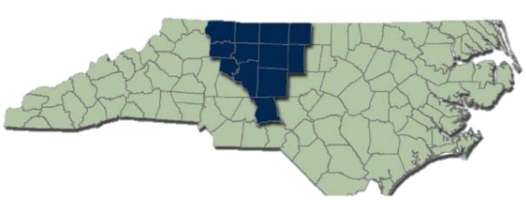
AUGUST 2018

PIEDMONT TRIAD

CLIMATE RESILIENCY TOOL KIT



PIEDMONT TRIAD
REGIONAL COUNCIL

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FOREWORD

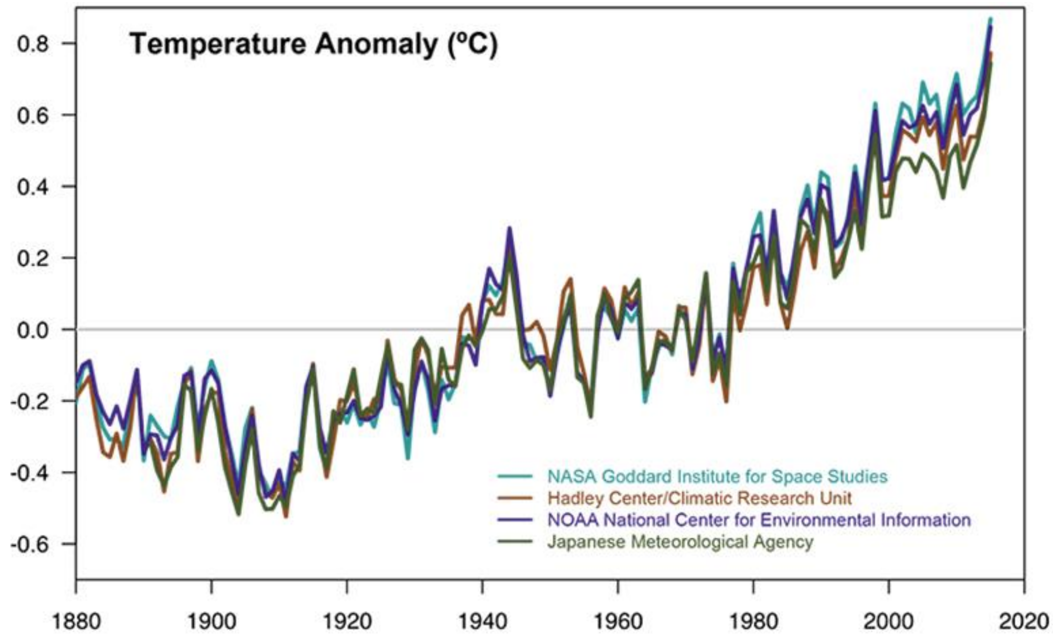
The Piedmont Triad Regional Council works closely with member governments to identify and address local and regional concerns. We recognize that there is a growing need for regional guidance on climate issues. Local decision makers need access to up-to-date and reliable information about current and projected changes in climate, the impacts of such changes, and strategies that communities can undertake to better prepare and adapt to a changing climate, so that they can make well-informed decisions and investments. The *Piedmont Triad Climate Resiliency Tool Kit* is intended to serve as a resource for the region's member communities and provide the background knowledge necessary to begin working towards a more resilient future. It summarizes existing climate data, discusses the likely local and regional impacts, and provides resources and recommendations to assist local communities in addressing these challenges. This project builds off of the *Piedmont Together Climate Adaptability Report*, which was developed in 2014 as part of a Housing and Urban Development (HUD) Sustainable Communities initiative. We hope that this report will raise awareness and understanding and better equip Piedmont Triad communities to tackle complex issues that climate change presents.

Contents

Climate Change Overview

Despite the technological advancements of modern society, the climate remains an integral part of our daily lives. It influences where we live, the food we eat, the air we breathe, and the water we drink. The climate also affects how much energy we use, our overall health, and the plants and animals that we share the planet with, which is why climate change is anticipated to be one of the most significant challenges of our time. Over the last century, Earth's average temperature has risen 1.5°F and is projected to increase another 2°F to 4°F in most areas of the United States over the next few decades (Melilo et al. 2014). 2017 was the third warmest year on record and nine of the ten hottest years have occurred since the turn of the century (Ingram et al. 2013; NOAA, 2015). These changes in global climate have contributed to the more rapid melting of the polar ice caps, warming and expansion of the world's oceans, and more frequent extreme weather events (IPCC, 2014).

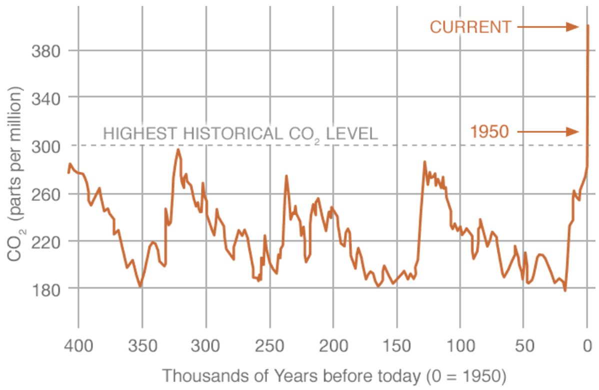
Figure 1: Observed Global Land & Ocean Surface Warming



Source: NASA 2018

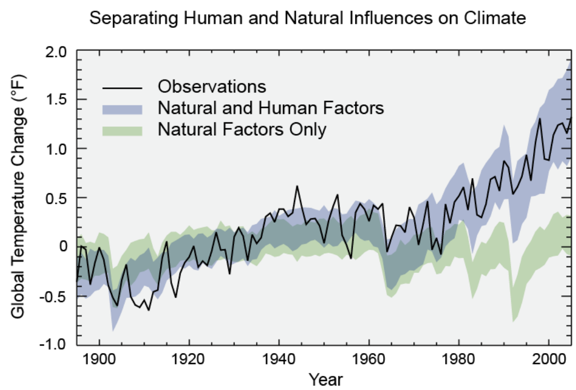
Many factors, both natural and human, can influence Earth's climate, including changes in Earth's orbit or the sun, changes in the composition of Earth's atmosphere, or changes in cloud or land cover. Historically, the Earth has gone through natural cycles of warming and cooling. However, recent warming has taken place at an unprecedented pace (Milman, 2016). 97% of scientists agree that this is mostly a result of human influence, in particular, the burning of fossil fuels (UCS, 2018). When burned, fossil fuels release CO_2 into the atmosphere, which causes what is referred to as the "greenhouse effect."

Figure 2: Observed CO_2 Levels



Source: NASA 2018

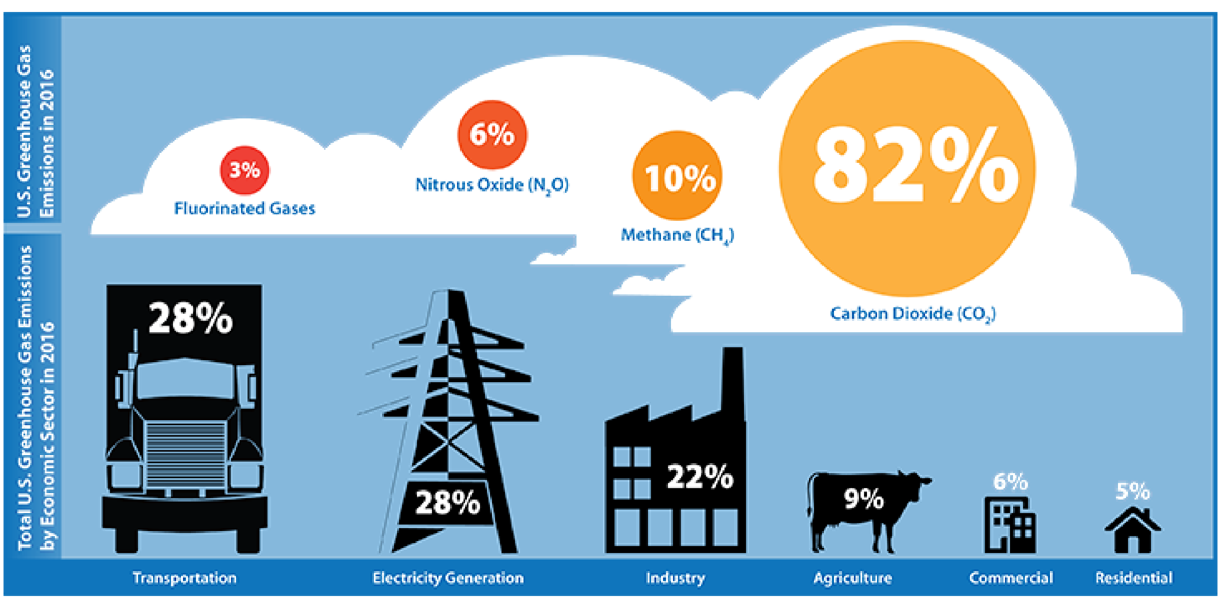
Figure 3: Human vs. Natural Influences on Climate



Source: U.S. EPA, 2017

The greenhouse effect occurs when Earth's atmosphere traps solar radiation because of the presence of certain gases, like CO_2, methane, and water vapor. It is important to note that the greenhouse effect is a natural phenomenon. In fact, without the greenhouse effect the Earth's average global temperature would be much colder and life on Earth as we know it would not be possible. However, when there are too many greenhouse gases in the atmosphere, it can result in excessive warming. Greenhouse gases are released into the atmosphere from a variety of sources. The most significant sources in the U.S. are transportation, electricity generation, and industrial processes (U.S. Environmental Protection Agency, 2018).

Figure 4: Greenhouse Gas Emissions by Economic Sector



Source: U.S. EPA, 2018

Due to the nature of greenhouse gas accumulation, we can anticipate that at least some degree of climate change and related impacts are inevitable. Greenhouse gases persist in the atmosphere for an extended period of time. Even if all greenhouse gas emissions were stopped tomorrow, the world would continue to experience accelerated changes in the climate for years to come. However, the amount and extent of those future changes will still largely be determined by societal choices (Melilo et al. 2014).

This range of climate outcomes is often represented in climate models and projections using scenarios called representative concentration pathways (RCPs). These scenarios were established by the Intergovernmental Panel on Climate Change (ICPP) to help ensure consistency between various climate studies. The four pathways include RCP 8.5, RCP 6, RCP 4.5, and RCP 2.6. RCP 2.6 represents the best case scenario in which both developing and developed countries make significant reductions in greenhouse gas emissions. RCP 8.5, on the other hand, describes the worst case scenario, in which emissions continue to rise throughout the early and mid-century (Vuuren et al. 2011).

While the impacts of climate change are global, many of its effects are felt locally. A survey of stakeholders within the Piedmont Triad revealed that 64.7% of respondents have already observed shifts in climate that have impacted their day-to-day operations – primarily temperature extremes, drought, changes in the length of seasons, and flooding. These and other consequences of climate change can hurt local businesses, strain local resources, and place additional burdens on already stressed systems. As weather patterns continue to change, Piedmont Triad towns and counties will encounter new risks, vulnerabilities, and challenges that may not be adequately addressed using existing practices.

It is crucial that local communities begin assessing their existing policies, infrastructure, and facilities now. Proactively preparing for climate change can reduce impacts, save money, and enable communities to more rapidly and efficiently respond to changes as they happen. This ability to anticipate, adapt, and flourish in the face of climate change is often referred to as climate resiliency (U.S. Federal Government, 2014). Such efforts are beginning at the federal, regional, state, tribal, and local levels, and in the corporate and non-governmental sectors, to build adaptive capacity and minimize any anticipated impacts.

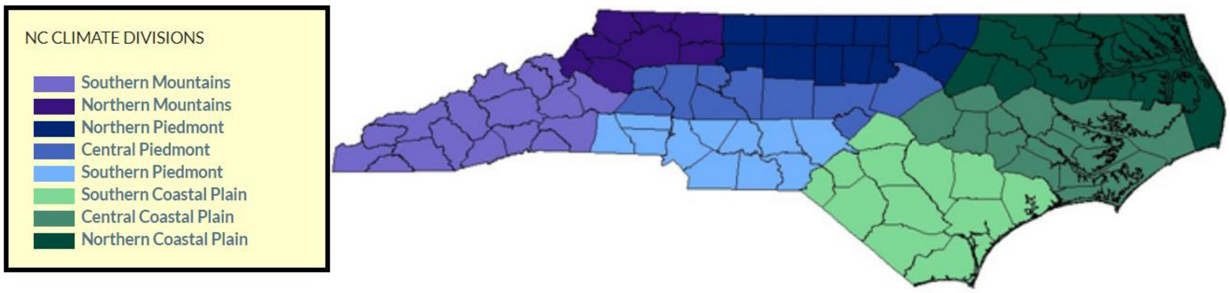
The *Piedmont Triad Climate Resiliency Tool Kit* is intended to serve as a resource for the region's member communities and provide the background information and resources necessary to begin working towards a more resilient future. The *Tool Kit* summarizes existing climate data for the region, discusses the likely local and regional impacts, and provides resources and recommendations to assist local communities in addressing these challenges. As indicated by our regional survey, climate change is already impacting the lives, economies, and environment of the Piedmont Triad. By taking proactive steps, we can mitigate these impacts and ensure that the region remains economically competitive, socially healthy, and environmentally resilient.

Climate in the Piedmont Triad

Introduction

Climate in the Piedmont Triad is primarily defined by North Carolina's humid, subtropical climate. Winters are typically short and mild, while summers are usually hot and humid. In most of the state, temperatures rarely go above 100°F or fall below 10°F, but differences in altitude and proximity to the ocean create significant local variations, resulting in eight climatological divisions throughout the state (North Carolina Climate, 2018). The Piedmont Triad includes three of these climate zones; the Northern Piedmont, Central Piedmont, and Southern Piedmont.

Figure 5: North Carolina Climate Divisions



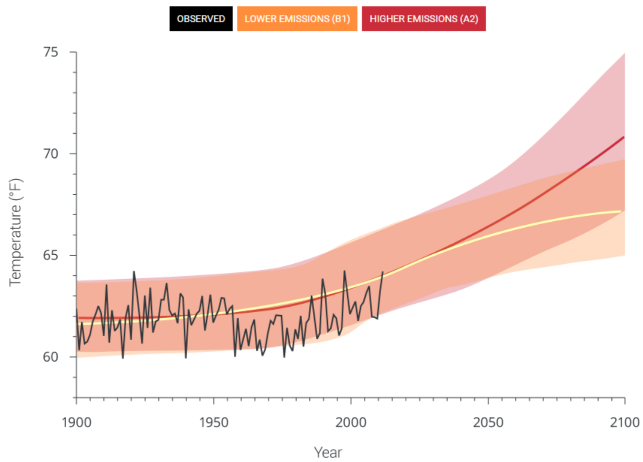
Source: North Carolina Climate, 2018

The region's climate also varies considerably over seasons, years, and decades, primarily due to natural cycles, such as the El Niño-Southern Oscillation (ENSO), differences in atmospheric pressure, and landfalling tropical weather systems. These cycles alter the occurrences of hurricanes, tornadoes, droughts, flooding, freezing winters, and ice storms in the region (Carter et al. 2014).

Temperature

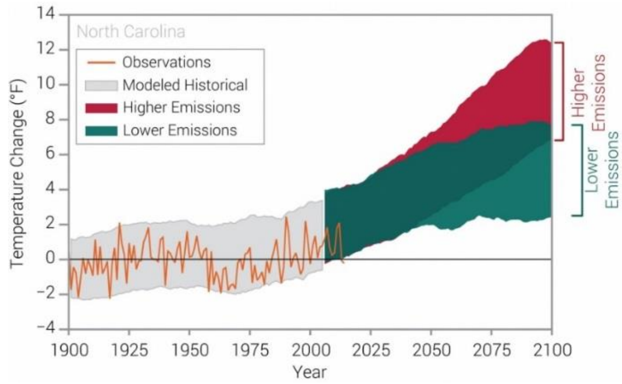
North Carolina and the larger southeastern region of the U.S. have exhibited little overall warming in surface temperatures over the 20th century. Since 1900, mean annual temperature has increased by under 1°F in North Carolina. Across the broader Southeast, mean annual temperatures have cycled between warm and cool periods, with a warm peak occurring during the 1930s and 1940s followed by a cool period in the 1960s and 1970s. Since that time, temperatures have increased again throughout the Southeast by an average of 2°F, with higher average temperatures during summer months. However, there has been a substantial increase in the numbers of days above 95°F and nights above 75°F since 1970, as well as a decrease in the number of extremely cold days. North Carolina has also experienced the warmest summer temperatures on record over the last decade (Frankson et al. 2017; Carter et al. 2014).

Figure 6: Southeast Temperature: Observed & Projected



Source: Carter et al. 2014

Figure 7: NC Temperature Change: Observed & Projected



Source: Frankson et al. 2017

Temperatures across the Southeast are expected to increase more drastically throughout this century, averaging 4°F to 8°F warmer by 2100 under both climate scenarios (Carter et al. 2014). Estimates for North Carolina predict similar results. Under a lower emission scenario temperatures are expected to increase by 4°F and roughly 9°F if emissions continue to grow (Frankson et al. 2017). This warming is anticipated to result in a significant increase in the number of extremely warm days (over 95°F) and a decrease in the number of days below freezing.

Figure 8: Projected Change in Number of Days Over 95°F

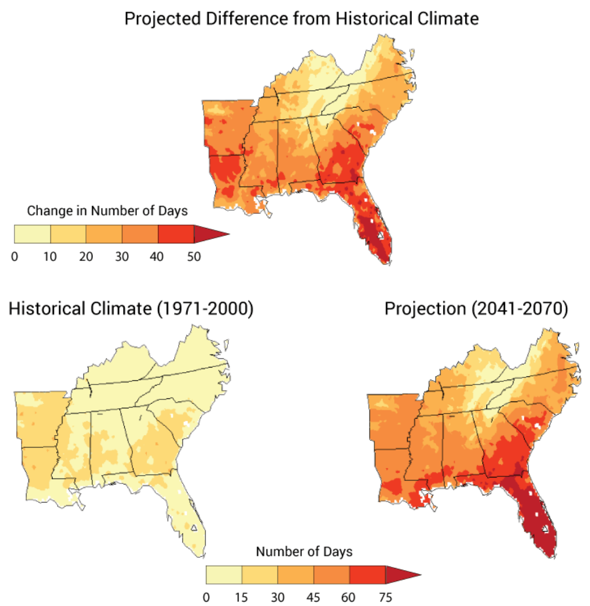
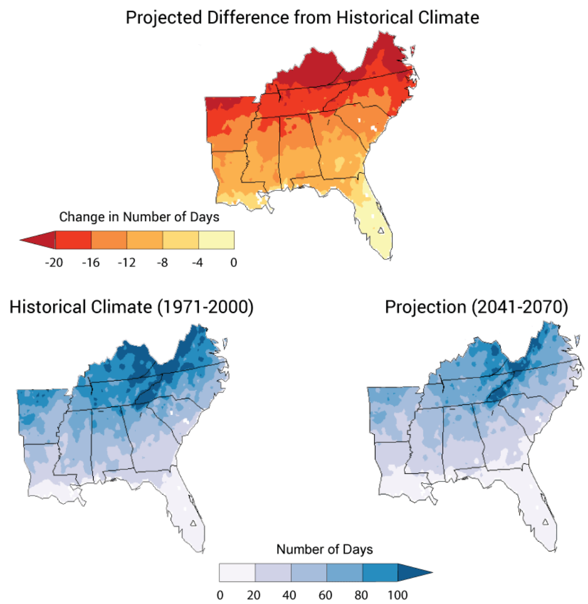


Figure 9: Projected Change in Number of Nights Below 32°F



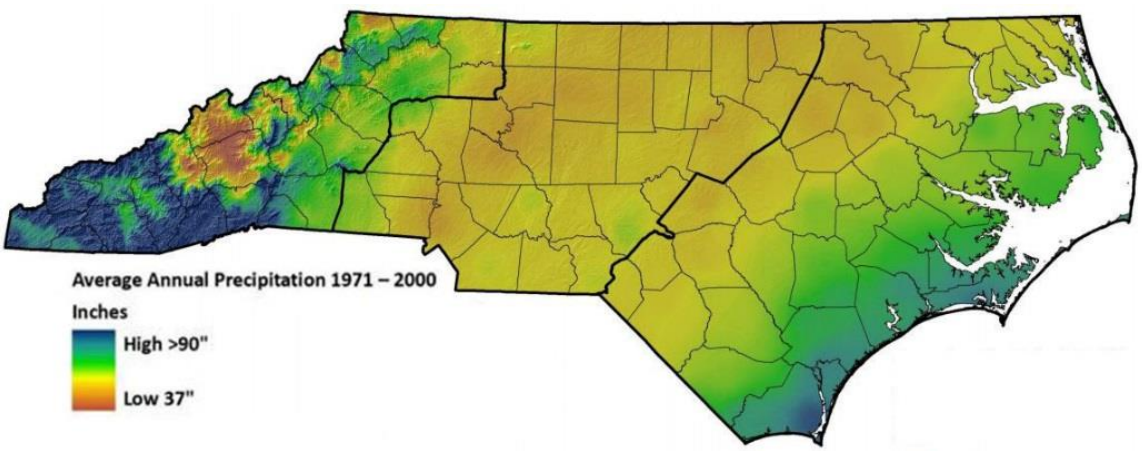
Source: Frankson et al. 2017

Precipitation

Average rainfall varies significantly between North Carolina's coast, Piedmont, and mountain regions. Statewide average annual precipitation has ranged from a low of 34.7 inches in 2007 to a high of 63.2 inches in 2003, with the driest multi-year periods occurring in the early 1930s and 1950s, and the wettest happening in the late 1900s, early 1940s, 1970s, and late 1990s. Between 1971 and 2000 the Piedmont Triad region observed an average of 45-55 inches of rainfall per year (Frankson et al. 2017; NC ILT 2012).

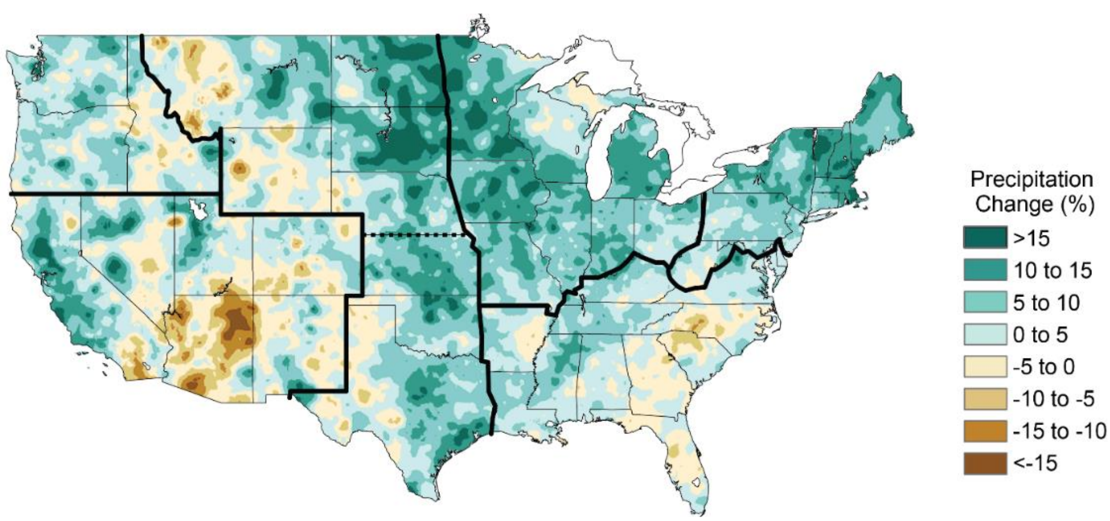
There have been no clear long-term trends in precipitation across North Carolina since 1895. However, there has been a slight upward trend in fall season precipitation and a slight downward trend in summer season precipitation. Generally, precipitation totals are highest in the summer, with a peak in July. The frequency of extreme precipitation events has also increased, particularly over the last two decades (Frankson et al. 2017; Carter et al. 2014).

Figure 10: Observed Precipitation in North Carolina



Source: NC ILT, 2012

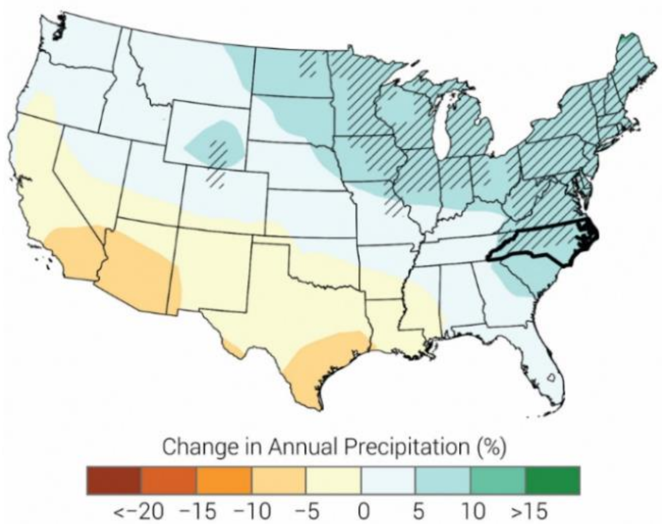
Figure 11: Observed Precipitation Change in the U.S. from 1991-2012 (compared to 1901-1960)



Source: Walsh, 2014

Projections of future precipitation patterns are less certain than projections for temperature increases because models are often unable to resolve regional and local-scale processes, like sea breezes and the location of the Bermuda High, a semi-permanent high-pressure system off the Atlantic Coast. The Southeast is also located in a transition zone between projected wetter conditions to the north and drier conditions to the southwest, which results in many of the model projections showing only small changes relative to natural variations. However, generally, the models have projected that annual precipitation will increase in North Carolina, especially in the winter and spring, by as much as 6% (NC ILT, 2012; Frankson et al. 2017).

Figure 12: Projected Change in Annual Precipitation

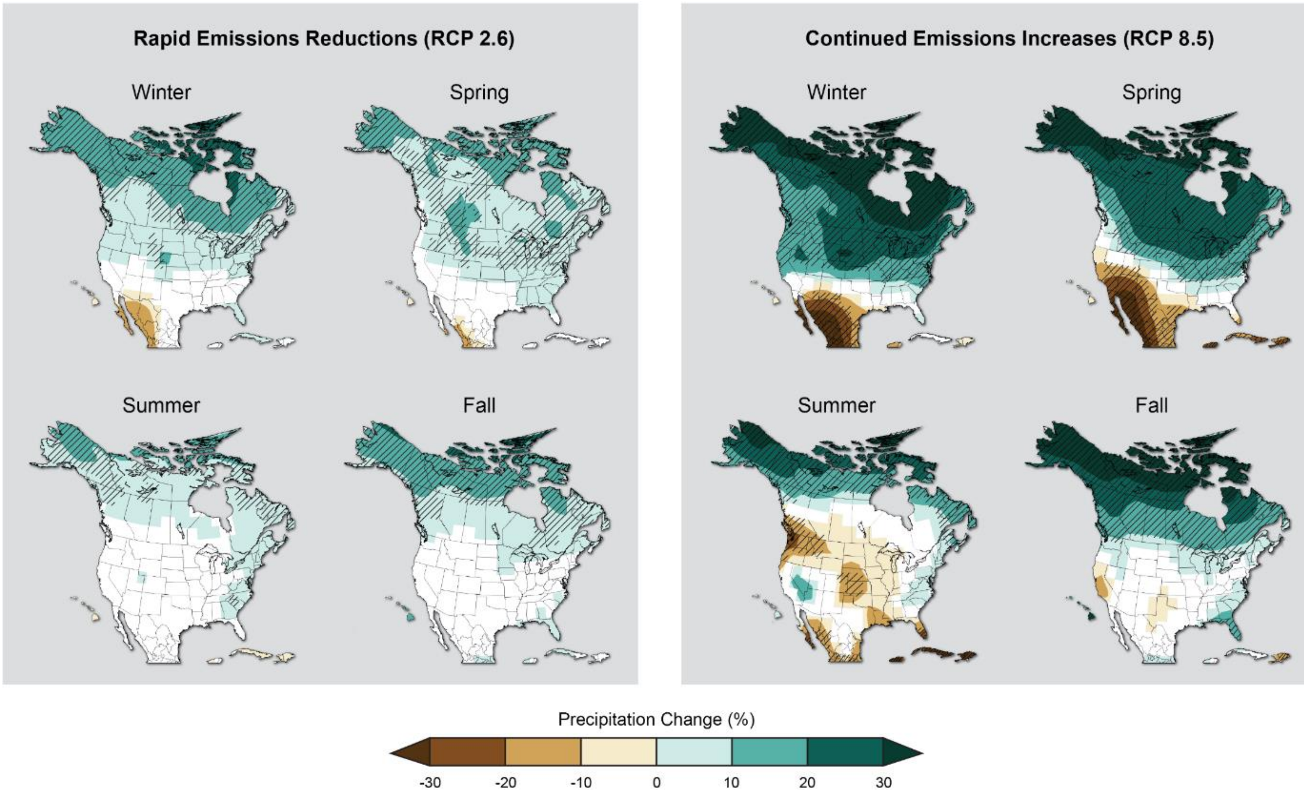


Projected change in annual precipitation (%) for the middle of the 21st century relative to the late 20th century under a high emissions pathway. Hatching represents portions of the state where the majority of climate models indicate a statistically significant change (Frankson et al. 2017).

