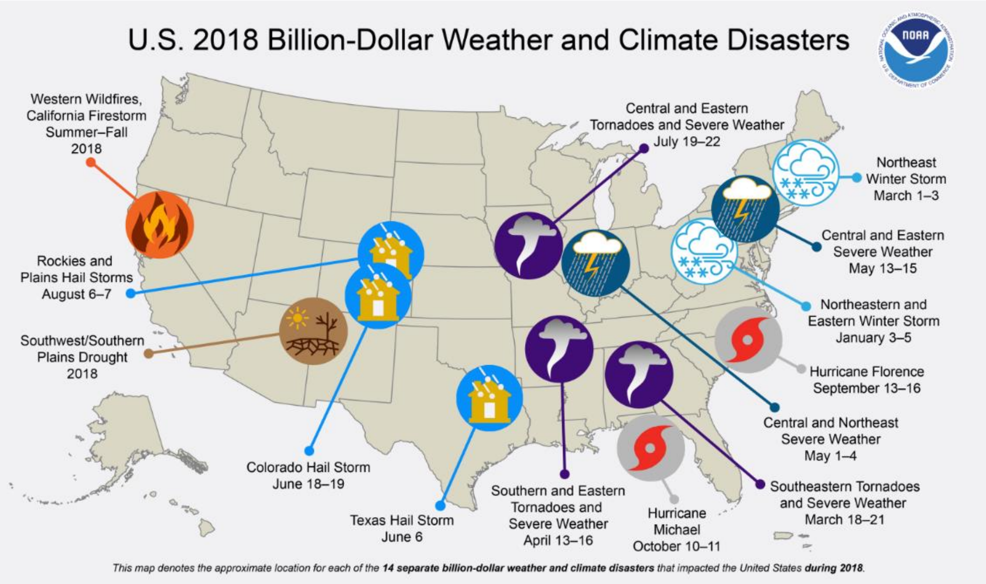
Benjamin F. Bowers, PhD, PE
Assistant Professor
Auburn University

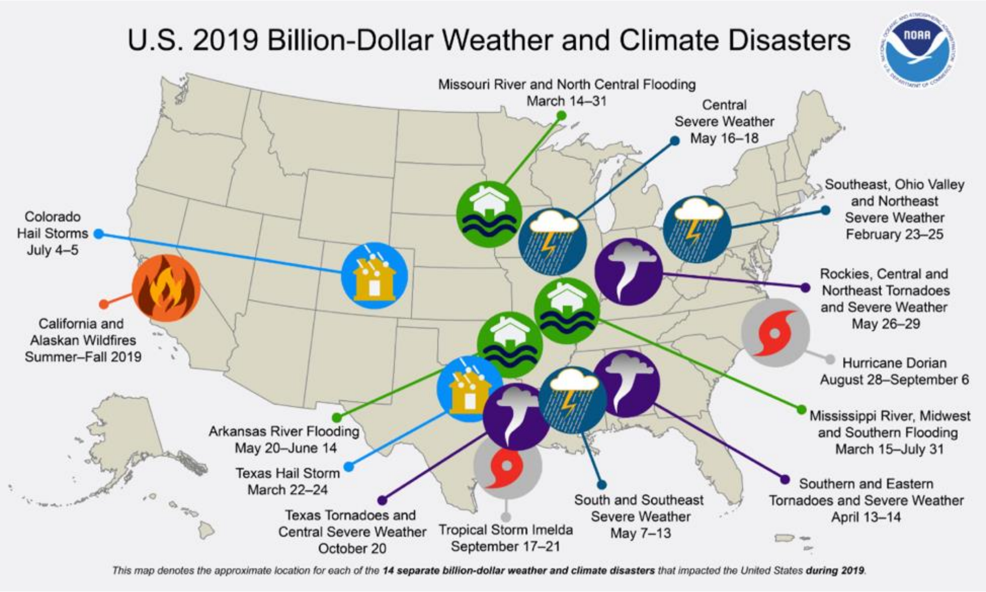
The importance of what we’re talking about today…

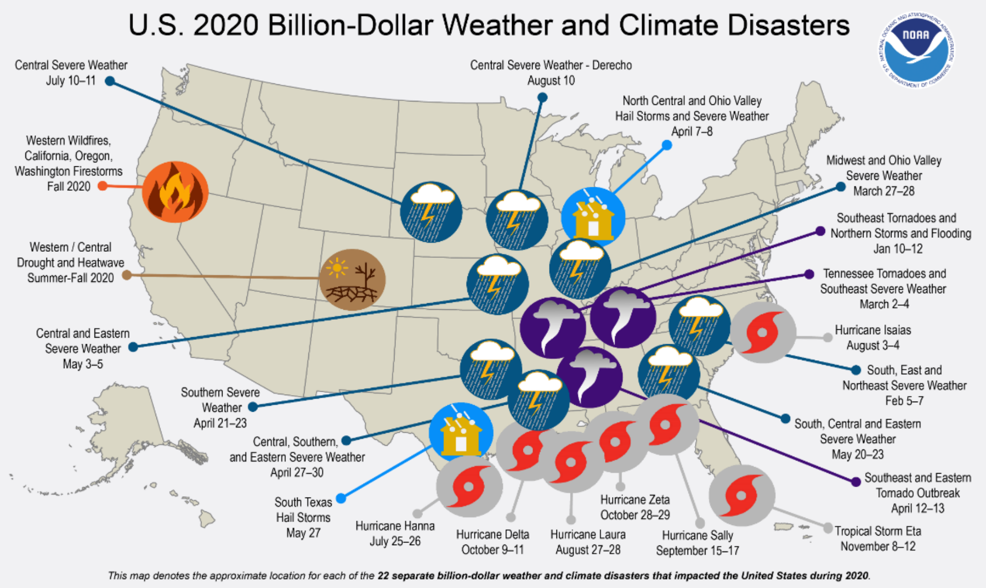


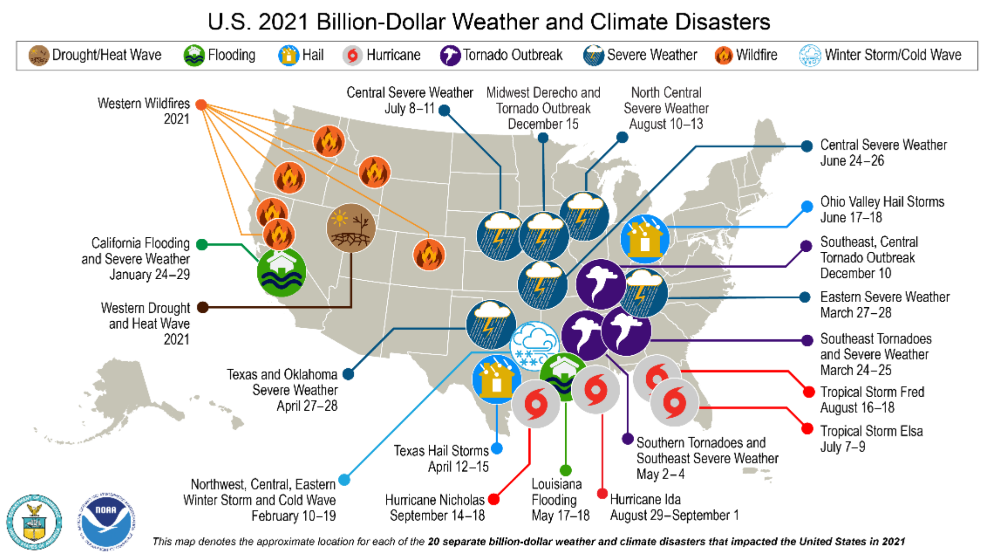
I-40 - https://www.newsobserver.com/news/weather-news/article234964002.html | Hurricane Michael - https://www.cnn.com/2018/10/09/weather/hurricane-michael-stats-superlatives-wxc-trnd/index.html | Bridge - Dr. Jose Vasconcelos, Auburn University
Hurricane Sally – NOAA | Landslide – Dr. Jack Montgomery, Auburn University

The need for resilience



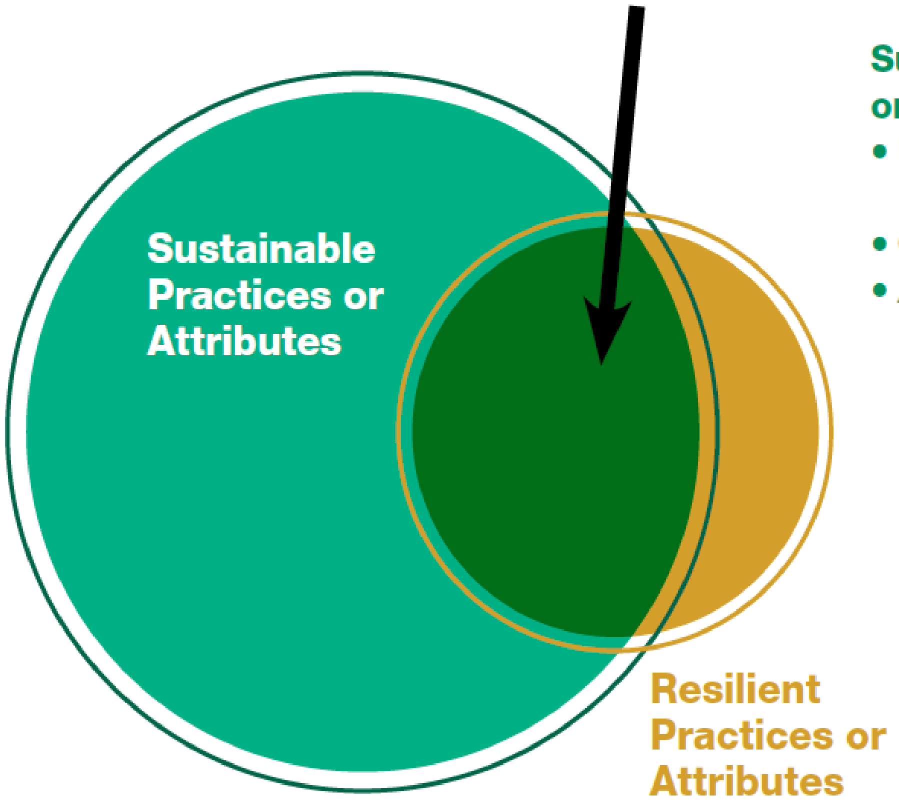






Resilience is *not* sustainability

Sustainable + Resilient Practices or Attributes



Sustainable Practices or Attributes
- Use of recycled materials
- Cold Recycled Asphalt
- Asphalt mix and plant optimization

Sustainable + Resilient Practices or Attributes
- Warm Mix Asphalt (low emissions + increase in haul distance)
- Porous pavement systems (stormwater management + nuisance flooding)
- Perpetual Pavement Design
- Deep reconstruction of pavement (increase deep layer moduli)
- Rapid construction
- Ability to adjust pavement design to climate / climatic events to extend pavement life

Resilient Practices or Attributes That Are Not Sustainable
- Use of novel materials with unknown environmental or safety risks
- Use of climate adaptable materials when the social and environmental benefits do not outweigh the costs (e.g., use of polymer modified binders for low volume roads)
- Over-designing for low-risk catastrophic events

Figure 1. Venn Diagram of Sustainable, Resilient, and Resilient + Sustainable Practices and Attributes for Asphalt Pavements

Bowers and Gu (2021) “Resilient Asphalt Pavements: Industry Solutions for the Resilience Goal”, NAPA SIP 105

However…
While resilient solutions may or may not be sustainable… a resilient system contributes to sustainability…

[adaptation]

- So we need to adapt to changing conditions
  - Temperature swings [record highs/lows and rapid changes]
  - Wildfires
  - Hurricanes
  - Major non-tropical precipitation events
  - Tornados
  - Sea level rise
  - Drought

Four adaptation "philosophies"

1 Hardening

WHAT IS IT? This is when we strengthen, rebuild, or protect our pavement to withstand any probable event the pavement might subjected to, eliminating or nearly eliminating disruption potential.

