Weathering the Storm: Impacts of Extremes on South Carolina's Natural & Built Environment

2017 – 2018 Workshop Series Final Report

2017-2018 Climate Connections Workshop Series

Weathering the Storm: Impacts of Extremes on South Carolina's Natural and Built Environment

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Introduction

In the fall of 2017 and spring of 2018, the South Carolina State Climatology Office hosted a series of climate related workshops in collaboration with the Carolinas Integrated Sciences and Assessments (CISA) and the SC Water Resources Center. The workshops, titled "Weathering the Storm: Impacts of Extremes on South Carolina's Natural and Built Environment" were motivated by the success of a previous series of climate workshops conducted in 2012 and stakeholder informational needs.

South Carolina has experienced a series of extreme events over the past several years including the October 2015 heavy rainfall and flooding event, Hurricanes Matthew and Irma, and the 2016 drought that led to an outbreak of wildfires in the western Carolinas. Invited speakers represented the State Climatology Office, the SC Flood Mitigation Program, the SC Dam and Reservoir Safety Program, the SC Department of Transportation, the SC Forestry Commission, and the Hydrology Section of the SC Department of Natural Resources. Speakers addressed impacts of these extreme events to the operations of their respective agencies and how they are adapting operations based on lessons learned from their experiences.

2012 Workshop Series

In the fall of 2012, the South Carolina State Climatology Office conducted a series of three climate related workshops in Greenville, Columbia, and Charleston, SC titled "The Climate Connection Workshop Series: Climate Variability and Impacts to South Carolina's Natural Resources". The purpose of these workshops was to increase awareness and utilization of climate knowledge to improve natural resource management. Over 26 speakers presented their research and perspectives on climate and natural resources to a total of 151 workshop participants. A list of attendees, workshop presentations, and the final workshop report can be accessed at www.dnr.sc.gov/ccworkshops. Overall feedback for the 2012 workshop series was positive, motivating a second workshop series in 2017-2018.

2017 – 2018 Workshop Series

Organizing Entities

The State Climatology Office (SCO) has represented South Carolina in climatological and meteorological matters within and outside South Carolina since its creation in 1986. The Office provides a unique service to the state by archiving and distributing climatological data to state agencies, educational and research institutions, and private citizens. The State Climatology Office is a division within the South Carolina Department of Natural Resources.

CISA is one of eleven NOAA-funded Regional Integrated Sciences and Assessments (RISA) teams working to integrate climate science into decision-making processes. CISA researchers, collaborating investigators, and graduate students conduct applied climate research in collaboration with a wide range of stakeholders across the Carolinas. CISA's work includes several cross-cutting activities that seek to advance scientific understanding of climate and hydrological processes in the Carolinas, improve the assessment of climate-related vulnerabilities and impacts, and provide timely and relevant information and tools for decision makers.

The SC Water Resources Center serves as a liaison between the U.S. Geological Survey, the university community, and water resources constituencies across South Carolina. It is one of 54 institutes working collectively through the National Institutes for Water Resources (NIWR). The Center serves as a research facilitator and acts as a conduit for information necessary in the resource management, decision-making, and policy arenas of the state.

Workshop Locations and Attendance

Workshops were held in Greenville, SC on December 12, 2017, Columbia, SC on February 22, 2018, and in Charleston, SC on March 22, 2018. Seven speakers from South Carolina state agencies discussed the impacts of recent extremes, how their agencies responded, and how lessons learned are shaping the future of their work. The series attracted a total of 212 attendees from federal, state, county, and city governments, scientists, academia, NGOs, land and water resource managers, utility representatives, private companies, and other interested stakeholders (Figure 1a-d). The Carolinas Integrated Sciences and Assessments (CISA), S.C. Sea Grant Consortium, National Estuarine Research Reserves (NERR), and National Weather Service (NWS) attendees are represented as federal organizations because of their affiliation with the National Oceanic and Atmospheric Administration (NOAA) in figures 1 a-d.

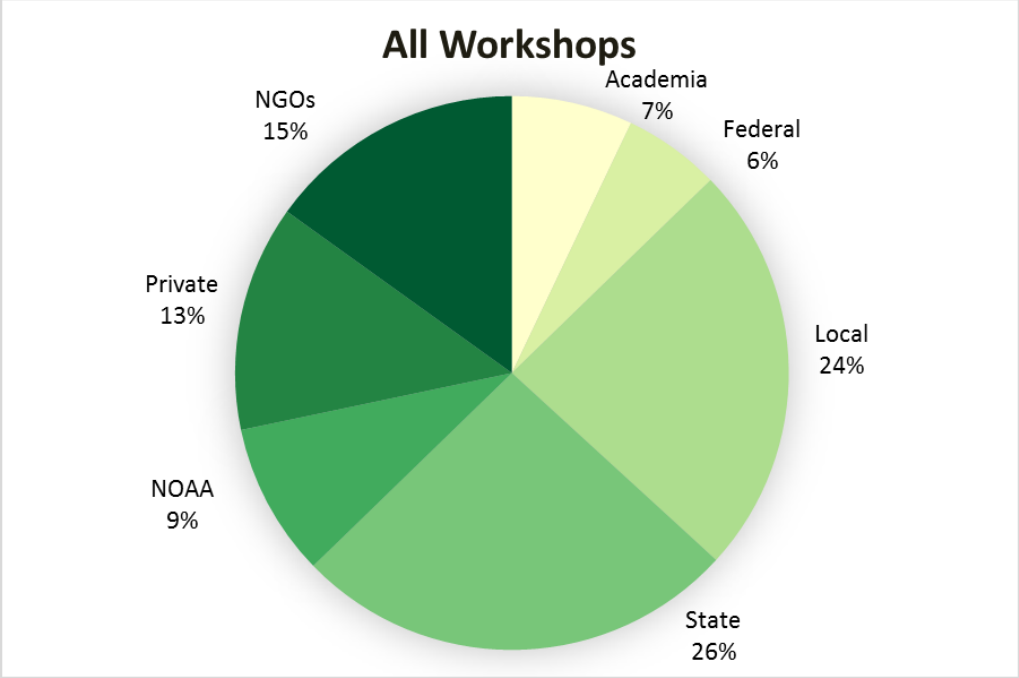

Figure 1a. Total Attendee Structure from Greenville, Columbia, and Charleston Workshops.

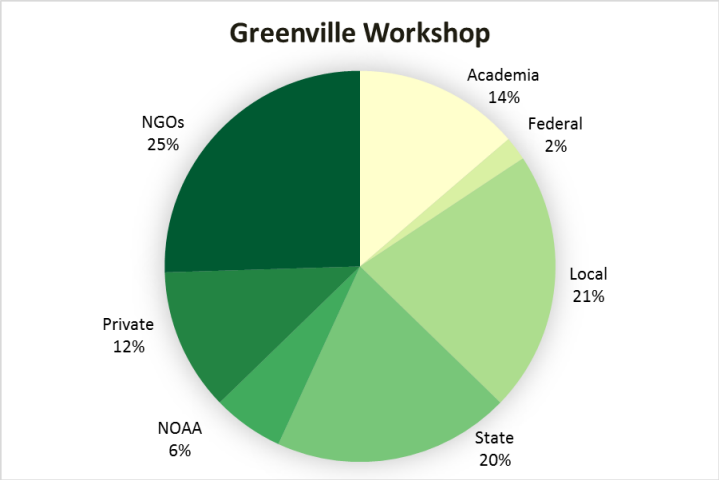

Figure 1a. Greenville Climate Connection Workshop Attendees.

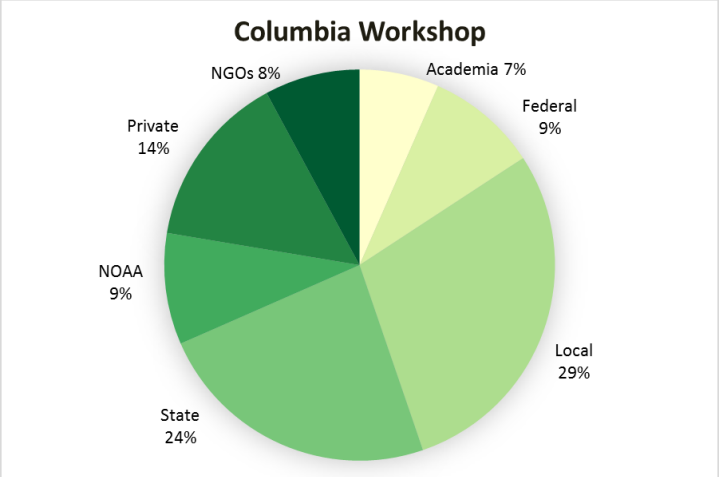

Figure 1b. Columbia Climate Connections Workshop Attendees.

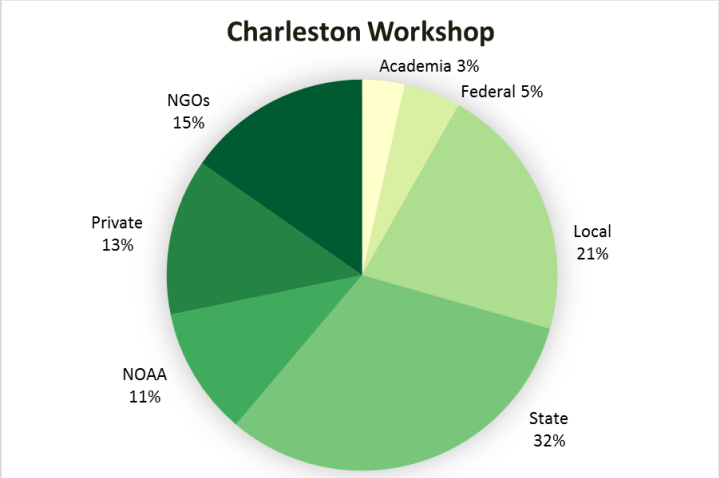

Figure 1c. Charleston Climate Connections Workshop Attendees.

In addition to speaker presentations, each workshop included an interactive session that utilized the Turning Technologies audience response system to poll audience members about their climate-related work activities and information needs. This system allowed us to engage the audience, gather opinions anonymously and generate productive discussion among participants. The data was then graphed and analyzed to be included in this report.

Climate Connections Workshop attendees in Columbia, SC on February 22, 2018. Photo courtesy of CISA.

Presentation Summaries

Hurricanes, Droughts, Rain Bombs, and More: An Overview of Recent Extreme Events Affecting South Carolina

Hope Mizzell, State Climatologist for the SC Department of Natural Resources State Climatology Office, gave an overview of recent extreme weather events that have impacted South Carolina.