Source: CICS-NC, NOAA NCEI, and NEMAC.

Scientists are more certain that there will be greater variability in precipitation within the region. Large increases in extreme precipitation have been observed during the last century and early this century, and are expected to continue as this century progresses. Naturally occurring droughts are also projected to be more intense as a result of higher temperatures.

Figure 13: Projected Precipitation Change by Season for 2071-2099 (compared to 1970-1999)



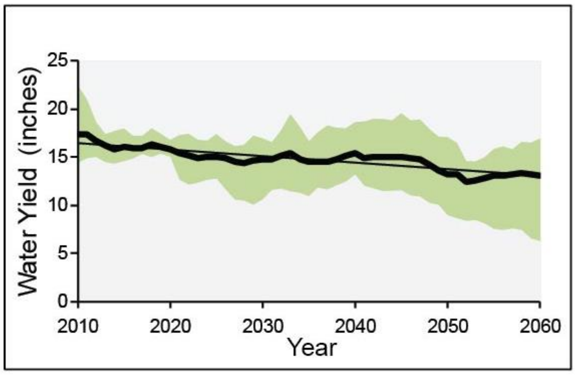
Source: NOAA NCDC / CICS-NC

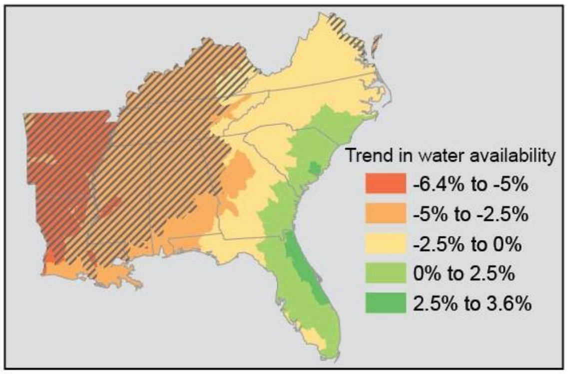
Water Availability

Historically, the Piedmont Triad and greater Southeast have been "water rich" regions where water is abundant. Several human-made reservoirs have been established across the region for both energy generation and water security. However, North Carolina and the Southeast have also experienced extensive droughts, such as the one in 2007, which severely strained North Carolina water resources and created major water conflicts between Georgia and Florida. While there is still some uncertainty about projected precipitation, it is reasonable to assume that water availability will be an increasing concern as temperatures continue to rise and precipitation becomes more erratic. Water yields are anticipated to decrease in the Southeast by around 3" and by 0-2.5% in the Piedmont region (Ingram et al. 2013).

Water supply and demand in the Piedmont Triad are influenced by many changing factors, including climate, population, and land use. The Piedmont Triad has seen a significant amount of growth in the past few decades and is expected to continue to grow in population over the course of this century. Warmer temperatures result in higher evaporation rates of local water resources and also cause higher water demand for agriculture and energy use. This, in combination with the increase in population and development, will increase water competition and threaten the region's economy and unique ecosystems.

Figure 14: Trends in Water Availability





Left: Projected trend in Southeast-wide annual water yield (equivalent to water availability) due to climate change. The green area represents the range in predicted water yield from four climate model projections based on the A1B and B2 emissions scenarios. Right: Spatial pattern of change in water yield for 2010-2060 (decadal trend relative to 2010). The hatched areas are those where the predicted negative trend in water availability associated with the range of climate scenarios is statistically significant (with 95% confidence). As shown on the map, the western part of the Southeast region is expected to see the largest reductions in water availability. (Figure source: adapted from Sun et al. 2013).

Source: Climate Change Impacts in the United States: The Third National Climate Assessment

Extreme Weather in the Piedmont Triad

Before discussing extreme weather and the potential impacts of global climate change on extreme events, it is important to distinguish between the terms “climate” and “weather.” “Climate is defined as the long-term average of the weather in a given place,” while “weather is the state of the atmosphere at any given time and place.” The history of the Piedmont Triad’s weather defines its climate; its current weather patterns may significantly deviate from this history or may be the same. The sources of any changes to local weather patterns may be local to the region or may stem from other places (NC ILT, 2012).

Over the past several decades, much of the U.S. has experienced more frequent and extreme weather and climate events. Heavy downpours and associated flooding have increased nationally, heat waves have become more frequent and intense, and the intensity, frequency, and duration of North Atlantic hurricanes, as well as the frequency of the strongest (Category 4 and 5) hurricanes, have all increased since the early 1980s (Walsh et al. 2014). While our understanding of how climate change affects extreme weather is still developing, there is mounting evidence that suggests that global changes in climate are contributing to these shifts in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events and that extreme weather will continue to intensify throughout the coming century (IPCC, 2014).

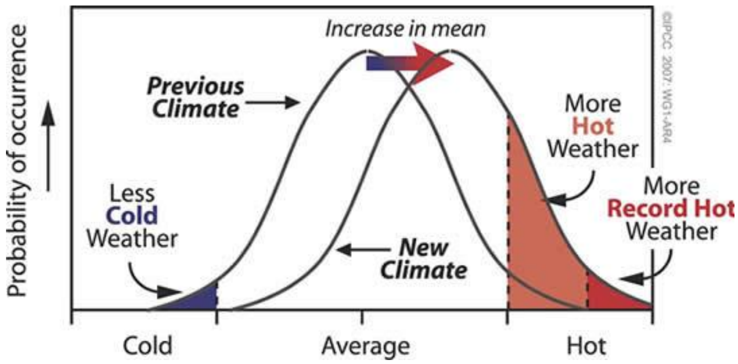
The International Panel on Climate Change (IPCC) regularly reviews scientific evidence of climate change and the influence that it may have on extreme weather. According to their analyses of current scientific research and knowledge:

Temperature Extremes	It is very likely that that increases in the frequency of warm daily temperature extremes and decreases in cold extremes are a result of human influence and it is virtually certain that temperatures will continue to warm through the 21st century.
Heat Waves	It is likely that the increases in heat wave frequency and duration over most land areas is a result of human influence and it is very likely that heat waves will continue to increase in frequency and duration through the 21st century.
Heavy Precipitation	There is medium confidence that increases in the frequency, intensity, and/or amount of heavy precipitation is a result of human influence and it is very likely that precipitation will continue to escalate through the 21st century.
Drought	There is low confidence that increases in the intensity and/or duration of drought is a result of human influence, but it is likely that episodes of drought will continue to worsen throughout the 21st century.
Tropical Cyclones & Hurricanes	There is low confidence that increases in intense tropical cyclone activity are a result of human activity, but it is more likely than not that the frequency and intensity of tropical cyclones will continue to increase throughout the 21st century.

Source: International Panel on Climate Change (IPCC)

The primary way climate change influences individual extreme weather events is by increasing the probability that they will occur. Small changes in the average distribution of many key climate variables can correspond to large changes in the frequency and intensity of extreme weather events. Like most instances, variability in weather can be represented by a bell-shaped curve. Typical weather events occur very frequently, while extreme events or outliers occur less often. A small increase in average temperature shifts the entire curve forward, establishing a new norm and increasing the likelihood of the rarest and most extreme events that were previously considered outliers (Trenberth et al. 2018).

Figure 15: How Shifts in Average Temperature Influence Extremes



Source: Trenberth et al. 2018

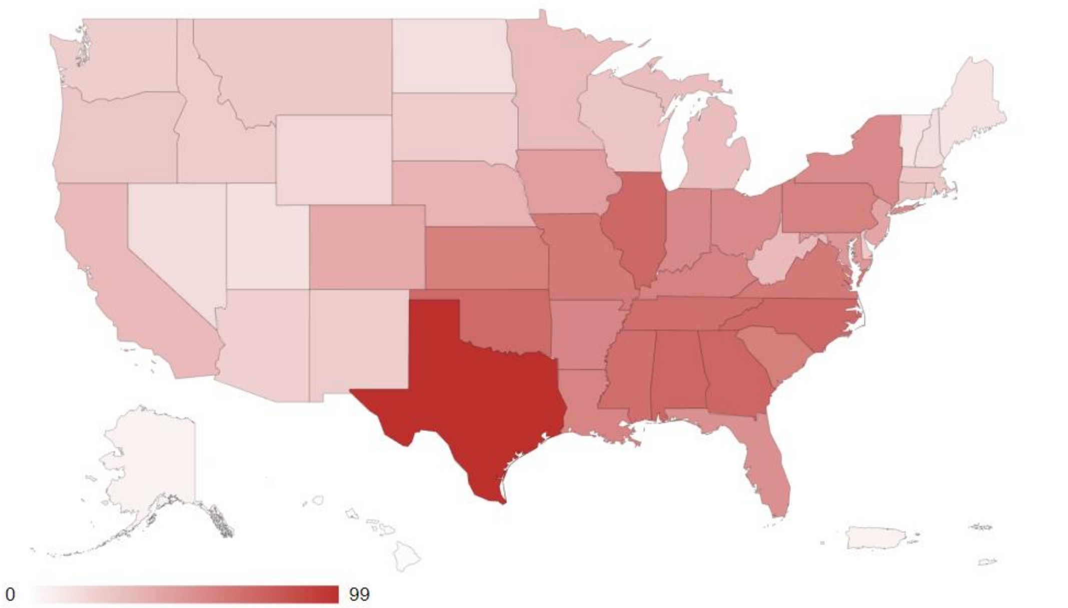
North Carolina and the Piedmont Triad encounter a wide variety of major weather events (except monsoons). In any given year, the region could face hurricanes, floods, droughts, heat waves, winter storms, cold spells, hail, high winds, lightning, wildfires, and tornadoes. While the Piedmont Triad is not a coastal region, it is also worth noting that North Carolina is at extreme risk from sea level rise (NC ILT, 2012). In recent years, there has been an exceptional number of extreme weather and climate events in North Carolina. Since 2006, the state has:

- Set statewide records for the all-time warmest month (August 2007), warmest summer (2010), and the warmest year on record (2017);
- Suffered its worst drought in more than 100 years (summer-winter 2007);
- Experienced its worst tornado outbreak in the modern record (April 2011);
- Been impacted by eighteen tropical cyclones (hurricanes, tropical storms, or tropical depressions), including Matthew and Irene; and
- Recorded at least one extreme precipitation event (3” or more in 24 hours) at half the state’s weather stations.

This trend of more frequent and extreme weather within North Carolina and the Piedmont Triad is expected to continue to increase as climate change progresses throughout the 21st century. Based on current research, the region is forecasted to experience more extreme heat and fewer days of freezing temperatures, more frequent drought and increased heavy precipitation events, more intense hurricanes, and fundamental changes in the native environment (NC ILT, 2012). These changes in local weather patterns pose significant risks to the region’s cultural resources, transportation systems and infrastructure, water supplies, agriculture, natural systems, public health, and citizens’ homes and livelihoods.

Climate change and extreme weather is not just an environmental issue, but an economic issue as well, as weather variability can be extremely costly. Since 1980, the number of weather and climate disasters exceeding $1 billion in the U.S. has increased by 400% and have altogether cost $1,585 billion. Weather disasters in the southeast have exceeded the total number of billion-dollar disasters experienced in all other regions of the country combined. North Carolina, in particular, has one of the highest rates of natural disasters nationally and receives more federal assistance for disaster recovery than most states in the U.S. (NCEI, 2018).

Figure 16: 1980-2018* Billion-Dollar Weather and Climate Disasters (CPI-Adjusted)



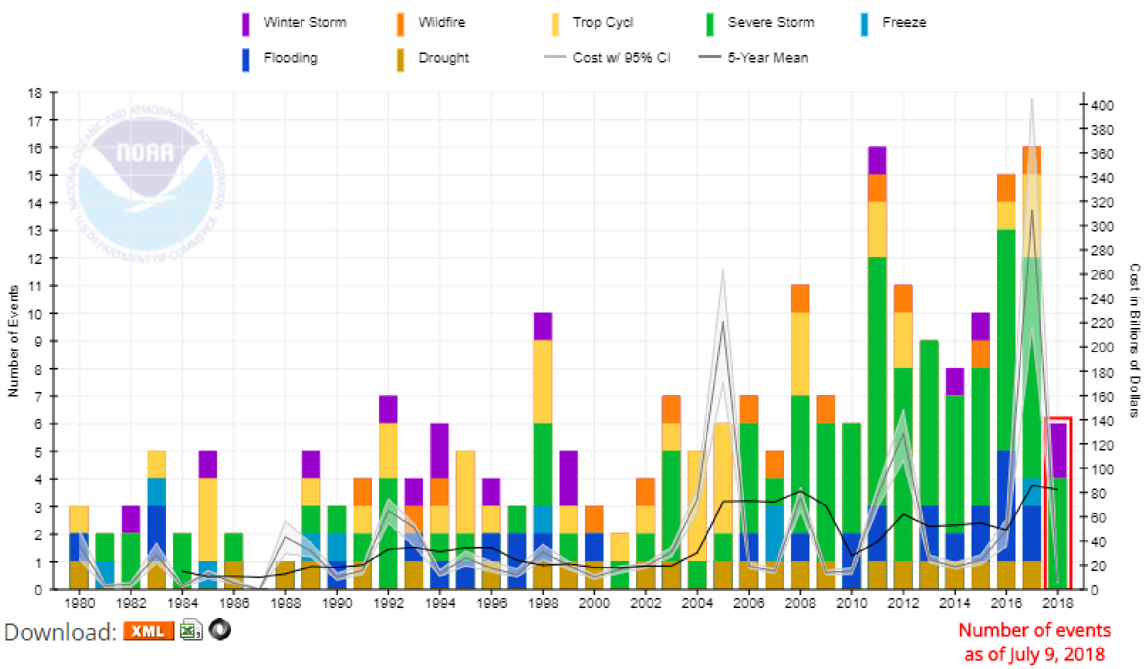
Please note that the map reflects a summation of billion-dollar events for each state affected (i.e., it does not mean that each state shown suffered at least $1 billion in losses for each event). Display as PNG

*as of April 6, 2018

Source: NOAA NCEI, 2018

The costs of extreme weather events in the U.S. continue to increase with every year. Part of this increase in costs is a result of increases in population and wealth. However, it is also a reflection of the observed increase in storm frequency and magnitude (Trenberth et al. 2018). Severe storms have been the most common type of extreme weather in the past decade, followed by flooding and tropical storms. These events disrupt businesses, damage infrastructure, and threaten lives.

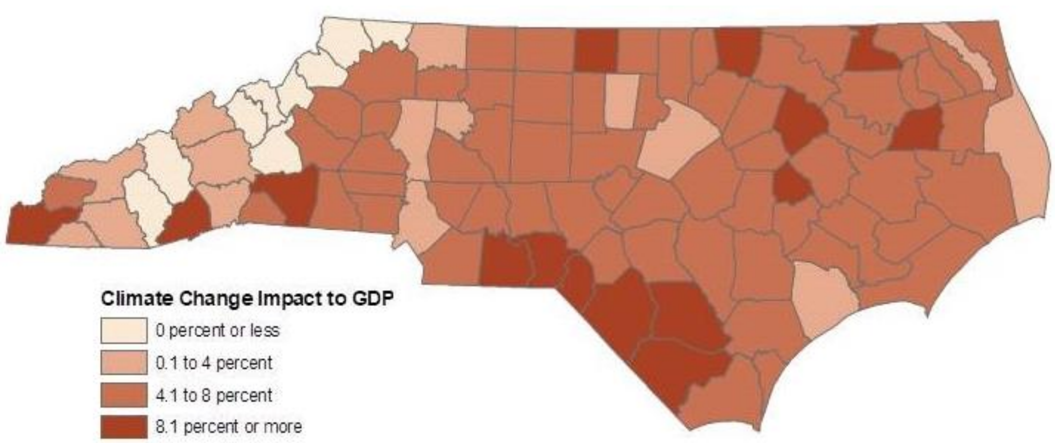
Figure 17: Billion-Dollar Disaster Event Types by Year (CPT-Adjusted)



Source: NOAA NCEI, 2018

Based on a recent study published in *Science* magazine, climate change could negatively impact Piedmont Triad counties by as much as 8% of their gross domestic product (GDP) by the end of this century (Toledo, 2017). This would place additional pressures on already strained local budgets and communities. It is clear that to protect the region's economy and quality of life, the Piedmont Triad needs to plan and make the investments necessary to improve resiliency and minimize any potential risks from climate change.

Figure 18: Projected Economic Impacts from Climate Change to North Carolina



Source: Toledo, 2017

Despite these alarming projections, climate change may less dramatically alter lifestyles and the environment in the Piedmont Triad than in other regions of the nation and the world. The region does not face the same water shortages as the western U.S. or threats of sea level rise as North Carolina's coastal communities. Nevertheless, based on previous extreme weather events, the region is not ready to address more of the same events, let alone the "new normal" in which extreme weather events are twenty times likelier to occur than they were fifty years ago (Ingram, *et al.,* 2013; NC ILT, 2012). Therefore, the region must be proactive and establish new policies and programs, as well as infrastructure investments, to improve resiliency and reduce the risks associated with a changing climate. The following sections explore in more detail the potential impacts that climate change may have on agriculture, stormwater, water supply, and drought and how the region can better protect available water resources.

Agriculture

Introduction

Weather and climate play an integral role in the success (or failure) of any agricultural operation. Plant and animal growth and survival depend heavily on a delicate balance of sunlight, water, and nutrients. Slight variations in these factors, especially at critical stages of life, can greatly impact the quality and yield of agricultural products (Vining, 1990). Weather also affects the logistics around planting, harvesting, and transporting goods, requiring farmers to make time-sensitive decisions to avoid losses.

The agricultural sector has continually adapted over the years to mitigate changing weather conditions through adjustments in crop rotations, planting schedules, genetic selection, pest and fertilizer management, water management, technological advancements, and other management strategies. However, more recent, rapid changes in climate are beginning to present new challenges for agribusinesses throughout the region. As these shifts continue over the next several decades, as anticipated by a consensus of the scientific community, it will be increasingly imperative that farm owners and operators be well informed and prepared to address such changes.

Agriculture within the Region

Agriculture is one of North Carolina's top industries, making up over 17% of the state's annual income and employing 17% of the state's workforce. The state ranks 8th in the nation in total agricultural cash receipts, and first in tobacco and sweet potato production. Agriculture, similarly, plays a significant role in the Piedmont Triad's regional economy. According to the most recent Census of Agriculture, which was completed in 2012, there is a total of 1,081,709 acres of farmland within the region, which makes up 10,373 individual farms (USDA NASS, 2012). About half of these farms are animal operations, while the rest produce crops for food or consumer products. The agribusiness sector has only increased since this time, showing 12.6% cluster growth between 2013 and 2016 (EMSI, 2016.4). Regionally, there has also been substantial growth within the agritourism industry, with more and more farms expanding their services to include entertainment, educational and recreational opportunities (USDA NASS, 2012).

Given the economic and cultural significance of agriculture within the region and weather's influence over farm management practices, it is vital that the region's agricultural industry be well-equipped to deal with anticipated shifts in climate. Climate change has the potential to both positively and negatively affect the location, timing, and productivity of crop, livestock, and fishery systems at local, national, and global scales (Hatfield et al. 2014). This directly impacts agricultural bottom lines, pricing, and the stability of food supplies, potentially creating new food security challenges for the region.

These impacts are not limited to just the Piedmont Triad region, however. Agricultural operations within the Piedmont Triad also participate in a larger, global economy, in which agricultural exports have outpaced imports within the U.S. for the past few decades. Climate change will affect the amount of produce available for export, as well as the balance between supply and demand globally (Hatfield et al. 2014). The following section dissects some of these anticipated challenges for local agriculture, their interconnections, and presents tools and strategies to help Piedmont Triad farmers better address these issues.

Direct Effects

Temperature

Plant growth and development is largely dependent upon the surrounding temperature. Each species has a temperature range that they are best suited for, typically represented by a minimum, maximum, and optimum temperature. The minimum and maximum temperatures are the boundaries for growth, while the optimum temperature allows for the greatest growth (Hatfield & Prueger 2015). Beyond a certain point, higher air temperatures negatively affect plant growth, pollination, and reproductive processes (Klein et al. 2007; Sacks and Kucharik 2011). However, as air temperatures rise beyond the optimum, instead of gradually decreasing, crop yield losses begin to accelerate rapidly (Hatfield & Prueger, 2015).

For vegetables, exposure to temperatures between 1.8°F to 7.2°F above optimal temperatures moderately reduces yield, while exposure to temperatures more than 9°F to 12.6°F above optimal temperatures often leads to severe if not total production losses. Researches have summarized the minimum, maximum, and optimum temperatures for a number of other plant species, as well as thresholds to use when assessing the potential effects of increasing temperature on crop growth (Hatfield et al. 2011). This information can be a useful resource for farm managers as they plan for future crop management and has been simplified for ease of use in Table 1.

Table 1: Optimal Temperatures (F°) for Economically Significant Crops

Crop	Min. Temp. Vegetative	Opt. Temp. Vegetative	Min. Temp. Reproductive	Opt. Temp. Reproductive	Opt. Temp. Range Vegetative Production	Opt. Temp. Range Reproductive Yield	Failure Temp. Reproductive Yield
Maize	46.4°	93.2°	46.4°	93.2°	-	64.4°-77°	95.0°
Sorghum	46.4°	93.2°	46.4°	87.8°	78.8°-93.2°	77°	95.0°
Bean	-	-	-	-	73.4°	73.4°-75.2°	89.6°
Cotton	57.2°	98.6°	57.2°	82.4°-86°	93.2°	77°-78.8°	95.0°
Peanut	50.0°	-	-	-	-	-	-
Rice	46.4°	96.8°	46.4°	91.4°	91.4°	73.4°-78.8°	95°-96.8°
Soybean	44.6°	86.0°	42.8°	78.8°	77°-98.6°	71.6°-75.2°	102.2°
Wheat	32.0°	78.8°	33.8°	78.8°	68°-86°	59.0°	93.2°

Source: Hatfield et al. 2011

These same temperature ranges were used in several simulation models which found that predicted increases in temperature could lead to yield declines between 2.5% and 10% across a number of agronomic species throughout the 21st century. Other evaluations have yielded mixed results. Lobell et al. (2011) showed estimates of yield decline between 3.8% and 5%, while Schlenker and Roberts (2009) estimated declines as high as 36% to 40% for wheat, corn, and cotton yield under a low-emissions scenario, and declines between 63% to 70% for a higher emissions scenario. Note that these simulation exercises did not incorporate effects of rising atmospheric CO_2 on crop growth, yield reductions due to pests, crop genetic variability, or management innovations such as new fertilizers, rotations, tillage, or irrigation, which could further impact crop yields.

Figure 19: Impacts of Climate Change on Major Crops

Source: Farming First, 2015

Under a reduced emissions scenario, mean daily temperatures are expected to increase, on average, by nearly 4° by 2100 within the Piedmont Triad region. However, under a higher emissions scenario, mean daily temperatures are expected to increase by as much as 8.5°F by 2100 (U.S. Federal Government, 2018). Based on suitable temperature ranges described above, this rise in temperature could result in several crop varieties facing temperatures above their optimal, resulting in yield losses. Selective breeding and genetic engineering for both plants and animals provide some opportunity to adapt to climate change and more extreme temperatures. However, development of new varieties in perennial specialty crops commonly requires 15 to 30 years or more, greatly limiting adaptability, unless varieties can be introduced from other areas (Hatfield et al. 2014).

Not all impacts from a warmer climate are negative, however. Increasing air temperature can result in a longer growing season, allowing for earlier planting during the spring if suitable moisture and soil temperature conditions also exist. A longer growing season allows more time for crops to accumulate biomass, resulting in more harvestable yields, as long as temperatures do not exceed optimum values (Walthall et al. 2012). However, it is important to note that the positive effects of higher temperatures could be offset by increased variation of precipitation and soil water availability for crops. Higher temperatures and a longer growing season will increase the amount of water needed. Also, larger plants use more soil water over the course of their development (Betts et al. 2007). These two factors, in combination with unpredictable precipitation and soil water could affect water availability, as well as weed and insect interactions with crops.

In addition to impacts to crop growth, increasing air temperatures can also affect livestock production. Changes in temperature affect animal production in four primary ways: 1) feed-grain production, availability, and price; 2) pastures and forage crop production and quality; 3) animal health, growth, and reproduction; and 4) disease and pest distributions (Hatfield et al. 2014). Similar to crops, animals have certain conditions in which they perform best in. Optimum animal core body temperatures are often maintained within a 4°F to 5°F range. In many species, deviations from this range can cause extreme stress, requiring animals to significantly alter their behavior and metabolic rate to regulate their core body temperature. This can disrupt performance, production, and fertility, limiting the animals' ability to produce meat, milk, or eggs. Deviations greater than 9°F to 12.6°F often, even result in death (Hatfield et al. 2014).

Livestock are typically affected worse by the number of days of extreme heat than by increases in average temperature. For cattle that breed during spring and summer, exposure to high temperatures reduces conception rates (Walthall et al. 2012). In addition, animals that are raised for meat are managed to maximize weight gain, which increases the potential risks when exposed to high temperatures. These impacts from exposure to high temperatures can be costly to producers and cost the agriculture industry over $1 billion in losses in 2011 (Hatfield et al. 2014). Elevated humidity can further exacerbate the impact associated with exposure to high temperatures on animal health and performance.

Animal operations that provide partial or total shelter can greatly reduce the risk and vulnerability associated with extreme heat. Typically, livestock, such as poultry and swine, are managed in housed systems where airflow can be controlled and housing temperature modified to minimize or buffer against adverse environmental conditions. However, management and energy costs associated with increased temperature regulation will increase for confined operations and may require modification of shelter and increased water use for cooling (Hatfield et al. 2014).