2 Adaptation through modification

WHAT IS IT? This is when we make adjustments to our pavement as it is, perhaps not completely hardening the system, but giving it a higher probability of surviving the disruption.

3 Accepting and planning

WHAT IS IT? This is when we accept that we will have a complete failure, account for the risk, and plan for funds to be made available to address the problem.

4 Abandonment

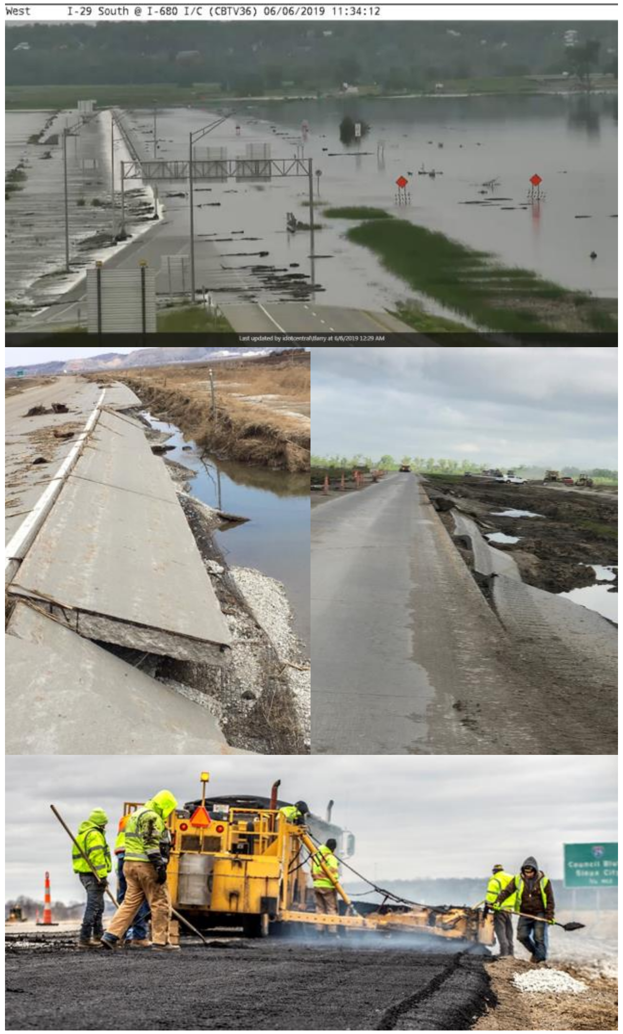
WHAT IS IT? This is when we take an honest look at the situation and decide that it makes more financial sense to completely abandon the route.

...so, what do we do?

Hardening and *Adaptation Through Modification*

- 2011 rigid concrete section faired well in first 2019 Iowa floods, so alternate design/build reflected that section…
  - Flexible section designed to be structural equivalent
  - Used PerRoad perpetual pavement design software to determine asphalt thickness

Hardening



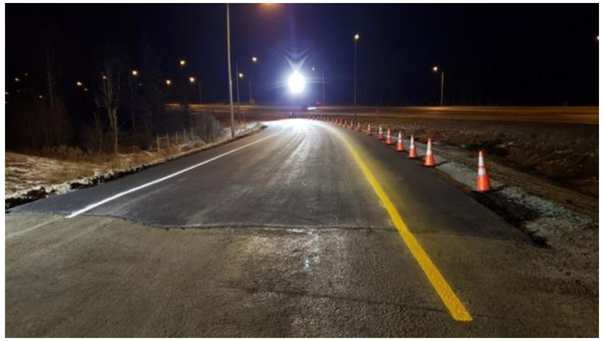
Adaptation Through Modification

- To prevent future issues, contractor paved an extra shoulder width
- Asphalt wedge also placed over erosion mat to help ensure it stays in place
- Underdrains installed at edge of mainline

  [note: Not at edge of shoulder]

Credit: Bill Rosener, Formerly Asphalt Pavement Association of Iowa

Accepting and Planning *or* Abandonment



There are some disruptions you cannot plan for… so how will you respond?

Accepting and Planning

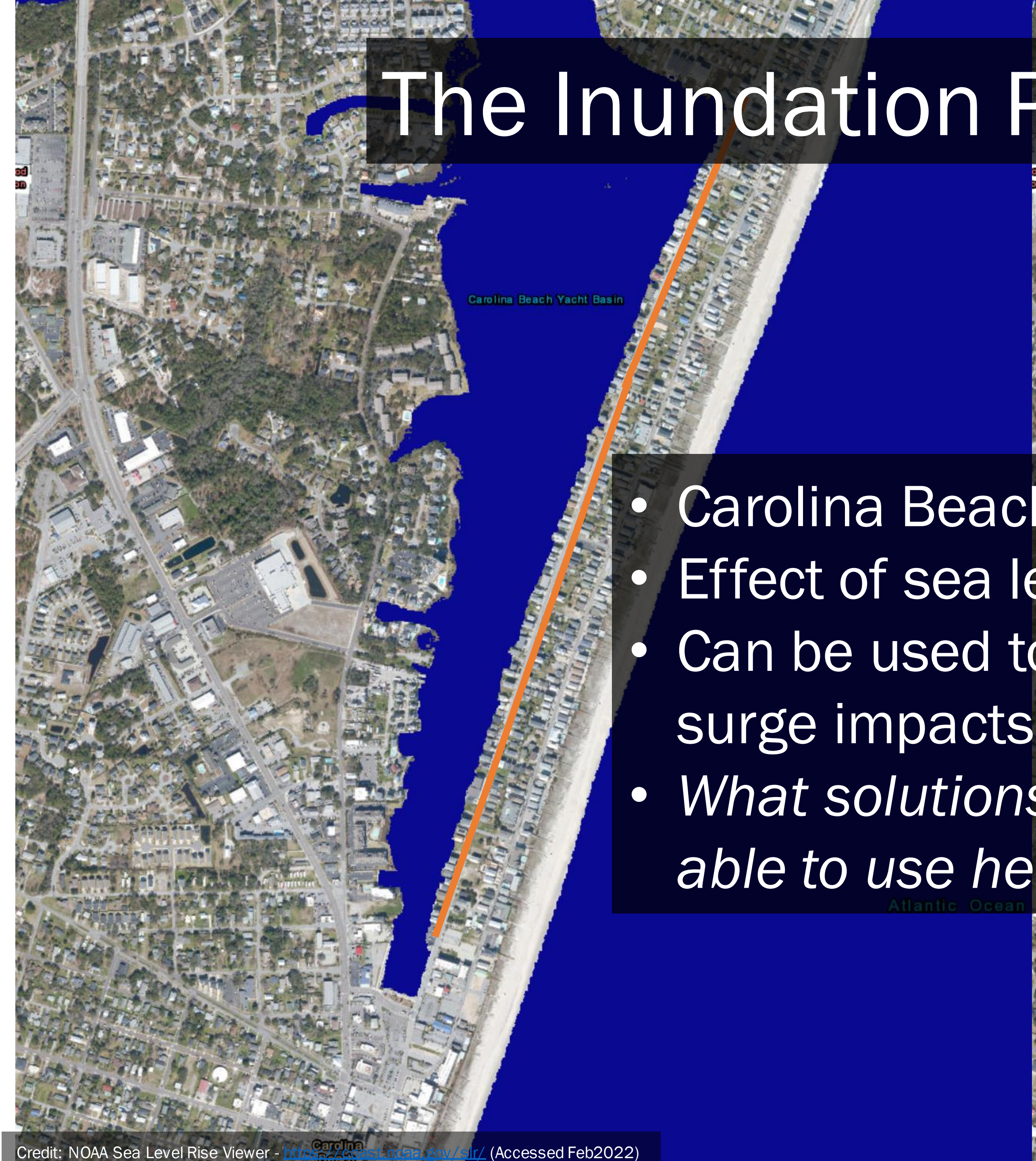
Abandonment

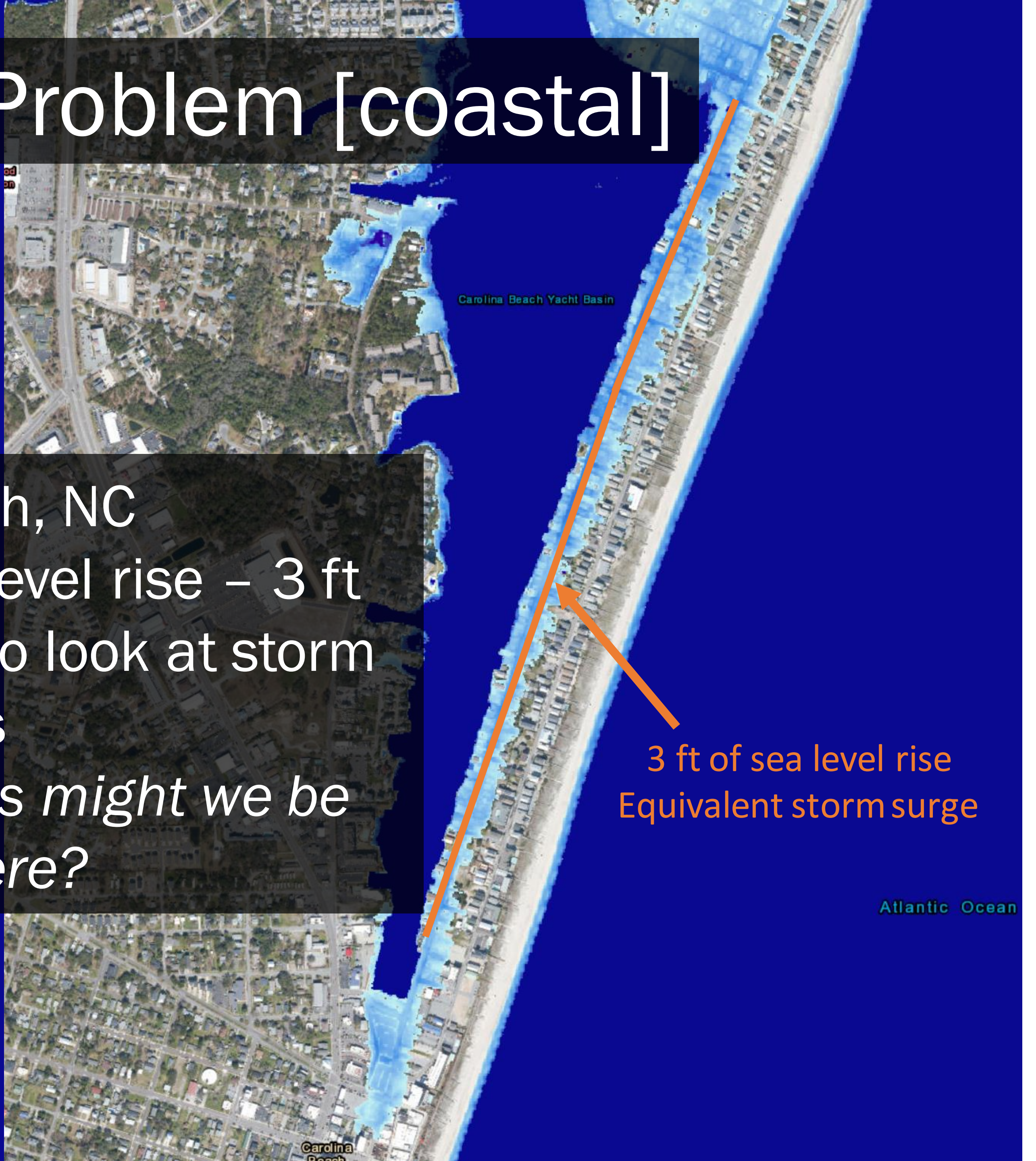
Sometimes abandonment is the only option…