- ***October 2015 Historic Rain and Flooding:*** A trifecta of weather systems, including Hurricane Joaquin, led to record-breaking rainfall totals across South Carolina over a four-day period in October 2015. The flooding displaced over 20,000 residents, closed over 500 roads and bridges, resulted in 47 dam failures, disrupted drinking water supplies to over 40,000 residents, and tragically took the lives of 19 people. More information is available via an Interactive Journal developed by the SC State Climatology Office, which was awarded the SC Notable State Documents Award.
- ***Hurricanes Matthew:*** Almost exactly one year after the October 2015 event, SC once again experienced devastating flooding from Hurricane Matthew, which made landfall on October 8, 2016 as a Category 1 Hurricane. A federal major disaster declaration was issued for 26 SC counties on October 11, 2016. The eminent landfall of the hurricane led to the evacuation of the entire SC coastline and a complete lane reversal of Interstate 26 from Charleston to Columbia. Seventy-seven emergency shelters were opened across the state. Matthew caused severe beach erosion and downed thousands of trees along the coast and inland areas. From 10 to 17 inches of rain were recorded increasing streamflow above major flood stage for many rivers. The town of Nichols, SC which is located near the Lumber River and just upstream of the confluence of the Little Pee Dee, was one of the towns hit hardest by the flooding from the storm. More information is available via an Interactive Journal developed by the SC State Climatology Office.
- ***2016 Upstate Drought:*** Between these two flooding events, the Upstate went into a severe drought in the late summer and fall of 2016. It was the 8th driest summer on record and the 2nd warmest. The drought began in early May 2016 in North and South Carolina. Drought severity quickly intensified in October 2016, with the peak of the drought in November 2016, when exceptional drought (D4) conditions were observed in the western Carolinas. The drought was officially over by May 2017. Despite the heavy rainfall from Hurricane Matthew along the coast during October 2016, the Upstate received only 0.2" of rain from the storm. So, while the Lowcountry was under water, the Upstate was parched. Dry conditions contributed to the Pinnacle Mountain Fire, described in more detail by Darryl Jones (see presentation notes below).
- ***Hurricane Irma:*** For the third year in a row, South Carolina was impacted by extreme weather as Hurricane Irma tracked up through Florida and led to heavy rainfall and wind gusts over 70 miles per hour in some places. The peak storm tide in Charleston Harbor as 9.92 feet, the third highest on record for this location. Palmetto Boulevard on Edisto Island, which was covered with 4 feet of sand after Hurricane Matthew, was once again buried by Hurricane Irma.
- ***Hurricane Harvey:*** Although Harvey did not impact South Carolina directly, Mizzell shared data she received from fellow state climatologist John Nielsen-Gammon in Texas, to discuss the severity of this event. Mizzell noted that, although unlikely, a storm of this magnitude could impact South Carolina. Learning from other communities who have suffered devastation in the face of such extremes is an important part of being better prepared for future events.

Mizzell's presentation set the stage for the other presenters who described how their agencies responded to these events and how their operations have changed to be better prepared for future extremes.

How Flashy is Your Flood Risk?: Understanding the SC Flood Mitigation Program

Maria Cox Lamm, Flood Mitigation Program Coordinator for the SC Department of Natural Resources Flood Mitigation Program provided an overview of the program and discussed the ways in which recent extremes and flooding have impacted their operations.

- As part of the National Flood Insurance Program (NFIP), the SC Flood Mitigation Program is responsible for floodplain mapping, management, and insurance. The success of each of these three components is critical to each of the others. In South Carolina, 235 communities participate in the NFIP. With over 200,000 policies, SC ranks 6th in the nation for number of flood insurance policies.
- Flood insurance policies are primarily concentrated along the coast. However, a key message for the SC Flood Mitigation Program is not whether a property is in or out of the floodplain, rather what the risk of flooding is. Lamm stressed that ALL properties are at some risk of flooding whether it be low, moderate or high.
- A property's risk is, to some extent, determined by location and how water moves through different regions of the state. For instance, from Columbia to the coast, floodplains are generally wide and flat which can lead to widespread flooding that may take days to recede such as in the case of the city of Nichols in the aftermath of Hurricane Matthew. On the other hand, floodplains from Columbia through the Upstate are typically narrower and contained in or near a channel. This leads to floodwaters that move at high velocities which can carry cars and other heavy debris and cause significant structural damage.
- The SC Flood Mitigation Program provided significant response and recovery information to first responders in the aftermath of recent extremes. Their mapping capabilities are able to estimate how high waters will be in different floodplains. These levels were verified by first responders.

Swamped Coast: Planning for Extreme Weather and Sea Level Rise

Sarah Watson is the Coastal Climate and Resilience Specialist, a joint position between both CISA and the S.C. Sea Grant Consortium. Watson gave a presentation during the March 22nd Charleston workshop to specifically discuss the unique nature of flooding and sea level rise in coastal South Carolina.

- Reiterating the devastating impacts of the October 2015 event and Hurricanes Matthew and Irma, Watson called for greater awareness about the risks SC residents face over and over again in the wake of such extremes.
- Beyond these singular events, the SC coastline is also experiencing more regular tidal flooding caused by sea level rise. The tide gauge in Charleston Harbor reached at least 7 feet above mean low water 35 days in 2015. This number rose to 50 days in 2016. This type of "nuisance flooding" leads to traffic disruption, public safety concerns, impacts to tourism, damage to infrastructure (both above and below ground), declining property values, and impacts to vulnerable community members. Sea level rise will lead to more frequent flooding and impacts.
- Communities have a variety of options for integrating sea level rise scenarios into future long-term planning such as hazard mitigation planning, comprehensive planning, and stormwater management. This type of planning can help to reduce risks and make a community more resilient to the impacts of nuisance flooding. Watson noted several communities in SC that are already addressing these issues, including Beaufort County, the City of Charleston, the City of Folly Beach, and the Charleston region more broadly through the Charleston Resilience Network.

After the Flood: Revitalization of the Dam Safety Program

Jill Stewart, Dam Safety Director with the SC Department of Health and Environmental Control's Dam and Reservoir Safety Program, provided an overview of the program and how recent events have led to improvements that will help improve future preparation, response, and recovery efforts.

The SC Dam and Reservoir Safety Program regulates dams that are over 25 feet in height, impound 50 acre-feet or more, or may lead to loss of human life should they fail, with three levels of hazard classifications (high, significant, and low) based on potential damage in the event of failure (Figure 2). The dam classifications are Class 1: High Hazard, dam failure would likely result in loss of life, Class 2: Significant Hazard, dam failure wouldn't likely result in loss of life, but property, roads and other key infrastructure would be damaged, and Class 3: Low Hazard, dam failure might cause minimal property damage to others. Loss of life is not expected.

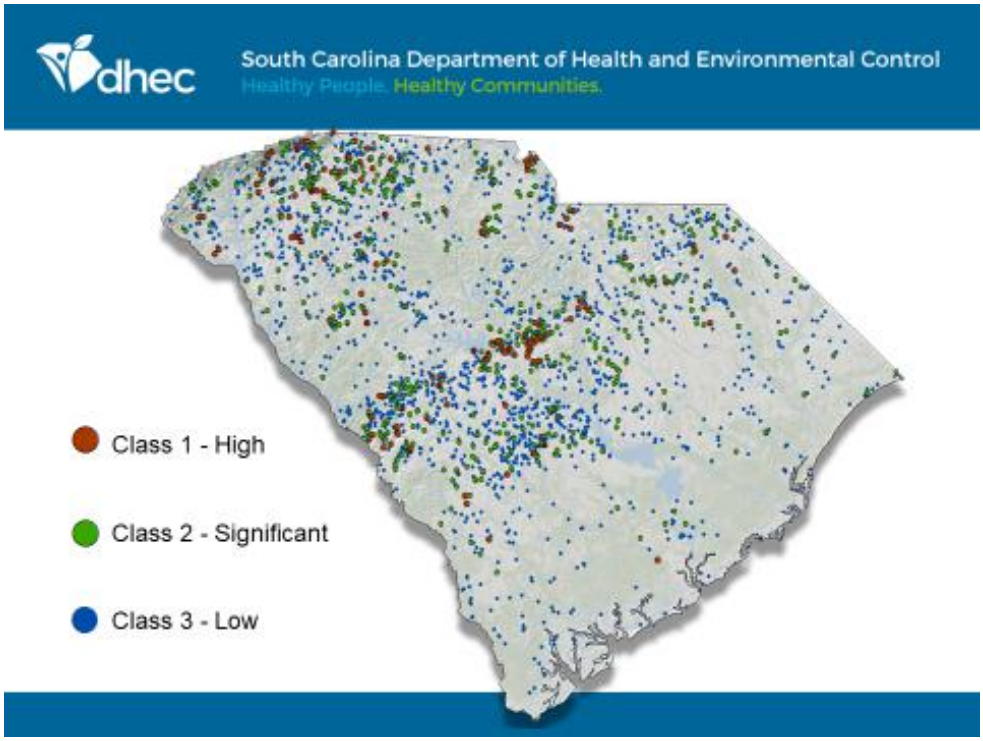

Figure 2. Map of regulated South Carolina dams and their hazard classification.

- The October 2015 heavy rainfall and flood event led to over 51 breached dams in 10 counties throughout South Carolina. The need for additional full-time staff and management for the program was quickly realized and set into place. Lessons learned from this event helped with the development of an event response protocol, which utilizes rainfall forecasts to determine which dam owners should be notified of potential threats.
- Hurricane Matthew allowed program management and staff to test these new protocols. Staff began monitoring potential impacts 4 days before the forecasted landfall. New communications methods were also utilized to notify dam owners of rainfall forecasts and the need to lower water levels. Four hundred and sixty-nine post-storm dam assessments were also conducted to ensure dams in threatened areas were secure.

- Before Hurricane Irma, pre-storm assessments were conducted to flag dams that may be at risk of failure during the event. This helped program staff target communications and monitoring throughout the storm.
- SC DHEC contracted with CDM Smith to develop inundation maps for high and significant hazard dams as well as low hazard dams where reclassifications were likely if no maps existed previously. Inundation maps available through DSS-WISE™ Lite, a FEMA-supported mapping system, are also being utilized. These maps give depth and speed of water flow following a failure as well as inundation depths.
- Revisions to Emergency Action Plans (EAPs) for high and significant hazard dams are also being implemented to ensure that the EAPs can help guide dam owners and first responders through managing a potential dam failure at each particular dam.

Climate Impacts on the Built Environment: Extreme Impacts to Transportation Infrastructure

Andy Leaphart, Chief Engineer for Operations with the SC Department of Transportation, spoke at the Greenville and Columbia workshops. Leaphart's presentation recounted the impacts of the October 2015 heavy rainfall and flood event and shared how new legislation to fund road improvements would help to mitigate future impacts.

- South Carolina has the fourth largest state-maintained road system in the United States at 41,000 miles, over 20,000 miles of which are neighborhood streets. The SC DOT has more miles of neighborhood streets in its inventory than the entire transportation system in 42 other states.
- Road closures peaked at 541 on the SC state roads system on October 5, 2015 (Figure 3). Over 900 sites needed repairs on the state system including 221 bridges that were impacted within floodways. In order to contain costs and expedite repairs, the SC DOT maximized utilization of their internal workforce by working outside traditional boundaries of responsibilities. Pre-positioned contracts also helped with a faster response and higher reimbursements. Roads and bridges were primarily repaired. Replacements were allocated only to infrastructure that was beyond repair.

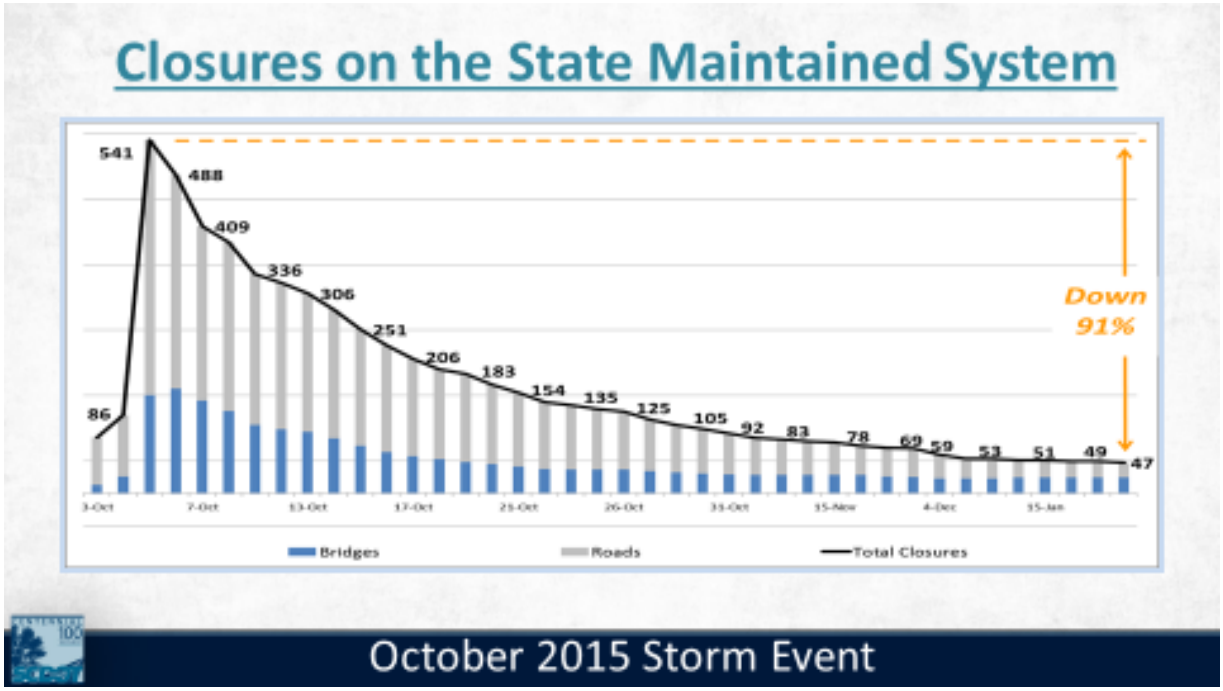

Figure 3. October 2015 South Carolina Bridge and Road Closures.