Figure 20: Piedmont Triad Livestock

Source: Reverence Farms, 2018

Precipitation and Soil

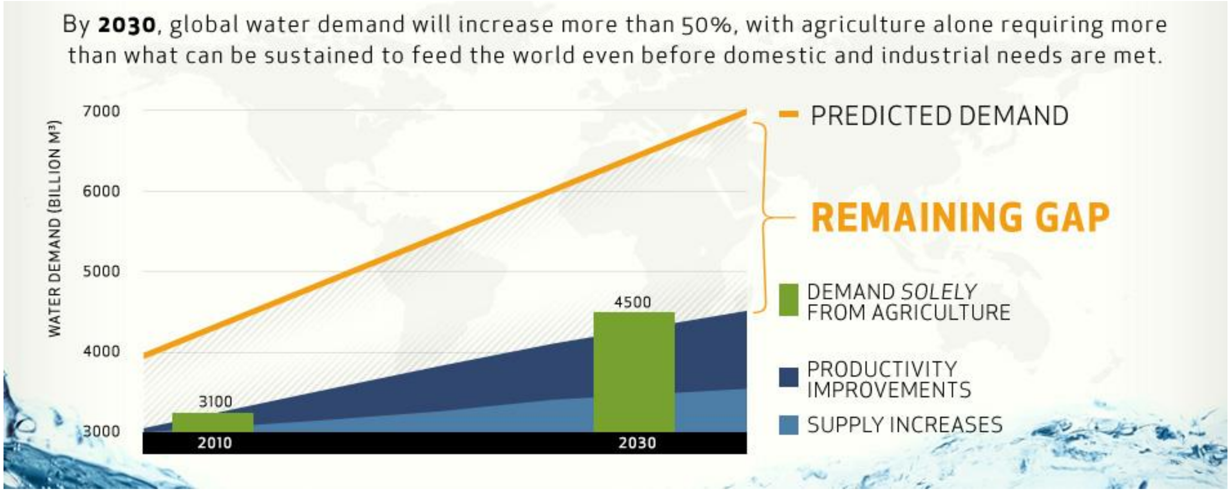
Changes in mean daily average precipitation are expected to be less extreme within the Piedmont Triad than changes in average air temperatures, varying less than .02 in/day from the current daily average and 4 inches from annual averages (U.S. Federal Government, 2018). However, precipitation has a direct influence on agriculture and is projected to increase in some areas, while decreasing in others. There is a high degree of certainty that climate change will result in an increase everywhere in the highest precipitation events, which is largely a result of the increase in atmospheric moisture caused by warming. There is also strong certainty that the maximum number of consecutive dry days will increase in most areas, especially in the southern and northwestern potions of the United States. Using a reduced emission scenario, annual maximum precipitation and the change in consecutive dry days are both expected to increase between 0% and 10% within the Piedmont Triad. Percentages rise for annual maximum precipitation up to 10% to 20% with continued emission increases (Hatfield et al. 2014).

Researchers have also used simulation models to predict seasonal changes in precipitation. It is anticipated that precipitation change for 2071-2011, as compared to 1970-199, will be between 0% and 10% drier during spring and summer, and between 0% and 10% wetter during the fall and winter under the reduced emissions scenario. With continued emission increases (the path we are currently on), precipitation will increase by between 0% and 10% during spring, summer, and fall, but increase as much as 10% to 20% during the winter (Hatfield et al. 2014).

Soil and water are essential resources for agricultural production. Precipitation and temperature affect the potential amount of water available for crops, but the actual amount of available water also depends on soil type, soil water holding capacity, and the rate at which water filters through the soil. Changes of the timing, intensity, and amount of rain and snow for a location will create more variation in soil water availability and will complicate delivering water to crops at the right time through irrigation systems and other practices. Excess precipitation can be as damaging as receipt of too little precipitation due to the increase in flooding events, greater erosion, and decreased soil quality (Hatfield et al. 2014).

Higher temperatures are also projected to increase the amount of water lost through evapotranspiration, both from land and water surfaces, as well as through transpiration from non-crop land cover. This could result in even less available water, even in areas where precipitation amounts increase, particularly in soils with limited soil water holding capacity (Hatfield and Prueger, 2011). These shifts in the distribution of water will, inevitably, drive changes in the allocation of resources and farm management strategies (Hatfield et al. 2014).

Figure 21: Projected Increase in Global Water Demand



Source: Farming First, 2015

Carbon Dioxide

One of the driving forces behind recent shifts in climate is an increase in the amount of carbon dioxide (CO^2) within the atmosphere. A continued increase in CO_2 could provide growth benefits to certain species of plants. For example, when wheat, rice, and soybeans under field conditions were exposed to 550 parts per million (ppm) of CO_2, as opposed to 370 ppm, yields increased approximately 12% to 15%.

Yields increased even further when CO_2 concentrations were raised to 700ppm. Cotton may also see substantial increases in yield as a result of higher CO_2 concentrations, while corn will have negligible impacts. The effects of elevated CO_2 on grain and fruit yield and quality are mixed. Some experiments have documented that elevated CO_2 concentrations can increase plant growth while increasing water use efficiency. There are often large variations in responses, even within varieties of the same species (Walthall et al. 2012).

Indirect Effects

Invasive Species, Pests, & Pathogens

Both warming and precipitation change can alter plant resources and competition from invasive species. This can have devastating effects on yields. Current estimates of losses in global crop production show that weeds cause the largest losses (34%), followed by insects (18%), and diseases (16%) (Oerke, 2006). Competition between crops and weeds will only be exacerbated as a result of climate change. Higher temperatures and CO_2 concentrations have been shown to have a disproportionately positive impact on several weed species and boost weed growth (Hatfield et al. 2014). Experimental warming has been found to favor invasive species in relatively wet areas (Verlinden & Nijs, 2010), but to have little effect on, or even prevent, invasive species in drier regions (Williams et al. 2007; Verlinden & Nijs, 2010; Dukes et al. 2011). This may be due to increases in evapotranspiration and less water availability.

Further increases in temperature and changes in precipitation patterns will induce new conditions that will affect insect populations, the incidence of pathogens, and the geographic distribution of insects and diseases. Increasing CO_2 boosts weed growth, adding to the potential for increased competition between crops and weeds. Several weed species benefit more than crops from higher temperatures and CO_2 levels (Hatfield et al. 2014; Ziska 2001 & 2003). In addition to altering the success of invasive species within plant communities, changes in climate are also expected to alter the distributions of those species (Walthall et al. 2012). This will introduce invasive species into areas where they were previously unable to survive, potentially harming native plant species and existing crops.

Insects are also directly affected by temperature, synchronizing their development and reproduction with warm periods and remaining dormant during cold periods. Increased air temperatures, as a result of climate changes, allow more insects to survive throughout the winter, as well as reproduce at higher rates during warmer months (Hatfield et al. 2014). It also enables many species of insects to expand their geographical range. However, as is the case for crops, insects have optimal temperatures under which they thrive, so not all insect populations will increase with increasing temperature (Walthall et al. 2012).

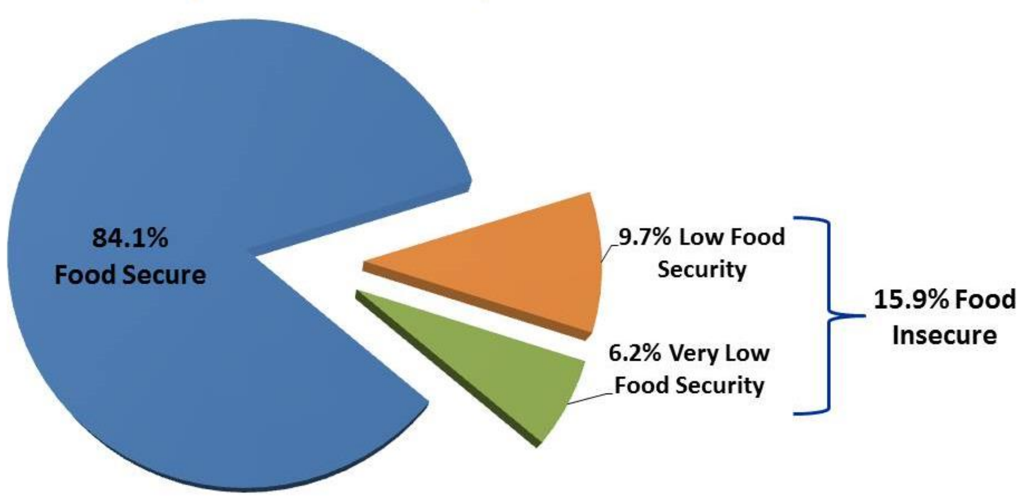
Pests are also typically associated with pathogens that can be spread and wipe out crop and animal populations. Under current climate conditions, even with efforts to manage disease in place, crop losses to pathogens are estimated to be approximately 11% of overall worldwide production (Oerke, 2006). These losses are anticipated to increase as a result of climate change. Yield and quality losses caused by diseases are influenced by increased temperatures, elevated CO_2 concentrations, altered rainfall patterns, drought and greater wind speeds, regional alterations in harvested areas and crop ranges, and changes in vector ranges and activity. These factors alter the geographic ranges and relative abundance of pathogens, their rates of spread, the effectiveness of host resistances, the physiology of host-pathogen interactions, rates of pathogen evolution and host adaptation, and the effectiveness of control measures. It is difficult to predict and quantify the impacts of such increases in pathogens since there are so many variables at play. The frequency and duration of epidemics will vary depending on the pathogen involved and geographic location, as well as the various environmental conditions that affect pathogen survival, such as moisture and temperature (Walthall et al. 2012).

Food Security

As mentioned earlier, changes in temperature, precipitation, and soil water content, as well as increased competition from invasive species, pests, and pathogens, will present new challenges for crop and animal production and likely lead to decreases in both yield and quality. This could result in food scarcity or affordability issues regionally, depending on food security and climate changes in other parts of the world.

Approximately one-fifth of all food consumed within the United States is currently imported. The import share has increased over the last two decades, and the U.S. now imports 13% of grains, 20% of vegetables (much higher in winter months), almost 40% of fruit, 85% of fish and shellfish, and almost all tropical products such as coffee, tea, and bananas (Hatfield et al. 2014). Climate extremes in regions that supply these products to the U.S. could cause sharp reductions in production and spikes in prices. Disadvantaged populations will be at particular risks during these situations if measures are not taken to mitigate impacts to food security. Some potential solutions may include reducing waste within the food system, diversifying sources or producing more products locally, and policies to ensure food access for disadvantaged populations and during extreme events (Hatfield et al. 2014).

Figure 22: Current Household Food Insecurity in North Carolina



Source: Kennedy II, 2016

Stormwater & Flooding

Introduction

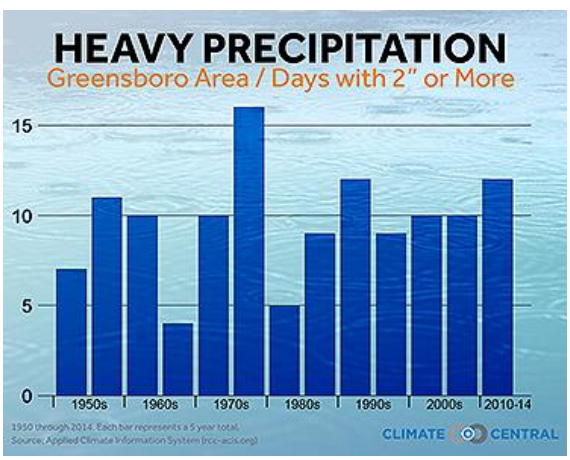
One of the associated impacts of climate change is an increase in precipitation extremes. As temperatures increase globally, water that is held in the ocean and other water bodies, plants, and soils, evaporates more quickly, which results in a greater average of annual rain and snowfall. A warmer atmosphere also means that it can hold more moisture, which contributes to more intense downpours (Climate Reality Project, 2011).

Heavy precipitation can pose substantial risks to local communities. It can result in flash floods, as well as longer-duration floods, which can cause property damage, impact infrastructure, and disrupt livelihoods. In extreme cases, such as tropical cyclones, flooding can even threaten lives. 2017's hurricane season highlighted just how devastating tropical storms and resulting flooding can be. Hurricane Harvey caused up to 60 inches of rainfall in some areas of Texas and resulted in over $180 billion in damages (Fritz, 2018). As the frequency of extreme events continues to increase, these risks become even greater.

Observed & Projected Trends

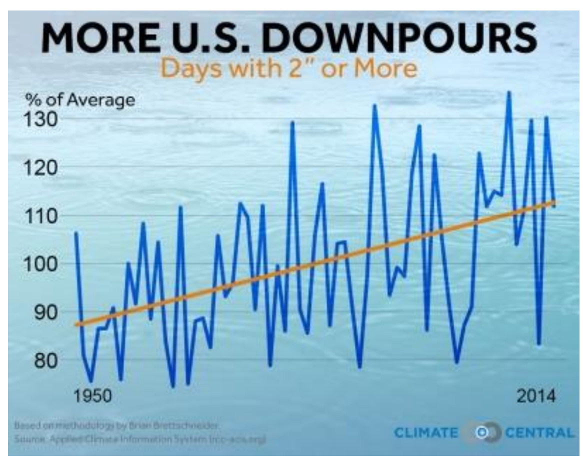
As mentioned earlier in this report, average rainfall varies greatly across North Carolina. While there have been no clear long-term trends in overall precipitation across North Carolina, there is evidence to suggest that the frequency of extreme precipitation events is increasing (Frankson et al. 2017, Carter et al. 2014). Since 1950, the Piedmont Triad has observed a 20% increase in the number of days with two inches or more of rainfall (States at Risk, 2014). A higher number of days with heavy rainfall means more flooding for the region, as well as greater stress on local water systems and infrastructure. It is anticipated that this trend of more frequent and intense precipitation will persist as global temperatures continue to rise.

Figure 23: Heavy Precipitation in the Piedmont Triad



Source: States at Risk, 2014

Figure 24: Heavy Precipitation in the U.S.



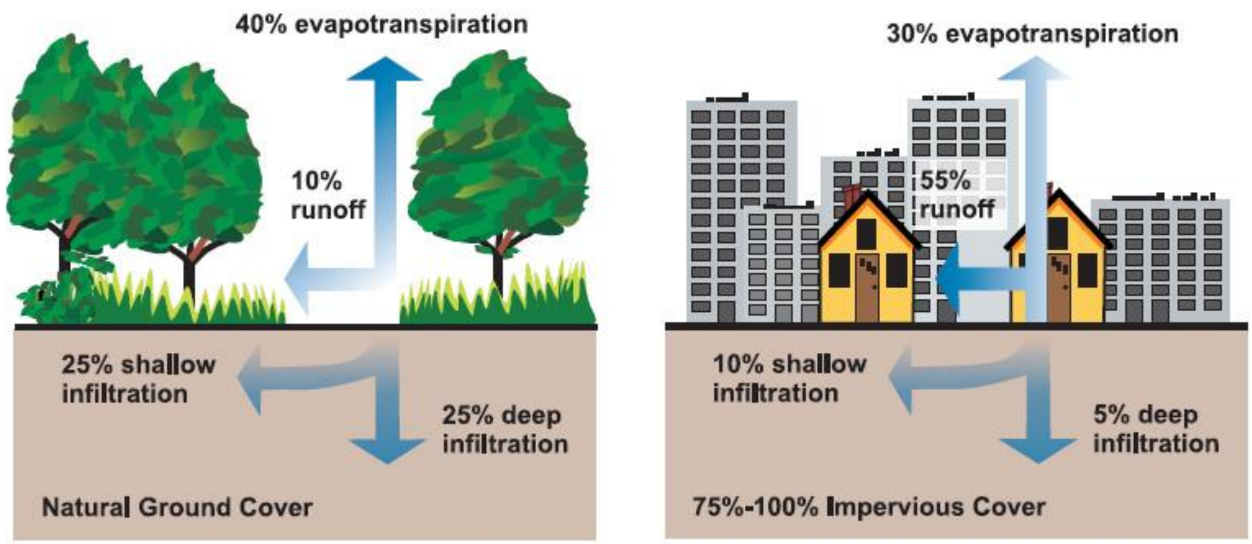
Source: States at Risk, 2014

Based on the recent scientific evidence, it is very likely that the "frequency, intensity, and/or amount of heavy precipitation will continue to escalate through the 21st century" (IPCC, 2014). In North Carolina, annual precipitation is projected to increase, especially in the winter and spring, by as much as 6% (NC ILT, 2012; Frankson et al. 2017). This could mean more stormwater runoff and flooding throughout the

Piedmont Triad. Climate Central, an independent organization of leading scientists and journalists, estimates that inland flooding could increase by as much as 20-40% in North Carolina by 2050. Similarly, flood severity is anticipated to increase by around 30% in North Carolina by 2050 (States at Risk, 2014).

However, it is not just the amount of rainfall that determines the risk of inland flooding. Soil composition, topography, land use and land cover also influence how much water runs off into nearby water bodies. Impervious surfaces such as roads, parking lots, and buildings prevent water from being absorbed back into the ground, which results in higher amounts of stormwater runoff and greater flood risks in urban areas. The amount of people living within the floodplain is another important factor to consider when evaluating the risks associated with heavier precipitation.

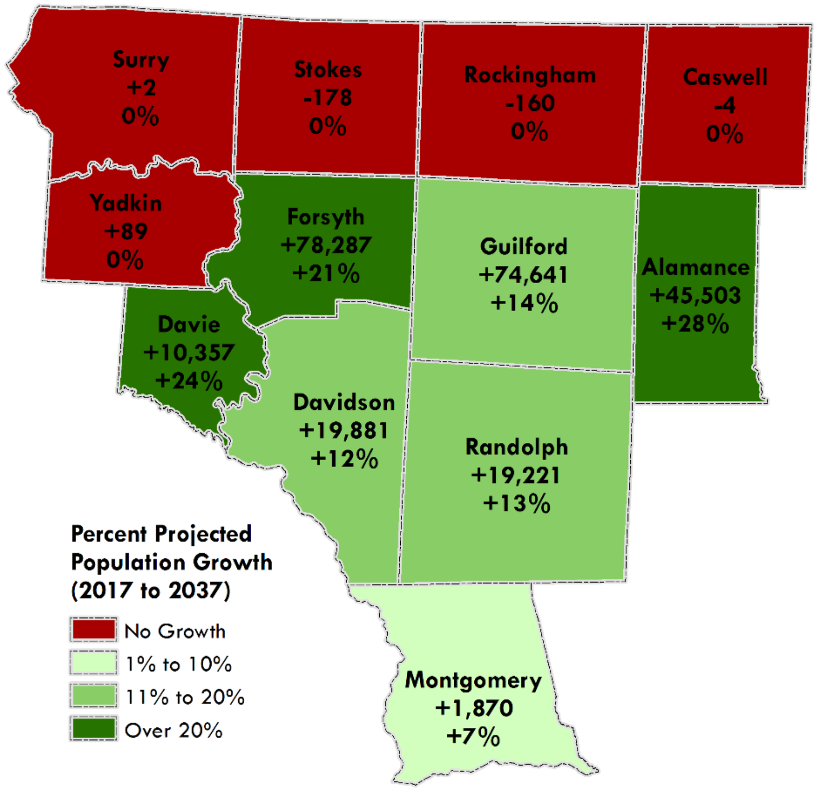
Figure 25: Relationship Between Impervious Cover and Stormwater Runoff



Source: FISWRG, 1998

Between 2017 and 2037 the Piedmont Triad region is expected to gain around 250,000 new residents, an increase of 14.6% from the current population (N.C. Office of State Budget & Management, 2017). Historically, population growth has not been equally distributed across the region. Urban areas throughout the Piedmont Triad have typically seen the fastest rates of growth, while rural counties have experienced more modest growth rates. This trend is expected to continue as more and more people move to the region. However, as urban development increases, so do the risks of flooding. The region will need to seek innovative development strategies to help mitigate the compounding impacts of more frequent and intense precipitation and urban expansion.

Figure 26: Map of Projected Population Growth in the Piedmont Triad



Source: N.C. Office of State Budget & Management, 2017

Potential Impacts

Property Damage

More frequent and intense precipitation and flooding could have a variety of impacts on the Piedmont Triad. One of the most significant impacts associated with heavy precipitation and flooding is damage to property and infrastructure, especially in low lying areas. The Federal Emergency Management Agency (FEMA) reports that each year approximately 90% of all disaster-related property damage results from flooding, averaging $3.5 billion in total costs per year (Rogers, 2006). While the Piedmont Triad does not face the same level of threats as coastal communities, it has over 2,000 streams, rivers, lakes, and other water bodies that pose risks from flooding due to excessive rainfall or snowmelt.

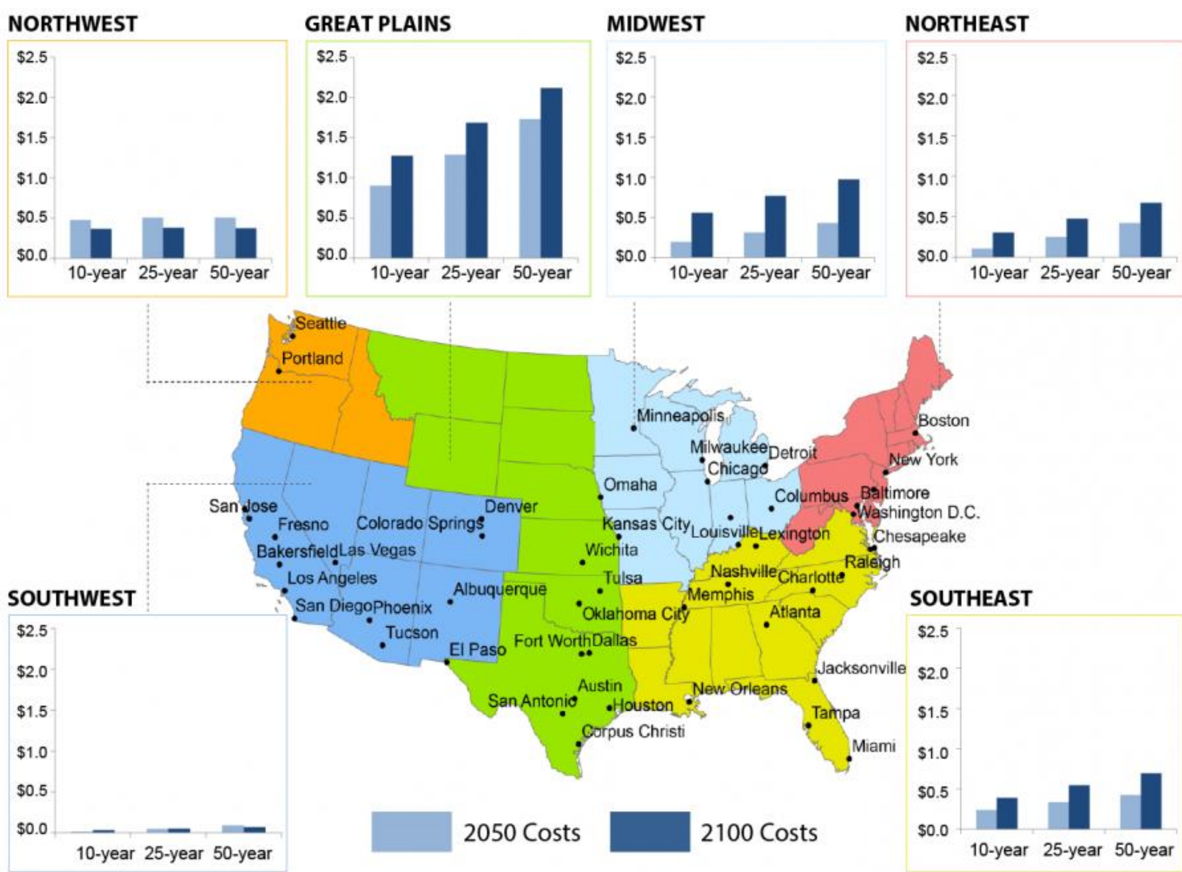
Insurance

As weather patterns continue to shift, more frequent and intense precipitation will establish a new norm in which there is a greater overall risk of flooding. This could not only mean more people are at risk from floods, but it could also increase the costs of flood insurance. According to a 2013 study that evaluated FEMA's National Flood Insurance Program (NFIP), floodplain depths and areas are anticipated to increase by an average of 40% by the year 2100 (AECOM, 2013). This would result in an increase in the overall number of NFIP policies by 80-100%, and an increase in average costs by approximately 50-90% by the year 2100 (AECOM, 2013). Such a demand increase could devastate an already overstretched flood insurance program. The NFIP currently owes close to $25 billion as a result of borrowing from the U.S. Treasury to cover damage claims (Haymon, 2017). Many suggest that this is because property owners do not currently bear the full cost of flood risks, which encourages people to rebuild in hazardous areas. A large proportion of flood-risk maps are also outdated and do not reflect the ever-increasing risks from changing weather patterns.

Infrastructure

Most of the infrastructure that we rely on for transportation, water, and other public services have been designed to withstand a certain level of a flood event. For example, stormwater conveyance systems are typically designed to bear a 10-year storm, while bridges or culverts are often designed to withstand a 50 to a 100-year storm. More intense rainfall events could produce higher flood heights that could overload stormwater systems, water or wastewater treatment facilities, as well as inundate roads, bridges, and rail lines, disrupting the mobility of people and goods. Emergency access can also be impeded, creating threats to human safety if transportation corridors become unnavigable. This problem is exacerbated by the fact that many areas of the Piedmont Triad have aging infrastructure and limited budgets for replacements and upgrades. However, there could be substantial costs, if local governments do not begin taking the steps necessary to proactively address these concerns. The U.S. EPA evaluated 50 cities within the U.S. and estimated that climate change could increase the costs to upgrade urban drainage infrastructure by as much as $700,000 (U.S. EPA, 2015).

Figure 27: Projected Costs of Unmitigated Climate Change on U.S. Drainage Systems



Source: U.S. EPA, 2015

If rain events are strong enough, they can also cause dams and flood control structures to overtop or fail. Many of the reservoirs throughout the Piedmont Triad serve as sources of municipal drinking water. Damage to intake structures or dams could produce a cascading series of damaging impacts, including a loss of drinking water, public health risks, or additional flooding downstream.

Agriculture & Forestry

It is not just the built environment that can be impacted by stormwater and flooding, but agriculture and forestry as well. In agriculture and forestry, increased soil erosion may occur as a result of more frequent heavy rainfall events. Crop productivity may decrease as a result of more frequent flooding of fields and delays to planting and harvesting. Forest productivity could also be affected because flooding affects trees at every stage of their development, from seed germination and flowering to sprouting and vegetative growth.

Figure 28: Runoff Leads to Soil Erosion

Source: Hatfield, 2014

Water Quality

Increased storm intensity and frequency may also have a negative impact on local water quality. Intense storms can erode streambanks and other exposed surfaces, loading waterways with excess sediment. Too much sediment can harm aquatic life and habitat, as well as clog drainage ditches, stream channels, and water intakes and reservoirs. Sediment is already one of the leading causes of water quality impairment in the Piedmont Triad. If storms continue to intensify, it could exacerbate water quality issues.

Stormwater can also carry a variety of other nutrients and contaminants into nearby streams, rivers, and reservoirs. Nutrients, such as nitrogen and phosphorus, stimulate algae and plant growth. In excess, these nutrients can cause algal blooms and eutrophication, which negatively impacts fish and other aquatic species. Litter and debris can also be picked up during heavy rains, which if left unmanaged can further pollute water resources and clog drainage systems.

Figure 29: How Stormwater Runoff Transports Pollutants

Source: Heal Our Waterways, 2018

More frequent overflows of wastewater systems, such as sewage systems, toxic waste facilities, or livestock waste lagoons are another potential concern. Intense rainfall over an extended length of time can quickly overload wastewater systems, especially if there are cracks in underground pipes or faulty covers or connections. This can cause untreated waste to be directly released into drinking water sources.