Credit: Amanda Gilliland, The Transtec Group | Mahear Abou Eid, Alaska DOT | Knik Construction | US Climate Resilience Toolkit

The Inundation Problem [coastal]

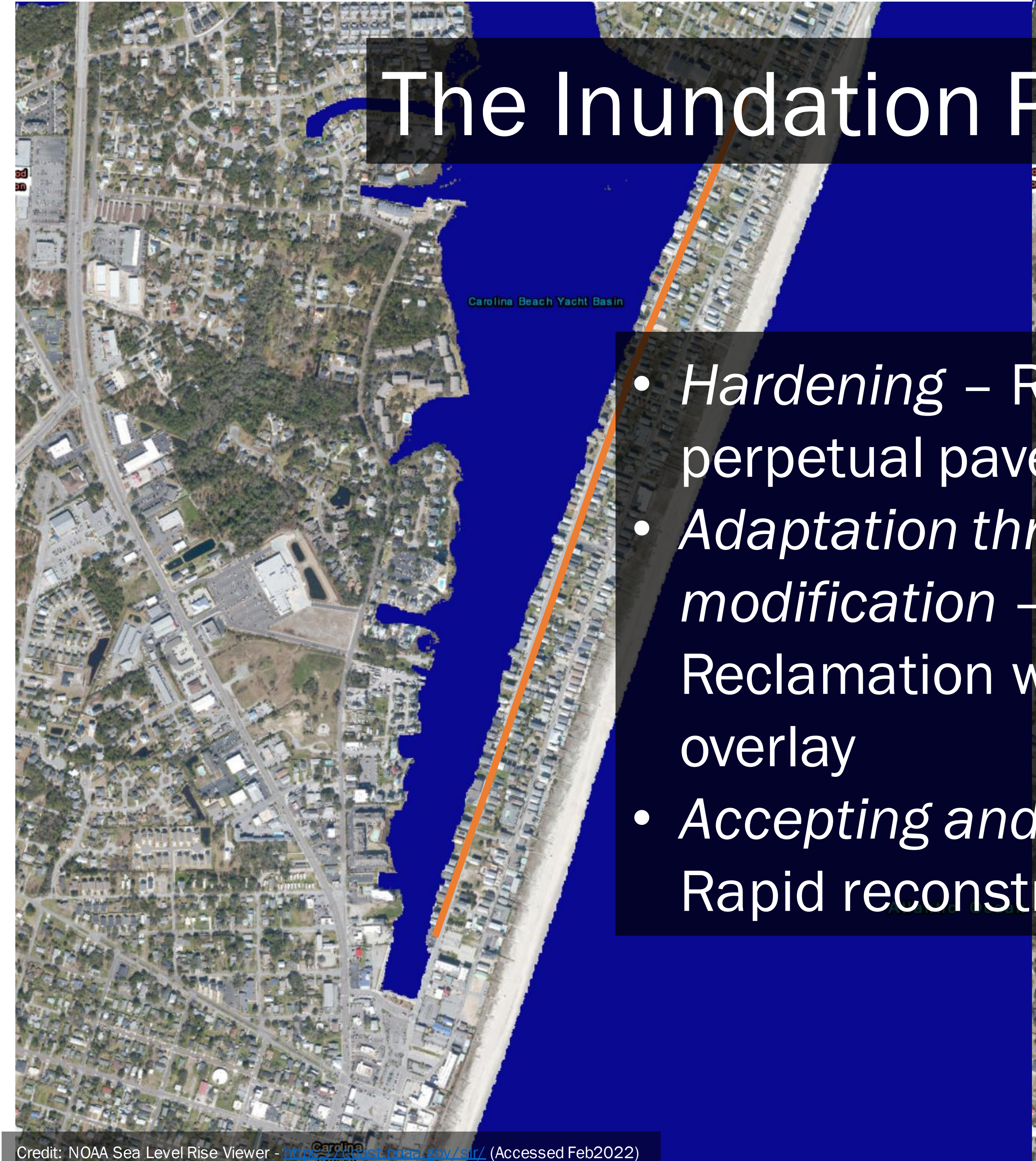
- Carolina Beach, NC
- Effect of sea level rise – 3 ft
- Can be used to look at storm surge impacts
- *What solutions might we be able to use here?*

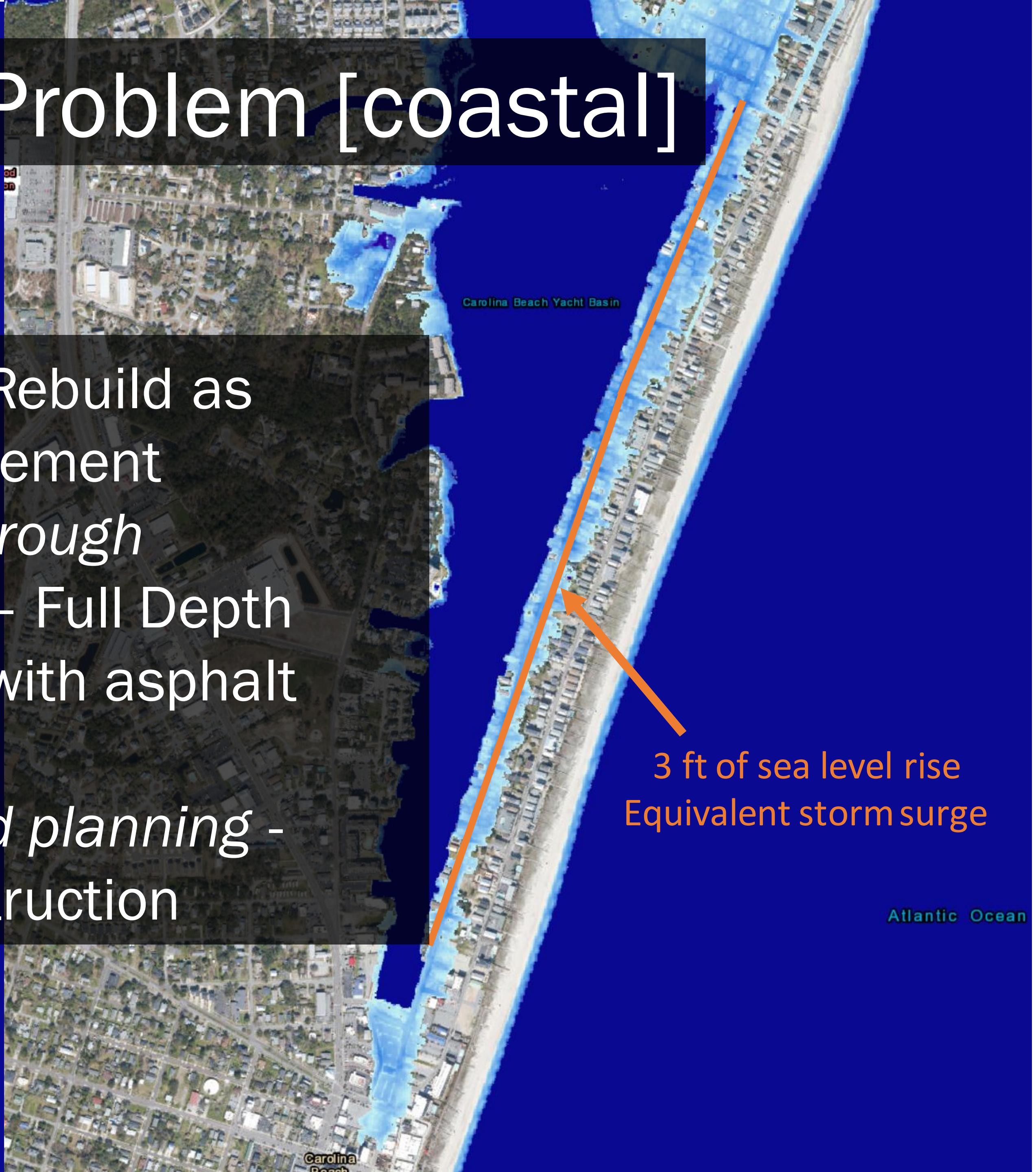




Credit: NOAA Sea Level Rise Viewer - https://coast.noaa.gov/slr/ (Accessed Feb2022)

The Inundation Problem [coastal]

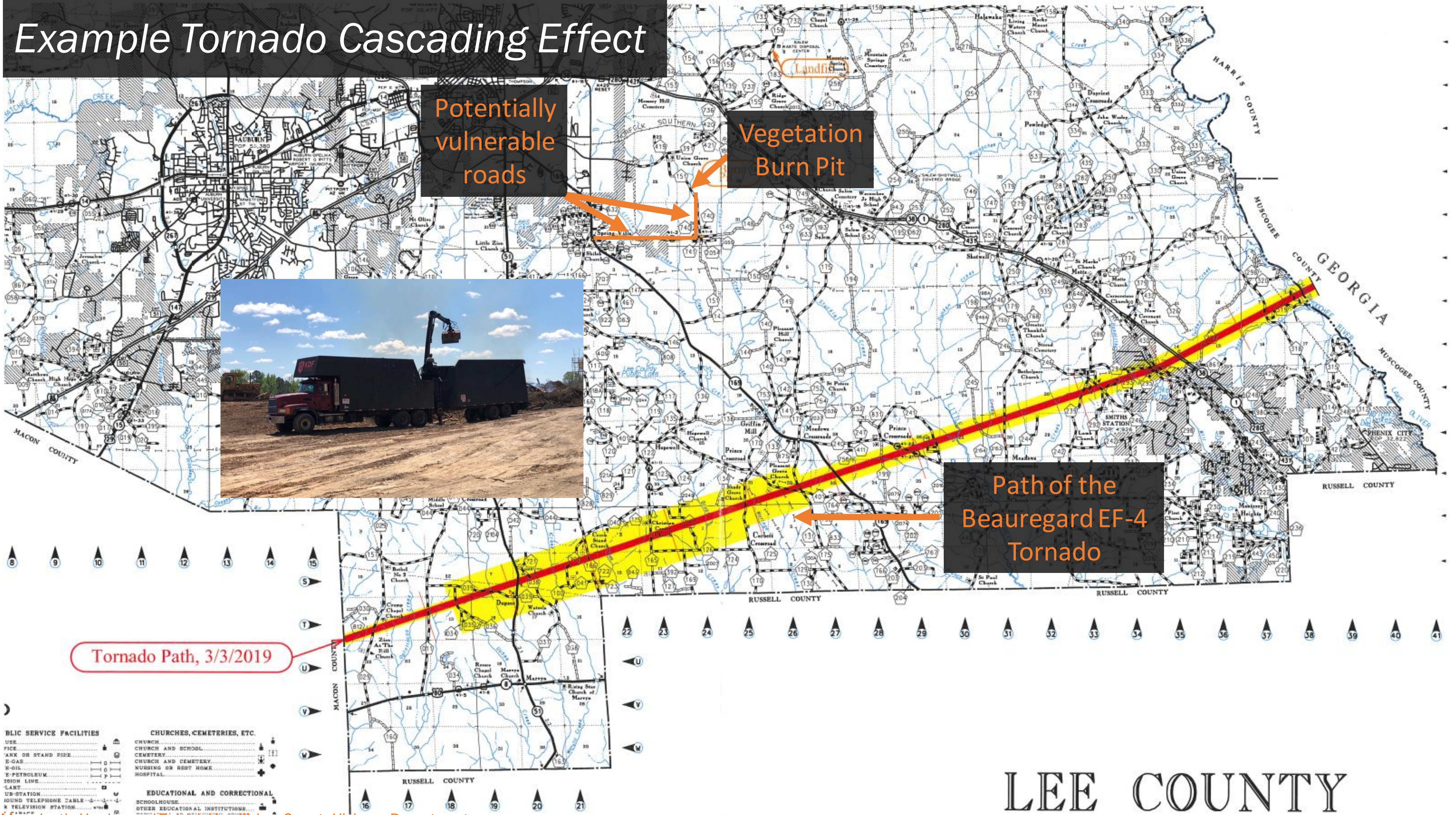




- *Hardening* – Rebuild as perpetual pavement
- *Adaptation through modification* – Full Depth Reclamation with asphalt overlay
- *Accepting and planning* - Rapid reconstruction