- New legislation over the past several years will allow for additional funding to the SC DOT to support much-needed highway repairs and improvements. These include a base funding increase of $200 million annually, the 2017 Roads Bill which will add another $600 million for infrastructure, and the 2 cent per year gas tax which began in 2017 and will increase by 2 cents each year until July 2022.
- Funds will be used to repair and rebuild bridges, widen interstates and implement a rural roads safety program contributing to 1,000 miles of safety feature upgrades on rural roads, 465 new bridges, and 140 miles of interstate improvements. A public involvement portal is available at www.scdot.org for residents to stay informed of planned and completed improvements.

From Too Much to Not Enough: South Carolina Water Planning…Planning for Which Drought?

Scott Harder and Alex Pellett, Hydrologists with the SC Department of Natural Resources Land, Water, and Conservation Division, shared details about steps being taken to develop a State Water Plan for South Carolina. In contrast to the previous presentations that focused primarily on flooding, their presentation raised questions about how drought affects water resources in the state.

- SC DNR and SC DHEC are working together to develop a State Water Plan. The plan is intended to help decision makers consider how future water demand, as well as impacts to water availability caused by drought, should be considered in water resources management.
- The process to develop the plan includes both surface and ground water availability assessments, development of water demand forecasts followed by regional water plans, and finally, the culmination of that information into the full plan. Project partners are also hosting stakeholder engagements in order to help South Carolina residents contribute to the process.
- Models developed for the surface water and groundwater availability assessments will help decision makers determine current water availability, project where and when water shortages might occur, test alternative management strategies, resolve water disputes, evaluate interbasin transfers and withdrawal permits, and support the development of drought management plans in each of the state's river basins.
- Water demand forecasts are intended to help decision makers consider future population and industrial growth that will place additional demand on available resources. A Technical Committee is overseeing the development of the forecasts, beginning with a pilot study in the Savannah River basin.
- Using these models and forecasts, and with oversight from State agencies, stakeholders will begin the process of developing regional water plans for each basin. Basin advisory councils will help to evaluate future water availability and assess management strategies to meet future demands and plan for change in future availability. These regional plans will be used to update the State Water Plan.
- Harder and Pellett concluded their presentations by raising questions about how future drought might impact the state's water resources and how projections for future drought scenarios might be incorporated into water demand forecasts and, ultimately, the regional and state water plans.

Catching Fire: Wildfire, Risks, Impacts, and Management

Darryl Jones, Forest Protection Chief with the SC Forestry Commission, followed the drought discussion begun by Harder and Pellett to educate attendees about wildfires in South Carolina. Jones shared the story of the most recent Pinnacle Mountain Fire in the Upstate, which was exacerbated by the 2016 drought.

- The SC Forestry Commission responds to an average of 3,000 wildfires each year, covering an average of 20,000 acres across the state at an average size of 7 acres per fire. Despite preconceptions that droughts

are the primary driver of wildfires, Jones emphasized that wildfires can occur anytime, independent of drought, including right after rain, and at any time of the year. Human activity is most often the cause of wildfire.

- In fall 2016, upstate South Carolina was deep in drought with Oconee, Pickens, and Anderson County designated in severe drought by the South Carolina State Drought Response Committee. The Keetch-Byrum Drought Index, a measure of available fire fuels, was at 701 out of 800 with wildfire occurrences in the Southern Appalachian Mountains increasing in October.
- Ignited by a campfire, the Pinnacle Mountain fire was estimated at two acres on November 9, 2016, when the SC Forestry Commission arrived on site. The initial response was hampered by rough terrain and difficult access, allowing the fire to spread quickly due to drought conditions. Over the 26 days when the fire was active, 10,623 acres were burned and a 31-mile fire perimeter was maintained. Over 350 personnel were deployed to support the containment effort, including many from other states. Thankfully there were no homes lost, no injuries to response crew, and no loss of life.

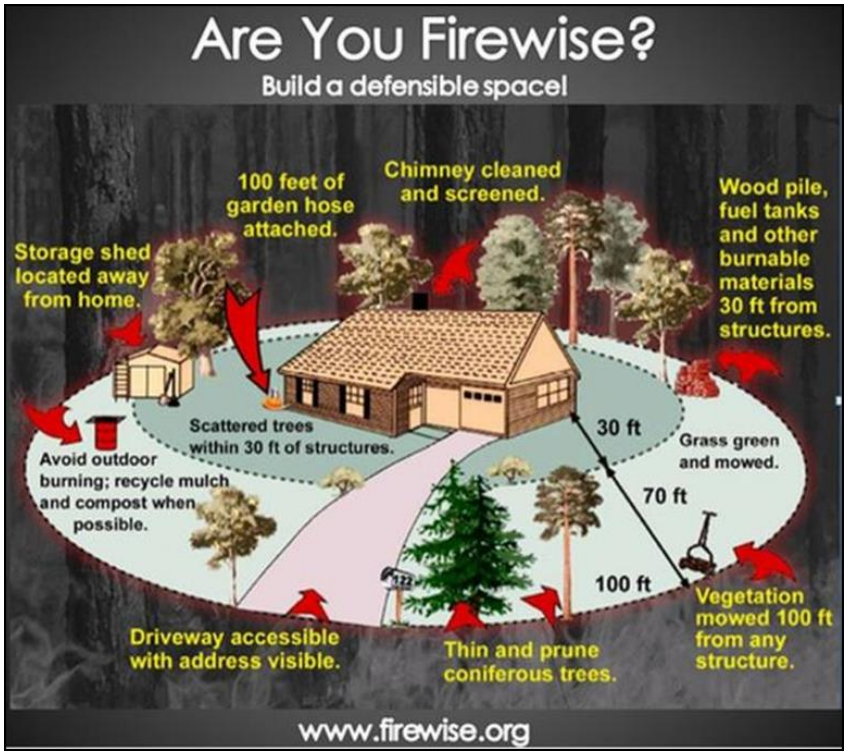

Figure 4. Are You Firewise Educational Graphic.

- As populations continue to grow, concerns about the Wildland Urban Interface, where homes and businesses are adjacent to woods and potential fire fuels, the need for public education and awareness about fire threats is tantamount. Firewise (Figure 4), sponsored by the National Fire Protection Association, sets standards and principals that can be used anywhere to minimize loss of life or property damage from wildfire.
- The Southern Wildfire Risk Portal is another free online tool that can be used by the public to visualize wildfire risk at the parcel level, print reports, and define areas of interest.

Audience Polling Results

Overview

Each of the Climate Connections workshops included an interactive discussion session which utilized the Turning Technologies audience response system to solicit feedback about a variety of climate-related topics as follow up to the presentations. This intuitive polling software is integrated with PowerPoint to collect real-time response data from participants. Sixteen questions were posed to workshop participants to learn more about how they are working to address climate-related impacts in their field, climate information challenges and needs, and impressions about the workshop that day. Weighted responses allowed participants to prioritize answer choices. Audience responses were instantly displayed to generate conversation around the various topics.

Many of the questions were very similar to questions posed during the 2012 workshops to allow for comparison between responses from the two workshop series. Results from similar questions in 2012 were displayed after 2017-2018 responses were received to promote discussion about how priorities and needs have changed over the past five years. Often these discussion centered on the types of resources participants use to support their work. A list of these resources as well as those shared by workshop presenters is available in Appendix 1. Polling response data is summarized in the sections below.

Audience Polling Results & Discussion

Participant Information

The first few questions helped the audience familiarize themselves with the Turning Technologies audience polling device using basic questions about why they attended the event and how long they have worked in their respective fields. The majority of attendees indicated that they attended the workshop to hear how South Carolina is working to better prepare for future extreme events and to learn how their agency or organization can use these lessons to be better prepared themselves for future events. Most attendees were seasoned veterans with 20+ years of experience and early career professionals with 1-5 years of experience of service in their respective fields (Figure 5).

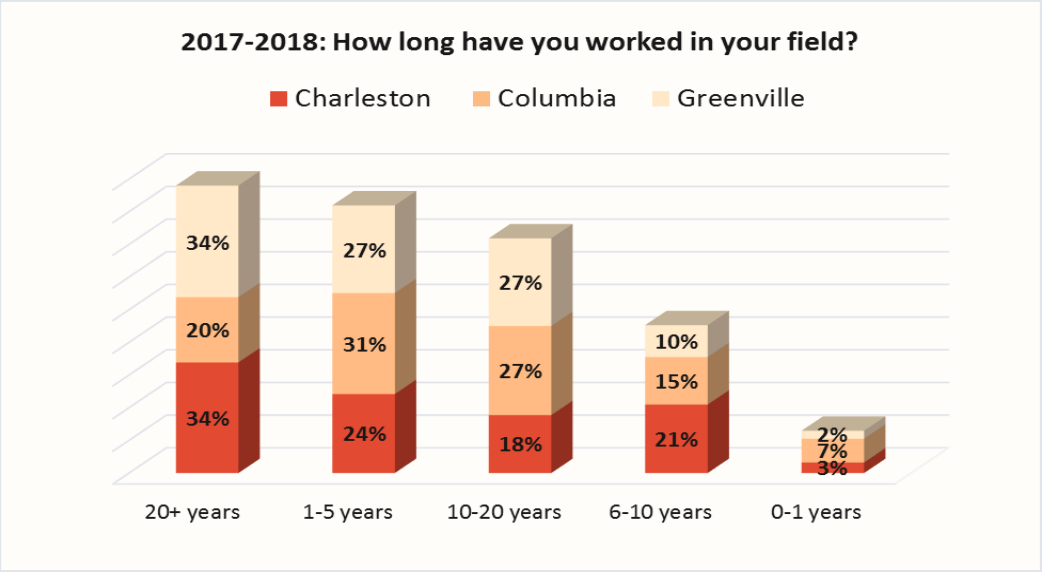

Figure 5. Attendee Years of Service in 2017-2018 Workshops.

Concerns about Climate Impacts in the Carolinas

The next set of questions helped to identify and prioritize attendees' primary concerns about climate-related issues and impacts to the natural and built environments in South Carolina.

What are the primary climate-related issues affecting South Carolina?

Workshop participants ranked floods, drought, and sea level rise as the three primary climate-related issues in the state during the 2012 and 2017-2018 workshops (Figure 6a and 6b). While flooding is a concern with all three areas, results are location specific and representative of current challenges in the different regions. Charleston participants are most concerned with sea level rise (30%), Greenville with droughts (29%), and Columbia with floods (30%). In 2012, drought ranked as the highest climate-related issue affecting the state (Figure 6b) with most of the state experiencing drought at that time. Severe weather received the fourth highest number of votes, followed by storm surge and temperature extremes. Winter weather and high winds received the lowest prioritization in 2017-2018, consistent with the 2012 results.