Figure 30: Sewer Overflow

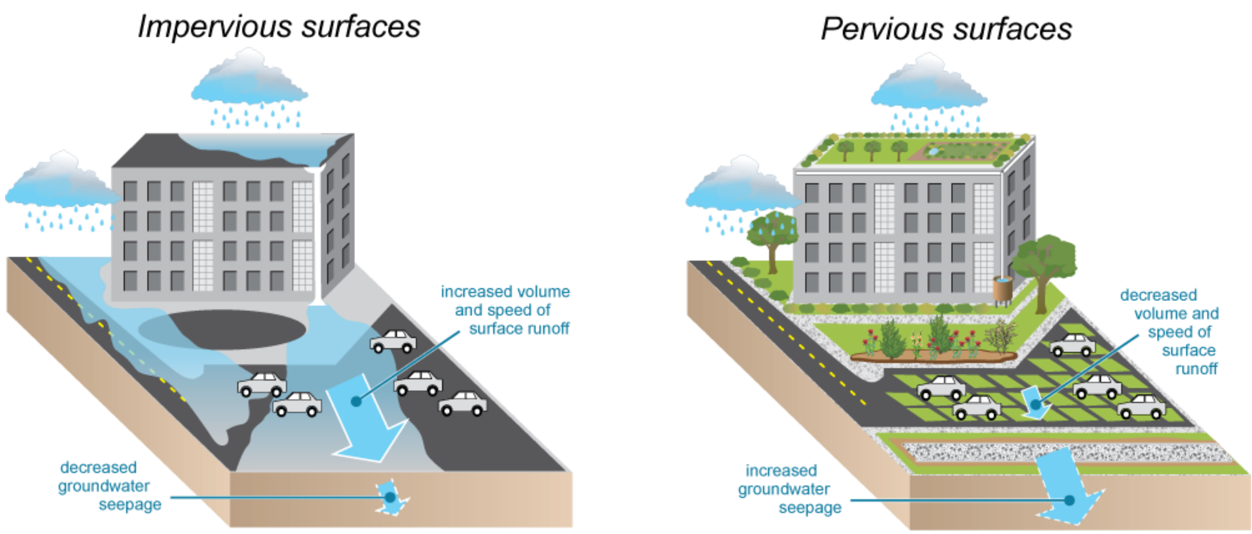
Source: Doremus, 2016

Adaptation Strategies

Modify Land Use

One strategy local governments can use to help mitigate climate change and reduce stormwater and flood risks is to increase the amount of green space in their community. Impervious surfaces, such as roads, buildings, and parking lots prevent water from being absorbed into the ground, which can compound stormwater issues and flooding. In contrast, naturally vegetated areas help retain and absorb water, reducing overall stormwater loads and flood risks. Trees and other vegetation also help remove carbon dioxide from the atmosphere, which is one of the primary causes of recent climate shifts.

Figure 31: Impervious Surfaces vs Pervious Surfaces



Source: Chesapeake and Atlantic Coastal Bays Trust Fund, 2013

Communities can increase green space in a variety of different ways – by increasing the amount of parks, trails, vegetated buffers, or conservation land, by incorporating street trees and other vegetation into urban areas, or by requiring stormwater control measures or best management practices. Best management practices are structural, vegetative, or managerial practices used to treat, prevent, and/or reduce stormwater and water pollution. By developing policies that prioritize green space, local governments can improve opportunities for stormwater retention and help mitigate stormwater or flooding impacts from climate change.

Integrate Climate Projections into Capital Improvements

Another way local governments can better prepare to address climate-related drainage issues is to begin integrating climate projections into capital improvement plans and projects. It is clear that precipitation throughout the Piedmont Triad will become more varied and intensify over the upcoming century, leading to more stormwater runoff and higher flood risks. However, not all communities are recognizing this threat and incorporating new knowledge into infrastructure improvements and their prioritization process. Local governments may save money in the long-term by making strategic investments now, rather than waiting until the local climate patterns have changed even further. There are a variety of tools that engineers have already begun using to incorporate climate predictions into projects, such as the U.S. EPA's Storm Water Management Model – Climate Adjustment Tool (SWMM-CAT, which can help weigh the costs or benefits of making infrastructure improvements to address climate projections.

Water Supply & Wastewater

Introduction

Water is a scarce natural resource in the Piedmont region. As the Piedmont Triad continues to grow and develop, and the demand for potable water increases, it has become increasingly important to monitor the surface water capacity available to fulfill our regional water demand. Short-term solutions to water issues are generally quick and necessary steps in reaction to immediate concerns. However, a long-term planning approach will better prepare local governments for the unique challenges facing our region. Investment in a deeper understanding of the complex and challenging political, regulatory, and environmental issues surrounding water supply will help guide decision-makers to consider future ramifications of options in resource planning.

This assessment of current and future (20-50 years) water resource needs and wastewater treatment plant capacity includes the 12-county Piedmont Triad Regional Council (PTRC) Region (Alamance, Caswell, Davidson, Davie, Forsyth, Guilford, Montgomery, Randolph, Rockingham, Stokes, Surry, and Yadkin Counties). Water supply and wastewater capacity are assessed within the context of surface water availability, projected population growth, geography, current laws and regulations, water quality, and patterns of water use (water conservation and water reuse).

Background

Drinking water comes from two primary sources, surface water or groundwater. Surface water is the water found above ground in the form of rainwater runoff, streams, rivers, lakes and reservoirs. Groundwater is unseen and deep in the ground saturating porous sandy soils or fractures of bedrock.

Surface water and groundwater affect each other. Groundwater comes to the surface (springs) and can help replenish surface water. When surface water seeps down into the soil to replenish groundwater, it is called recharge. How we use our land and dispose of our waste dramatically influences the purity of all our water sources.

For most of the unincorporated areas in the 12 county Piedmont Triad Regional Council (PTRC) region, groundwater from private wells is the primary source of drinking water. However, the region's underlying crystalline bedrock aquifer has relatively little storage capacity, and well yields are not enough to support an extensive public water supply system. For that reason, the public drinking water systems in the Piedmont Triad rely primarily on surface water as their supply source. Therefore, the primary focus of this study is available surface waters which supply public drinking water systems in our region.

As North Carolina continues to grow, the pressure on our public water and wastewater treatment capacities will continue to increase. No region is more aware of this than the Piedmont region of North Carolina. Surface water suppliers in the Cape Fear, Yadkin and Roanoke River Basins all experienced problems during past droughts which bring to light the reality that public water supply sources, while renewable, can be depleted in relatively short time.

In the Upper Cape Fear River Basin, Greensboro entered into a Stage 2 B Emergency Water Restriction Plan when the water supply dropped to 125 days. Though probably hit hardest by the drought because of its limited reservoir capacity, it was not the only city or town in the area to impose water use restrictions. In July 2002, Governor Easley called on water systems, agricultural and industrial water users in the Cape Fear River and the Yadkin River Basin experiencing "exceptional" or "extreme" drought to reduce water use by at least 20 percent through mandatory restrictions. Many if not all counties in the Piedmont region were impacted by the call for mandatory water restrictions.

In the Yadkin River Basin, decreasing river and lake levels quickly and unexpectedly in 2002. Water suppliers like Davidson Water saw its 84 MGD (million gallons per day) allocation diminish rapidly. The Federal Energy Regulatory Commission (FERC) relicensing process with Alcoa and Progress Energy is designed to balance the needs of hydroelectric generation, water suppliers, water or recreation dependent business and industry, and the environment. However, drought conditions can upset that balance. The license agreement may require significant drawdowns of water to meet downstream needs and maintain the production of electricity from the hydroelectric dams at High Rock, Falls, Narrows, and Tillery Dams which may impact water suppliers. In the Roanoke River Basin, Mayodan, Madison, and Eden experienced water shortages due to low levels of the Dan River. Fortunately, in 2003, the region experienced one of the wettest years on record that replenished surface waters and stream flows to normal levels.

Groundwater supplies are a concern in our region not only from the standpoint of the quantity but the quality of that water. Continued growth equates to the more impervious surface areas which result in less groundwater recharge. Recharge rates vary from place to place due to the amount of rainfall, infiltration, and surface vegetation. Throughout the most recent drought, which lasted from 1998 through 2002, the NC Division of Water Resources received county reports that many new wells were being drilled to replace shallow bored wells that ran dry.

Groundwater recharge is a slow process. Though lake levels and stream flows return to normal with adequate rainfall over the course of a few months, it can take much longer – years - for water to make its way to the saturated zone to replenish the groundwater. Apart from the public surface water supply systems, groundwater is the primary source of water for the remaining areas in the Piedmont region. The exception being the dependency on groundwater to supply the public water supply systems in the towns of Liberty and Milton which are relatively isolated and do not have emergency interconnections with other water systems. While groundwater is perceived as available and clean, groundwater contamination, mainly from underground storage tanks, has been an issue for well water users in a number of our region’s counties. When contamination is severe enough, and remediation is not possible, groundwater users are forced to install expensive filtration systems or hook up to a municipal surface water system.

The growing pressure on our drinking water supplies is a visible problem that is gaining public attention. However, public understanding of the impact of wastewater treatment capacity on local growth, development, and water supply is limited. The Upper Cape Fear Basin is experiencing the most pressure due to wastewater discharge into the small streams of the headwaters area and the increased regulations these streams are facing.

Wastewater treatment is the greatest challenge to Greensboro’s future growth. The time is coming where regional cooperation will be necessary for the Piedmont region to meet its water and wastewater demands. An important step is an assessment of where the region is currently and what is likely to happen in the future.

Factors Affecting Water Supply & Waste Water Capacity

The primary factors affecting water supply and wastewater capacity in the region are geography, urban growth, and development, water quality, urban and stormwater runoff, current laws and regulations about water use, the drought cycle and patterns of water use.

Geography

Geography is a significant factor in determining adequate water supply for an area. A public water system's surface water supply is located within its river basin or subbasin. Within the PTRC region, there are three major river basins and multiple subbasins. However, water is not equally distributed across them. Many water supply systems meet service area water demands through sources within its basin. Some water supply systems located within a basin that does not have an adequate surface water source to meet demand and must look to other geographic areas for a water supply. [See Map 1, page 7]

At the top of every river basin, the headwaters with its small streams are the starting point of a river system. Headwater tributary streams are the small drainage ways, creeks, and streams that feed into larger streams and eventually form rivers and reservoirs. If these small streams in the headwaters of a river basin are degraded or destroyed, they become significant contributors of pollutants to downstream waterbodies. Also, since headwaters are comprised of small streams of origin, their streamflow is dramatically affected in times of drought.

Population Growth and Development

Expanding urban and suburban populations result in higher demands for potable water. As water use increases, so does the amount of wastewater that needs treatment and returned to the environment. Wastewater is used water from our homes, industries, and businesses which must be treated before it is released back as discharge into a stream or water body.

The primary aim of wastewater treatment is to remove suspended solids and kill fecal coliform bacteria as much as possible before the remaining water, called effluent, is discharged back to the environment. The process of "primary treatment" removes about 60 percent of suspended solids from wastewater. Since the decaying matter uses up the oxygen needed by plant, animals and living things in our water, primary treatment includes aerating by stirring the water to increase the dissolved oxygen content. Secondary treatment removes more than 90 percent of suspended solids. When this level of treatment is insufficient to protect the receiving waters of the effluent discharge, advanced or tertiary treatment is needed. Advanced treatment is basically, additional treatment steps wastewater treatment plants provide to further remove toxins, organic materials or nutrients from the wastewater.

Water Quality

The Triad's streams, rivers, lakes, and reservoirs are valuable resources, providing water for drinking, irrigation, fishing and industrial processing. There are 1,602 miles of Healthy Waters in the Triad region. The NC Division of Water Resources (NC DWR) designates these waters as "Good" or "Excellent" based upon their biology and chemistry. These designations generally apply to ecological conditions but are also used to proactively protect drinking water supplies.

There are 596 miles of impaired waters in the Triad region. Impaired streams fail to meet water quality standards for biological and chemical parameters. The sources of impairment vary, though impacts from sediment and stormwater runoff are the Triad's two largest water quality concerns, as they are across most of the United States. Sedimentation is a result of erosion that clouds waters, suffocates fish and other organisms, and raises the costs of treating water to drink. Nutrient pollution is due to natural causes, manure from farms, over-fertilization of lawns and farmland, failing septic systems, and failures in larger municipal wastewater systems. The impacts of nutrient pollution can be seen in the dead zones of Chesapeake Bay, where high nutrient levels cause algae blooms and consume all of the oxygen in these waters when they die. Watershed stabilization through proactive and creative development ordinances and buffering stream and river corridors are effective strategies for reducing sediment pollution. All of these practices rely upon greater tree cover in watersheds to intercept pollution.

Stormwater and Urban Runoff

Stormwater runoff, urban runoff, and industrial waste are significant factors leading to stream and waterbody impairment. Water quality problems affect both the water supply and the effluent discharge of wastewater treatment plants. Twenty-four streams are on North Carolina's 303(d) impaired stream list in the region. Nine of these streams are targeted for stricter regulation to decrease fecal coliform levels. Many of the streams feeding area reservoirs in the region are also on the impaired stream list.

Current Regulatory Environment

NPDES Phase I and Phase II Regulations: The first NPDES regulations, in the 1970s, were aimed at cleaning up point source dischargers like WWTP and industrial plants. Thirty years later, these plants discharge a much cleaner effluent. However, many streams remain impaired. Therefore in the 1990s, Phase I and II NPDES regulations were created to force cities and counties to be accountable for non-point source pollution and stormwater runoff from within their jurisdictions.

Though these regulations are necessary to protect water quality, the stringent standards for discharge into streams limit the capacity of a municipality to expand its WWTP and therefore, its water supply system. Through regulation, strict rules are now in place to begin controlling urban and stormwater runoff, which is a primary source of the pollutants degrading our streams. For instance, in the Haw River Subbasin, a nutrient cap was created in 2007 to decrease the number of nutrients reaching Jordan Lake, which is the primary drinking water supply for the Triangle Region, making it more difficult and more expensive to expand WWTPs in the future.

- Interbasin transfers of water: To meet water demands, it is sometimes necessary to transfer water from basin to another. An interbasin transfer also occurs when a water system has intakes in one river basin but discharges wastewater into a different basin. An interbasin transfer is the piping of surface water from one river basin or subbasin into another. Any new removal of water across river basins or subbasins requires a transfer certificate if the new transmission is two (2) million gallons per day (MGD) or more, or if there is an increase in an existing transfer by 25 percent or more and the total, including the increase, is two (2) MGD or more. However, if a facility using interbasin transfers of water existed or was under construction on July 1, 1993, a certificate is not required up to the full capacity of that facility to transfer water, regardless of the transfer amount.

- FERC Licensing Process: The FERC relicensing process for the hydroelectric dams along the Yadkin River may establish new requirements for drawdowns at High Rock Lake which could affect water levels both up and downstream. Any change in the current operating procedure will impact water suppliers to some degree, especially during drought episodes.

Drought Cycle and Patterns of Water Use

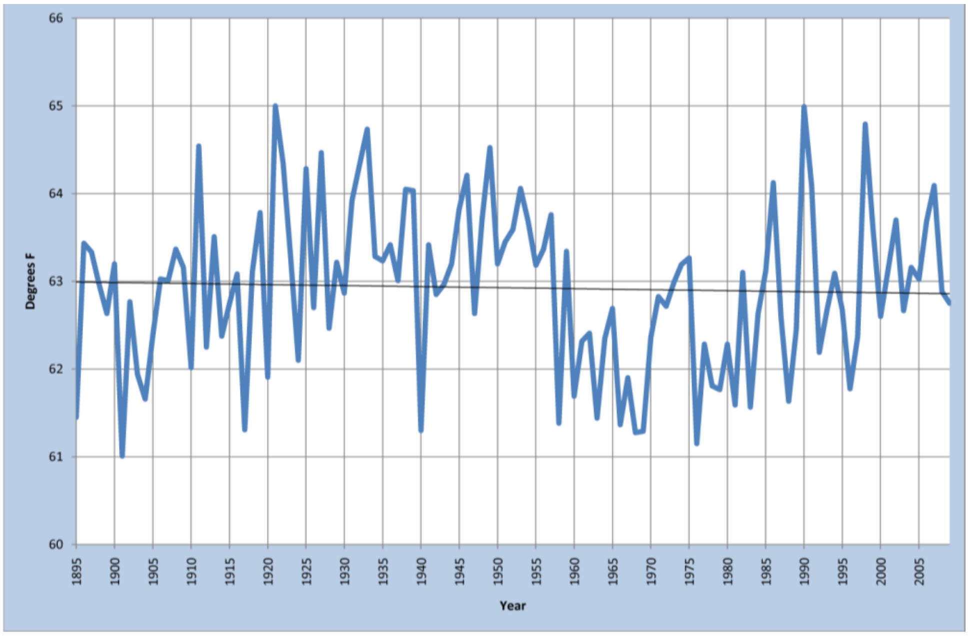
Because periods or drought occur throughout the region in a cyclical pattern, most water systems understand the need for a water shortage response program and have put measures in place to respond to future drought episodes. For most water supply systems, the degree of commitment to water conservation programs is dependent on the water supply conditions and the presence or absence of drought. In times of drought, local government activates a water conservation program through mailers, and displays in public buildings. When not under drought water conservation measures are perceived as unnecessary and water becomes a significant source of revenue for local governments.

Changes in the amount of rain falling during storms provide evidence that the water cycle is already changing. Over the past 50 years, the amount of rain falling during heavy precipitation events has increased for most of the United States. Warming winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year. This alters the timing of streamflow in rivers that have their sources in mountainous areas (U.S. Environmental Protection Agency, 2016).

As temperatures rise, people and animals need more water to maintain their health and thrive. Many important economic activities, like producing energy at power plants, raising livestock, and growing food crops, also require water. The amount of water available for these activities may be reduced as Earth warms and if competition for water resources increases (U.S. Environmental Protection Agency, 2016)

The following figure shows the variability of annual average temperatures the Southeast has faced since 1895.

Figure 32: Annual Average Temperature – Southeastern United States



The annual average temperature of the southeast United States for the period 1895-2009. The trend line shows a decrease in average temperature.

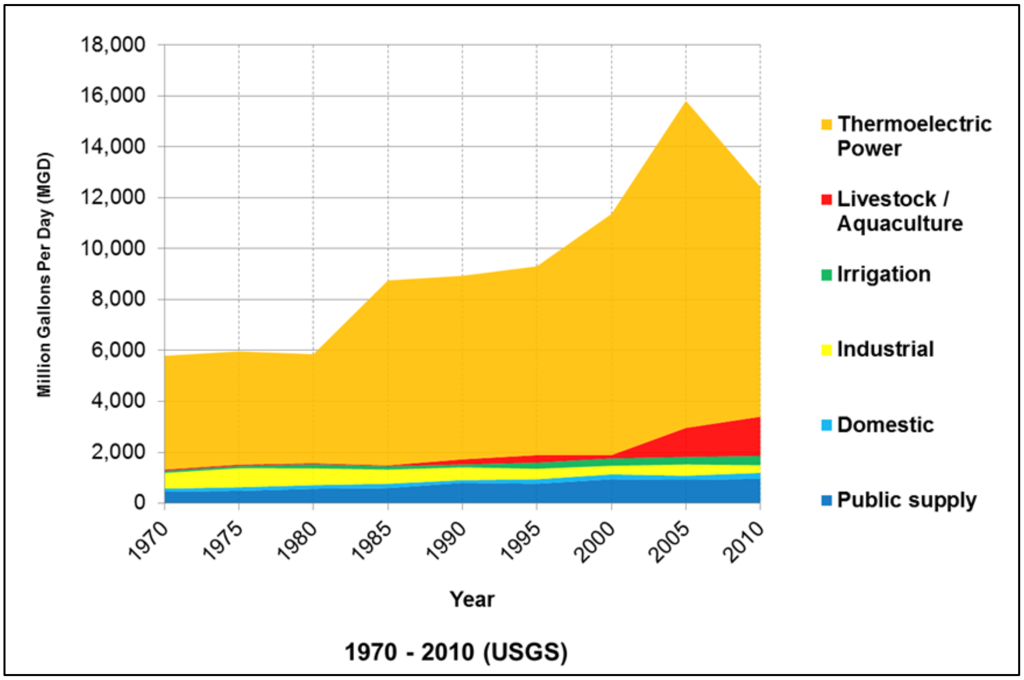
Source: North Carolina Climate Office

Existing Suppliers & Projected Demand

Statewide Overview of Water Demand

Since 1970, water usage within North Carolina has primarily been used for thermoelectric power. Livestock and aquaculture are the second largest users who have seen a significant increase since 2000. Other significant uses of water in the state include those for irrigation, industrial applications, domestic, and public supply.

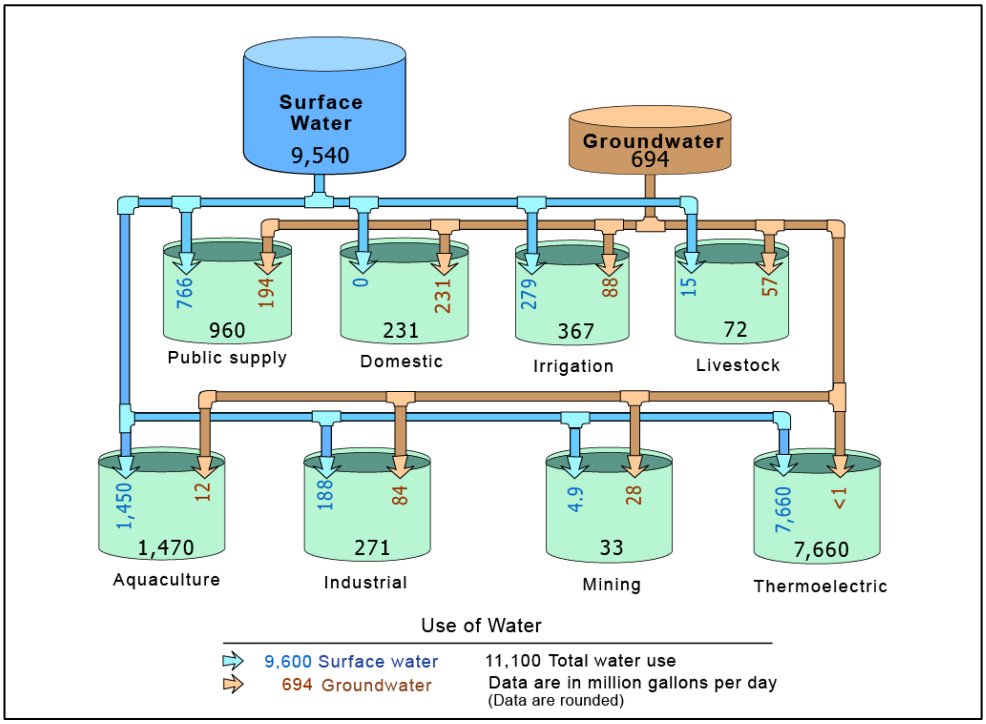
Figure 33: Estimated Water Use in North Carolina



Source: USGS

Water demand is anticipated to rise by about 25% due to a growing agricultural sector, population growth, and increasing energy demands. While North Carolina has ample storage for freshwater supplies that may be recharged during wet winters, hotter temperatures, and more persistent droughts may decrease available stored supplies in the summers (American Rivers 2009). Investments in grey and green infrastructure and greater forest cover in rural and urban communities are central to better ensuring a reliable and sustainable future for the region's waters.

Figure 34: Source and Use of Freshwater in North Carolina, 2010



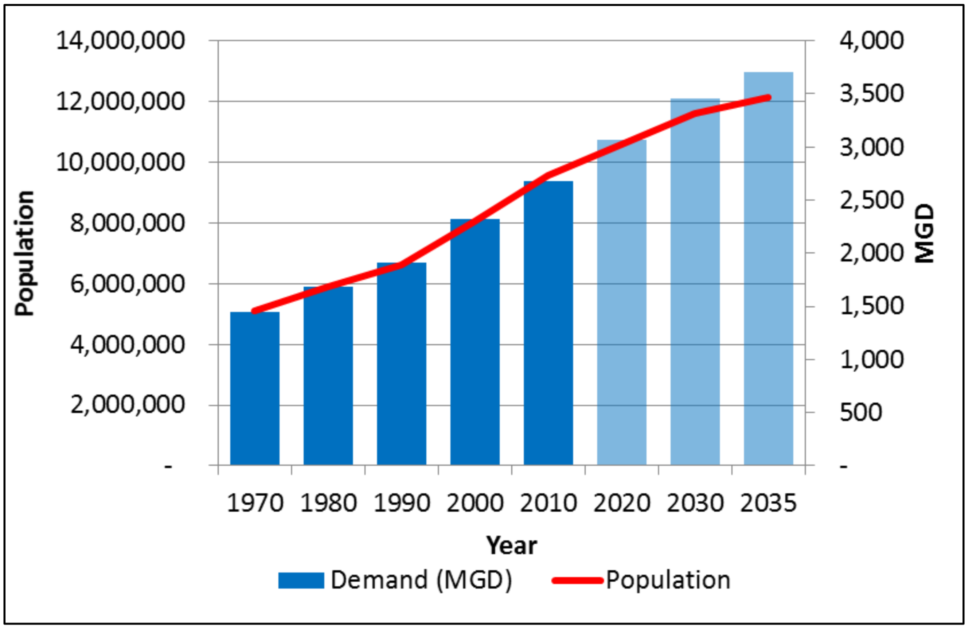
Source: USGS

This diagram uses a "cylinder and pipe" layout to show the source (surface water or groundwater) of the North Carolina's freshwater and for what purposes the water was used in 2010. The data are broken out for each category of use by surface water and groundwater as the source. The top row of cylinders represents where America's freshwater came from (source) in 2010, either from surface water (blue) or from groundwater (brown). The pipes leading out of the surface-water and groundwater cylinders on the top row and flowing into the bottom rows of cylinders (green) show the categories of water use where the water was sent after being withdrawn from a river, lake, reservoir, or well. Each green cylinder represents a category of water use (Credits: Howard Perlman, Hydrologist, Source: Water use in North Carolina, 2010).

Regional Overview of Water Supply

Water demand in the 12 county region has grown steadily since 1970 which has been a drive in large part by population trends. As shown in the chart below, this trend is expected to stay constant looking ahead to 2035 and beyond.

Figure 35: Water Demand in Piedmont Triad



Source: NC DEQ

Regional Water Supply versus Demand

The region is expected to see an increase in the percentage to water supply versus demand in the following decades going from 22% in 2016 to an estimated 35% in 2060 as shown in the following table.

Table 2: Regional Water Supply Vs. Demand in the Piedmont Triad

Year	Population	Total Service Area Demand (in mgd)	Total Available Supply (in mgd)	Permitted WTP Capacity (in mgd)	Demand vs. Supply (%)
2016	1,392,778	143.0	636.3	260.3	22%
2020	1,475,271	151.8	639.0	260.3	24%
2030	1,649,920	170.0	644.6	260.3	26%
2040	1,840,577	187.6	654.4	260.3	29%
2050	2,045,263	208.2	659.3	260.3	32%
2060	2,311,782	230.4	659.3	260.3	35%

Source: NC DEQ

Existing Suppliers & Projected Demand by River Basin

This assessment of current and future (20-50 years) water resource needs and wastewater treatment plant capacity is for the 12-county PTRC region (Alamance, Caswell, Davidson, Davie, Forsyth, Guilford, Montgomery, Randolph, Rockingham, Stokes, Surry, and Yadkin Counties) and covers portions of the

Cape Fear, the Roanoke, and Yadkin River Basins. A small part of the Lumbar River Basin is located in the southeast part of Montgomery County, but it is not included in this assessment since there is no major town or water supply system within the boundaries of the basin. Water supply will be assessed within the context of surface water availability, projected population growth, geography, water quality, patterns of water use (water conservation and water reuse), and current laws and regulations.

Table 3: Surface and Ground Water Suppliers & Purchasers

Water systems using surface or ground water:	Water Systems using purchased water:
Cape Fear River Basin **Haw River Subbasin** ▪ Greensboro ▪ Burlington ▪ Graham ▪ Mebane ▪ Reidsville ▪ Orange-Alamance **Deep River Subbasin** ▪ High Point ▪ Randleman ▪ Ramseur ▪ Liberty ▪ Piedmont Triad Regional Water Authority **Roanoke River Basin** ▪ Danbury ▪ Eden ▪ Yanceyville ▪ Mayodan ▪ Madison **Yadkin-Pee Dee River Basin** **Yadkin River Subbasin** ▪ Davie County ▪ King ▪ Elkin ▪ Dobson ▪ Pilot Mountain ▪ Mount Airy ▪ Mocksville ▪ Davidson Water, Inc. ▪ Thomasville ▪ Lexington ▪ Denton ▪ Montgomery County **Uwharrie River Subbasin** ▪ Asheboro	**Cape Fear River Basin** **Haw River Subbasin** ▪ Alamance ▪ Elon ▪ Gibsonville ▪ Green Level ▪ Haw River ▪ Stokesdale ▪ Ossipee Sd **Deep River Subbasin** ▪ Jamestown ▪ Archdale ▪ Franklinville ▪ Star ▪ Biscoe ▪ Seagrove-Ulah Metro Water District **Roanoke River Basin** ▪ Walnut Cove ▪ Stoneville ▪ Dan River Water, Inc. ▪ Rockingham County ▪ Stokes County Wasa **Yadkin Pee Dee River Basin** **Yadkin River Subbasin** ▪ Troy ▪ Mt. Gilead ▪ Candor ▪ Handy Sanitary District ▪ Gentry Road

Cape Fear River Basin

The Cape Fear River Basin is the largest major river basin in North Carolina flowing southeast from the north central Piedmont to the Atlantic Ocean near Wilmington. The Cape Fear River is formed at the confluence of the Haw River and the Deep River below the B. Everett Jordan Lake Dam. The Haw River Subbasin and the Deep River Subbasin in the Piedmont Triad Region is among the most densely populated areas in the entire basin. Greensboro, High Point, Burlington, and the Piedmont Triad Regional Water Authority are all major water suppliers located within the headwaters of these subbasins.