Credit: NOAA Sea Level Rise Viewer - https://coast.noaa.gov/slr/ (Accessed Feb2022)

Example Tornado Cascading Effect



Map: Justin Hardee and Patrick Harvill, Lee County Highway Department

Surface Transportation, Sea Level Rise, and Coastal Storms: A Sustainable Path to Increased Resilience

NOAA Effects of Sea Level Rise Program

AUBURN UNIVERSITY

Dr. Benjamin Bowers, PE (PI)
Dr. Jose Vasconcelos
Dr. J. Brian Anderson, PE
Dr. Frances O'Donnell
Rob Holmes
Dr. Wendiam Sawadgo

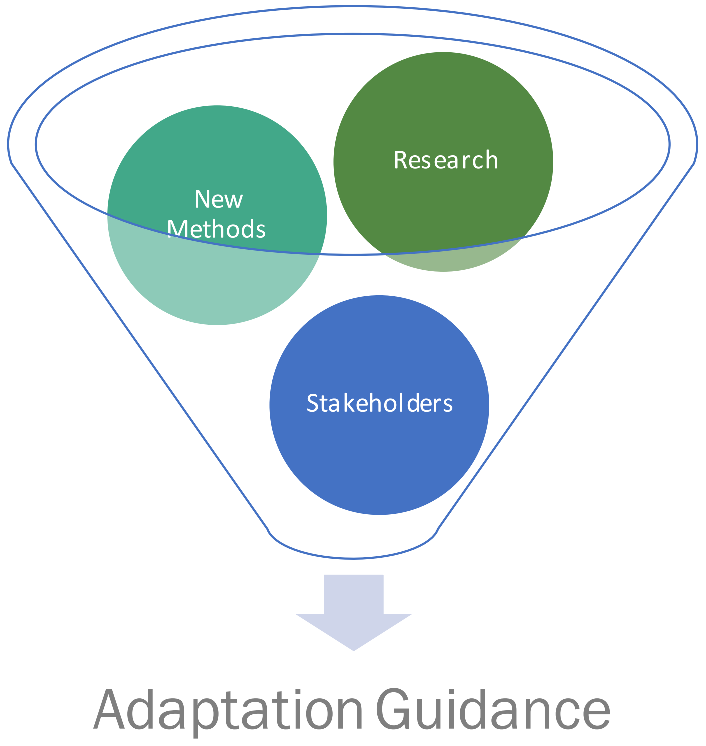
Dr. Bret Webb, PE

Dr. Daniel Wright, PE

Research Question: *How do we make our transportation infrastructure more resilient?*

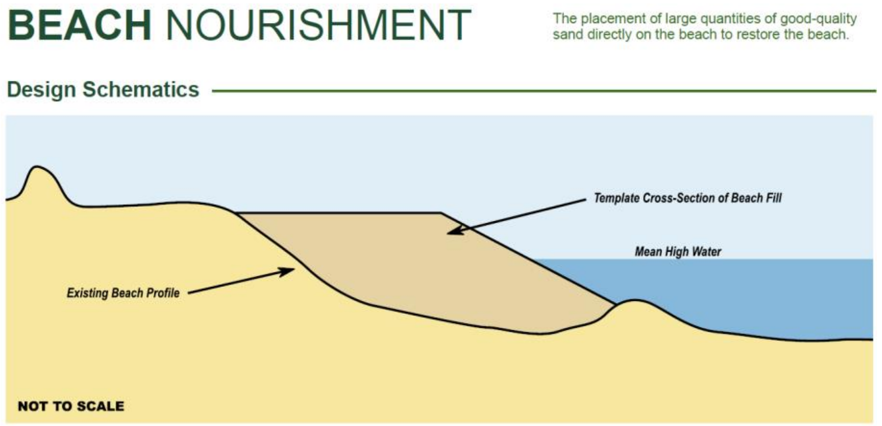
Summary Project Objectives

- **Quantify** vulnerability of coastal communities, infrastructure, and ecosystems to Sea Level Rise and disruptions;
- **Understand** and quantify social, economic, and/or ecological benefits of natural and nature-based features and gray infrastructure;
- **Predict** the effects of SLR and inundation on ecosystems, communities, and infrastructure under varying risk management strategies



What is a “natural or nature-based feature”?

- “Use natural materials and processes to reduce erosion, wave damage, and flood risks”[1]
- Examples include conservation, restoration, or construction of:
  - Beaches
  - Dunes
  - Marsh
  - Mangrove
  - Maritime forests
  - Reefs



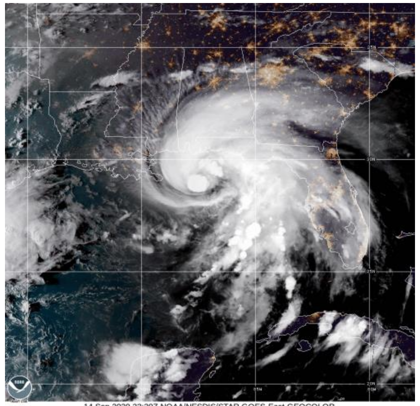
[1]Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide, Webb et al., FHWA-HEP-19-042 | Living shoreline credit: NOAA https://www.habitatblueprint.noaa.gov/living-shorelines/

Research Site: On and along AL-180, Fort Morgan Road

Our approach: Multi-disciplinary and holistic

Stressor

- Sea Level Rise
- Groundwater
- Coastal Storms

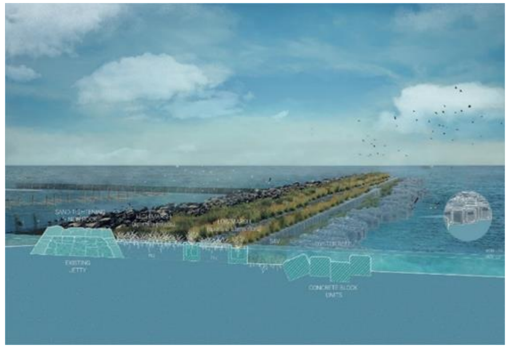


Infrastructure

- Asphalt Pavements
- Coastal Roads
- Multiple Exposures

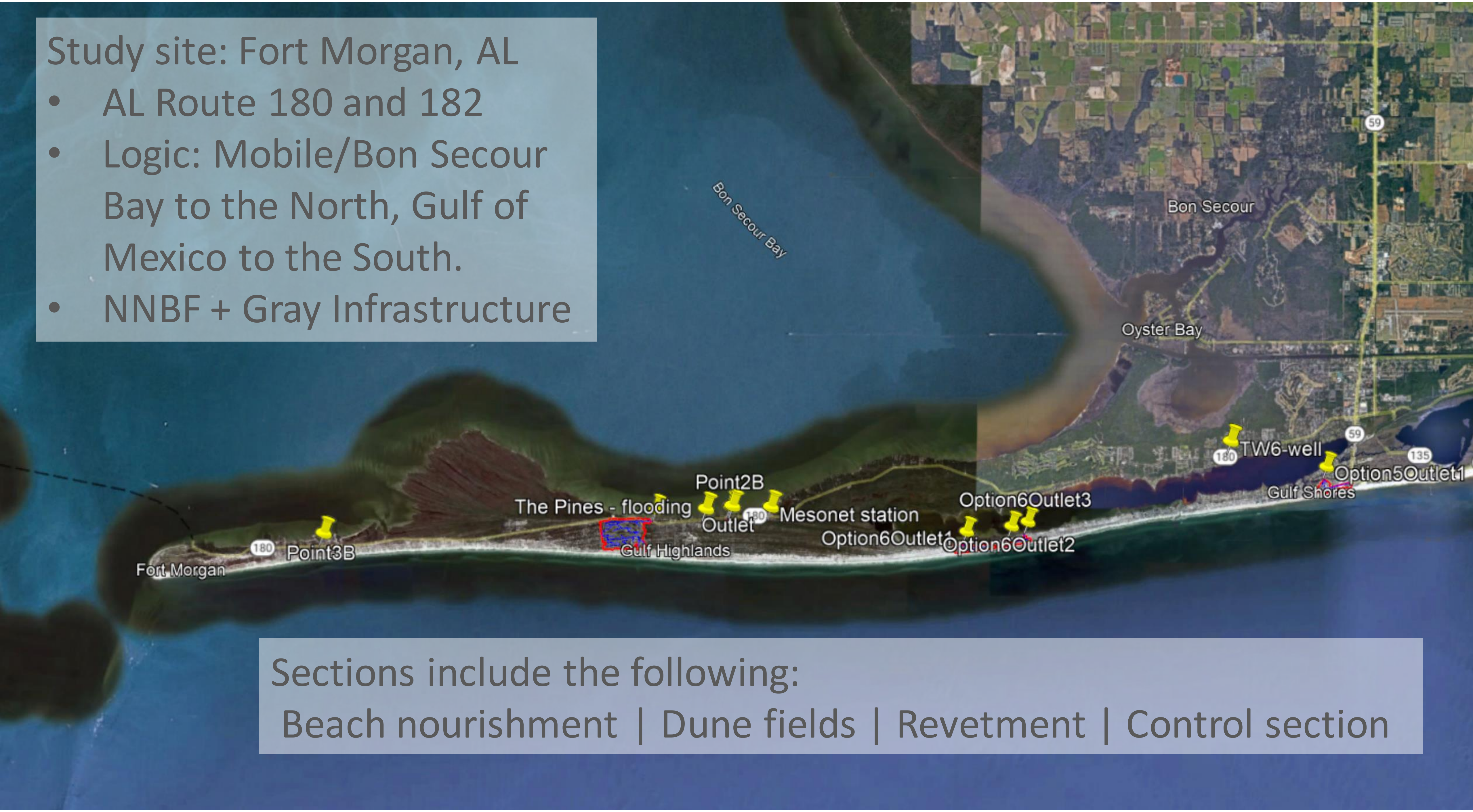
Socioecological

- Natural and Nature Based Feature Alternatives
- Costs & Benefits
- Resilient Systems



Study site: Fort Morgan, AL

- AL Route 180 and 182
- Logic: Mobile/Bon Secour Bay to the North, Gulf of Mexico to the South.
- NNBF + Gray Infrastructure



Sections include the following:

Beach nourishment | Dune fields | Revetment | Control section

Outcomes, milestones, and partners

- **Goal:** *Science-based, practically grounded, implementable research outcomes and guidance for decision makers to make our coastal infrastructure more resilient.*
- This will save tax dollars, enhance decision making.
- **Partners:**

Alabama DOT | FHWA | US Army Corps of Engineers | Local Stakeholders

Questions?