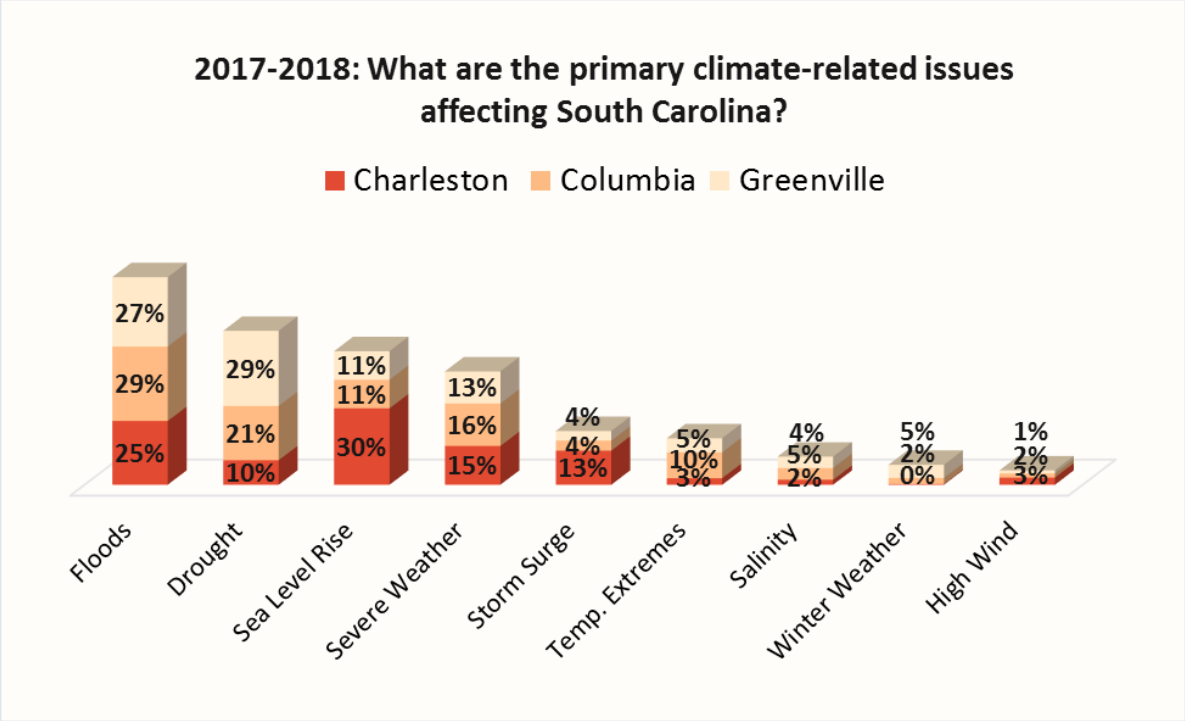

Figure 6a. Primary climate-related issues affecting South Carolina in 2017-2018.

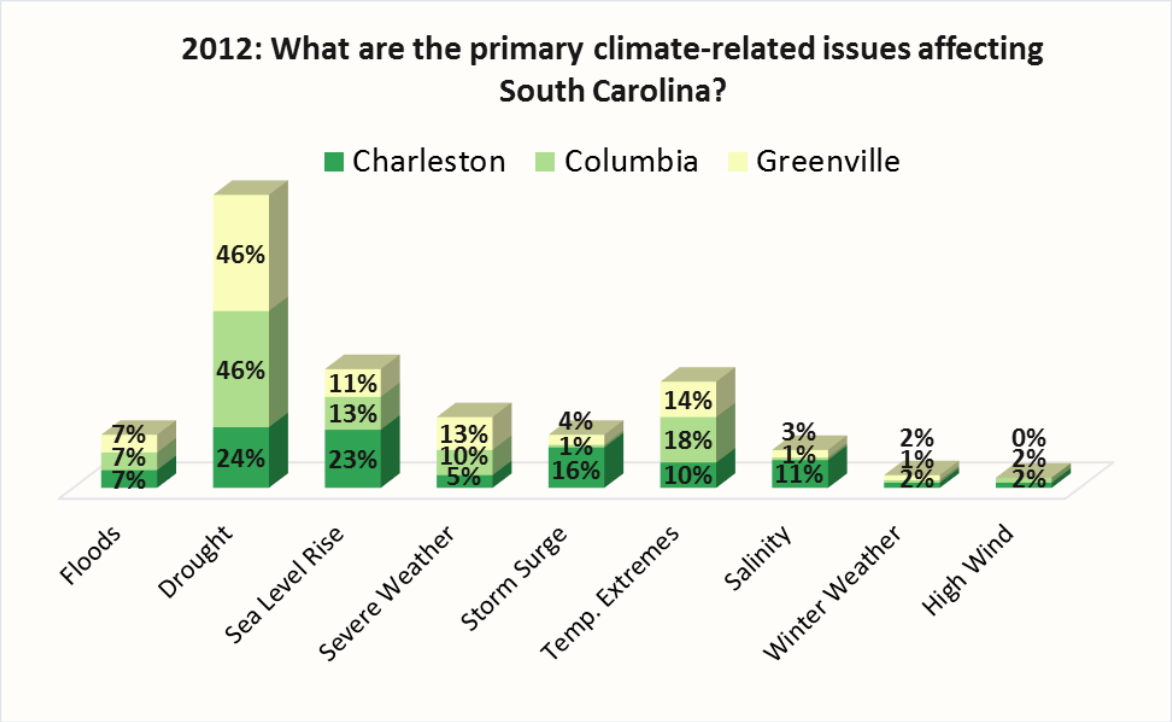

Figure 6b. Primary climate-related issues affecting South Carolina in 2012.

What are your top 3 concerns about climate-related impacts in South Carolina?

The top concerns about climate-related impacts were flooding from heavy downpours, water quality issues, infrastructure impacts, and water shortages (Figure7a). Other attendee concerns were indicative of the regional environment where the different workshops were held. Charleston participants ranked infrastructure impacts, shoreline erosion, and sunny day coastal flooding the highest. Columbia participants were most concerned with water quality issues, water shortages, and public health impacts. Greenville ranked agricultural impacts, water shortages, and water quality impacts as their top three concerns.

Attendees articulated a shift in concerns about climate issues and impacts between the first workshop series in 2012 (Figure 7b) and the 2017-2018 series. The focus shifted from climate variability and impacts on natural resources to the impacts of climate extremes on the natural and built environments. This is likely indicative of the different speakers and presentation topics during the two different workshop series.

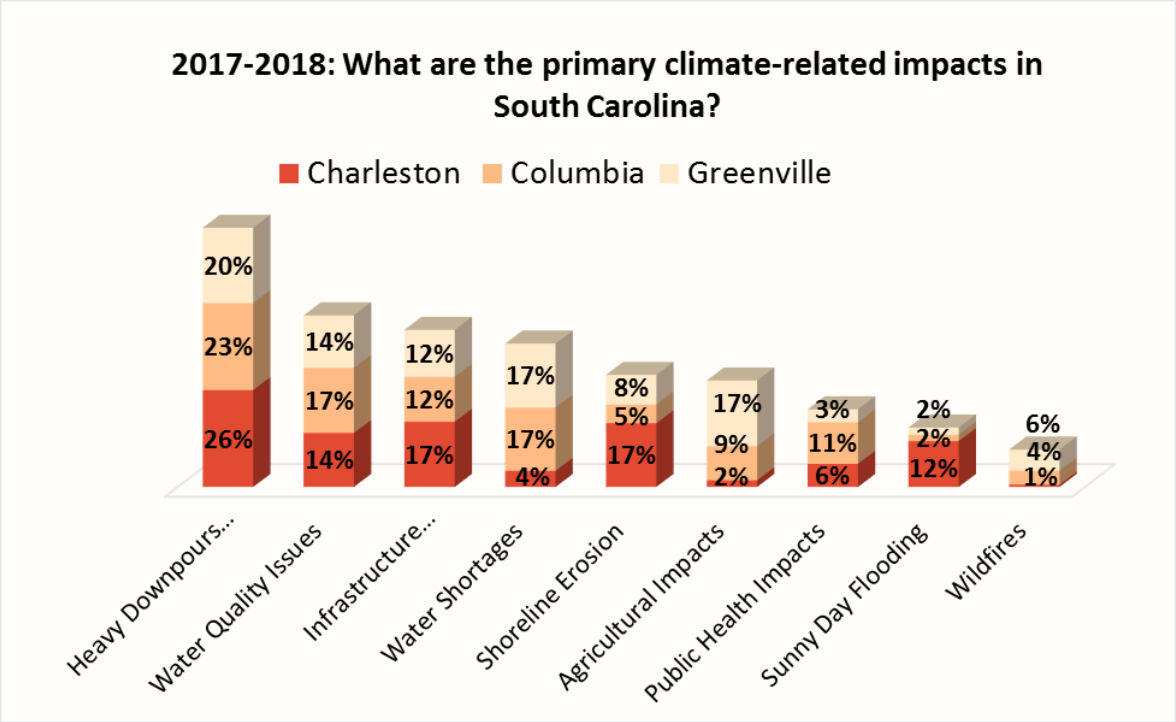

Figure 7a. Top concerns about climate-related impacts in 2017-2018.

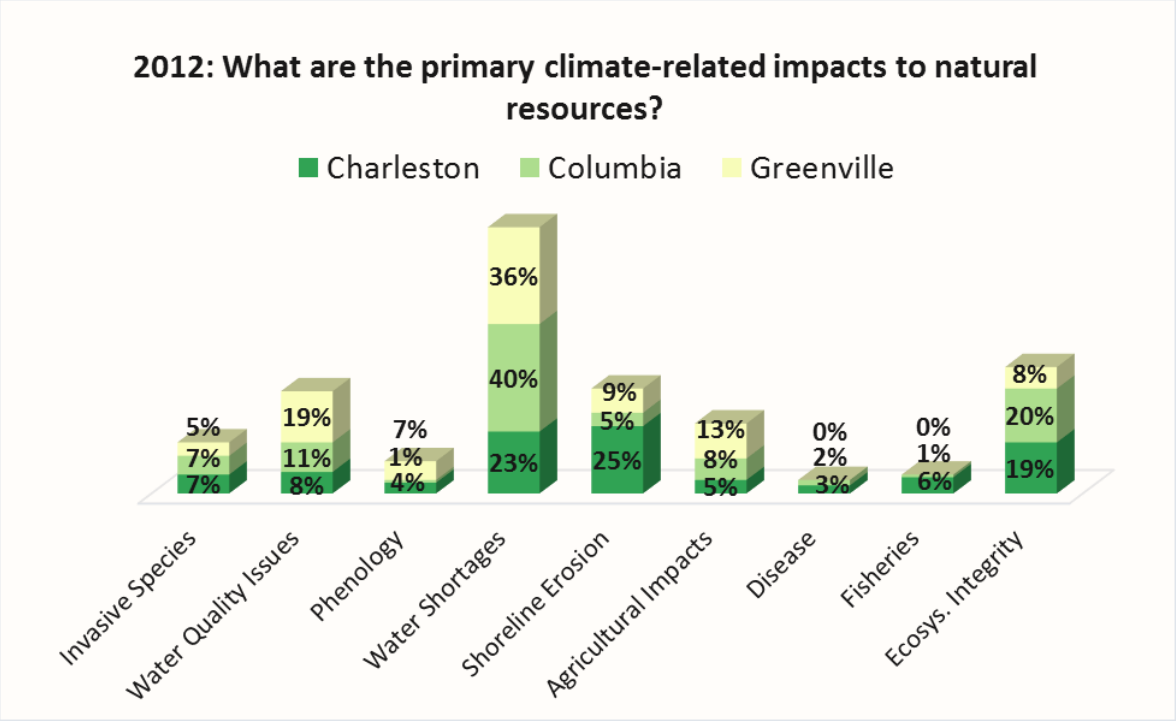

Figure 7b. Primary climate-related impacts to natural resources in 2012.

Actions to Address Climate-Related Concerns

The next questions aimed to identify what specific actions agencies and organizations have taken to address climate-related issues in the state. Most attendees conduct outreach and education initiatives, partner with other agencies, and are planning strategically to address climate-related issues (Figure 8). Target audiences for education and outreach efforts are the general public, local governments, and an organization's own employees (Figure 9a). Strategies to address climate-related impacts on the ground were monitoring, research, and developing adaptation strategies (Figure 10a).