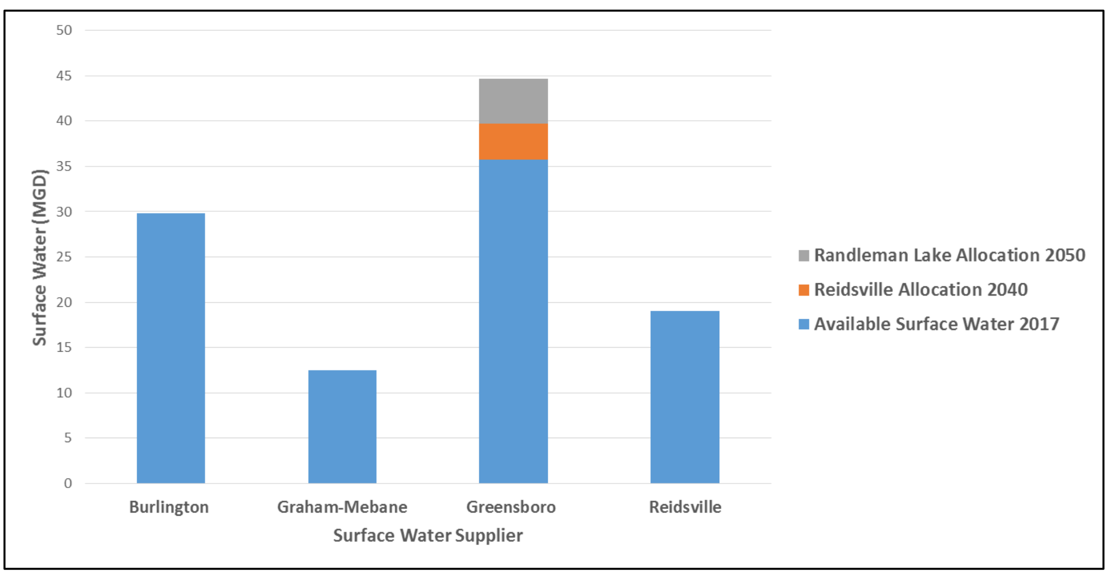
Haw River Subbasin

Surface Water Supplies

Burlington, Graham, Mebane, Greensboro, Reidsville, and Orange-Alamance are the water supply systems located in the Haw River Subbasin. Burlington water supply system is the largest provider of surface water in Alamance County. Burlington operates two water treatment plants with a combined capacity of 34 MGD. Lake Mackintosh and Stoney Creek are the primary surface waters supplying approximately 50.2 MGD. Burlington has interconnections with, and sells water for regular use to Greensboro, Ossippee Sanitary District, Elon, Gibsonville, Haw River, Village of Alamance, and Whitsett.

The Graham-Mebane water supply system provides water to the Graham, Green Level, Mebane, and Swepsonville and has interconnections with Burlington, Haw River, and the Orange-Alamance system for emergency use. Surface water is supplied through Graham-Mebane Lake (formally named Quaker Lake Reservoir)

Figure 36: How River Subbasin - Available Surface Water



Source: NC DEQ

The cities of Graham and Mebane jointly own a water treatment plant serving both areas. Total plant capacity is 12 MGD with 8 MGD available for Graham and 4 MGD available for Mebane.

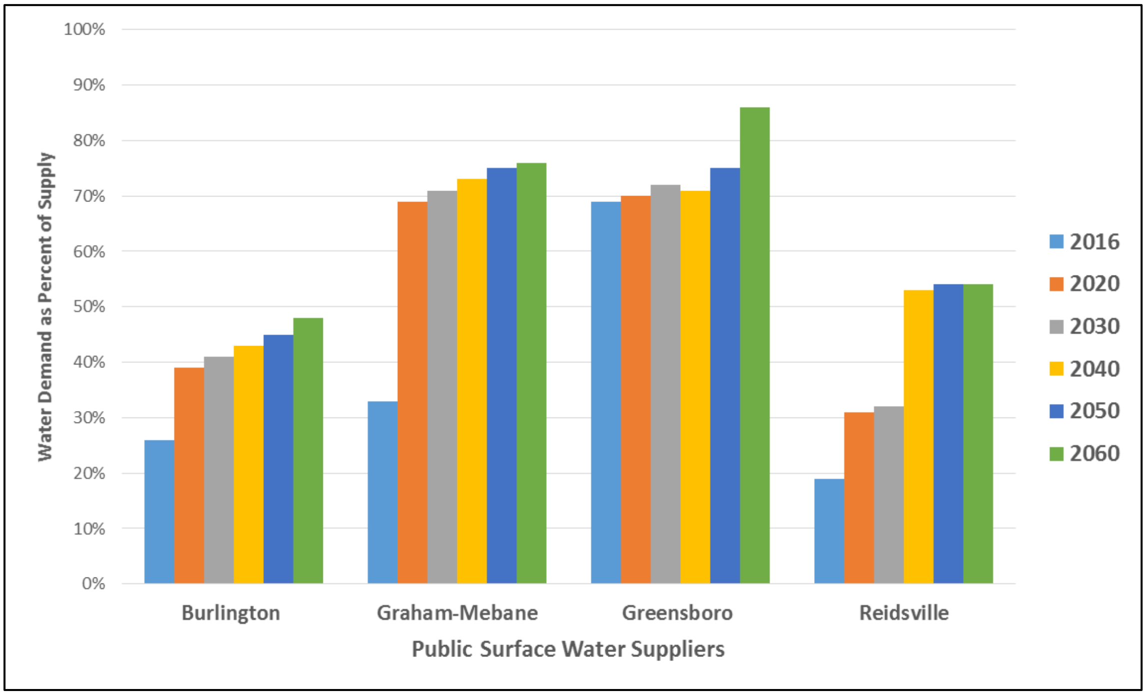
Greensboro's size, population, developed area, and location in the headwaters of the Haw River Subbasin present serious challenges in managing its water resources. In the headwaters of the subbasin, with no major river nearby, Greensboro depends solely on rainfall in the watershed area to fill Lake Brandt, Lake Townsend, and Lake Higgins. The rain falls directly in the lakes or drains into them from Brush, Reedy Fork and Horse Pen Creek. Supply in these reservoirs is limited to 36 MGD. To augment its surface water supply Greensboro purchases water from Burlington, Reidsville, Winston-Salem, and the Piedmont Triad Regional Water Authority (PTRWA). The City of High Point can also provide water to Greensboro for emergencies. In the future, Greensboro also has a contract in place with Reidsville to receive water through 2040 and the PTRWA through 2050. Because the water supply need continues to be critical, Greensboro is expanding the T.Z. Osborne Water Reclamation Facility to reach a daily average maximum capacity of 56 MGD from 40 MGD with the decommissioning of the North Buffalo Water Reclamation Facility.

The Town of Reidsville withdraws water from Lake Reidsville for regular use and Lake Hunt for emergencies. The available supply from the Lake Reidsville reservoir is 19 MGD. Both water supply reservoirs are located on Troublesome Creek.

Water Supply Outlook 2002-2050

Greensboro's water supply has been critically low in the past, but thanks to proper planning and investment, the city is in better shape as the city now has a 50-year supply relying on both supply from within its reservoirs and water purchased from adjacent systems. Through to 2050, Greensboro water supply outlook is stabilized with the Randleman Lake and Reidsville allocations. However, after 2050, surface water to satisfy demand becomes once again, a critical issue. The water supply capacity depicted in the outlook does not contain future purchase agreements and reflects that identifying a future water source is exceptionally critical at 70-80% capacity, but as yet, is undetermined. By 2060 water supply demand will likely exceed 80% of capacity.

Figure 37: Haw River Subbasin - Water Supply Outlook 2016-2060



Source: NC DEQ

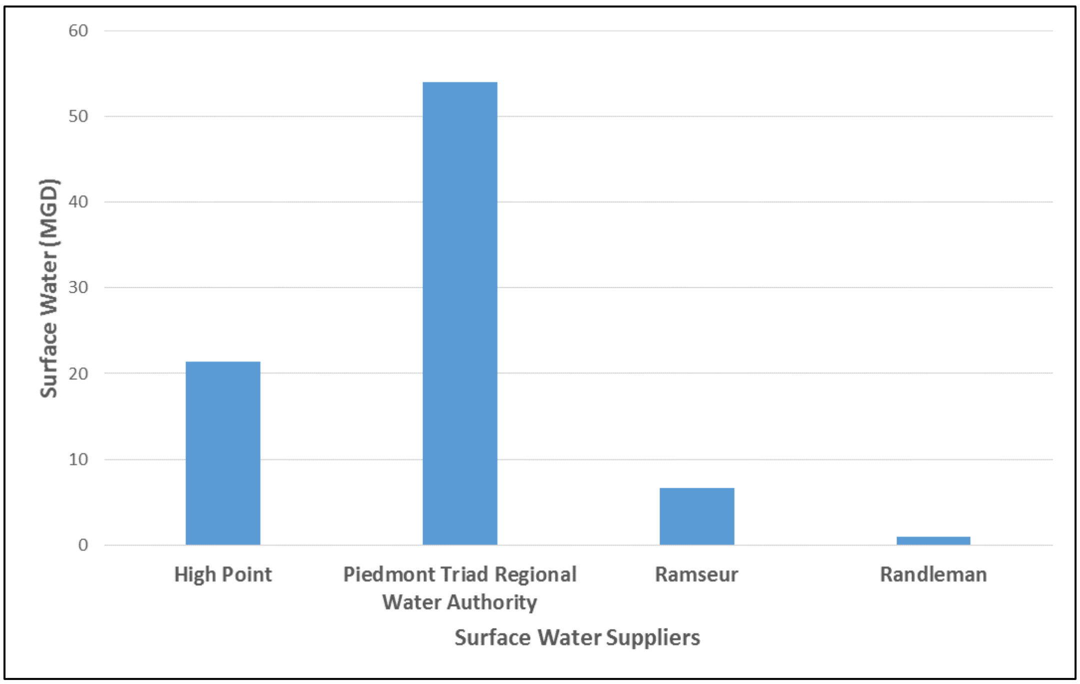
Burlington and surrounding areas in Alamance County show abundant water supply through 2060. However, the Graham-Mebane water supply is expected to approach 76% by the same year and will need to seek out additional sources to keep from reaching 80%. If the Burlington water supply could be sufficient enough to meet countywide demands should the need arise.

Deep River Subbasin

Surface Water Supplies

The High Point water supply system draws surface water from High Point City Lake and Oak Hollow Lake to deliver to its service area, and through purchase agreement to Archdale and Jamestown. High Point also purchases water from Davidson Water Inc. and the Piedmont Triad Regional Water Authority. Also, one directional emergency connections exist from High Point to Greensboro and Thomasville. The Piedmont Triad Regional Water Authority currently has an available supply of 54 MGD.

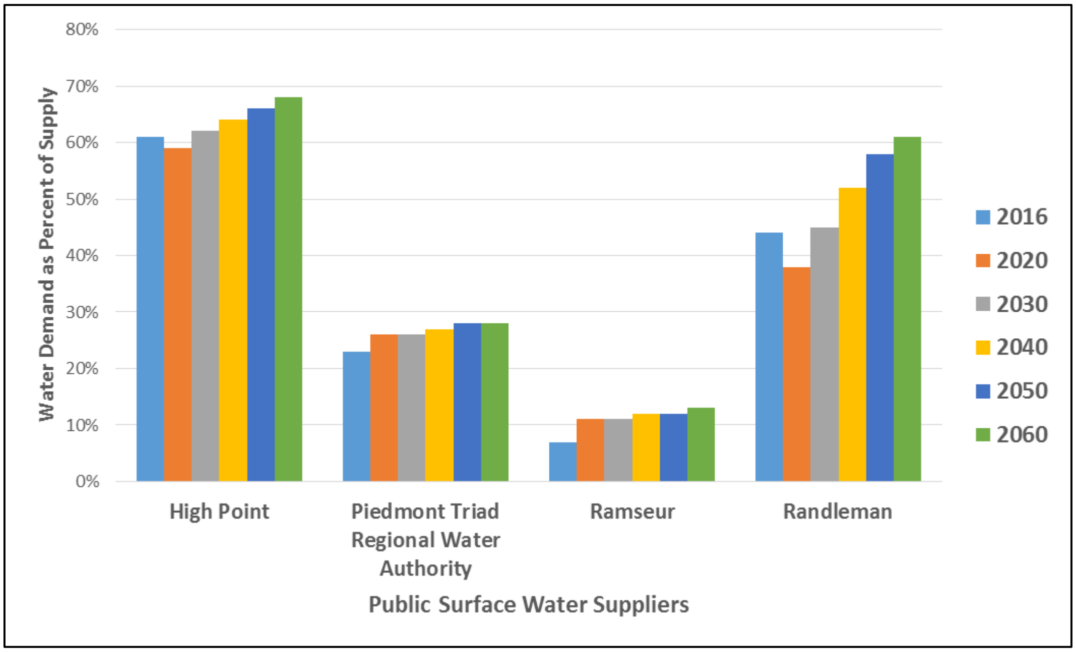
Figure 38: Deep River Subbasin - Available Surface Water in MGD



Source: NC DEQ

The City of Randleman currently 1 MGD capacity from the surface water supply Randleman Lake. The Town of Ramseur withdraws water from Sandy Creek which has available 6.6 MGD. In addition, Ramseur's water treatment plant has a capacity of 1.5 MGD. The Town of Franklinville depends on Ramseur as its sole source of water.

Figure 39: Deep River Subbasin - Water Supply Outlook 2016-2060



Source: NC DEQ

Yadkin Pee Dee River Basin

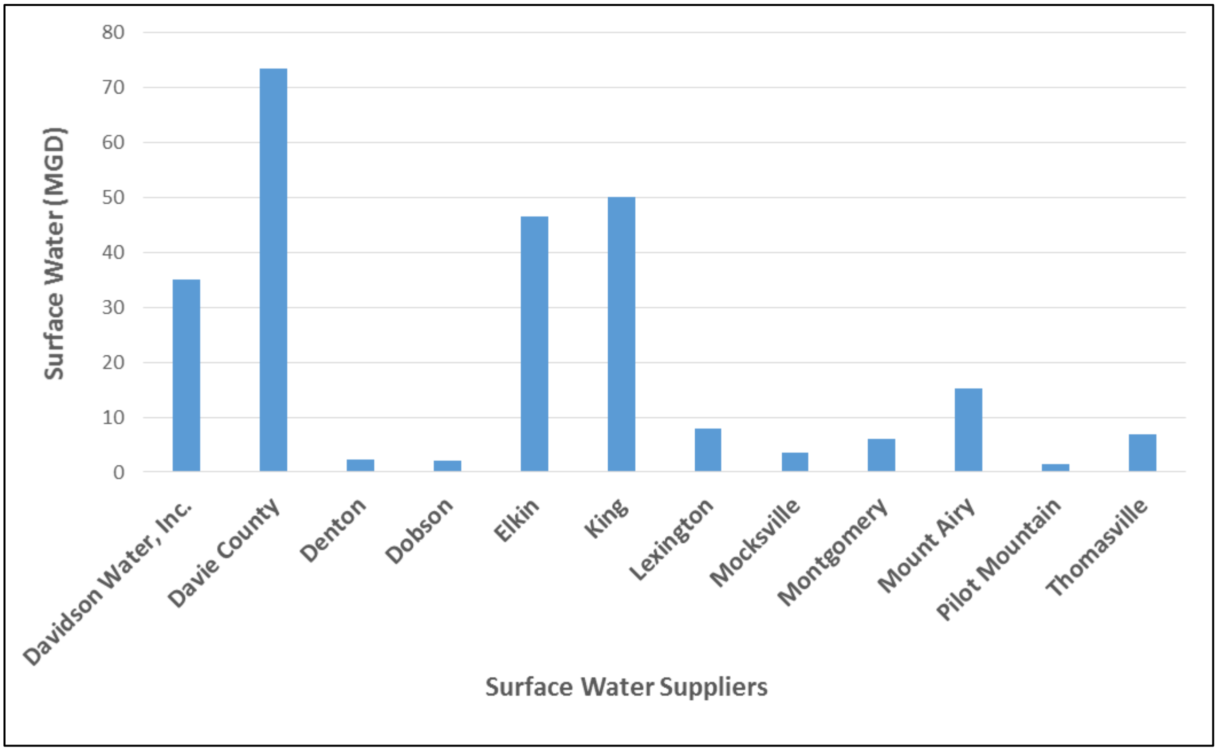
The Yadkin-Pee Dee Basin is in the northern portion of an extensive river system flowing from Virginia, through North Carolina and South Carolina to the Atlantic Ocean. The Yadkin River segment within the PTRC region is impounded by a series of dams forming a chain of lakes consisting of High Rock Lake, Tuckertown Reservoir, Badin Lake, and Lake Tillery. Public water supply systems serving our region are located in two of the four subbasins which make up the greater Yadkin Pee Dee River Basin. The Yadkin River Subbasin covers most of Davidson County and Montgomery County and parts of western Randolph County. The Uwharrie River subbasin straddles the Davidson County and Randolph County line and continues down to the southern half of the Uwharrie basin is within the Uwharrie National Forest.

Yadkin River Subbasin

Surface Water Supplies

Thomasville and Lexington's primary source of surface water are Lake Thom-A-Lex, which supplies a total of approximately 13.9 MGD; 6.95 MGD for each city. Additionally, Lexington City Lake provides 1 MGD of additional surface water to the City of Lexington service area for emergency or supplemental use as necessary. Lake Thom-A-Lex was determined to exhibit elevated biological productivity (eutrophic conditions) in 2009, 2010 and 2011 based on calculated North Carolina Trophic State Index (NCTSI) scores. Lake Thom-A-Lex is on the 2010 303(d) List of Impaired Waters for violations of the North Carolina's chlorophyll a standard.

Figure 40: Yadkin River Subbasin - Available Surface Water in MGD



Source: NC DEQ

Denton water intake is immediately below High Rock Dam on the Yadkin River. High Rock Lake has an available supply of 2.3 MGD water from Tuckertown Reservoir. At this time Denton supplies Handy Sanitary District with 0.728 MGD of surface water. Denton does not have an emergency interconnection to another system; however, Handy Sanitary District is interconnected with Davidson Water, Inc.

High Rock Lake was determined in 2011 to exhibit elevated biological productivity (eutrophic conditions) on May 2, May 31 and August 8, and extremely high biological productivity (hypereutrophic conditions) on July 11 and September 13. High Rock Lake is listed on the 303(d) List of Impaired Waters for standards violations of chlorophyll a, turbidity and pH.

Montgomery County water system uses Lake Tillery as its surface water source serving all five municipalities within the county and the communities of Carolina Forest and Wood Run. Montgomery County can also supply the Town or Robbins in Moore County with up to 0.250 MGD. Total available water supply is 6 MGD.

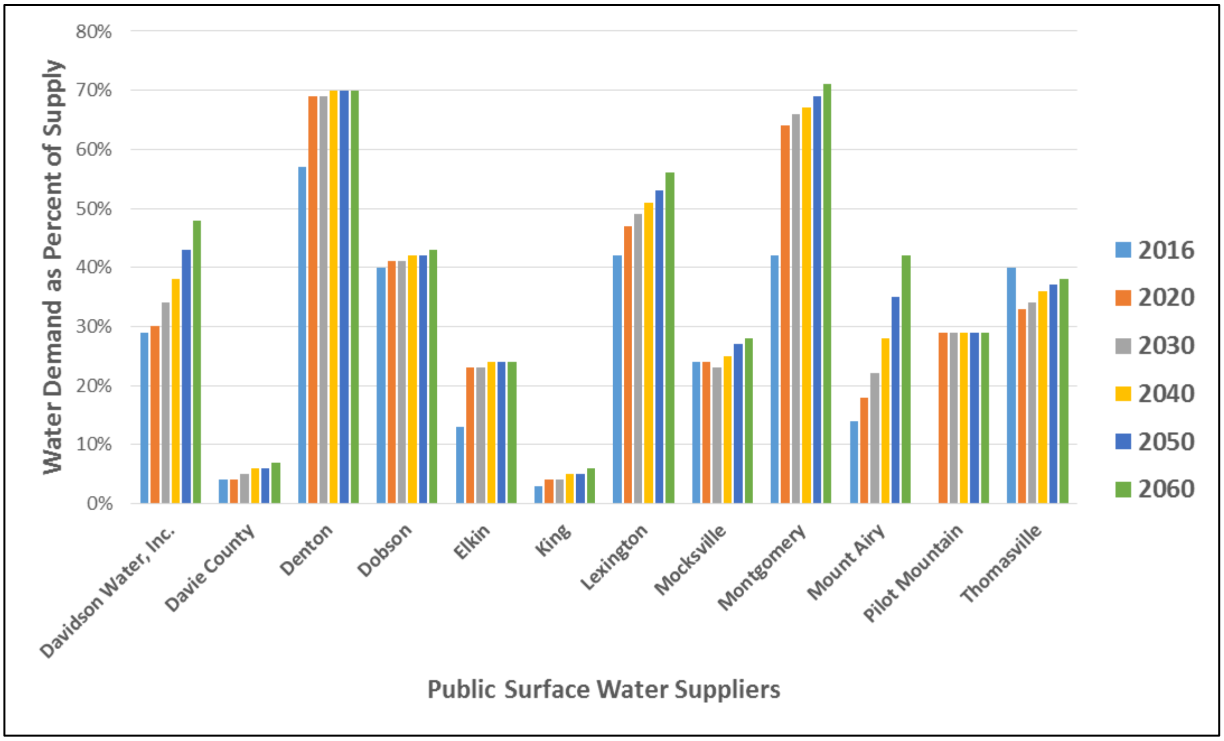
Water Supply Outlook 2002-2050 – Yadkin River Subbasin

Water supply from Lake Thom-A-Lex shows a steady increase in demand over time. Thomasville, Lexington, and Denton use conservative figures in estimating projected growth for its municipal jurisdictions. Even so, water supply by 2030 begins to be a critical issue. Lake Thom-A-Lex Dam will likely need restorative work from 2020 to 2030. Because of water system design and location, the Denton service area demand will have minimal growth through 2060. Handy Sanitary service area surrounds Denton and demand within this water system may show a higher degree of growth through 2060.

Davidson Water, Inc., with 36 MGD raw water supply, will be at or below 48% capacity by 2060 and will be in a strong position to be a major water supplier for the county.

In the Lower Yadkin River Subbasin, the Montgomery County water supply system's outlook to 2060 puts water demand as a percent of supply at about 70%. The chief concern for the Montgomery County system is developing interconnections with another system for emergency water supply.

Figure 41: Yadkin River Subbasin - Water Supply Outlook 2016-2060



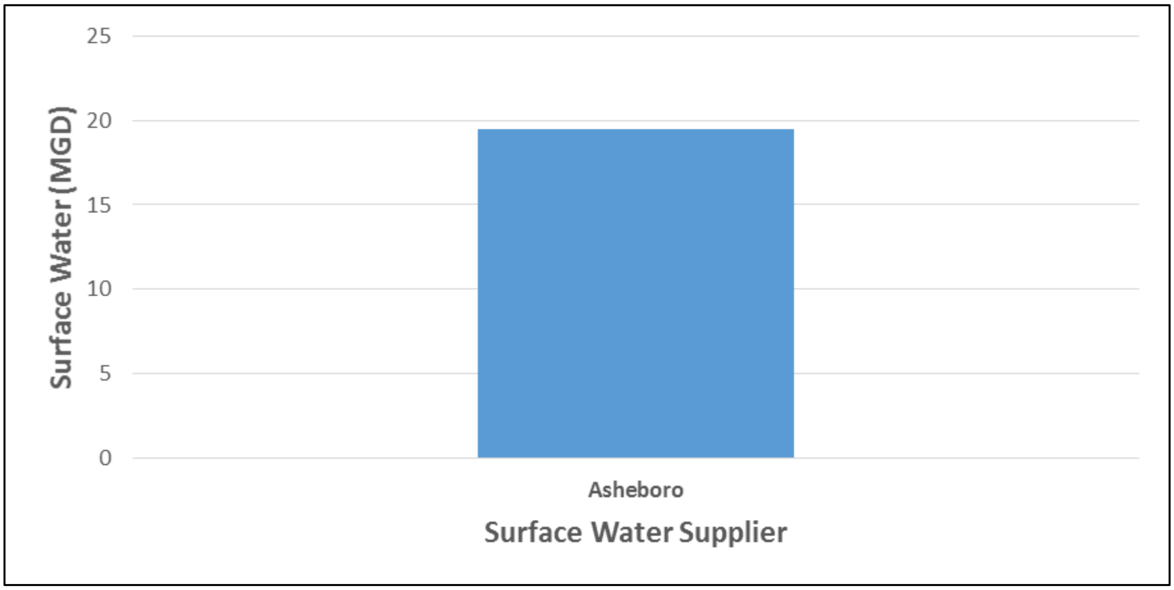
Source: NC DEQ

Uwharrie River Subbasin

Surface Water Supplies

The headwaters of the Uwharrie River Subbasin drain portions of Thomasville, Randleman, and Asheboro. The southern half of the Uwharrie basin is within the Uwharrie National Forest.

Figure 42: Uwharrie River Subbasin - Available Surface Water in MGD



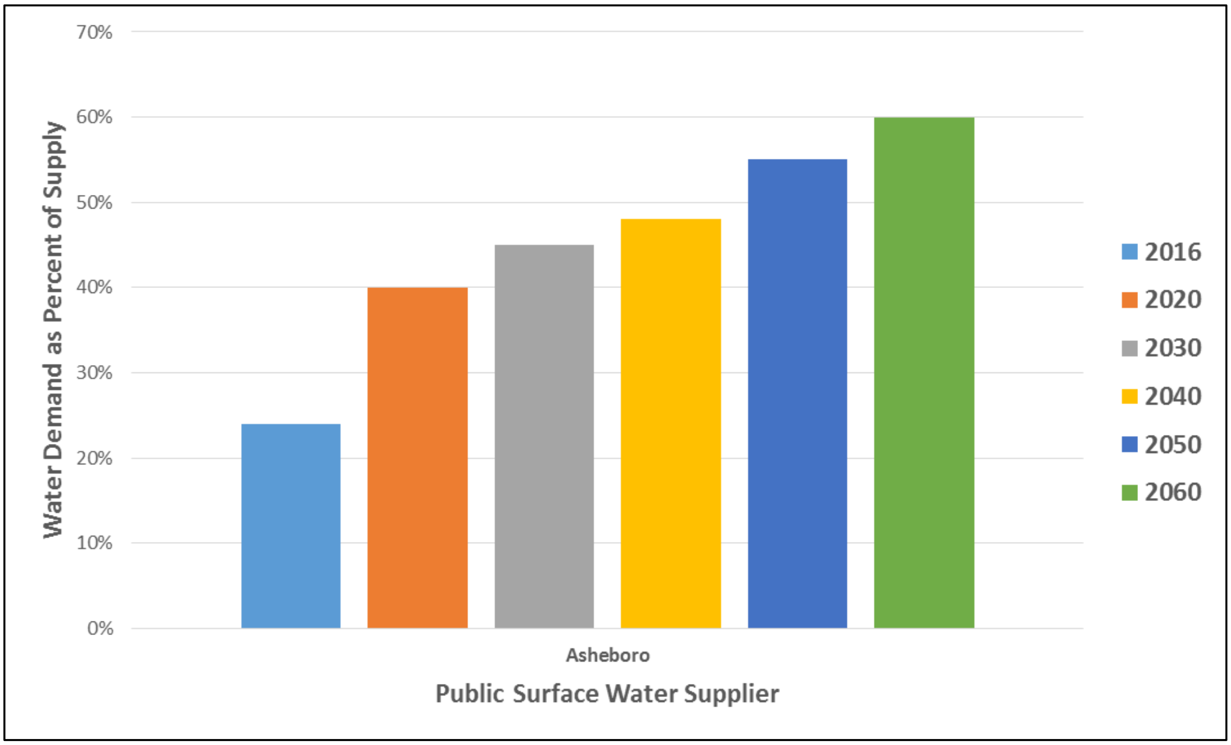
Source: NC DEQ

Asheboro Water Supply system is the only public water system in the Uwharrie River Subbasin. Lake Lucas and Lake Reese supply Asheboro's Water Supply System with its primary source of surface water for regular use. Total raw water supply is 19.5 MGD. Surface water in Lake McCrary and Lake Bunch is for emergency use although the amount of raw water available in these lakes is not recorded in the local water supply plans.