Benjamin F. Bowers, PhD, PE
Assistant Professor | Auburn University
🖂 bfbowers@auburn.edu | 💻 aub.ie/bfbowers

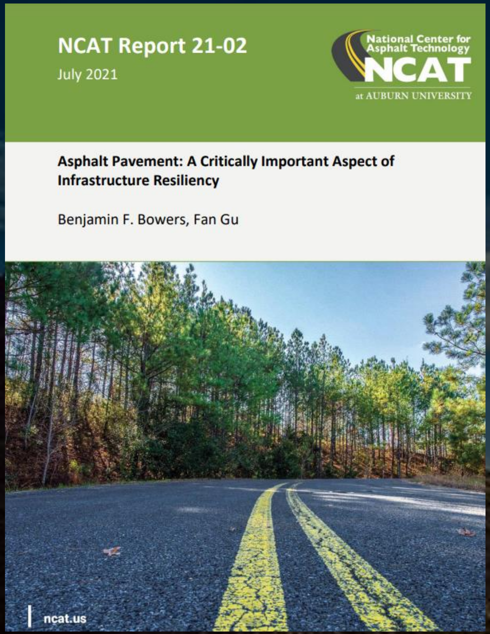
RESILIENT SOLUTIONS FOR ASPHALT PAVEMENTS

JOSEPH SHACAT

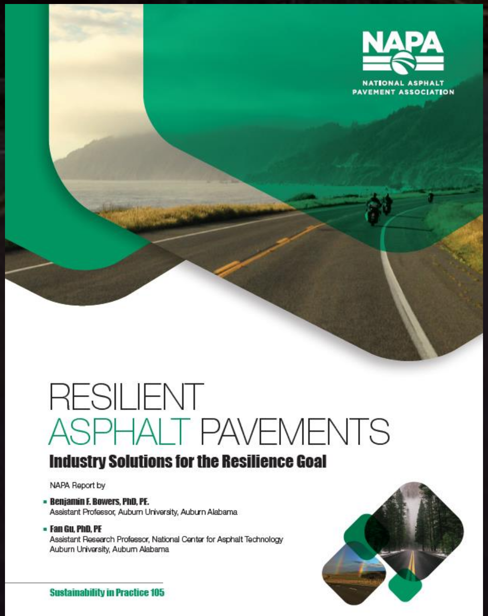
STRATEGIES TO IMPROVE PAVEMENT RESILIENCE

NAPA

NATIONAL ASPHALT PAVEMENT ASSOCIATION



https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep21-02.pdf

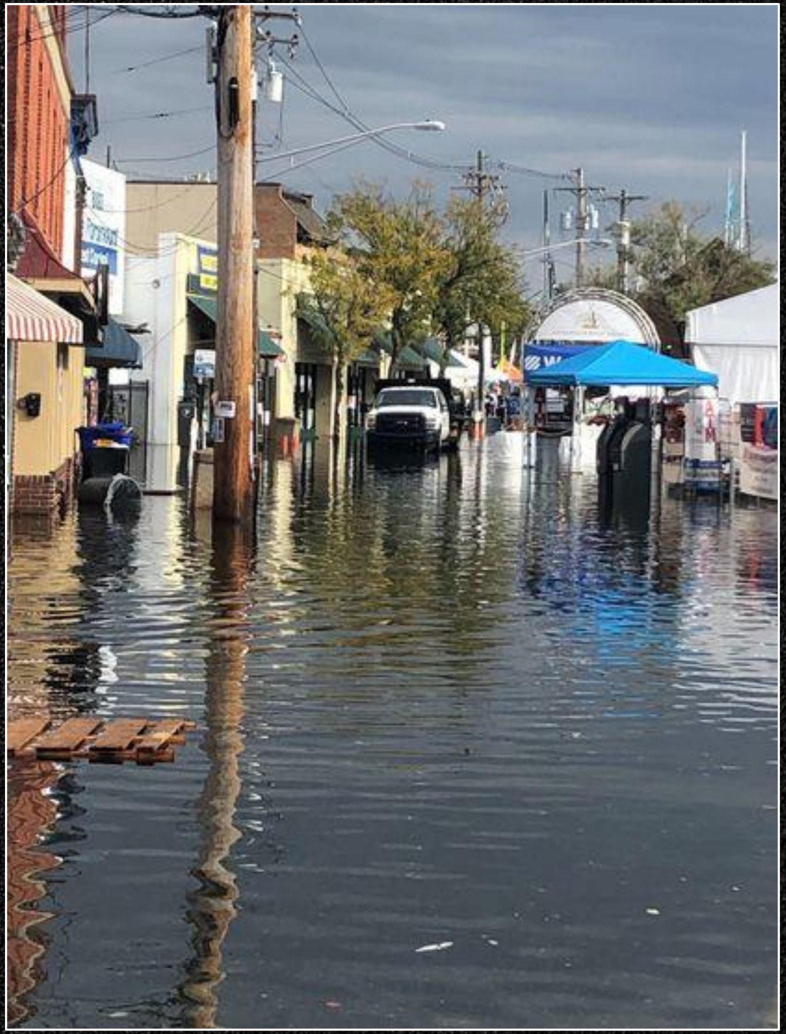


https://member.asphaltpavement.org/Shop/Product-Catalog/Product-Details?productid={6399F00E-2392-EB11-B1AC-000D3A9A6645}

2019 Industry Workshop

Resilience Tools for Asphalt Pavements Case Studies

- Hardening
- Adapting
- Asphalt as a “first responder”



https://www.capitalgazette.com/maryland/annapolis/ac-cn-city-dock-flooding-20191012-20191012-xkx4c2gozvaqfpwmoo7hmmlfii-story.html

Hardening Asphalt Pavements

Perpetual Pavement Design

- Thick pavement design resists moisture damage
- Reduces life cycle cost
- Reduces life cycle GHG emissions

U.S. Department of Transportation
Federal Highway Administration

SUSTAINABLE PAVEMENTS PROGRAM

IMPROVED ASPHALT PAVEMENT SUSTAINABILITY THROUGH PERPETUAL PAVEMENT DESIGN

FHWA-HIF-19-080

The Iowa Department of Transportation constructed an innovative asphalt pavement project featuring perpetual pavement long-life design concepts in 2016. The award-winning project, located on a 3.5-mile stretch of State Highway 100 near Cedar Rapids, provided reduced life-cycle costs and reduced environmental impacts as compared to conventional design approaches.

WHAT WAS THE MOTIVATION?

The Iowa Department of Transportation (Iowa DOT) is continuously looking for ways to improve the performance of its highway network while also reducing costs. The short service lives associated with many conventional asphalt pavements, along with their recurring maintenance and rehabilitation requirements and associated traffic disruptions, have led the Department to evaluate perpetual asphalt pavement designs offering extended service lives, lower life-cycle costs, and increased sustainability. With the perpetual pavement, the Iowa DOT expects to be able to limit future rehabilitation activities to the surface course while preserving the base and foundation. This will minimize the impacts to traffic by limiting long-term work zones and costly reconstruction alternatives in the future.

WHAT WAS DONE?

In 2016, the Iowa DOT constructed a perpetual pavement on a stretch of Iowa State Highway 100 (Iowa 100), a four-lane divided highway that loops around Cedar Rapids from Edgewood Road on the north and westward to Covington Road (see figures 1a and 1b). Perpetual pavements make use of a fatigue-resistant lower asphalt layer coupled with rut-resistant surface layers to produce a long-lasting pavement that can last for decades with only minimal maintenance to the surface layer (NAPA 2018). In the proper application, the enhanced performance and durability associated with perpetual pavements can result in significant economic (lower life-cycle costs), environmental (less material usage/production), and social (fewer lane closures) benefits.

The portion of the Iowa 100 paving project featured in this case study was completed in 2016 and included a 12.5-inch asphalt pavement over a 15.5-inch modified subbase (see figure 2 [Schram 2018]), a design that is expected to carry the traffic on this stretch of highway for over 60 years with only minor periodic milling and resurfacing. The initial cost of the project was $15.1 million (including safety features and project management), with the pavement construction accounting for approximately $6.5 million. The $15.1 million cost was about $5 million less than the original engineer's estimate.

1

JANUARY 2020
FHWA-HIF-19-080

https://www.fhwa.dot.gov/pavement/sustainability/case_studies/hif19080.pdf

Safety Improvements Boost Resilience to Flooding

- Rural highways in Louisiana
- Low-cost RAP mix for shoulders to reduce road departures
- Developed in late 1990s
- Roads with reinforced shoulders withstood 2 hurricanes in 2020

RECYCLED ASPHALT PROVIDES A LOW-COST SOLUTION TO PROTECT ROADS IN LOUISIANA

Fixing a disaster-ravaged road is a challenge that requires anticipation, preparation, and a rapid response. Louisiana inadvertently discovered a process that saved its roads from needing repairs after flooding events from major storms. In the late 1990s, two parishes worked with Prairie Contractors LLC to develop a low-cost solution to reduce serious and fatal accidents on rural roads.

Drivers who edged off these roads often found themselves sliding into a ditch, resulting in significant accidents. Cameron Parish and Calcasieu Parish decided to use a reclaimed asphalt pavement (RAP) mix to expand roadway shoulders and support vehicles from slipping off the shoulder, enabling vehicles to regain traction and safely return to the road.

Portable RAP fractionation unit.

Calcasieu Parish Police Jury using exclusive use of hot-RAP shoulders.

James Winford, Jr., Ph.D., P.E., president of Prairie Contractors, described the mix design as stone with just enough asphalt binder to hold it together. The state used 6-10 inches of the mixture to develop the shoulder. "The parishes adopted the mix as standard use for rural roads," said Winford.

The mix did the job but also delivered unexpected benefits. "In 2020, Louisiana was hit by two hurricanes in a single year," said Winford. "Parish engineers found that the inexpensive RAP shoulder mixture kept the floods from undermining the roads. This saved the state millions of dollars in road repairs."

Asphalt continues to be an excellent choice for maintaining or repairing roads in the wake of natural disasters like flooding and hurricanes. A community's ability to bounce back from a natural disaster is greatly enhanced with asphalt mixtures that adapt to our changing climate and are constructed to withstand these events.