Research, the highest ranked action taken by organizations at the 2012 workshops, ranked fourth during the 2017-2018 workshop series (Figure 8a). Only 1-2% of participants indicated not doing anything to address climate-related issues, a major drop from 4-15% of respondents at the 2012 workshop (Figure 8b).

Education and outreach efforts by the respondents mostly target general public and local governments, followed by their organization's own staff/employees, and legislators/elected officials (Figure 9a). Since 2012 (Figure 9b), education and outreach efforts targeting landowners, industry, and outdoor enthusiasts have increased.

Most attendees responded that their agencies are addressing climate-related impacts on the ground through monitoring and research (Figure 10a), which is consistent with the 2012 workshop responses (Figure 10b). Other popular responses were developing adaptation strategies, reducing stressors, and restoration activities. Land acquisition and doing nothing received the lowest response rates.

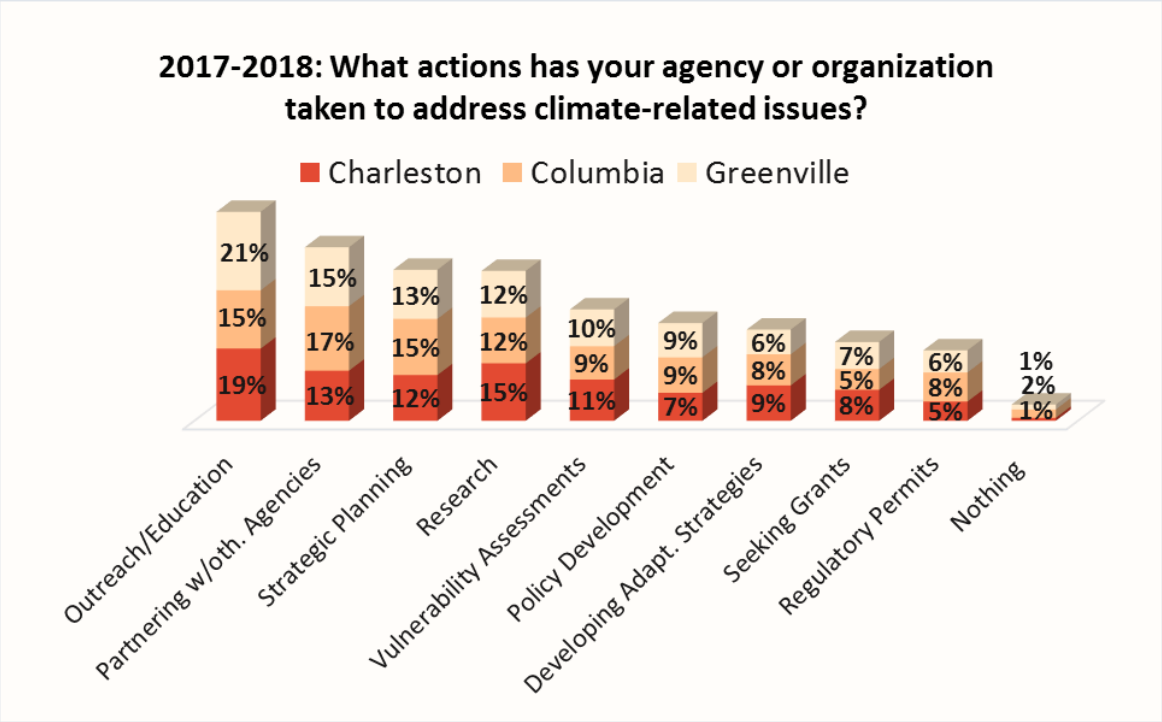

Figure 8a. Actions to address climate related issues 2017-2018.

Figure 8b. Actions to address climate related issues 2012.

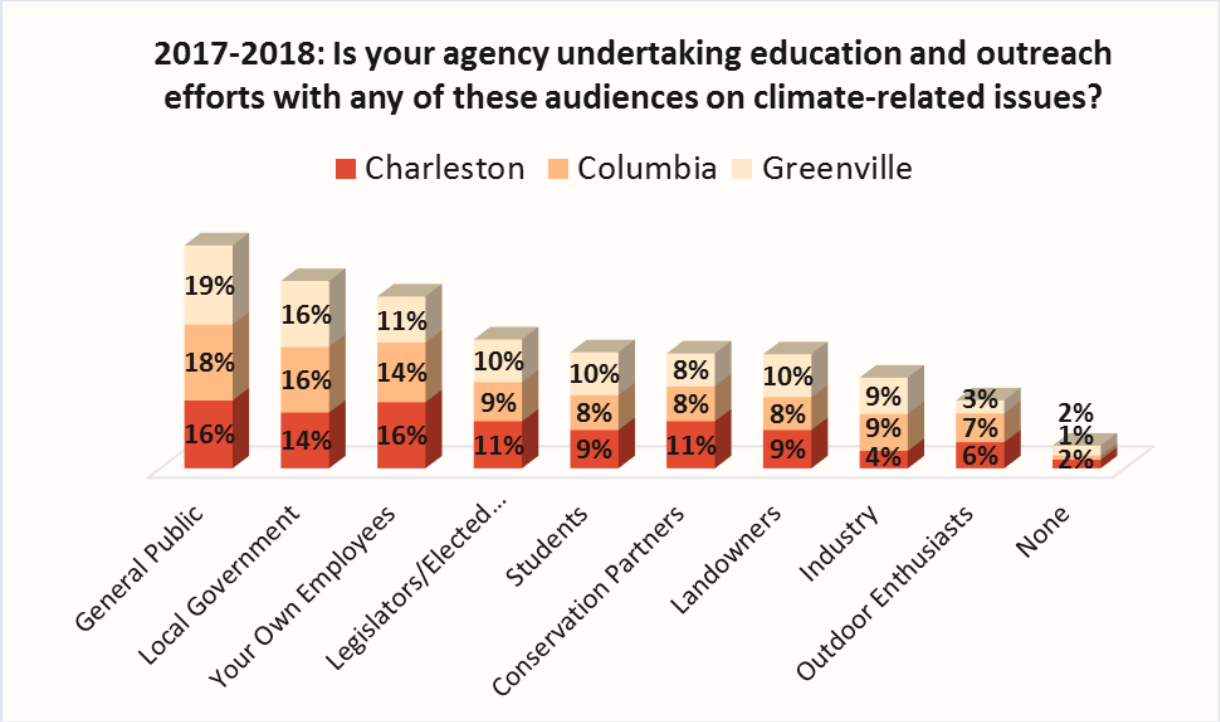

Figure 9a. Education and outreach efforts on climate-related issues in 2017-2018.

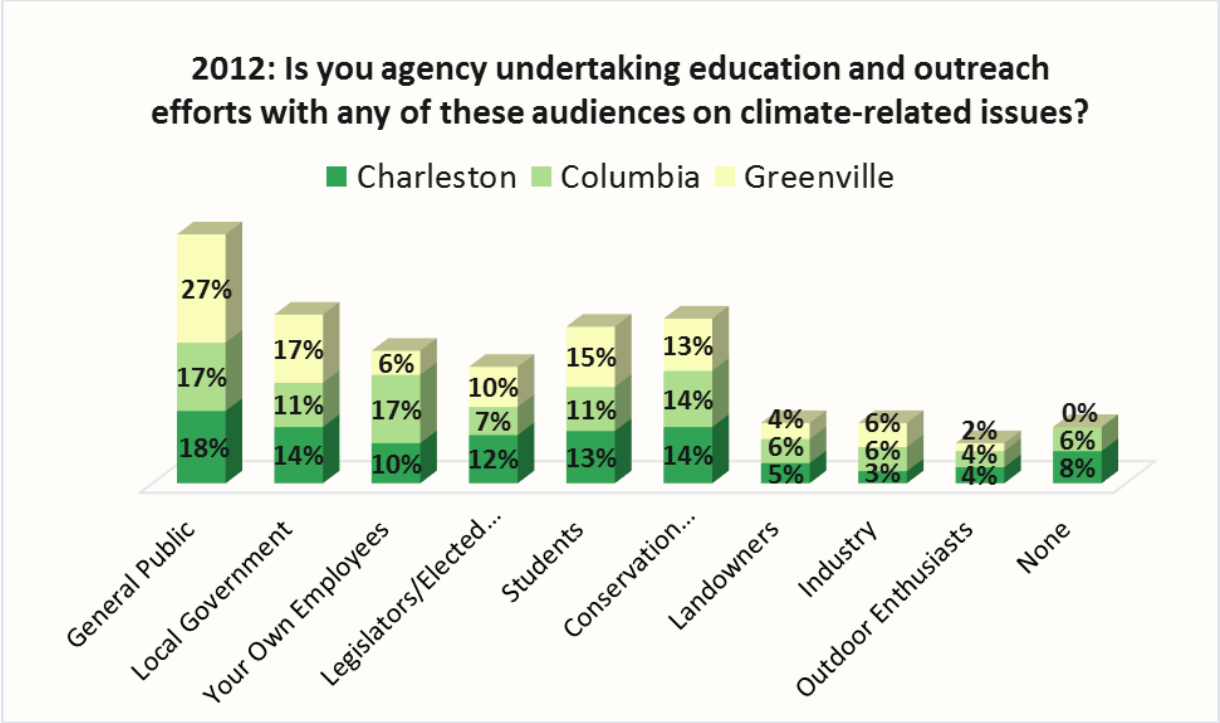

Figure 9b. Education and outreach efforts on climate-related issues and natural resources in 2012.

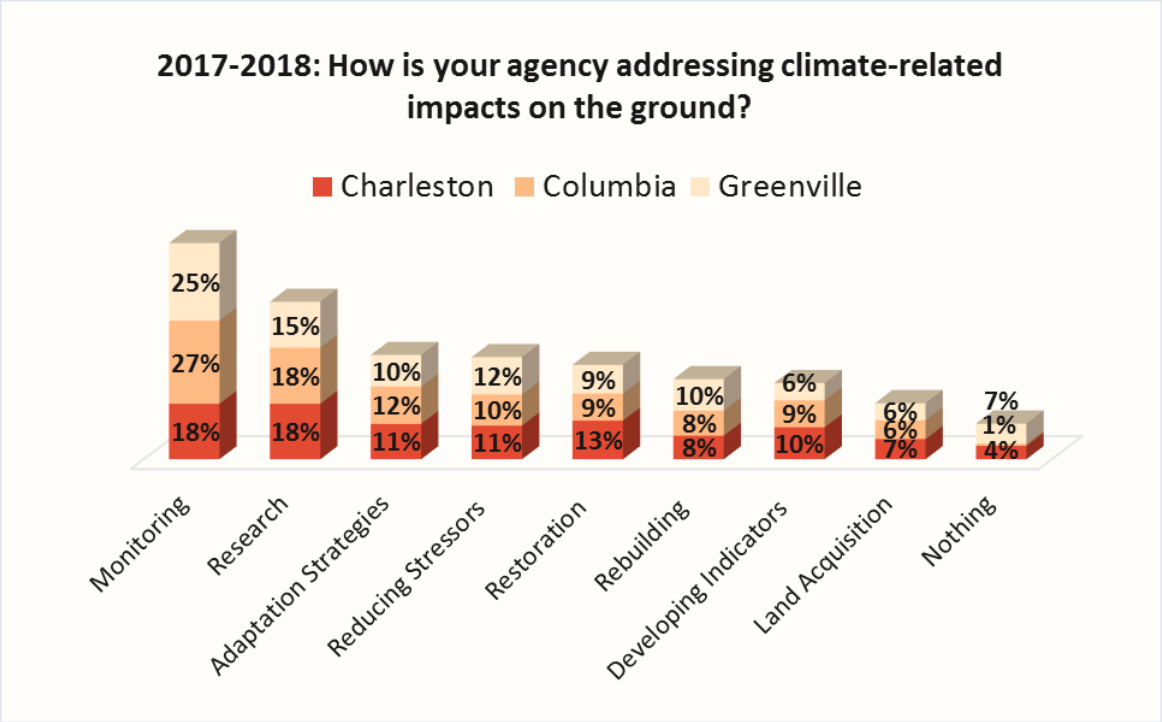

Figure 10a. Addressing climate-related impacts on the ground in 2017-2018.