Water Supply Outlook 2002-2050 - Uwharrie River Subbasin

Water supply from Lake Lucas and Lake Reese show a steady increase in demand over time. Even with only 60% water demand as percent of supply by 2060, but the City of Asheboro may need interconnection with other systems to augment supplies in case of emergency.

Figure 43: Uwharrie River Subbasin - Water Supply Outlook 2016-2060



Source: NC DEQ

Roanoke River Basin

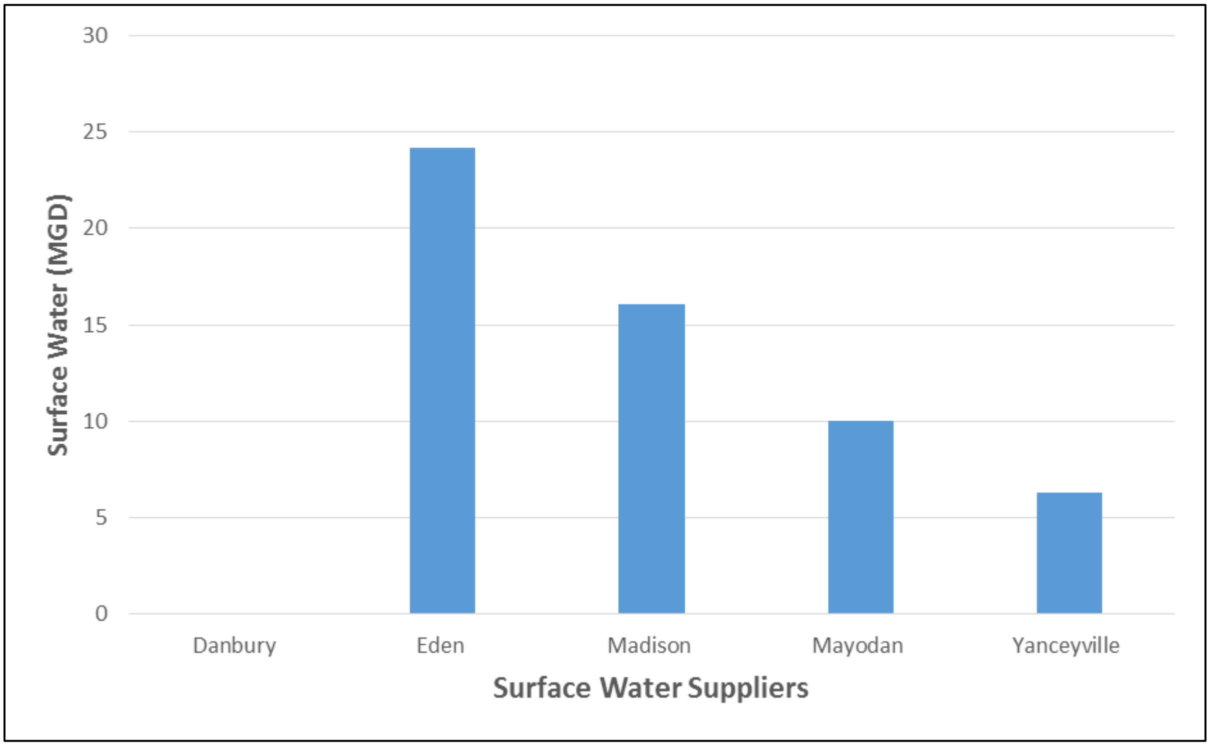
The North Carolina portion of the Roanoke River Basin includes the Dan River and its tributaries, the Mayo River, and Country Line Creek.

Roanoke River Subbasin

Surface Water Supplies

The City of Eden draws its water from the Dan River and has 24.17 MGD of raw water supply available for use. The Town of Mayodan has a river intake capable of withdrawing 1.292 MGD surface water from the Mayo River. Total available water supply is approximately 10 MGD raw water.

Figure 44: Roanoke River Subbasin - Available Surface Water in MGD



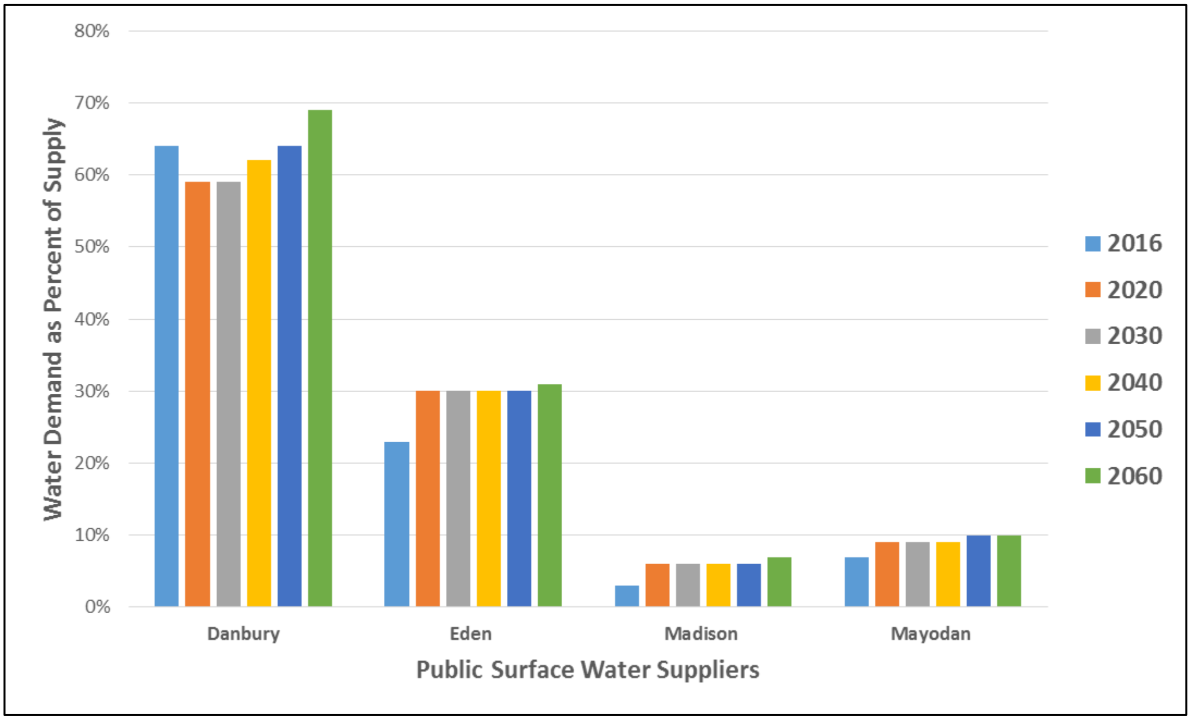
Source: NC DEQ

Danbury draws its supply from Roanoke River and two wells. Overall usage is low due to the low number of customers. The Town of Madison draws its supply from the Dan River. Water treatment plant capacity is limited to 1.5. Its total raw water supply available for use is 16.1 MGD. The Town of Yanceyville gets its surface water from County Line Creek. Yanceyville water treatment plant capacity is 1 MGD; its available raw water supply is 6.3 MGD.

Water Supply Outlook 2002-2050 – Roanoke River Basin

In the Roanoke River Basin, Eden's local water supply plan reflects its strategy to use the abundant surface water resource as a draw for economic development water use intensive industries. It uses an unusually high water usage per day per person (120 g/d per person) to calculate residential water demand and has large growth rates in industrial water use. For the purposes of this study the residential use was adjusted to 62 g/d per person in order to better compare water demand and supply across the region. Eden's has an abundant water source and the supply is in excess of demand through 2050. Eden is interconnected with and supplies water to Dan River Water, Incorporated.

Figure 45: Roanoke River Subbasin - Water Supply Outlook 2016-2060



Source: NC DEQ

Yanceyville in Caswell County has an abundant water supply to meet its future needs but lacks an interconnection with another system to provide water in an emergency. Madison and Mayodan have sufficient surface water to meet service area demands and contractual demands through 2060.

Wastewater Capacity

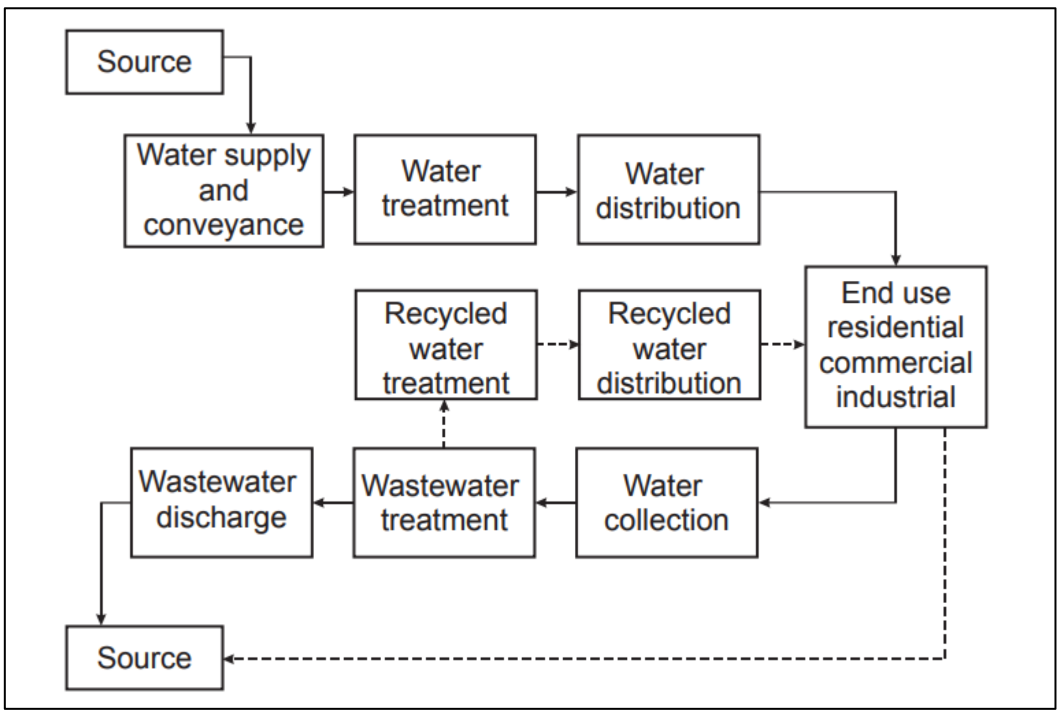
Introduction

Adequate wastewater infrastructure plays a vital role in the health of streams, rivers, and lakes, where discharged wastewater and stormwater runoff often end up. Wastewater infrastructure must also become more resilient to the impacts of climate change, including stronger and more frequent storms, flooding, and drought within the Piedmont Triad.

Typical Water-Use Cycle for Cities

The water supply and wastewater management within the Piedmont Triad is not unlike other parts of the country. The following diagram is a summary of the path taken by water from its source, through treatment, and use, and eventually to its discharge back to the source.

Figure 46: Typical Water-Use Cycle for Cities and Other Developed Supplies



Source: Major, D. C., et al.

Regional Overview

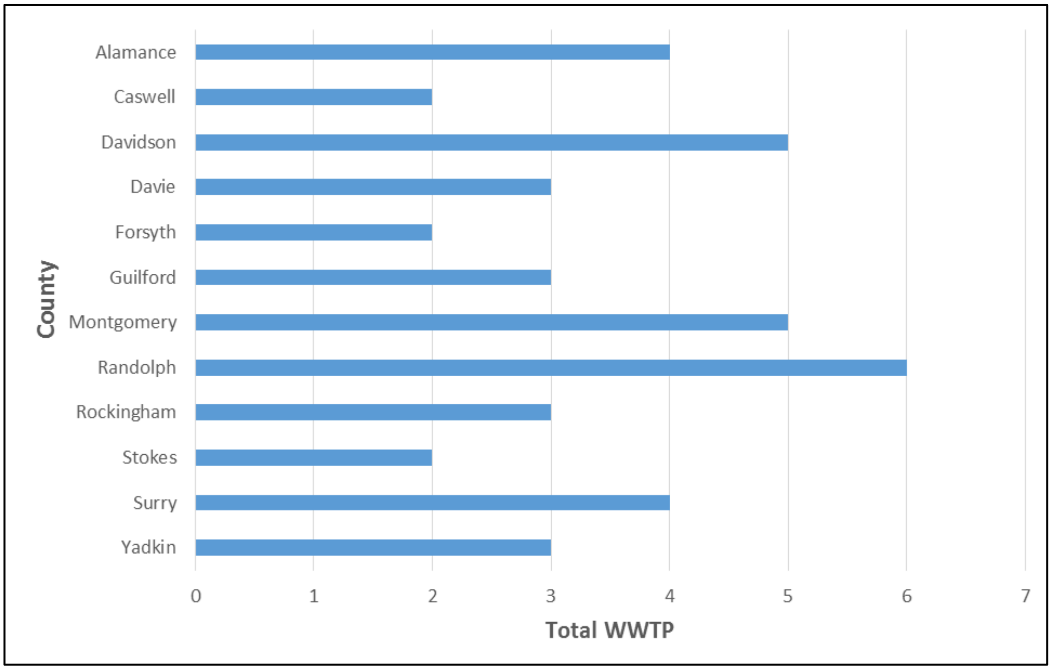
The 12 counties of the Piedmont Triad region contain 42 wastewater treatment plants (WWTPs) across all three major river basins. Out of the counties, Randolph contains the most WWTPs with six total, followed by Davidson and Montgomery Counties each with five total.

Table 4: Typical Water-Use Cycle for Cities and Other Developed Supplies

<table>
<tr><th>Cape Fear River Basin</th><th>Yadkin-Pee Dee River Basin</th><th>Roanoke River Basin</th></tr>
<tr>
<td>Deep River Subbasin
Asheboro WWTP
Ramseur WWTP
High Point Eastside WWTP
Randleman WWTP
Franklinville WWTP
Liberty WWTP
Trinity WWTP
Haw River Subbasin
South Burlington WWTP
East Burlington WWTP
Graham WWTP
Mebane WWTP
North Buffalo WWTP
T.Z. Osbourne WWTP
Reidsville WWTP</td>
<td>Upper Yadkin Subbasin
Dobson WWTP
Mt. Airy WWTP
Pilot Mountain WWTP
Yadkin Valley Sewer Authority WWTP
Boonville WWTP
Archie Elledge WWTP
Lower Muddy Creek WWTP
Yadkinville WWTP
East Bend WWTP
Handy Sanitary District
South Yadkin Subbasin
Cooleemee WWTP
Dutchman Creek (Mocksville) WWTP
Lower Yadkin Subbasin
Bermuda Run WWTP
Lexington WWTP
Hamby CK WWTP (Thomasville)
Denton WWTP
High Point Westside WWTP
Upper Pee Dee Subbasin
Troy WWTP
Biscoe WWTP
Mount Gilead WWTP
Star WWTP
Candor WWTP</td>
<td>Upper Dan Subbasin
Milton WWTP
Yanceyville WWTP
Lower Dan Subbasin
Mebane Bridge (Eden) WWTP
Mayodan WWTP
Danbury WWTP
Walnut Cove WWTP</td>
</tr>
</table>

Source: Source: U.S. Environmental Protection Agency, 2012.

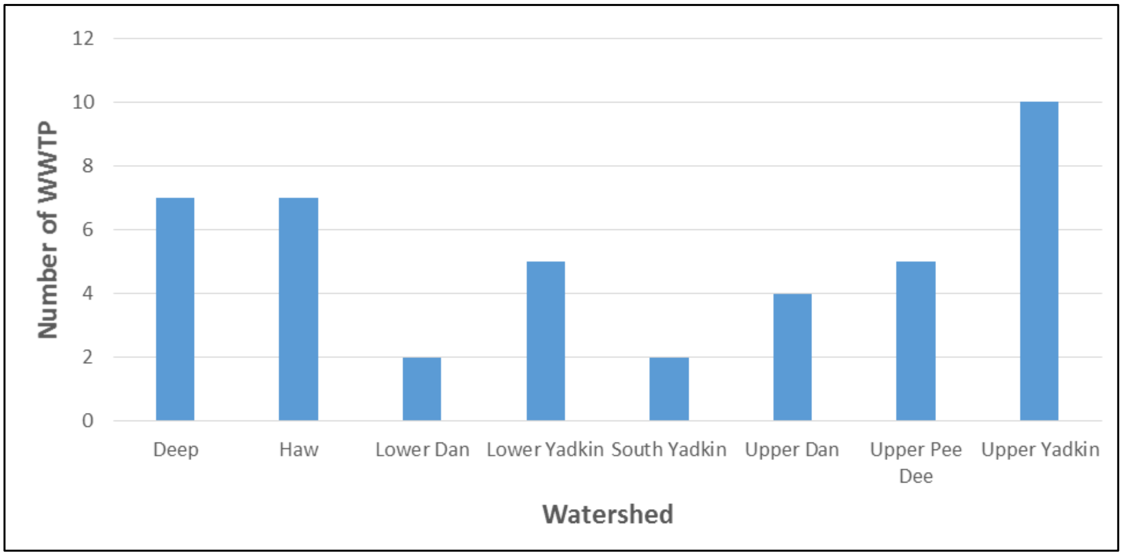
Figure 47: Wastewater Treatment Plants (WWTPs) by County



Source: Source: U.S. Environmental Protection Agency, 2012.

Out of the watersheds, the Upper Yadkin contained the most WWTPs with 10 total, followed by the Deep River and Haw River with seven each.

Figure 48: Total WWTP by County



Source: Source: U.S. Environmental Protection Agency, 2012.

Wastewater Infrastructure Improvements

In 2016, the United States Environmental Protection Agency released a survey showing that nation-wide, $271 billion is needed to maintain and improve the nation's wastewater infrastructure, including the pipes that carry wastewater to treatment plants, the technology that treats the water, and methods for managing stormwater runoff (U.S. Environmental Protection Agency).

Across the Piedmont Triad, the total needed to maintain and improve the region's wastewater infrastructure is $375,406,846 using 2012 calculations. The top five WWTPs needing the most improvements are shown in the table below.

Table 5: Typical Water-Use Cycle for Cities and Other Developed Supplies

Facility/Project	Total Official Needs	Authority	County	Watershed
T.Z. Osbourne WWTP	$85,941,350	City of Greensboro	Guilford	Haw River
Trinity WWTP	$69,544,184	City of Trinity	Randolph	Deep River
Lower Muddy Creek WWTP	$49,987,564	Winston-Salem/Forsyth County Utilities Division	Forsyth	Upper Yadkin River
Archie Elledge WWTP	$16,203,356	Winston-Salem/Forsyth County Utilities Division	Forsyth	Upper Yadkin River
Handy Sanitary District	$11,082,067	Handy Sanitary District	Davidson	Upper Yadkin River

Source: U.S. Environmental Protection Agency, 2016.

Regional Water Connectivity

An interbasin transfer (IBT) is the transfer of surface water from one basin to another basin or vice versa. Currently, the Piedmont Triad has 18 water suppliers with interbasin transfers which are listed in the table below. From the available date, most transfers occur between the Yadkin-Pee Dee basin (Yadkin River and Uwharrie River) and the Cape Fear basin (Deep River and Haw River). However, one system transfers water from the Neuse River to the Haw River (Cape Fear).

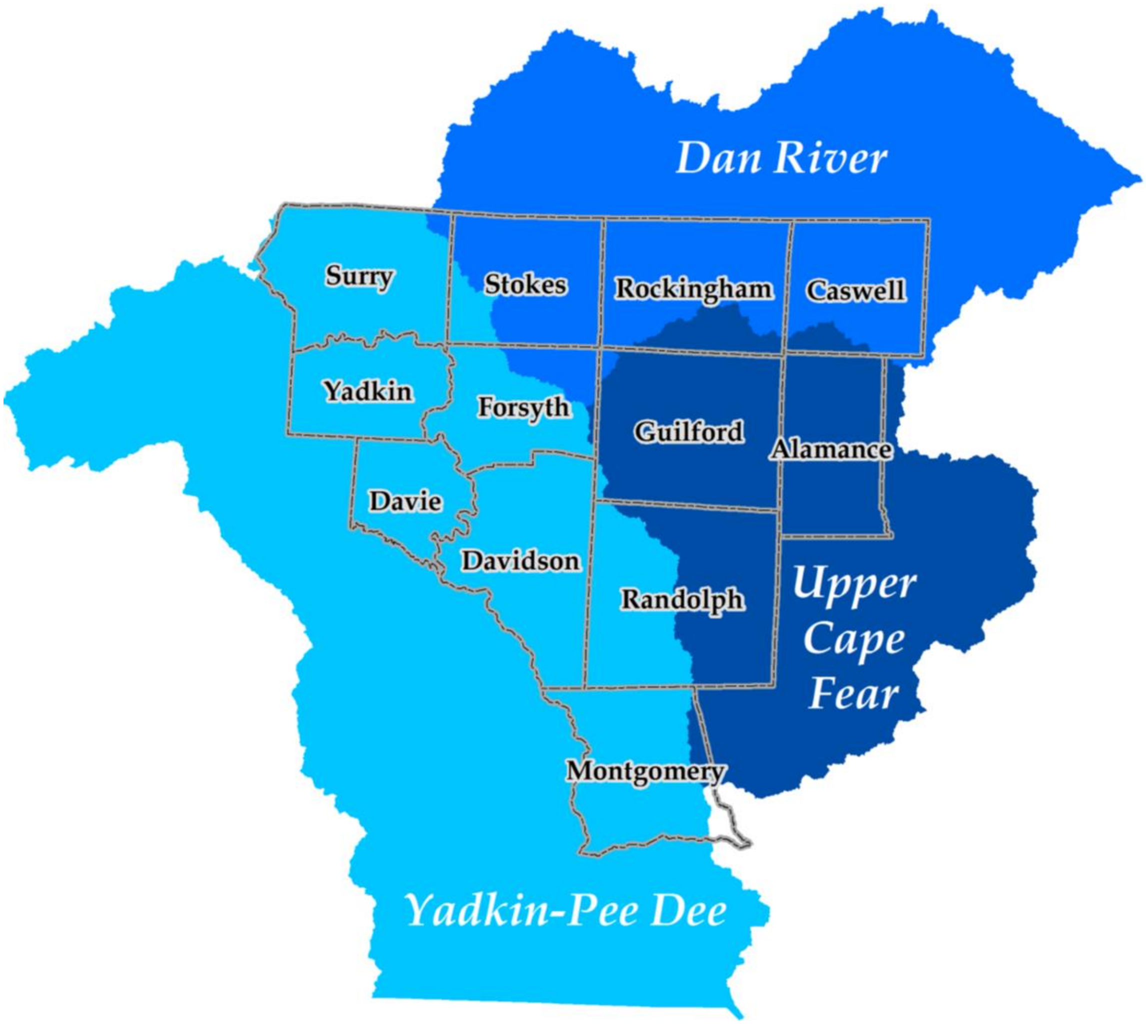
Table 6: Current Interbasin Transfers

System Name	County or Counties	Primary Source Basin	Primary Receiving Basin	Most Recent Transfer Amount (in mgd)
Handy Sanitary District	Davidson	Yadkin River	Uwharrie River	0.142
Davidson WI	Davidson	Yadkin River	Uwharrie River	1.78
Mocksville	Davie	South Yadkin River	Yadkin River	0.8
Winston Salem	Forsyth	Yadkin River	Haw River	0.38
Jamestown	Guilford	Deep River	Deep River	0.785
Greensboro	Guilford	Deep River	Haw River	7.2
Archdale	Guilford and Randolph	Deep River	Yadkin River	0.002
High Point	Guilford, Randolph, Davidson, Forsyth	Deep River	Yadkin River	3.9
Biscoe	Montgomery	Yadkin River	Deep River	0.045
Candor	Montgomery	Yadkin River	Haw River	0.116
Montgomery County	Montgomery	Yadkin River	Deep River	0.481
Star	Montgomery	Yadkin River	Deep River	0.051

Orange Alamance WS	Orange and Alamance	Neuse River	Haw River	0.1
Randleman	Randolph	Uwharrie River	Deep River	0.101
Asheboro	Randolph	Uwharrie River	Deep River	4.51
Reidsville	Rockingham	Haw River	Roanoke River	0.06
Rockingham County	Rockingham	Haw River	Roanoke River	0.03
King	Stokes and Forsyth	Yadkin River	Roanoke River	0.019

Source: NC DEQ - Water Supply Planning Branch

Figure 49: Piedmont Triad River Basins



Source: PTRC, 2011

Interbasin Transfer Notes

Abbreviations:

- IBT = Interbasin Transfer
- LWSP = Local Water Supply Plan
- MGD = Millions of Gallons per Day
- PTRWA = Piedmont Triad Regional Water Authority
- WWTP = Wastewater Treatment Plant

<u>Handy Sanitary District</u>

2016 LWSP: 70% service area in Yadkin and 30% in Uwharrie. Water purchased from Denton (0.725), source in Yadkin basin and emergency purchase from Davidson WC (0.037 mgd over 10 days = 0.001 mgd annual average), source in Yadkin. Wastewater interconnection with Troy, discharge 0.085 mgd to Yadkin basin. System has 806 sewer connections and 2,319 connections with septic. Estimated IBT from Yadkin to Uwharrie = (0.725+0.001) - 0.085 = 0.641*0.3 = 0.192*0.74 (74% septic) = approx. 0.142 mgd.

<u>Mocksville</u>

2016: Water source is from South Yadkin River basin (0.854 mgd) and purchase 0.442 mgd from Davie County (source is both South Yadkin and Yadkin basin). Sold 0.007 mgd to Davie County. Service area is 74% in Yadkin River basin and 26% in South Yadkin River basin. Wastewater discharge (0.452 mgd) to Yadkin River basin. Wastewater interconnection with Davie County (0.221 mgd), discharges mostly to Yadkin River basin and South Yadkin basin. System has 2,419 sewer connections and 288 service connections with septic. No water balance tables. Estimated IBT is 0.8 mgd from South Yadkin to Yadkin due to wastewater discharge to Yadkin and septic, with 74% service area in Yadkin.

<u>Jamestown</u>

2016: Purchases water from PTRWA (0.447 mgd), comes from Deep River basin and from High Point (0.044 mgd), most comes from Deep River basin and some from Yadkin River basin. Service area is 100% in Deep River basin. Wastewater interconnection with High Point (1.276 mgd) to Eastside WWTP which discharges to Deep River basin. High wastewater discharge because more sewer connections than water connections; Adams Farm development is served water by Greensboro (water comes from Haw River basin), sewer by Jamestown. IBT is primarily attributed to transfer of water from Greensboro system (Haw) and discharged to WWTP (in Deep) - estimated IBT is 1.276 mgd - 0.491 mgd = 0.785 mgd.

<u>Archdale</u>

2016 LWSP: 93% service area in Deep River and 7% in Uwharrie. Purchase 0.851 mgd from Piedmont Triad Regional Water Authority (source is Deep River basin); emergency purchase of 0.041 mgd from Davidson Water (source is Yadkin River basin). Emergency sale of 0.002 mgd to Davidson Water (to Yadkin basin). Wastewater interconnection with High Point (East Side Treatment Plant), discharged to Deep River basin. Only transfer for which Archdale is responsible is the emergency sale of 0.002 mgd, which goes to Yadkin basin.