888-468-6499
AsphaltPavement.org

10/2021

https://www.driveasphalt.org/uploads/documents/211005_-_Cameron_and_Calcasieu_Parish_Case_Study.pdf

Modified Binder Helps Permafrost Challenges

- Reconstructed 6 miles of Chena Hot Springs Road in Fairbanks
- Roadway sinks and cracks when permafrost melts
- Existing road had patches up to 12 ft thick!
- Used geogrid and polymer modified binder to reinforce the roadway

MODIFIED ASPHALT MIX REDUCES THERMAL CRACKING

Alaska DOT and contractors are taking adaptive measures to deal with the state's extreme temperatures and permafrost. Alaska's rapidly changing climate is causing problems with permafrost — ground that stays colder than 32°F continuously for at least two years. Permafrost that stays frozen doesn't cause issues. But ice-rich, thaw-unstable permafrost is susceptible to thawing.

In some places, up to 12 feet of old patched asphalt had to be removed.

When roads are built through permafrost-rich areas, the surface layer of the ground is stripped away of permafrost-insulating vegetation. Organic soil is replaced with gravel, exposing the ground to solar radiation and warmer temperatures. When the active layer of permafrost thaws in the summer, dips in the road develop as ice in the underlying subbase melts and settles. This settlement increases as the active layer gets deeper with warmer weather, causing larger dips in the road. "Permafrost makes it hard to do the job of keeping Alaska moving," said Jeff Currey, Materials Engineer with Alaska DOT.

This was the case with Chena Hot Springs Road in Fairbanks. ADOT contracted Exclusive Paving to rehabilitate 6 miles of the road that had not been reconstructed since 1998. Martin Gray, Project Engineer with Exclusive Paving, said the biggest challenge Exclusive encountered was deep asphalt. At bid time, ADOT thought the asphalt thickness might be 2-3 feet deep. However, annual patching by ADOT Maintenance due to permafrost thaw revealed the thickest section of asphalt to be 12 feet.

ADOT has adapted, changing the binder grade specified in its asphalt mixtures to significantly reduce thermal cracking issues caused by extreme low temperatures due to asphalt's flexibility and ability to stretch and recover. Currey said that PG52E-40, in accordance with AASHTO M 332, modified with approximately 3% SBS polymer, was used on the Chena Hot Springs Road project. Exclusive placed 3 in. of asphalt, on top of a 4-in. asphalt base course. To reduce road settlement due to permafrost thawing, Exclusive placed geogrid layers in six locations. Currey said the polymer-modified mixes are performing well.

The vast majority of pavements in Alaska are built with asphalt. Richard Giessel, Statewide Quality Assurance Engineer with ADOT, explained, "A rigid pavement leads to faulting. A flexible pavement is very important in areas where you have differential surface movement from deep frost penetration, which you have just about everywhere in Alaska." Asphalt's attributes are the appropriate resilient solution to Alaska's extreme climate.

Learn more: AsphaltPavement.org/Resilience

888-468-6499
AsphaltPavement.org

04/2022

https://www.driveasphalt.org/uploads/documents/NAPA_Case_Studay_Resilience_-_Adapt_-_Alaska.pdf

Adapting Asphalt Pavements to Changing Conditions

Resilience – Sea Level Rise

- Increasing frequency of sunny day flooding
- Effects are exacerbated during storm events
- Rising groundwater heights can saturate the base and accelerate pavement deterioration

https://statesatrisk.org/maryland

https://www.delmarvanow.com/story/news/local/maryland/2017/11/16/king-high-tides-future-flooding/834301001/

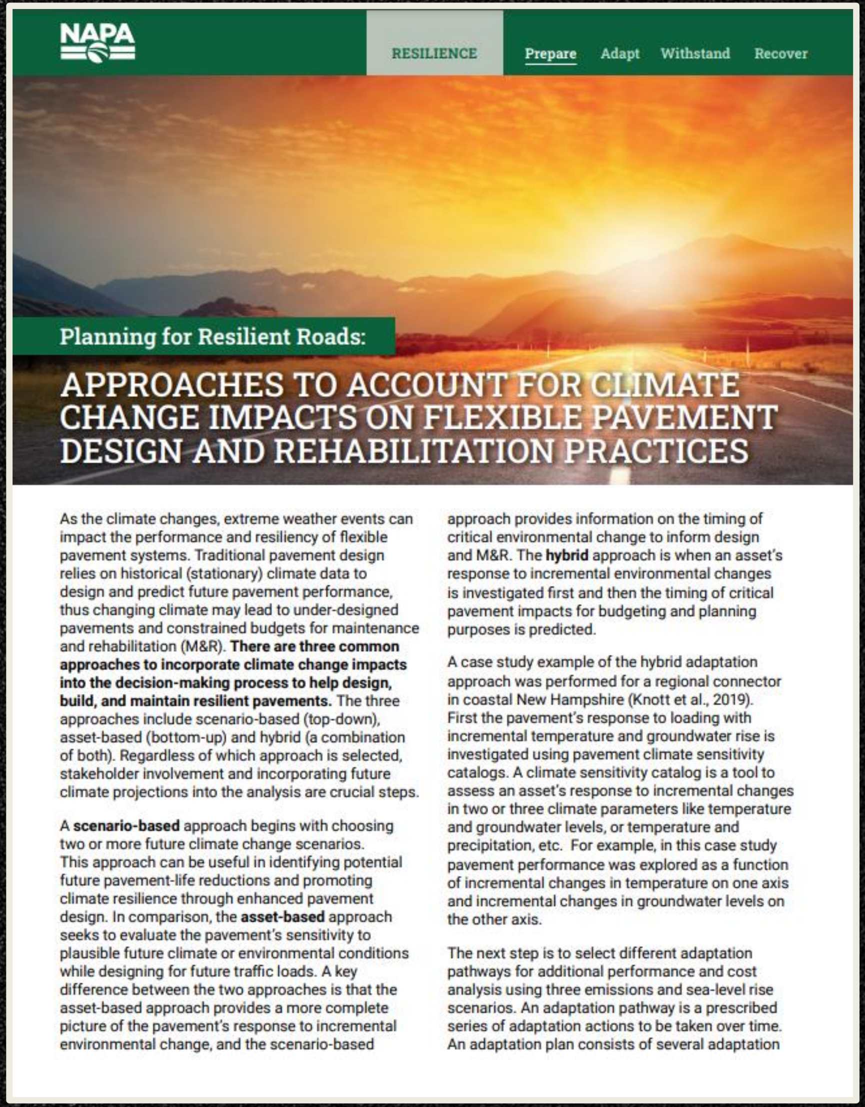
Resilience – Sea Level Rise

- Highway 80, Tybee Island Access Road
- Caused by king tides and shifting currents
- Short term – raise road ~8 inches
- 3,000+ residents
- October 27, 2015
- Long term – raise road ~2 feet

https://www.ajc.com/blog/politics/supermoon-rising-sea-levels-put-tybee-island-access-under-water/kE3PD96bMn0XJDPSHt0JtO/

Resilience – Climate Models

- Use climate models to predict changing environmental conditions
- Evaluate alternatives:
  - Pavement materials
  - Structural designs
  - Long-term maintenance & rehabilitation schedules


NAPA

RESILIENCE Prepare Adapt Withstand Recover

Planning for Resilient Roads:

APPROACHES TO ACCOUNT FOR CLIMATE CHANGE IMPACTS ON FLEXIBLE PAVEMENT DESIGN AND REHABILITATION PRACTICES

As the climate changes, extreme weather events can impact the performance and resiliency of flexible pavement systems. Traditional pavement design relies on historical (stationary) climate data to design and predict future pavement performance, thus changing climate may lead to under-designed pavements and constrained budgets for maintenance and rehabilitation (M&R). **There are three common approaches to incorporate climate change impacts into the decision-making process to help design, build, and maintain resilient pavements.** The three approaches include scenario-based (top-down), asset-based (bottom-up) and hybrid (a combination of both). Regardless of which approach is selected, stakeholder involvement and incorporating future climate projections into the analysis are crucial steps.

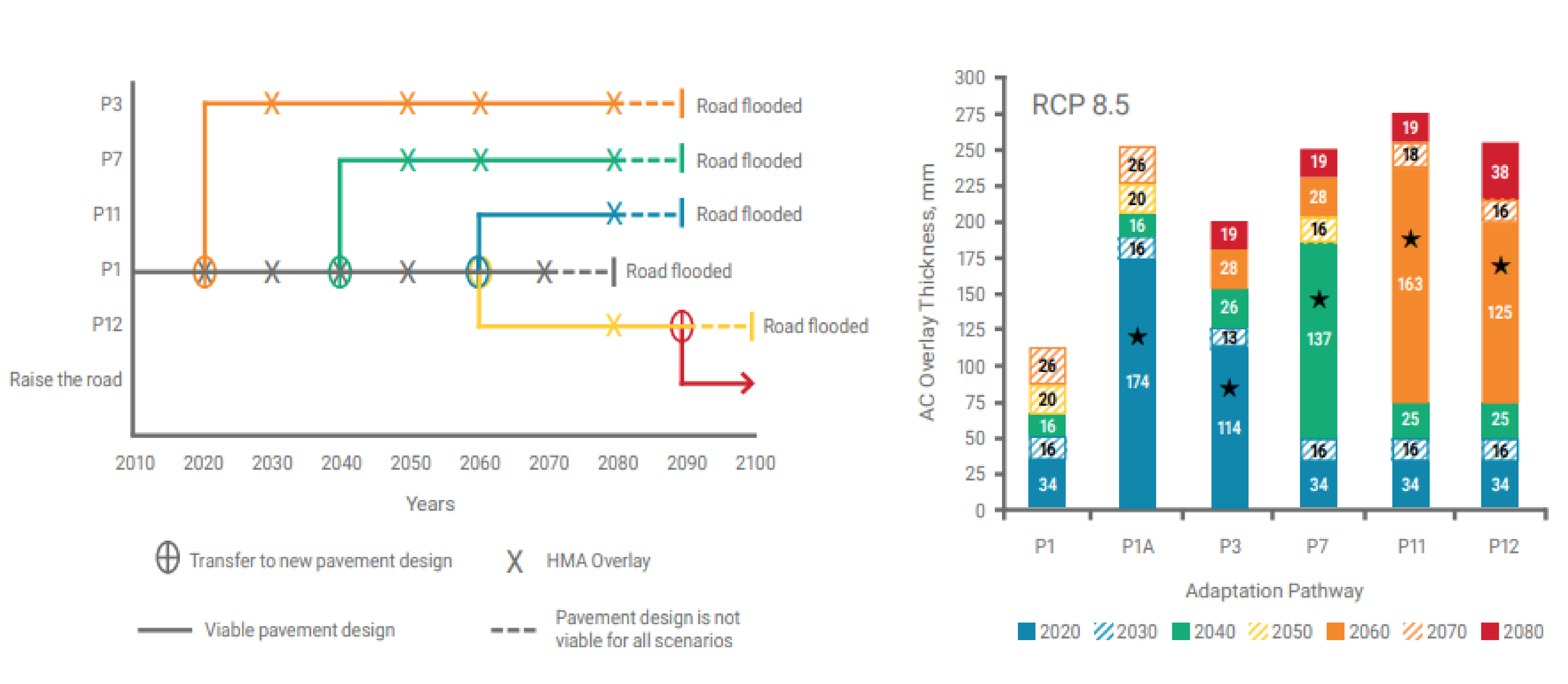
A **scenario-based** approach begins with choosing two or more future climate change scenarios. This approach can be useful in identifying potential future pavement-life reductions and promoting climate resilience through enhanced pavement design. In comparison, the **asset-based** approach seeks to evaluate the pavement's sensitivity to plausible future climate or environmental conditions while designing for future traffic loads. A key difference between the two approaches is that the asset-based approach provides a more complete picture of the pavement's response to incremental environmental change, and the scenario-based approach provides information on the timing of critical environmental change to inform design and M&R. The **hybrid** approach is when an asset's response to incremental environmental changes is investigated first and then the timing of critical pavement impacts for budgeting and planning purposes is predicted.