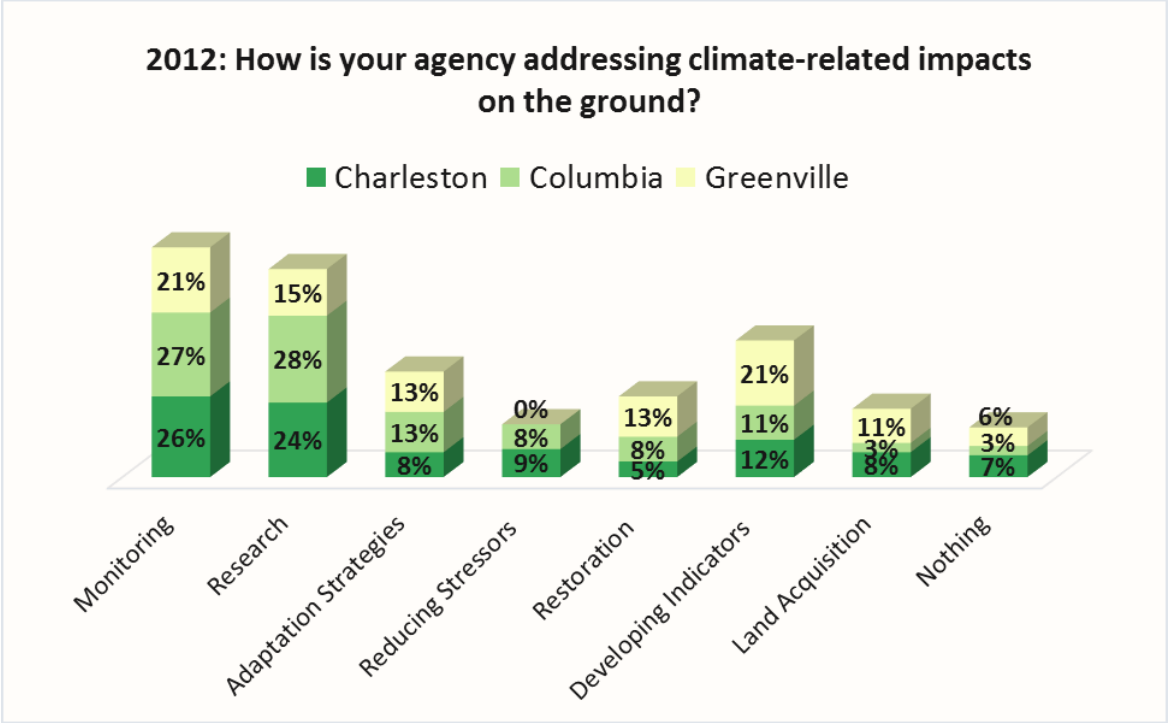

Figure 10b. Addressing climate-related impacts on the ground in 2012.

Climate Information Needs and Challenges to Climate-related Work in South Carolina

The following set of questions explored the needs for climate-related data, information and resources, as well as challenges that limit participants from focusing on climate-related work. When asked about information needs (Figure 11) to help better prepare for future extremes, most participants expressed the need for 1) case studies and examples of what other communities and organizations are doing and 2) projections for future land use change and related impacts to water availability. Public education and outreach to improve preparedness, projections for population growth, and case studies for long-term planning within local government ranked highly throughout the state. Greenville and Columbia participants expressed a high interest in training events to practice extreme event responses. Among attendees of the workshops, the main challenges and barriers to climate-related work are political support, time, and funding, similarly to the 2012 workshop results (Figure 14a).

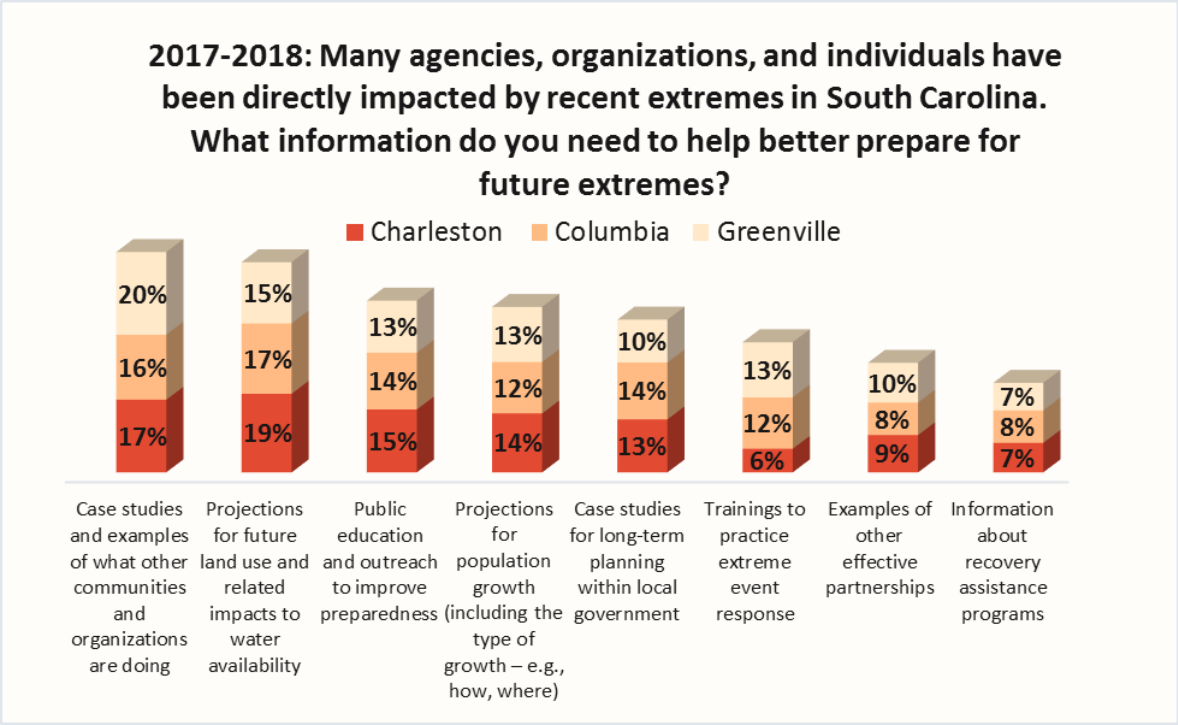

Figure 11. Information needs to prepare for future extremes in 2017-2018.

The next question helped to identify the types of climate information that are most relevant to respondents (Figure 12a). Long-term, historical climate data (e.g., temperature and precipitation) was ranked the highest in Greenville and Charleston. Columbia participants ranked real-time conditions as the most relevant climate information for their work. The second most popular answer for all three workshops is real-time conditions, followed by information about extreme events, then forecasts and outlooks.

In comparison, the 2012 workshop attendees rated simplified climate information and increased station coverage as their top climate data needs (Figure 12b). Not surprisingly, Charleston participants ranked the need for sea level rise information higher than attendees at other workshop locations. Columbia attendees indicated a need for information about regulations and policies related to climate higher than either Charleston or Greenville participants.

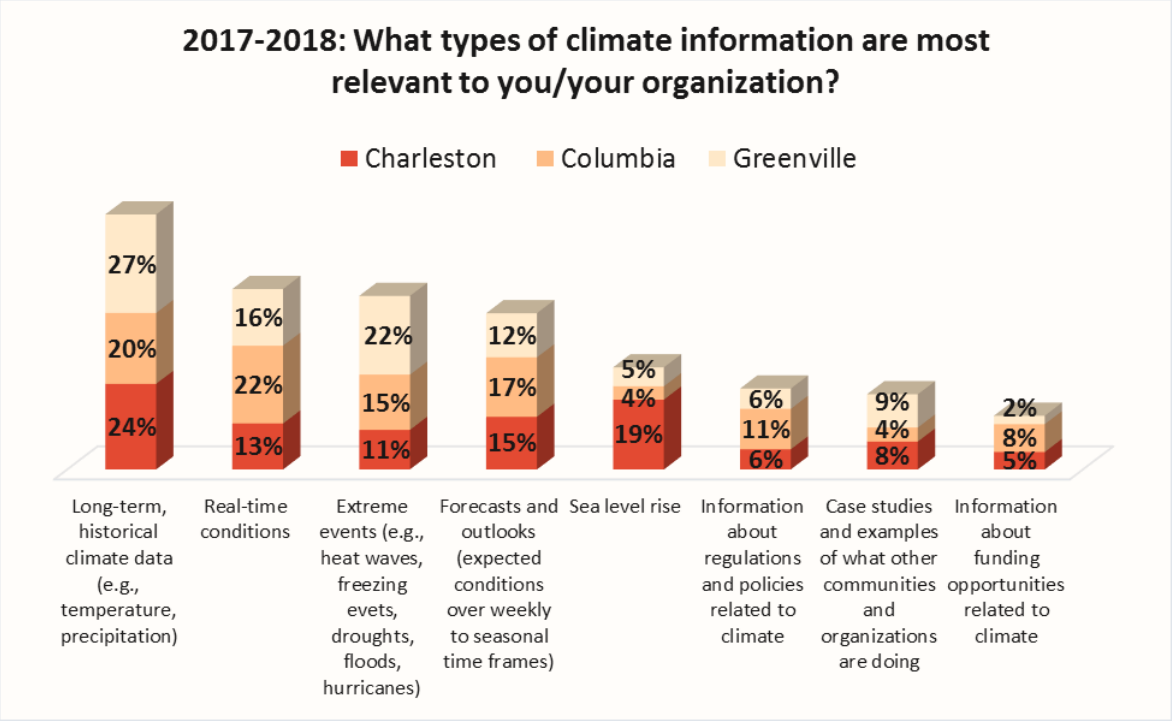

Figure 12a. Types of the most relevant climate information in 2017-2018.

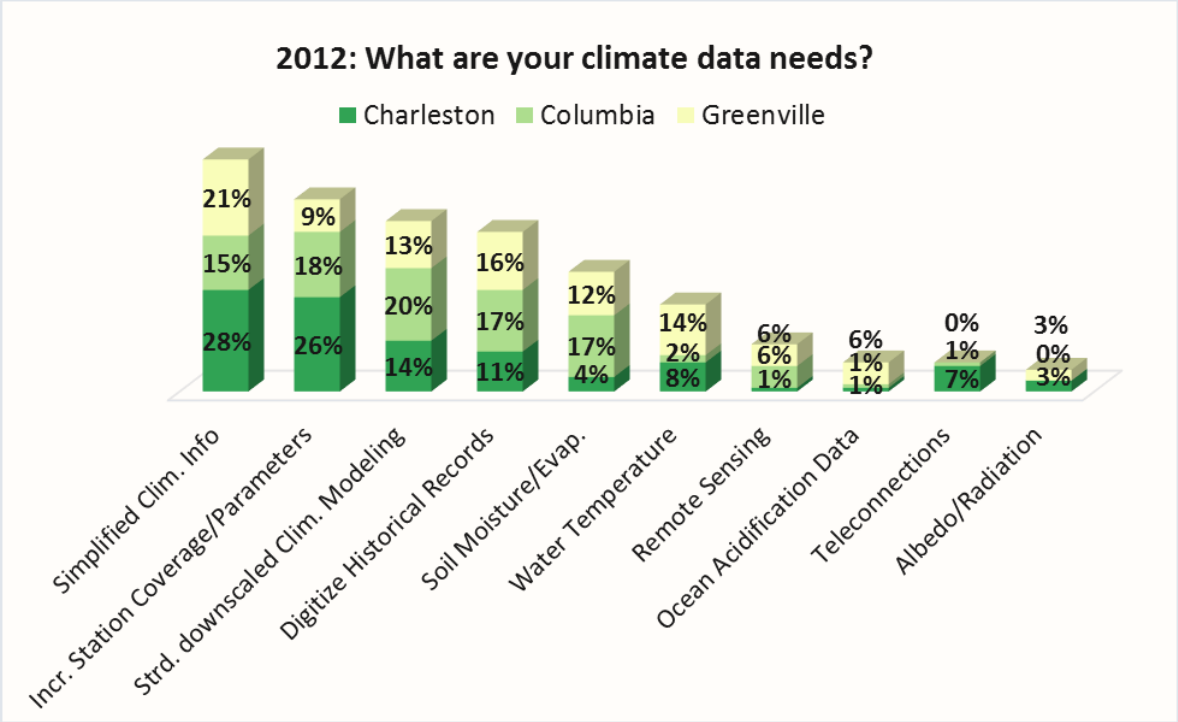

Figure 12b. Climate data needs in 2012.