Biscoe

2016 LWSP, Biscoe purchases water from Montgomery Co. (0.319 mgd), source is Yadkin. Wastewater (0.263 mgd) is discharged back to Yadkin basin. LWSP reports 100% of service area is in Yadkin, but looking at IBT map, Biscoe straddles Yadkin and Deep. LWSP reports 760 sewer connections and 127 septic (14% of water connections). If all septic is in Deep, 14 % of water distributed is 0.319 mgd*0.14 = 0.045 mgd.

Candor

2017 LWSP: 50% service area in Yadkin and 50% in Deep. All water supply (0.123 mgd) is purchased from Montgomery County (Yadkin). Wastewater (0.11 mgd) is discharged to Deep basin. System has 327 sewer connections and 20 connections with septic. Estimated IBT = 0.11 + 0.5(0.013) = 0.116 mgd.

Montgomery County

2017: Montgomery County's water source (2.57 mgd) is in Yadkin River basin. Wastewater discharge to Yadkin basin. Service area is 86% Yadkin basin; 10% Deep basin; 3% Lumber basin; and 1% Uwharrie basin. IBT due to consumptive loss/septic estimated at: 0.12 mgd from Yadkin to Deep; 0.03 mgd from Yadkin to Lumber; 0.01 mgd from Yadkin to Uwharrie. Sales to Towns of Biscoe, Candor, Mt. Gilead, Robbins, Star, and Troy result in IBT of 0.361 mgd from Yadkin to Deep and 0.106 mgd from Yadkin to Uwharrie. Total estimated IBT from sales and consumptive loss in respective service areas is: 0.481 mgd from Yadkin to Deep; 0.116 mgd from Yadkin to Uwharrie; and 0.03 mgd from Yadkin to Lumber

Star

2017: Star purchases all water (0.064 mgd) from Montgomery Co., source is Yadkin River basin. Reports 100% service area in Yadkin basin. Wastewater discharge (0.051 mgd) to Deep River basin. IBT attributed to wastewater discharge, estimated to be 0.051 mgd from Yadkin to Deep.

Orange Alamance WS

2016: Orange Alamance surface water supply (0.248 mgd) from Neuse River basin. Water also purchased (0.391 mgd) from Town of Haw River in Haw River basin. WTP process water (0.019 mgd) discharged to Neuse. Sewer interconnection with Mebane, discharges to Haw. Service area is 70% Haw and 30% Neuse, with 90% of system connections on septic. Approximate IBT is 0.1 mgd from Neuse to Haw.

Randleman

2016 LWSP: 100% service area in Deep River; purchase 0.829 mgd from Piedmont Triad Regional Water Authority (Deep River); purchase 0.101 mgd from Asheboro (Uwharrie). Wastewater discharge (0.822 mgd to Deep River; also interconnection with Asheboro (0.004 mgd discharge to Deep River). Therefore, IBT attributed to Randleman's purchase from Asheboro (0.101 mgd), transfer from Uwharrie to Deep River.

Reidsville

2015: Reidsville's water source (4.49 mgd) is from Haw River basin. Sales totaled 1.18 mgd to Greensboro (discharges to Haw basin) and 0.06 mgd to Rockingham Co. (2 wastewater interconnections, both discharge to Roanoke). Wastewater discharge (3.52 mgd) to Haw River basin. Service area is 70% Haw basin and 30% Roanoke basin. IBT is attributed to sale to Rockingham County. Estimated IBT is 0.06 mgd from Haw basin to Roanoke basin.

Rockingham County

According to 2016 LWSP, Rockingham purchases water from Reidsville, source is the Haw River basin, and discharges wastewater through two interconnections to the Roanoke River basin. Service area is 70% in Haw and 30% in Roanoke. 2016 average purchase from Reidsville was 0.104 mgd. Reported 139 sewer connections and 399 septic. Average day water balance table submitted by Rockingham County in June 2018 reported estimated transfer of 0.03 mgd from Haw to Roanoke.

King

2016 LWSP: 97% service population in Yadkin, 3% in Roanoke. Water source from Yadkin basin (1.617 mgd). Discharge wastewater (0.09 mgd) to Yadkin basin; interconnection with Winston-Salem (0.52 mgd), discharge to Yadkin basin. System has 3,172 sewer connections and 5,089 connections with septic. Estimated IBT from Yadkin to Roanoke in 3% of service area with 62% septic = approx 0.019 mgd.

Conclusion & Recommendations

As our region continues to grow and develop and the demand for potable water increases, it will be important to monitor the surface water capacity available to fulfill demand. Short-term solutions to water issues are generally quick and necessary steps in reaction to immediate concerns. However, a long-term planning approach will better prepare local governments for the unique challenges facing our region. Investment in a deeper understanding of the complex and difficult political, regulatory, and environmental issues surrounding water will help guide decision-makers to consider future ramifications of options in resource planning.

Recommendations:

- There is great opportunity to increase available water supply in the region through comprehensive and sustained water conservation programs. An effective and sustained water conservation program may result in enough water use reductions to delay the need to augment supplies through the purchase or development of new water supplies.
- Water conservation efforts should include, at a minimum, an increasing water rate structure, water audits, leak detection program, and metering of all water users.
- For water supply systems with the most critical need, continue to seek innovative water supply solutions such as water reuse and reclamation, and regional water supply projects, which may involve interbasin transfers of water.
- Some local governments in the PTRC region will need to seek regional solutions to their water supply issues. Regional water supply planning and management are critical to the successful long-term protection of the quality and quantity of surface water.

- Continue to monitor surface water supplies and wastewater treatment plant capacity.
- All water supply systems should have a Water Shortage Response Plan in place to respond to drought episodes, water contamination, or mechanical water system failure.
- Develop interconnections among systems for emergency water supply, to ensure continuous water supply and increase efficiency and reliability. Events such as mechanical failures, pipe breaks, or contamination of water sources, can be mitigated by acquiring and maintaining interconnections to other systems.
- Water systems with an average daily water demand approaching 80 percent of available water supply should be actively managing water demand and pursuing additional water supplies.
- All wastewater treatment plants approaching 80 percent capacity should plan for expansion, and consider upgrades to advanced treatment to protect water quality.

Glossary

Aquifer: A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Chlorine: One of the most common chemicals used in the treatment of public water supplies because it is highly effective in killing harmful microorganisms.

Clean Water Act (CWA): The Clean Water Act is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to waters of the United States.

Coliforms: Bacteria which is used as an indicator of the bacteriological safety of a domestic water supply.

Conservation: Methods of using water wisely with the minimum amount of water being wasted.

Contamination: The introduction of a harmful substance into the water either at the supply or during distribution.

Discharge: The amount of water or substance which flows into a water body from a point or non-point source. Wastewater treatment plant discharge means treated sewage discharged from a sewage treatment plant.

Dissolved oxygen: The amount of oxygen gas dissolved in a given volume of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water.

Drought: A period of lower-than-normal precipitation that can lead to a water shortage.

Effluent: The discharge of a contaminant or contaminants with water from animal production or industrial facilities or wastewater treatment plant.

Effluent limitations: Restrictions imposed on the quantities, discharge rates, and concentrations of pollutants that can be discharged from point sources of pollution into waterways. These restrictions are incorporated into each polluter's NPDES permit under the Clean Water Act.

Eutrophication: The process of surface water nutrient enrichment is causing a water body to fill with aquatic plants and algae. The increase in plant life reduces the oxygen content of the water. Eutrophic lakes often are undesirable for recreation and may not support normal fish populations.

Federal Energy Regulatory Commission (FERC): The governing federal agency responsible for overseeing the licensing/relicensing and operation of hydroelectric projects in the United States.

FERC licensing/relicensing process: The hydroelectric relicensing process which begins five years before license renewal. FERC conducts an independent analysis of the licensee's proposal to determine whether to grant a new license to continue operations of a hydroelectric dam for a 50 year period. It is the regulatory process which involves consultations, studies and application preparation which includes the preparation of an environmental assessment EA or environmental impact statement (EIS) after the application is filed.

Filtration: The process by which organic and inorganic particles are removed from the raw water.

Fecal coliform: A portion of the coliform bacteria group originating in the intestinal tract of warm-blooded animals and passes into the environment as feces.

Groundwater: Water that occupies voids, cracks, or other spaces between particles of clay, silt, sand, gravel or rock within the saturated zone. Water in the saturated zone is the only subsurface water available to supply wells and springs.

Groundwater recharge: The process where water enters the soil and eventually reaches the saturated zone. Recharge varies from place to place due to the amount of rainfall, infiltration, and surface vegetation.

Hydrologic cycle: Also called the Water Cycle. This is the natural cycle of water, including evaporation, transpiration, condensation, precipitation, and percolation.

Impaired stream/river/waterbody: Waterbodies (i.e., stream reaches or lakes) that have been placed on the Section 303(d) list because they exceed water quality standards for one or more pollutant(s).

Intake: The part of a surface water treatment facility where water from a lake, river or stream is drawn into the plant for filtration, treatment, and distribution to customers.

National Pollutant Discharge Elimination System (NPDES): In 1972, the National Pollutant Discharge Elimination System program was established under the authority of the Clean Water Act. It is a national system for issuing, modifying, revoking, monitoring and enforcing permits. NPDES permits regulate point sources of pollution. The system also imposes and enforces pretreatment requirements.

NPDES Phase I: Phase I of the NPDES stormwater program was established in 1990 and required NPDES permit coverage for large or medium municipalities that had populations of 100,000 or more. The City of Greensboro was among the six communities identified in Phase I.

NPDES Phase II: Phase II of the NPDES Stormwater program was signed into law in December 1999. This regulation requires that smaller communities, also known as small municipal separate storm sewer systems (MS4s), be permitted. Regulated small MS4s applied for permit coverage by March 2003. Those communities permitted under Phase II are required to develop and implement a comprehensive stormwater management program that includes six minimum measures: (1) public education and outreach on stormwater impacts; (2) public involvement/participation; (3) illicit discharge detection and elimination; (4) construction site stormwater runoff control; (5) post-construction stormwater management for new development and redevelopment; and (6) pollution prevention/good housekeeping for municipal operations.

Non-point source pollution: Water runoff without a single point of origin that flows over the surface of the ground by irrigation water or stormwater and is then introduced to surface or ground waters. Npss include atmospheric deposition and runoff or leaching from agricultural lands, urban areas, un-vegetated lands, onsite sewage treatment and disposal systems, and construction sites.

Nutrient: An element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Potable water: Water that is safe to drink after the raw water has gone through the filtration and treatment process.

Point source: An identifiable and confined discharge point for one or more water pollutants, such as a pipe, channel, vessel, or ditch.

Pollution: An undesirable change in the physical, chemical, or biological characteristics of air, water, soil, or food that can adversely affect the health, survival, or activities of humans or other living organisms.

Public water supply: Water provided to a group of homes or an entire city through a water utility via underground pipes and water mains.

Raw water: The water from a surface water or groundwater source before filtration or treatment.

Recharge: The increase in groundwater levels after rainwater soaks into the ground and the saturated zone.

Recharge area: An area of land that allows rainwater to drain or soak into the earth's surface to replenish groundwater sources.

Reservoirs: Man-made storage areas for water. Sometimes a reservoir will be open, like a man-made lake, or it may be a fully enclosed tank, either above-ground or underground.

Receiving waters: Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and treated or untreated waste are discharged, either naturally or in man-made systems.

Reclaimed water: Product produced by tertiary treatment of wastewater.

Residence time: The length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.

Reverse osmosis: Tertiary water treatment method used to remove dissolved inorganic chemicals and suspended particulate matter from a water supply. Water, under pressure, is forced through a semi-permeable membrane that removes molecules larger than the pores of the membrane. Large molecules are flushed into waste waters. Smaller molecules are removed by an activated carbon filter.

River basin - The land area drained by a major river and its tributaries.

Runoff: Precipitation or irrigation water that does not infiltrate but flows over the land surface toward a surface drain, eventually making its way to a river, lake or an ocean.

Secondary treatment: Second stage of wastewater treatment that uses a biological process in which bacteria consume organic matter, then settle out as sludge.

Subbasin: A drainage area which drains to a river which is part of a larger drainage basin or area. A subdivision of a larger river basin.

Surface water: Any source of water that is found on top of the earth's surface, such as a lake, river or stream.

Tertiary treatment: The use of filtration to remove microscopic particles from wastewater that has already been treated to a Secondary Level. Anthracite coal is the filter medium used by the MWWD.

Suspended solids - Solids in water that can be trapped by a filter. Suspended solids can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage.

Treatment: The process by which substances are added to the water to make it safe to drink or look and taste better.

Wastewater treatment plant: A facility with a series of tanks, screens, filters, and other processes used to clean wastewater before it is returned to the environment.

Water meter: A device that records the amount of water being used in your home.

Watershed: Also called a drainage basin. This is an area of land that allows rainwater to flow into creeks, streams, and rivers. Watersheds range in size from a few acres to large areas of the country.

Data Resources

Name:	Ag Weather Tools
Creator:	Farms.com/Telvent DTN, LLC
Link:	http://www.farms.com/agriculture-apps/weather/ag-weather-tools
Description:	Ag Weather Tools provides GPS-based roaming alerts, as well as forecasts, touch screen interactive weather displays, and ag commentary. The app also gives users advance notice to weather risks, and provides farm-level forecasts.

Sample Images:

NORTH CAROLINA CLIMATE OFFICE

<table>
<tr><td>**Name:**</td><td>**NC Climate Office Agriculture Tools**</td><td>**Creator:**</td><td>State Climate Office of North Carolina</td></tr>
<tr><td>**Link:**</td><td colspan="3">http://climate.ncsu.edu/tools/agriculture</td></tr>
<tr><td>**Description:**</td><td colspan="3">Explore climate impacts to various crop and plant species. Resources include:
• PineMap Decision Support System – Explore future climate-based risks and opportunities as well as regional productivity model output for loblolly pine tree growth and development.
• Thrips Infestation Predictor for Cotton – Designed for cotton growers, view seasonal forecasts for thrips infestations in cotton for user-entered locations across the Southeast.
• Blueberry Chill Model – Retrieve chill unit accumulations to estimate rest completion in blueberries using weather data from stations across the Southeast.
• Blueberry Heat Model – Generate heat unit accumulations for blueberries (beginning when 25% corolla drop observed, and ending when 25% of fruit on the same bushes are ripe) using weather data from stations across the Southeast.
• Blackberry Chill Model – Retrieve chill unit accumulations to estimate rest completion in blackberries using weather data from stations across the Southeast.
• Climate Voyager – Investigate projected changes in temperatures, precipitation, and other climate variables using data from a suite of downscaled global climate models.</td></tr>
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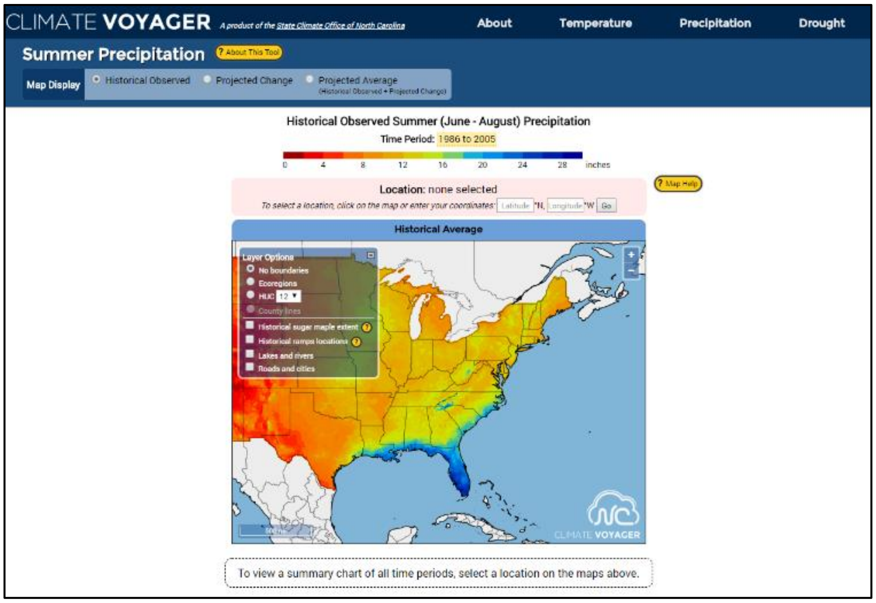
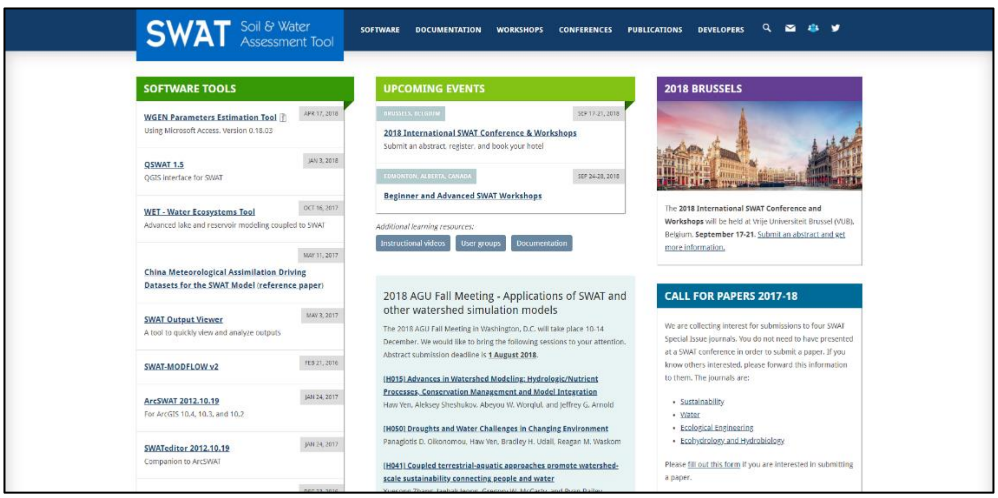
Sample Image:



Name:	**Soil and Water Assessment Tool (SWAT)**	**Creator:**	US Department of Agriculture
Link:	https://swat.tamu.edu/		
Description:	Watershed model used to simulate the impacts of land use, land management, and climate on water quantity and quality.		

Sample Image:

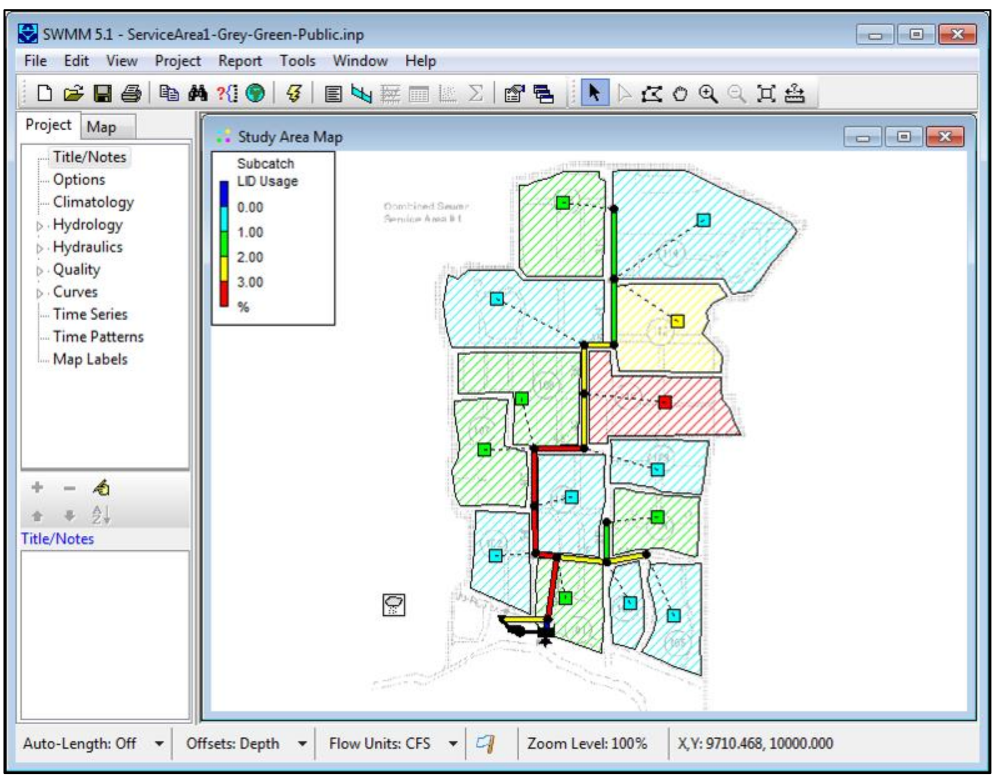


Name:	**Stormwater Management Model with Climate Adjustment Tool (SWMM-CAT)**	**Creator:**	US Environmental Protection Agency

Link: https://www.epa.gov/water-research/storm-water-management-model-swmm

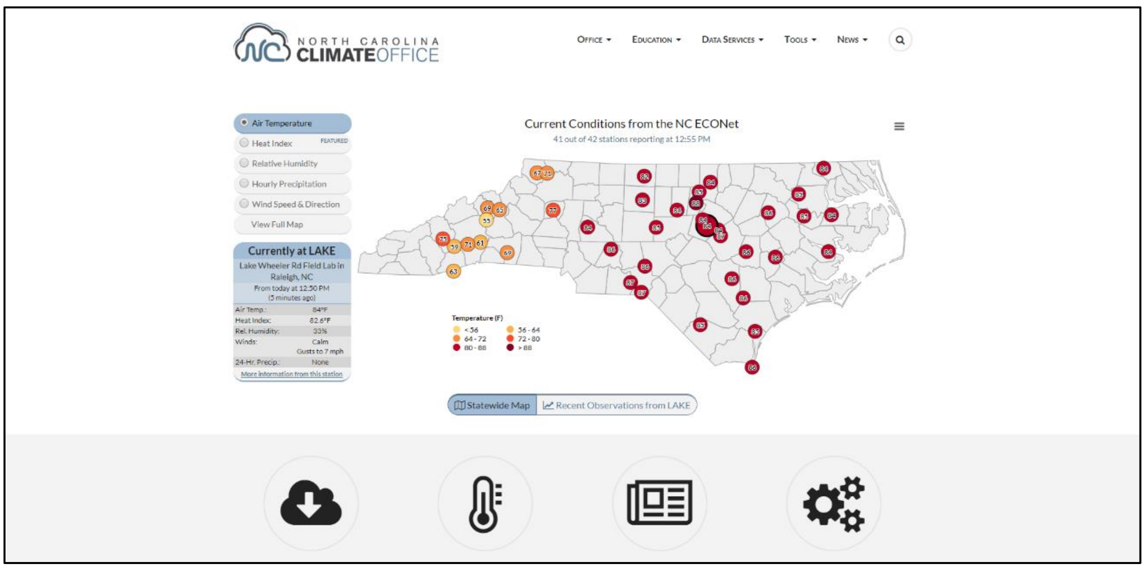
Description: Downloadable program used to simulate the quality and quantity of rainfall over urban and suburban areas. The Climate Adjustment Tool add-on enables users to add climate projections based on the IPCC's climate change scenarios to existing simulations.

Sample Image:



Name:	**NC Climate Office Weather Data**	**Creator:**	State Climate Office of North Carolina
Link:	http://www.nc-climate.ncsu.edu/		
Description:	Current weather data for North Carolina and related resources.		

Sample Image:

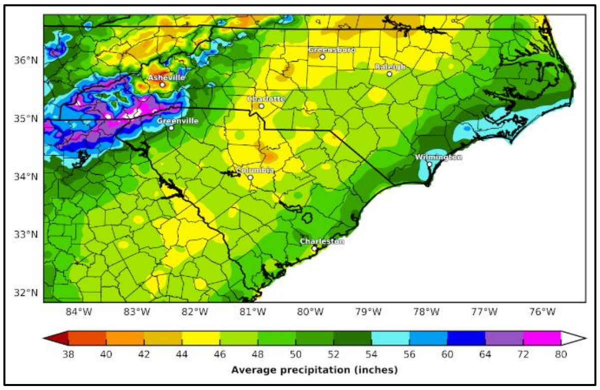


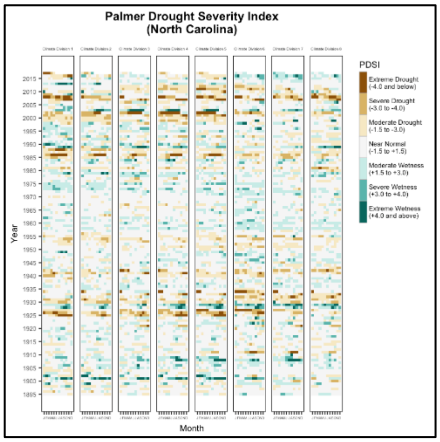
Name:	**Carolinas Precipitation Patterns & Probabilities**	**Creator:**	Carolinas Integrated Sciences and Assessments (CISA)/ National Integrated Drought Information System

Link: http://www.cisa.sc.edu/atlas/index.html

Description: Provides maps, graphics, and related information about rainfall amounts and droughts in the region.

Sample Images:



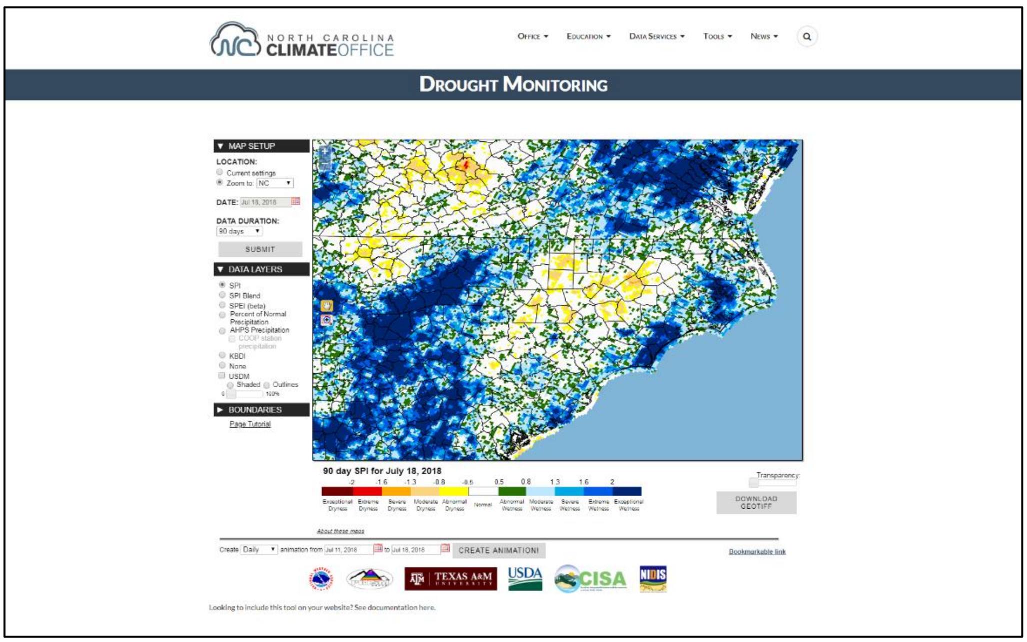


Name:	**Drought Monitoring**	**Creator:**	State Climate Office of North Carolina

Link: http://climate.ncsu.edu/drought/map

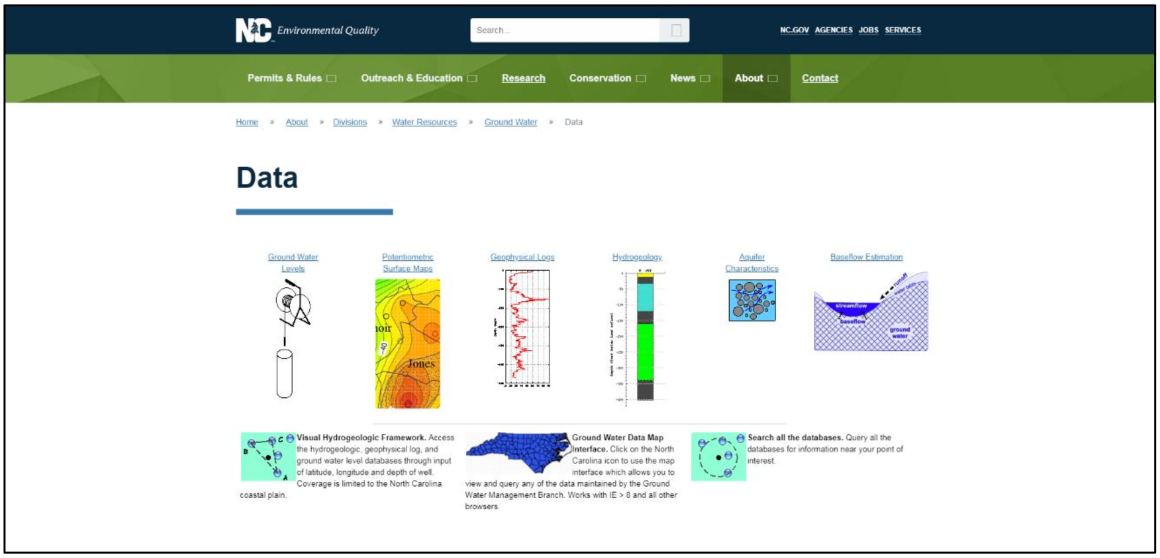
Description: View maps and time series of gridded drought indices, surface gauge precipitation, and other information useful for drought monitoring.