A case study example of the hybrid adaptation approach was performed for a regional connector in coastal New Hampshire (Knott et al., 2019). First the pavement's response to loading with incremental temperature and groundwater rise is investigated using pavement climate sensitivity catalogs. A climate sensitivity catalog is a tool to assess an asset's response to incremental changes in two or three climate parameters like temperature and groundwater levels, or temperature and precipitation, etc. For example, in this case study pavement performance was explored as a function of incremental changes in temperature on one axis and incremental changes in groundwater levels on the other axis.

The next step is to select different adaptation pathways for additional performance and cost analysis using three emissions and sea-level rise scenarios. An adaptation pathway is a prescribed series of adaptation actions to be taken over time. An adaptation plan consists of several adaptation

https://www.driveasphalt.org/uploads/documents/NAPA_Case_Studay_Resilience_Prepare_Approaches.pdf

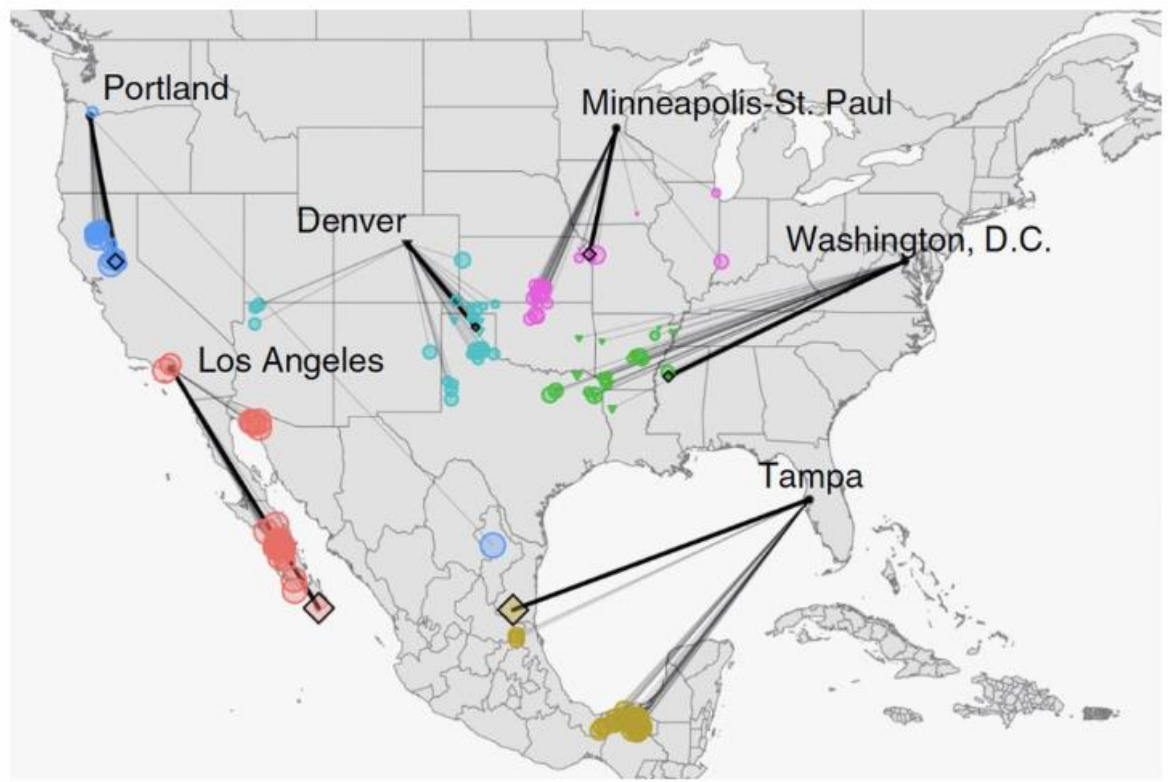
Mapping Alternative Adaptation Pathways



https://www.driveasphalt.org/uploads/documents/NAPA_Case_Studay_Resilience_Prepare_Approaches.pdf

Resilience – Will Roads Melt as the Temperatures Heat Up?

- Climate models provide long-term expected temperature changes
- Adjust **binder grades** to accommodate predicted conditions
- Time scale of changes is **decades**
- Can be a part of **routine maintenance** overlays



MATT FITZPATRICK/UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE

https://www.wired.com/story/this-scary-map-shows-how-climate-change-will-transform-your-city/?verso=true

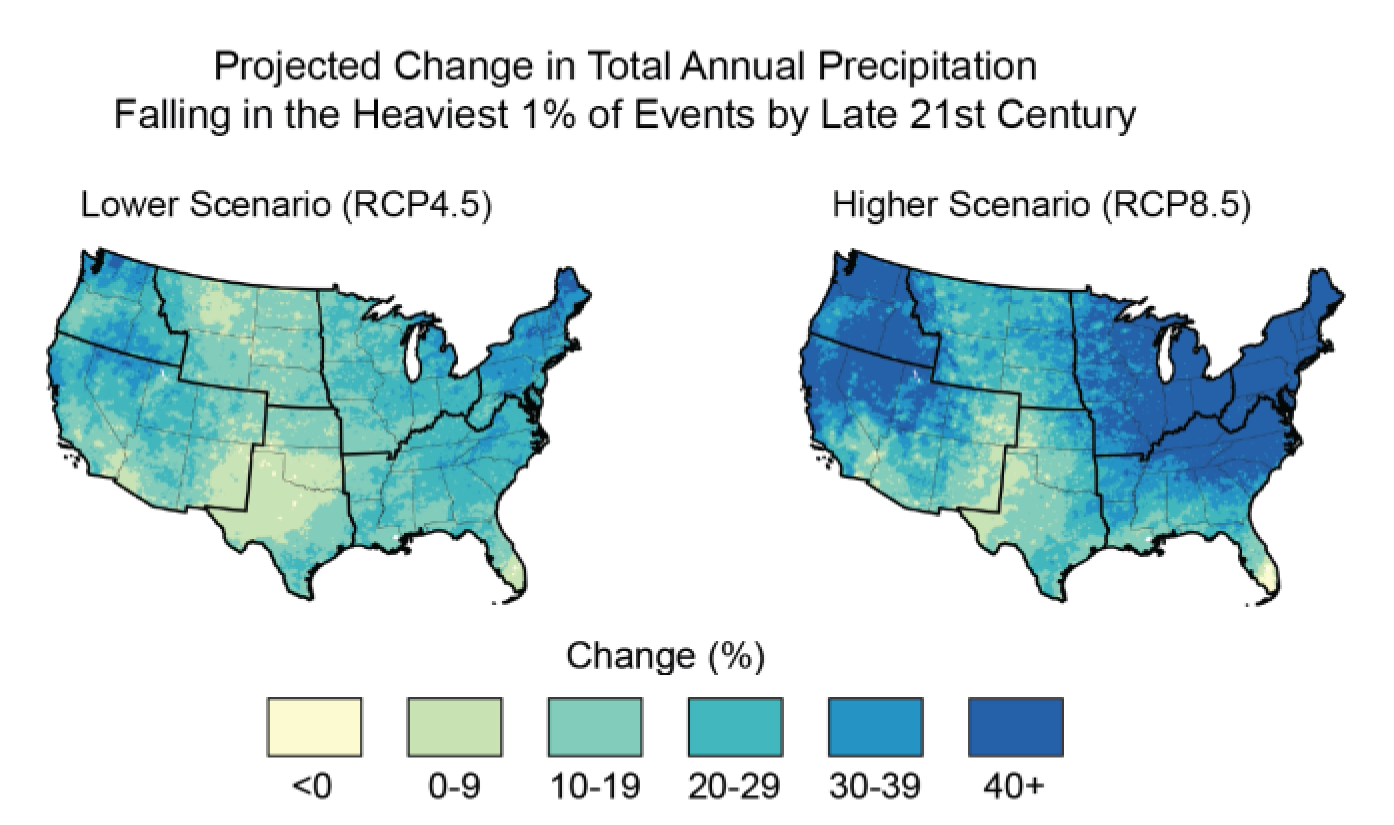
Sea Level Rise

- Honoapiilani Highway serves 20,000+ residents in West Maui
- Hardening the shoreline would damage marine habitat
- Relocation to be funded by Federal RAISE grants

http://seagrant.soest.hawaii.edu/coastal-and-climate-science-and-resilience/ccs-projects/building-resilience-to-coastal-hazards-and-climate-change-in-hawaii/

Planning for Heavier Rainfall Events

- Many regions will see heavier rainfall events



https://nca2018.globalchange.gov/

Adapting to Heavier Rainfall Events

- Porous asphalt can reduce impervious surface
- Reduce storm water discharge volume and peak flow rate

https://sustainablebuildingsinitiative.org/toolkits/climate-resilience-toolkits/stormwater-mgmt/paving-and-asphalt?toolkit=230

Responding – Asphalt as a First Responder

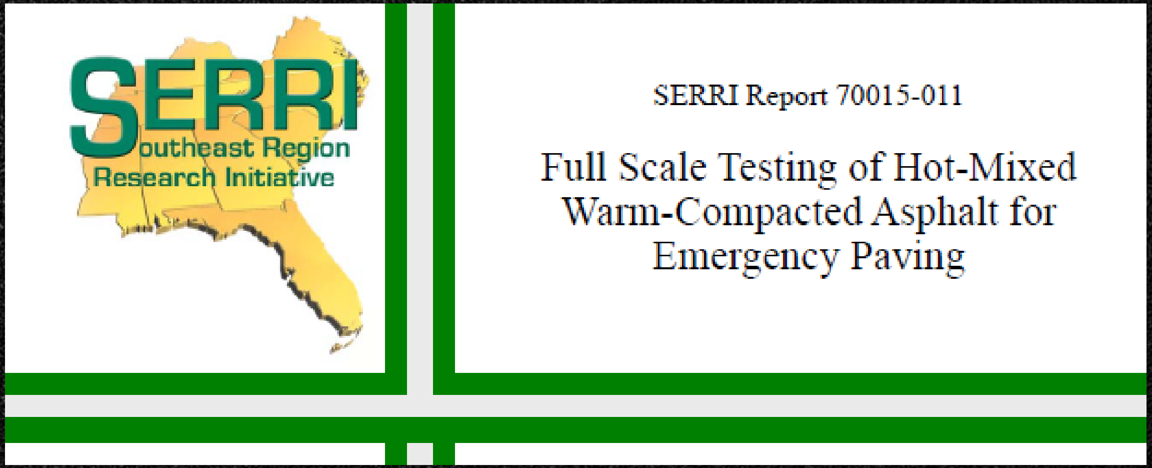
Resilience – Hurricane Damage

- Hurricane Michael severely damaged U.S. 98 in Franklin County, Florida (October 2018)
- 40-mile stretch of highway affected, 15 miles badly damaged
- Lanes were reopened to traffic after every shift

https://www.tallahassee.com/story/news/2018/10/11/u-s-98-closed-east-lanark-village/1601275002/

Resilience – Warm Mix to the Rescue

- What happens when local plants can't operate?
- Use of warm mix studied after Hurricane Katrina
- Haul distances up to **8-10 hours** can be used with warm mix technology
- Fine graded mixes are more easily compacted