Participants were asked about their critical information needs and/or tools that would decrease climate-related impact in South Carolina (Figure 13a). Greenville participants prioritized monetary resources, a centralized climate information hub, and localized modeling as their first top answers, respectively. Columbia attendees prioritized monetary resources, public outreach and education, and predictive impact modeling. In contrast, Charleston participants ranked legislation the highest, followed by monetary resources and public outreach/education.

Overall, monetary resources and legislation were ranked as the first two choices for critical information needs to reduce climate impacts in all three locations. In comparison, 2012 workshop attendees focused on information needs about local effects and impact, monetary resources, and centralized information (Figure 13b).

2017-2018 workshops participants identified primary challenges and barriers that limit their focus on climate-related work as political support, time, funding, and organizational capacity. The 2017-2018 results (Figure 14a) were similar to the responses from the 2012 workshops (Figure14b). In 2012, however, the responses ranged from funding being the highest, followed by time, expertise, and political support.

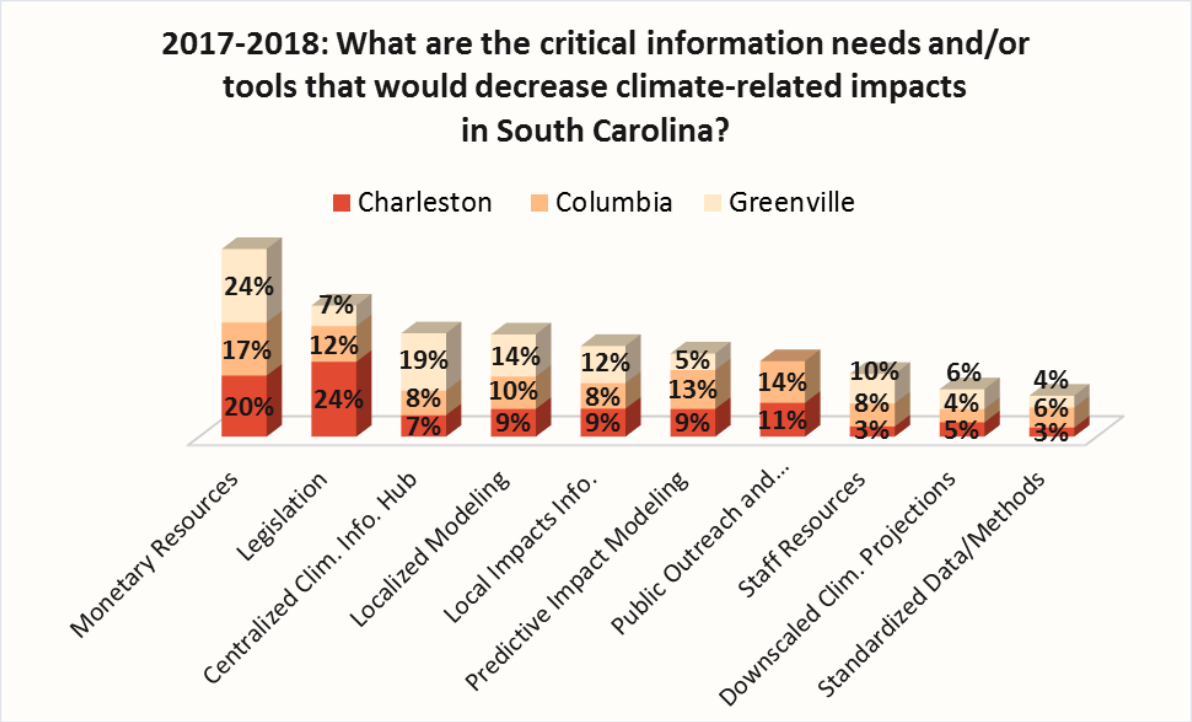

Figure 13a. Critical information needs and/or tools to decrease climate-related impacts in 2017-2018.

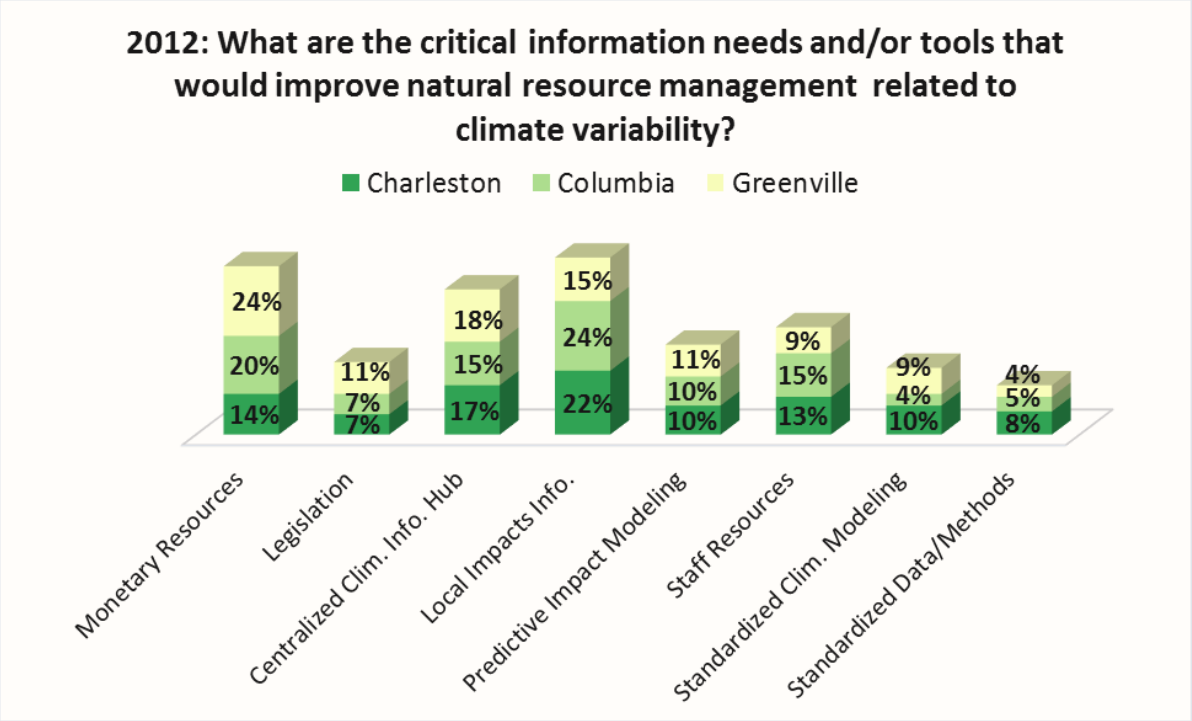

Figure 13b. Critical information needs and/or tools to improve natural resource management, 2012.

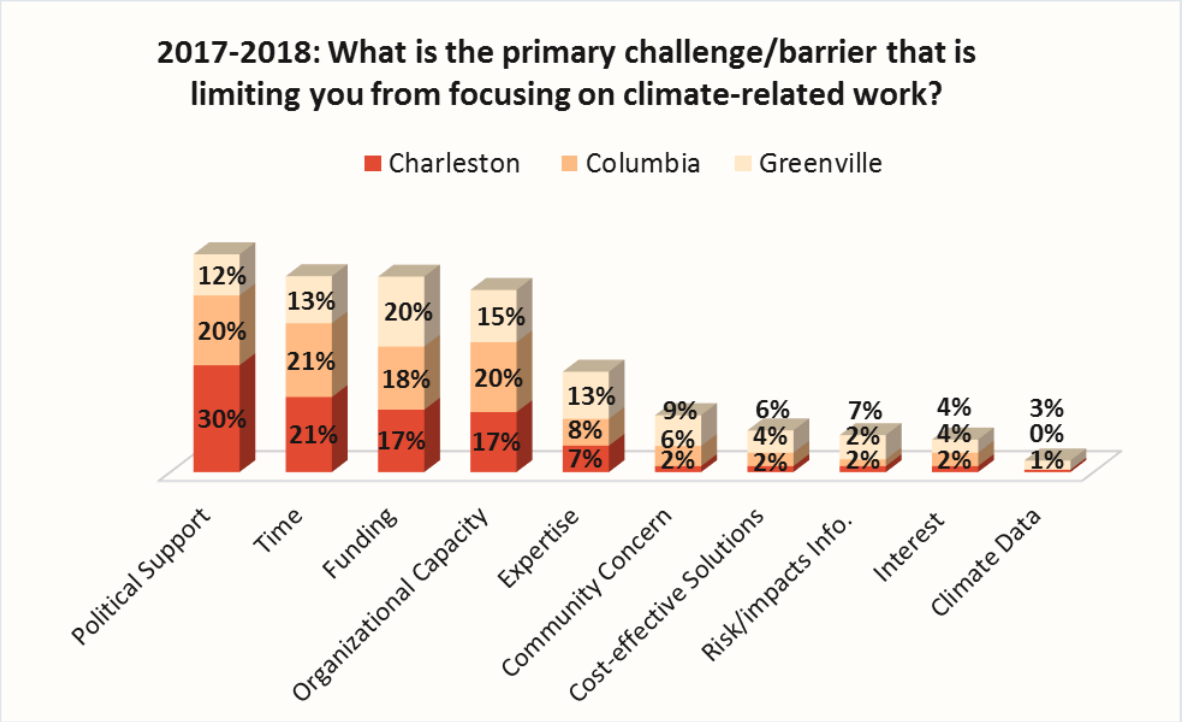

Figure 14a. Limitations to climate-related work in 2017-2018.

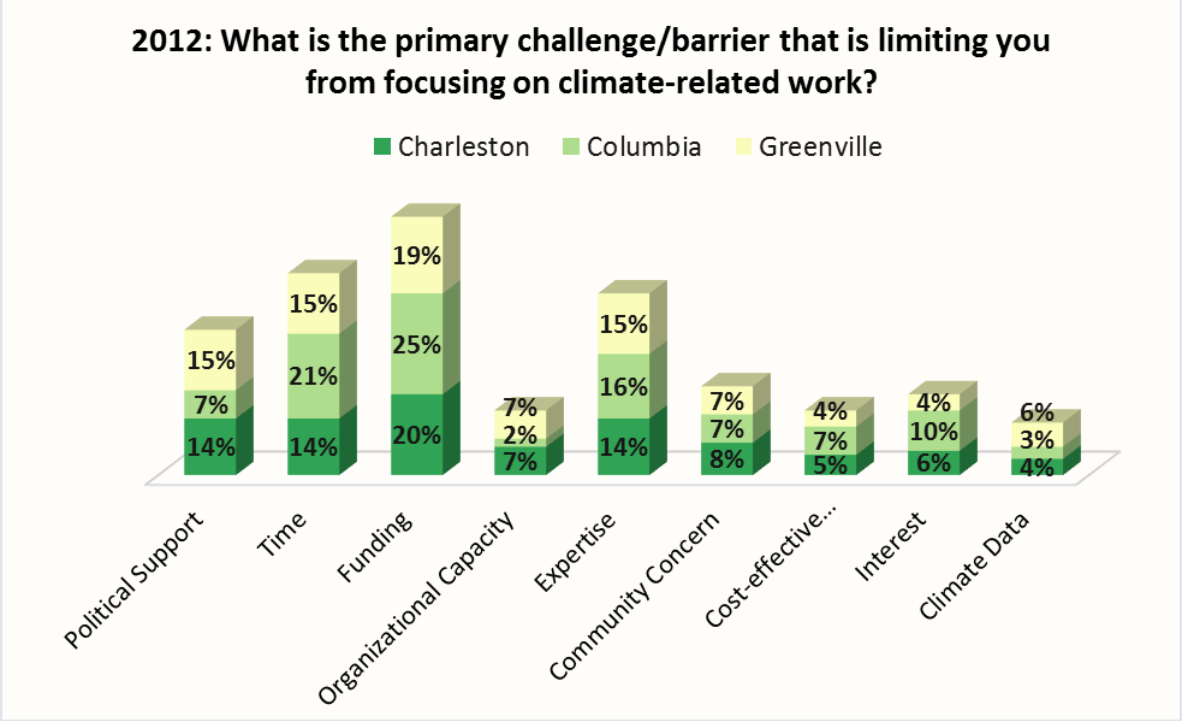

Figure 14b. Limitations to climate-related work in 2012.