SERRI Southeast Region Research Initiative

SERRI Report 70015-011

Full Scale Testing of Hot-Mixed Warm-Compacted Asphalt for Emergency Paving

http://driveasphalt.org/resource-library/full-scale-testing-of-hot-mixed-warm-compacted-asphalt-for-emergency-paving

Resilience – Warm Mix to the Rescue
U.S. 34, Colorado, 2013

- 3-hr. haul distances
- Late season paving at high elevation
- Steep canyons with little sun and high winds
- Warm mix was key to getting the job done

https://www.roadsbridges.com/asphalt-paving-able-reconnect https://www.cpr.org/2016/09/29/brace-yourself-northern-colorado-us-34-big-thompson-canyon-closure-is-almost-here/

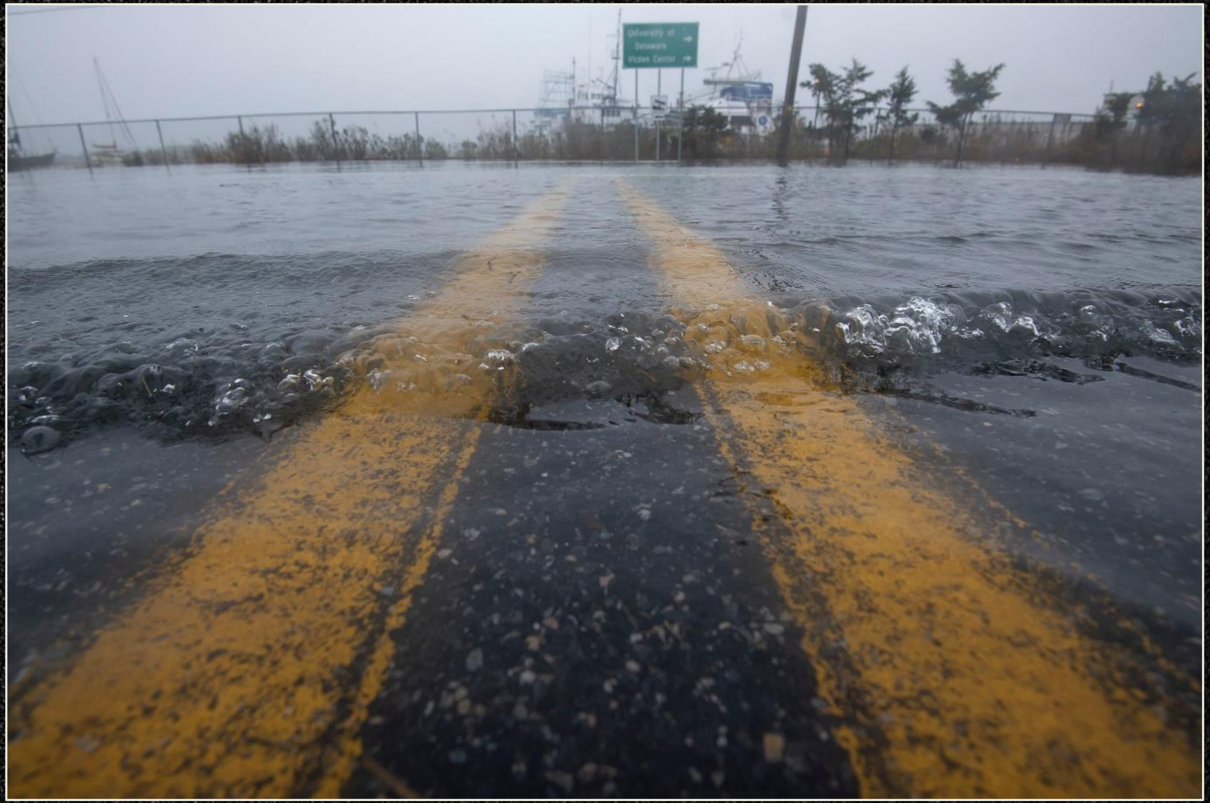
Resilience – Role of the Contractor

- Relationships & trust
- Asphalt plant considerations
- Material supply (aggregates, asphalt binder)
- Trucking logistics
- Work force

Summary

Tools for Hardening Asphalt Pavements

- Perpetual Pavement design
- Hardening shoulders
- Modified binders
- Deep reconstruction to stabilize base and subgrade



https://www.delawareonline.com/story/news/2019/08/27/roads-flooding-delaware-fix/2129785001/

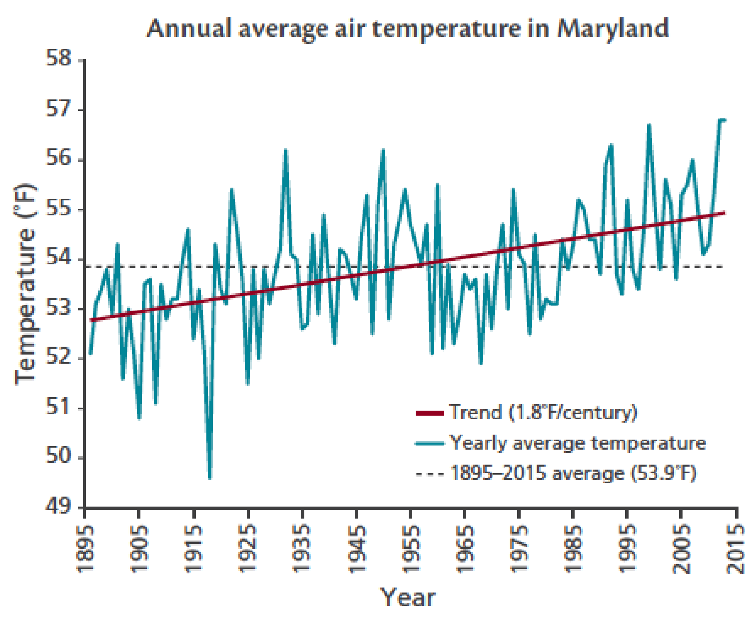
Adaptation Tools for Asphalt Pavements

- Use of climate models in pavement design and material selection

- Leverage maintenance overlays with climate adaptable materials

- Porous asphalt for flood mitigation

- Complement hardening or adaptation with nature-based solutions



https://climatechange.maryland.gov/science/

https://sustainablebuildingsinitiative.org/toolkits/climate-resilience-toolkits/stormwater-mgmt/paving-and-asphalt?toolkit=230

Tools for Asphalt as a "First Responder"

- Rapid construction to repair damaged roads and reduce user delay costs
- Warm mix asphalt to improve pavement quality during cold weather paving and long transport distances
- Recycled materials when supply chains are disrupted
- Contingency planning for asphalt plant and construction operations

https://www.infrastructure-exchange.com/single-post/roads-vs-extreme-weather-designing-more-resilient-roads

Learn more at

www.asphaltpavement.org/resilience

Joseph Shacat

JSHACAT@asphaltpavement.org

Photo Credit: Granite Construction

Today's presenters

Louay Mohammad
Louaym@lsu.edu
LSU
LOUISIANA STATE UNIVERSITY

Amir Golalipour
amir.golalipour@dot.gov

Ben Bowers
bfbowers@auburn.edu
AUBURN
UNIVERSITY

Joseph Shacat
jshacat@asphaltpavement.org
NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

https://www.trb.org/AnnualMeeting/Registration.aspx

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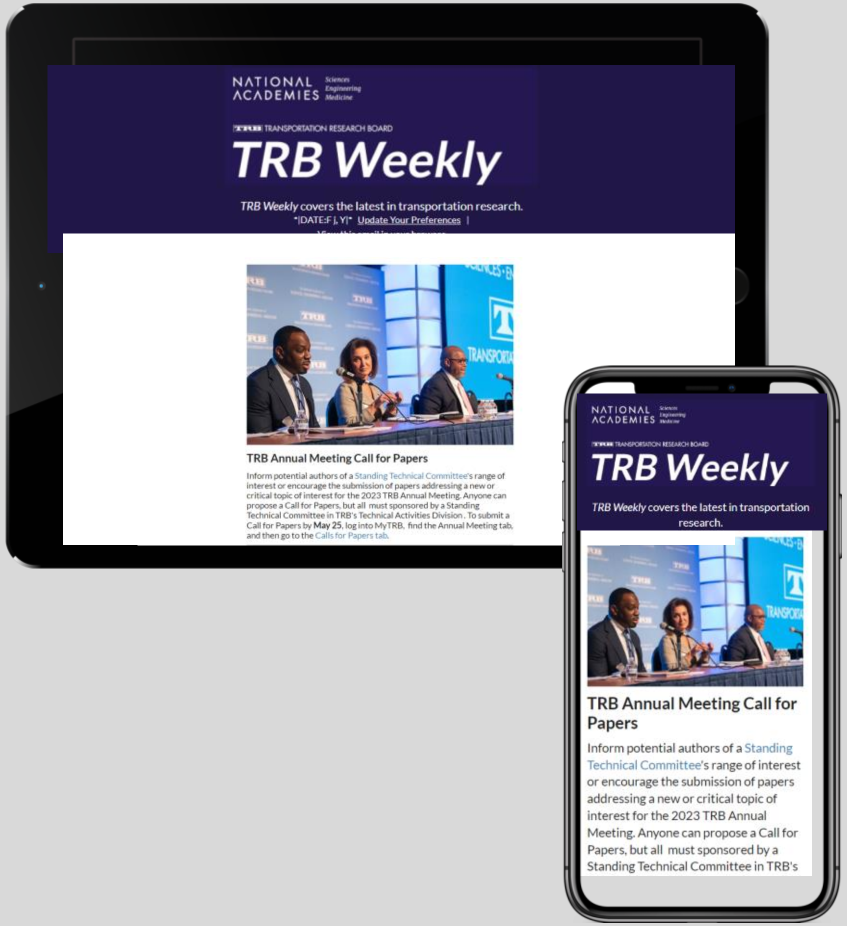

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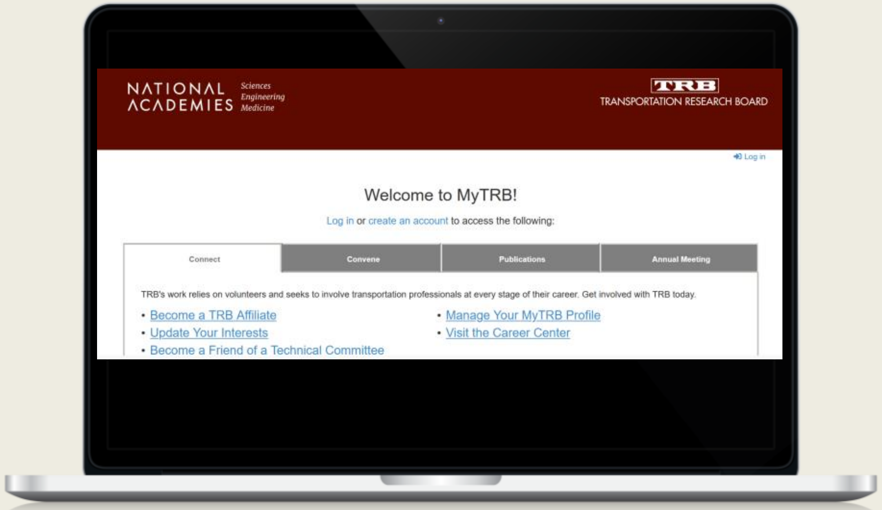

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