Next Steps

Workshop information will be housed on the South Carolina State Climatology Office's website. This will include workshop agendas, attendee lists, and presentations as well as a copy of this final report.

Direct post-workshop goals for the state climatologist's office include utilizing connections, communicating resources, and exploring future workshops and training opportunities. The SC State Climatology Office will utilize attendee lists and comments to foster networks among decision makers. Discussion during the workshops brought forth connections between decision maker needs and resources currently available.

Communicating with decision makers will inform ways that the SC State Climatology Office might fill information gaps in available resources, potential future collaborative work, as well as workshops and training. Continued improvement in online resources, such as the recent update of the SC DNR Drought Portal, will expand the network of users that the SC State Climatology Office serves throughout the state.

Climate Connections Workshop attendees in Greenville, Charleston and Columbia, SC. Phots courtesy of CISA.

Appendix 1: Additional Resources

The table below provides a number of online resources shared by workshop presenters and attendees for extreme weather prediction and forecasts, planning tools for addressing long-term change, and case studies detailing how other communities are addressing similar issues related to extreme weather and climate change.

Organization or Resource	Description	For more information, visit:
Association of State Floodplain Managers Green Guide	This guide is intended to be used alongside the Community Rating System Coordinator's Manual, highlighting a portion of the available point elements in the manual that have "co-benefits" of reducing flood risk in a way that promotes a sustainable, healthy environment.	https://www.floodsciencecenter.org/products/crs-community-resilience/green-guide/
Carolinas Integrated Sciences and Assessments	The Carolinas Integrated Sciences & Assessments (CISA) team conducts applied research in North Carolina and South Carolina that incorporates climate information into water, health and coastal management and decision making.	http://www.cisa.sc.edu/
Carolinas Precipitation Patterns & Probabilities	An atlas of drought and heavy precipitation events in the Carolinas, including a section on impacts of events of record	http://www.cisa.sc.edu/atlas/
Decision Support System for Water Infrastructure Security	A FEMA-supported mapping system for dam safety which gives depth and speed of water flow following a failure as well as inundation depths.	https://dsswiseweb.ncche.olemiss.edu/
Georgetown Climate Center Adaptation Clearinghouse	Resources posted to this online clearing house are intended to help policymakers at all levels of government reduce or avoid the impacts of climate change on communities in the U.S.	http://www.adaptationclearinghouse.org
Hurricane Matthew Online Interactive Journal	Developed by the SC State Climatology Office, this site provides details about precipitation totals, wind gusts, flooding, and impacts caused by Hurricane Matthew.	https://scdnr.maps.arcgis.com/apps/MapJournal/index.html?appid=2ac87a4a698c4e26902c1babbdba871b
National Fire Protection Association's Firewise Program	This public education program sets standards and principals that can be used anywhere to minimize loss of life or property damage from wildfire.	https://www.nfpa.org/Public-Education/By-topic/Wildfire/Firewise-USA
NOAA Digital Coast Stories from the Field	The case studies provided through NOAA's Digital Coast website provide examples of communities throughout the U.S. who have utilized Digital Coast products and tools to incorporate climate resilience into long term planning and preparedness.	https://coast.noaa.gov/digitalcoast/stories/

NOAA National Hurricane Center	The National Hurricane Center issues watches, warnings, forecasts, and analyses of hazard tropical weather, working to increase understanding of these hazards to advance warnings for potentially impacted communities.	https://www.nhc.noaa.gov
NOAA National Weather Service Forecast Offices	There are eight NWS Weather Forecast Offices that issue local public, marine, aviation, fire and hydrology forecasts for county warning areas in the Carolinas.	https://www.weather.gov/jetstream/wfos
NOAA NWS Storm Prediction Center	The National Storm Prediction Center delivers watch and forecast products and information dealing with tornadoes, severe thunderstorms, lightening, wildfires, and winter weather.	http://www.spc.noaa.gov
NWS Southeast River Forecast Center	Specializing in hydrometeorological data, the River Forecast Center provides river flood forecasts and inland flood warnings caused by tropical cyclones and hurricanes.	https://www.weather.gov/serfc
October 2015 Heavy Rainfall and Flood Online Interactive Journal	Developed by the SC State Climatology Office, this resource provides information about the causes of the event, rainfall totals, streamflow records, and impacts to South Carolina's residents.	http://scdnr.maps.arcgis.com/apps/MapJournal/index.html?appid=bc1ea6edf5eb495189be4968e0cd0edb
South Carolina Coastal Low Impact Development Manual	This customized LID manual provides stormwater engineering specifications, land use planning resources, and site design practices tailored for conditions along the SC coast. Appendix G contains guidance for adaptation stormwater management to future climate conditions.	http://northinlet.sc.edu/lid
South Carolina Department of Transportation Public Information Portal	This public information portal includes an interactive map to view the status of projects to be completed through new SC DOT funding allocations as well as a space for public comment.	http://www.scdot.org/projects/public-involvement-portal.aspx
South Carolina Flood Mitigation Program	The South Carolina Department of Natural Resources (SCDNR), Flood Mitigation Program (FMP) administers the National Flood Insurance Program (NFIP). The mission of the SCDNR Flood Mitigation Program is to work with South Carolina citizens and communities to minimize losses due to flood conditions.	http://www.dnr.sc.gov/flood/

South Carolina State Climatology Office	The Office provides a unique service to the State by archiving and distributing climatological data to State agencies, educational and research institutions, and private citizens; much of the data is provided at no cost, or for a nominal fee. The State Climatology Office is a division within the South Carolina Department of Natural Resources.	http://www.dnr.sc.gov/climate/sco/
South Carolina Water Resources Center	The SC Water Resources Center serves as a research facilitator and acts as a conduit for information necessary in the resource management, decision-making, and policy arenas of the state.	https://www.clemson.edu/public/water/scwater/
South Carolina Water Resources Assessment Public Information Portal	This site, maintained by the SC Water Resources Center, provides updated information about the various stages in the development of the State Water Plan.	http://www.clemson.edu/public/water-assessment/
Southern Wildfire Risk Portal	A free online tool that can be used to visualize wildfire risk at the parcel level, print reports, and define areas of interest.	http://www.southernwildfirerisk.com
US Army Corps of Engineers Sea Level Change Curve Calculator	Designed for a more technical audience, this calculator allows users to develop sea level rise graphics that can be used to assess the vulnerability of a location to future sea level rise.	http://www.corpsclimate.us/ccaceslcurves.cfm

Appendix 2: Workshop Agendas

Greenville December 12, 2017 – Presentations and Agenda
Greenville County Square, Greenville, SC

9:30 **Welcome and Introductions**

9:45 **Hurricanes, Droughts, Rain Bombs, and More**
An Overview of Recent Extreme Events Affecting South Carolina
Hope Mizzell, SC State Climatologist
SC Department of Natural Resources, State Climatology Office

10:15 **How Flashy is your Flood Risk?**
Understanding the SC Flood Mitigation Program
Maria Cox Lamm, SC Flood Mitigation Program Coordinator
SC Department of Natural Resources, Flood Mitigation Program

10:45 **Break**

11:15 **After the Flood**
Revitalization of the SC Dam Safety Program
Jill Stewart, SC Dam Safety Director
SC Department of Health and Environmental Control, Dam & Reservoirs Safety Program

11:45 **Climate Impacts on the Built Environment**
Extreme Impacts to Transportation Infrastructure
Andy Leaphart, Chief Engineer for Operations
SC Department of Transportation

12:15 **Lunch**

1:00 **From Too Much to Not Enough**
South Carolina Water Planning….Planning for Which Drought?
Scott Harder, Hydrologist
SC Department of Natural Resources, Hydrology Section

1:30 **Catching Fire**
Wildfire Risks, Impacts, and Management
Darryl Jones, SC Forest Protection Chief
SC Forestry Commission

2:00 **Q&A and Discussion**

3:30 **Adjourn**

Columbia February 22, 2018 – Presentations and Agenda
The Phillips Market Center, West Columbia, SC

9: 30 **Welcome and Introductions**

9:45 **Hurricanes, Droughts, Rain Bombs, and More**
An Overview of Recent Extreme Events Affecting South Carolina
Hope Mizzell, SC State Climatologist
SC Department of Natural Resources, State Climatology Office

10:15 **After the Flood**
Revitalization of the SC Dam Safety Program
Jill Stewart, SC Dam Safety Director
SC Department of Health and Environmental Control, Dam & Reservoirs Safety Program

10:45 **Break**

11:15 **How Flashy is your Flood Risk?**
Understanding the SC Flood Mitigation Program
Maria Cox Lamm, SC Flood Mitigation Program Coordinator
SC Department of Natural Resources, Flood Mitigation Program

11:45 **Climate Impacts on the Built Environment**
Extreme Impacts to Transportation Infrastructure
Andy Leaphart, Chief Engineer for Operations
SC Department of Transportation

12:15 **Lunch (provided)**

1:00 **From Too Much to Not Enough**
South Carolina Water Planning….Planning for Which Drought?
Alex Pellett, Hydrologist
SC Department of Natural Resources, Hydrology Section

1:30 **Catching Fire**
Wildfire Risks, Impacts, and Management
Darryl Jones, SC Forest Protection Chief
SC Forestry Commission

2:00 **Q&A and Discussion**

3:30 **Adjourn**

Charleston March 22, 2018 – Presentations and Agenda
SC DNR Marine Resources Center on Ft. Johnson, Charleston, SC

9: 30 **Welcome and Introductions**

9:45 **Hurricanes, Droughts, Rain Bombs, and More**
An Overview of Recent Extreme Events Affecting South Carolina
Hope Mizzell, SC State Climatologist
SC Department of Natural Resources, State Climatology Office

10:15 **Swamped Coast**
Planning for extreme weather and sea level rise
Sarah Watson, Coastal Climate and Resilience Specialist
CISA/SC Sea Grant Consortium

10:45 **Break**

11:15 **From Too Much to Not Enough**
South Carolina Water Planning….Planning for Which Drought?
Alex Pellett, Hydrologist
SC Department of Natural Resources, Hydrology Section

11:45 **Catching Fire**
Wildfire Risks, Impacts, and Management
Darryl Jones, SC Forest Protection Chief
SC Forestry Commission

12:15 **Lunch**

1:00 **After the Flood**
Revitalization of the SC Dam Safety Program
Jill Stewart, SC Dam Safety Director
SC Department of Health and Environmental Control, Dam & Reservoirs Safety Program

1:30 **How Flashy is your Flood Risk?**
Understanding the SC Flood Mitigation Program
Maria Cox Lamm, SC Flood Mitigation Program Coordinator
SC Department of Natural Resources, Flood Mitigation Program

2:00 **Q&A and Discussion**

3:30 **Adjourn**

Appendix 3: Greenville Attendees

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