Sample Image:



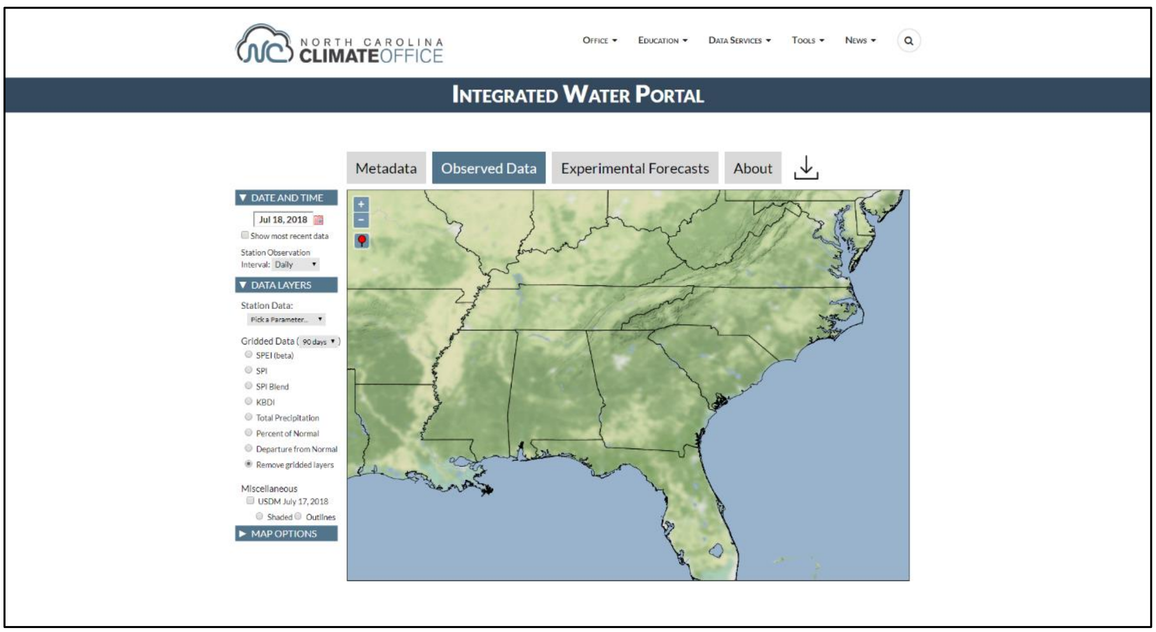
Name:	**Ground Water Management Branch Database**	**Creator:**	NC Water Division of Water Resources
Link:	https://deq.nc.gov/about/divisions/water-resources/water-planning/ground-water-management-branch		
Description:	Database of groundwater monitoring tools, monitoring well networks, and drought indicator wells.		

Sample Image:



Name:	**Integrated Water Portal**	**Creator:**	State Climate Office of North Carolina
Link:	http://climate.ncsu.edu/water/map		
Description:	View surface and groundwater observations, drought information, and experimental reservoir forecasts.		

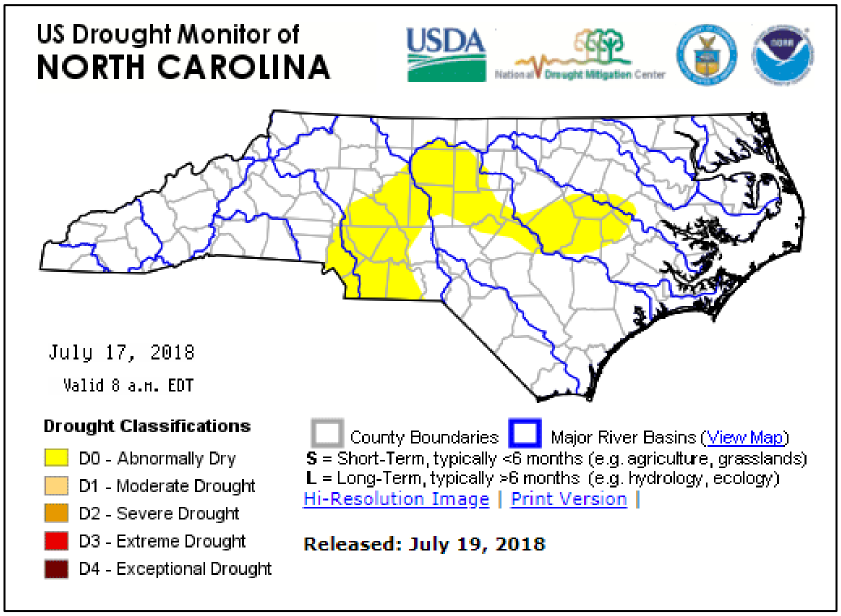
Sample Image:



NORTH CAROLINA
Drought Management Advisory Council

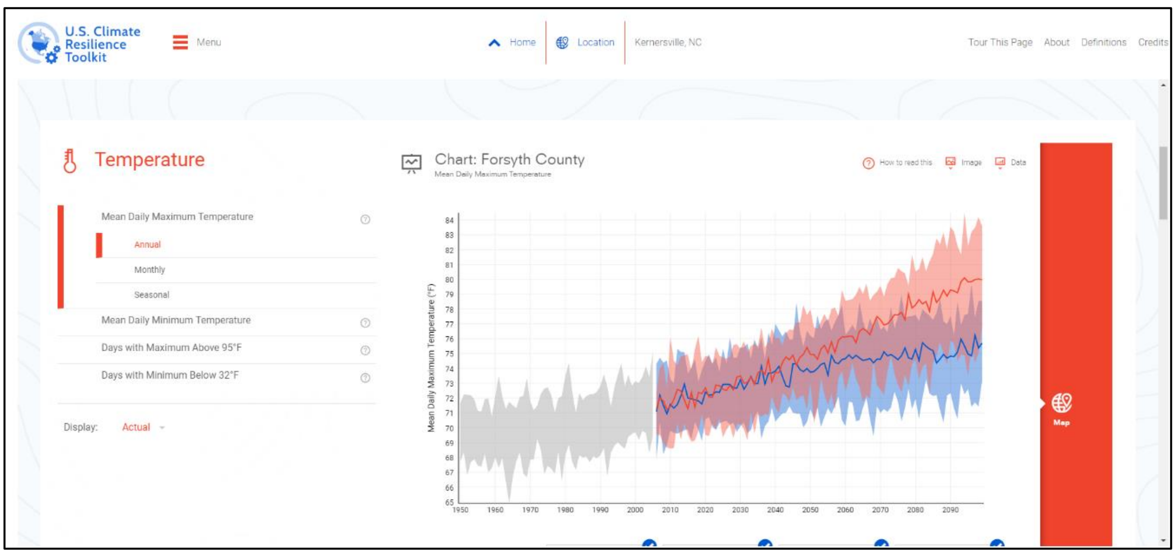
Name:	NC Drought Advisory	Creator:	NC Drought Management Advisory Council
Link:	http://www.ncdrought.org/		
Description:	Current drought conditions indicated on weekly basis and drought monitor archives available.		

Sample Image:



Name:	**Climate Explorer**	**Creator:**	National Oceanic and Atmospheric Administration
Link:	https://toolkit.climate.gov/climate-explorer2/		
Description:	Explore interactive graphs and maps of climate projections and observations for any county in the contiguous US. Display historical temperature and precipitation observations for hundreds of climate stations.		

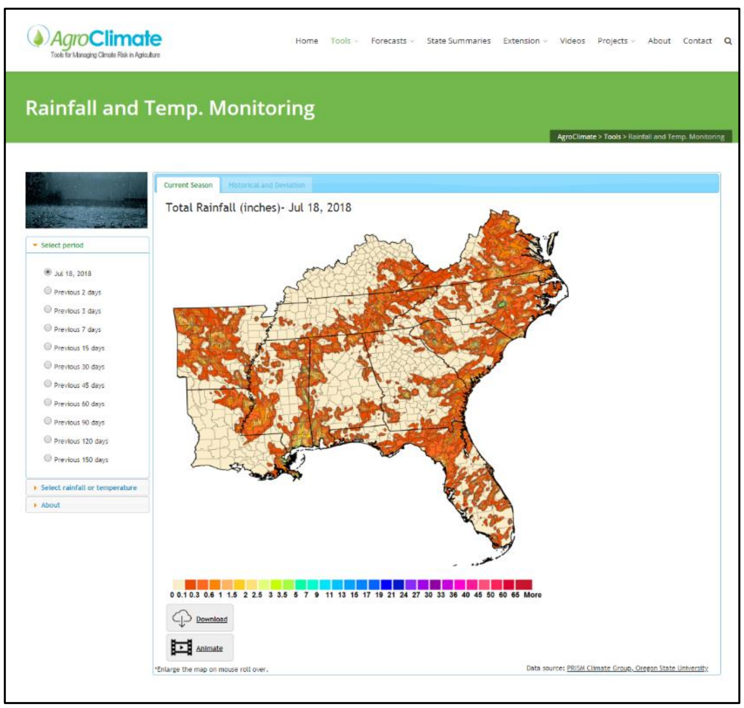
Sample Image:



AgroClimate
Tools for Managing Climate Risk in Agriculture

Name:	AgroClimate	**Creator:**	Southeast Climate Consortium
Link:	http://agroclimate.org/		
Description:	Tools for managing climate risks in agriculture.		

Sample Images:



United States
Environmental Protection
Agency

Name:	**Climate Resiliency Evaluation and Awareness Tool (CREAT)**	**Creator:**	US Environmental Protection Agency

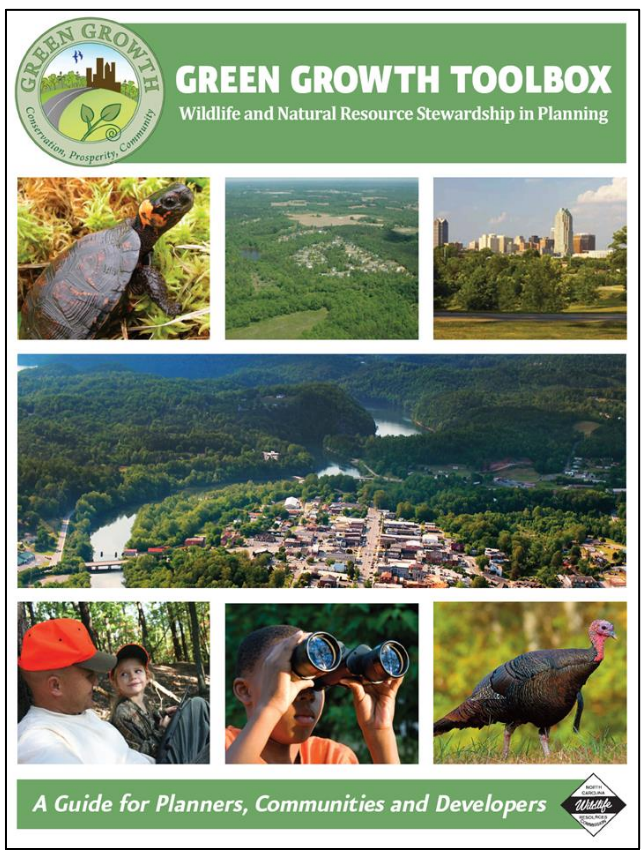
Link:	https://www.epa.gov/crwu/creat-risk-assessment-application-water-utilities
Description:	Risk assessment application that helps utilities to adapt to extreme weather events by better understanding current and long-term weather conditions.
Sample Image:	

United States
Environmental Protection
Agency

Name:	**Flood Resilience: A Basic Guide for Water and Wastewater Utilities**	**Creator:**	US Environmental Protection Agency
Link:	https://www.epa.gov/waterutilityresponse/flood-resilience-basic-guide-water-and-wastewater-utilities		
Description:	With a user-friendly layout, embedded videos, and flood maps to guide you, EPA's Flood Resilience Guide is your one-stop resource to know your flooding threat and identify practical mitigation options to protect your critical assets.		
Sample Image:			

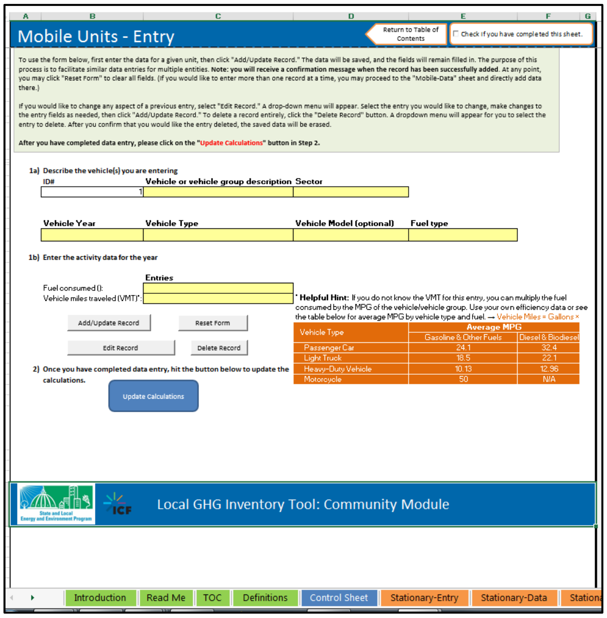
Name:	**Green Growth Toolbox**	**Creator:**	North Carolina Wildlife Resources Commission
Link:	http://ncwildlife.org/Conserving/Programs/Green-Growth-Toolbox		
Description:	The Green Growth Toolbox is a technical assistance tool designed to help communities conserve high-quality habitats as communities and developers continue to build new homes, workplaces, and shopping centers.		

Sample Image:



Name:	**Greenhouse Gas Inventory Tool**
Creator:	US Environmental Protection Agency
Link:	https://www.epa.gov/statelocalenergy/local-greenhouse-gas-inventory-tool
Description:	Spreadsheet tool that can be used to calculate greenhouse gas emissions for your community or local government operations.

Sample Image:



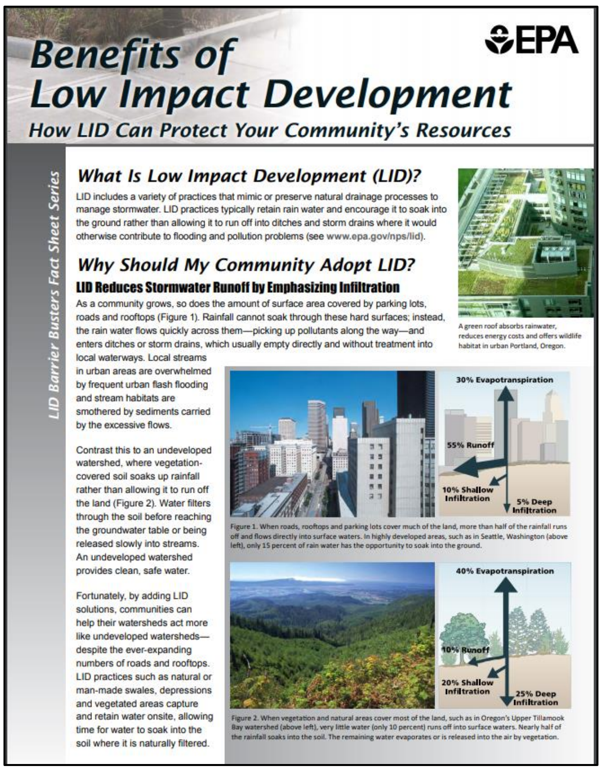
United States
Environmental Protection
Agency

Name:	**Low Impact Development (LID)**	**Creator:**	US Environmental Protection Agency

Link:	https://www.epa.gov/nps/urban-runoff-low-impact-development

Description:	Fact sheets and technical reports on LID.

Sample Image:



Benefits of Low Impact Development

How LID Can Protect Your Community's Resources

LID Barrier Busters Fact Sheet Series

What Is Low Impact Development (LID)?

LID includes a variety of practices that mimic or preserve natural drainage processes to manage stormwater. LID practices typically retain rain water and encourage it to soak into the ground rather than allowing it to run off into ditches and storm drains where it would otherwise contribute to flooding and pollution problems (see www.epa.gov/nps/lid).

Why Should My Community Adopt LID?

LID Reduces Stormwater Runoff by Emphasizing Infiltration

As a community grows, so does the amount of surface area covered by parking lots, roads and rooftops (Figure 1). Rainfall cannot soak through these hard surfaces; instead, the rain water flows quickly across them—picking up pollutants along the way—and enters ditches or storm drains, which usually empty directly and without treatment into local waterways. Local streams in urban areas are overwhelmed by frequent urban flash flooding and stream habitats are smothered by sediments carried by the excessive flows.

Contrast this to an undeveloped watershed, where vegetation-covered soil soaks up rainfall rather than allowing it to run off the land (Figure 2). Water filters through the soil before reaching the groundwater table or being released slowly into streams. An undeveloped watershed provides clean, safe water.

Fortunately, by adding LID solutions, communities can help their watersheds act more like undeveloped watersheds—despite the ever-expanding numbers of roads and rooftops. LID practices such as natural or man-made swales, depressions and vegetated areas capture and retain water onsite, allowing time for water to soak into the soil where it is naturally filtered.

A green roof absorbs rainwater, reduces energy costs and offers wildlife habitat in urban Portland, Oregon.

30% Evapotranspiration
55% Runoff
10% Shallow Infiltration
5% Deep Infiltration

Figure 1. When roads, rooftops and parking lots cover much of the land, more than half of the rainfall runs off and flows directly into surface waters. In highly developed areas, such as in Seattle, Washington (above left), only 15 percent of rain water has the opportunity to soak into the ground.

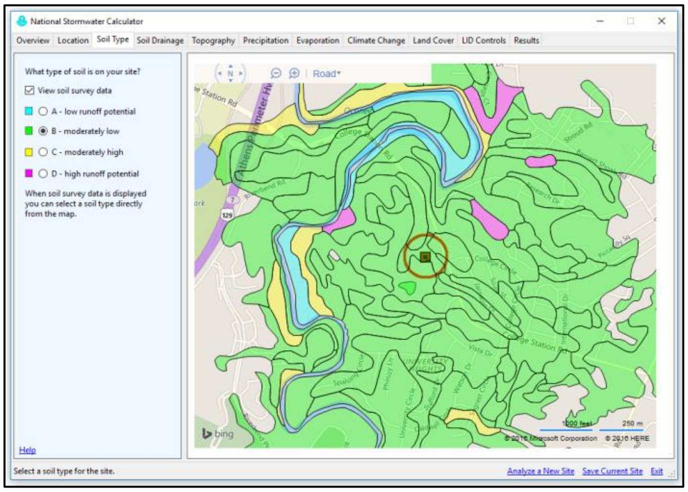
40% Evapotranspiration
10% Runoff
20% Shallow Infiltration
25% Deep Infiltration

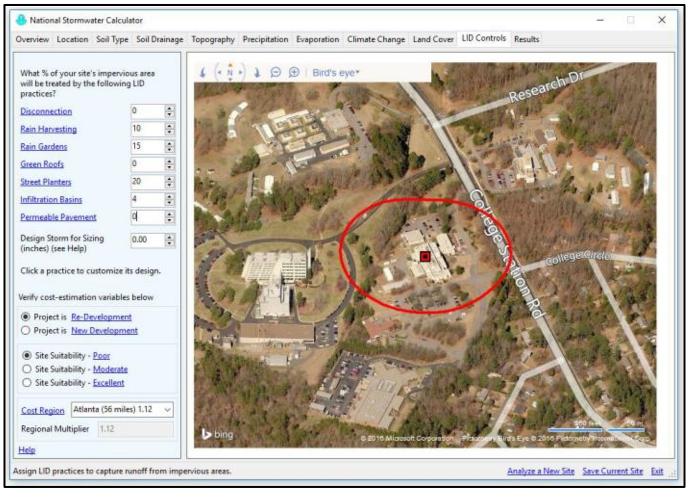
Figure 2. When vegetation and natural areas cover most of the land, such as in Oregon's Upper Tillamook Bay watershed (above left), very little water (only 10 percent) runs off into surface waters. Nearly half of the rainfall soaks into the soil. The remaining water evaporates or is released into the air by vegetation.

United States
Environmental Protection
Agency

Name:	**Stormwater Calculator**	**Creator:**	US Environmental Protection Agency
Link:	https://www.epa.gov/water-research/national-stormwater-calculator		
Description:	A software application that estimates the annual amount of rainwater and frequency of runoff from a specific site.		

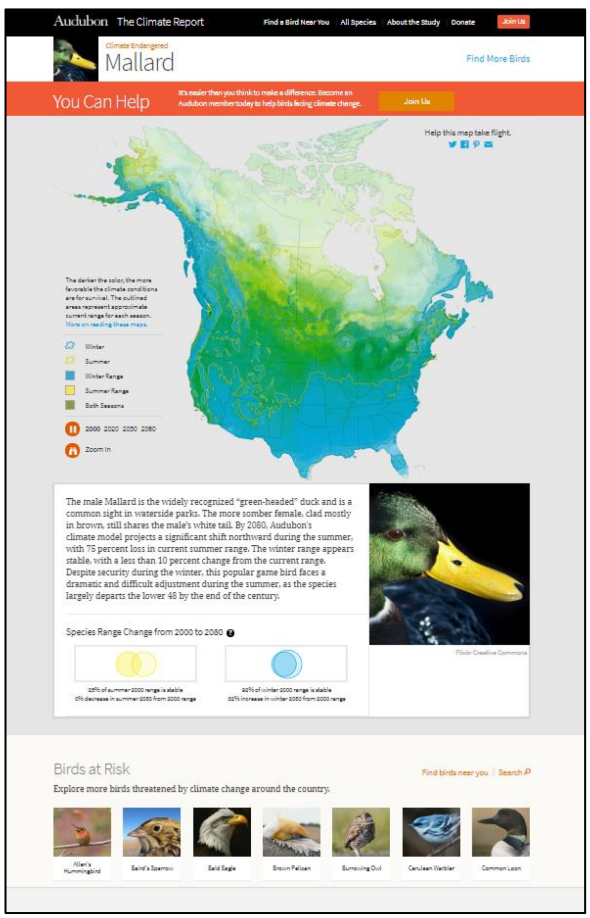
Sample Images:





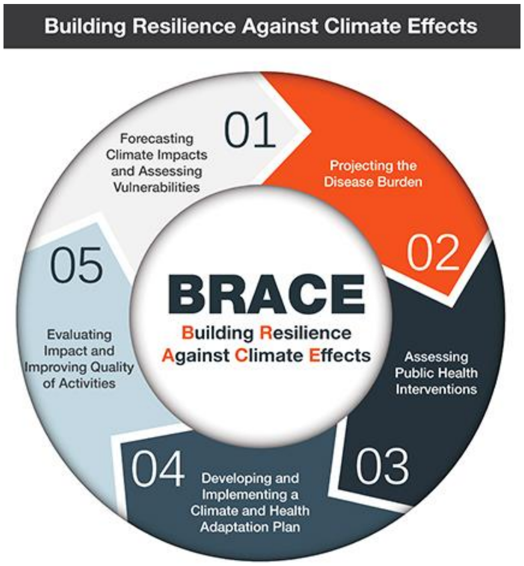
Name:	**Audubon Birds and Climate Report**
Creator:	Audubon Society
Link:	http://climate.audubon.org/
Description:	Citizen science observations and sophisticated climate models predict how birds in the US and Canada will react to climate change.

Sample Image:



Name:	**Building Resilience Against Climate Effects (BRACE)**	**Creator:**	Centers for Disease Control and Prevention
Link:	https://www.cdc.gov/climateandhealth/BRACE.htm		
Description:	The BRACE Framework allows health officials to develop strategies and programs to help communities prepare for the health effects of climate change.		

Sample Image:



ATSDR

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Name:	**The Social Vulnerability Index**	**Creator:**	Agency for Toxic Substances & Disease Registry (ATSDR)

Link: https://svi.cdc.gov/

Description: This index uses US census variables at tract level to help local officials identify communities that may need support in preparing for hazards, or recovering from disaster.

Sample Image:

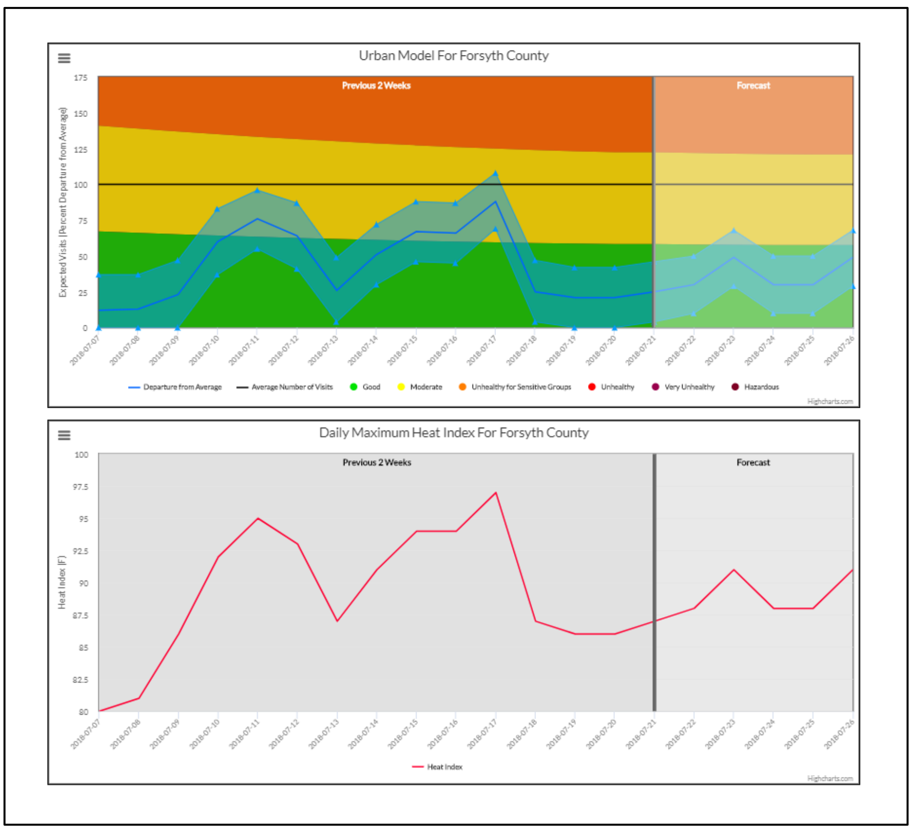
CISA
Carolinas Integrated Sciences and Assessments
A NOAA RISA TEAM

Name:	**Convergence of Climate-Health-Vulnerabilities**	**Creator:**	Carolinas Integrated Sciences and Assessments (CISA)

Link:	https://convergence.unc.edu/

Description:	Online tools and resources to assess heat-related risks and prepare for extreme weather events.

Sample Image:



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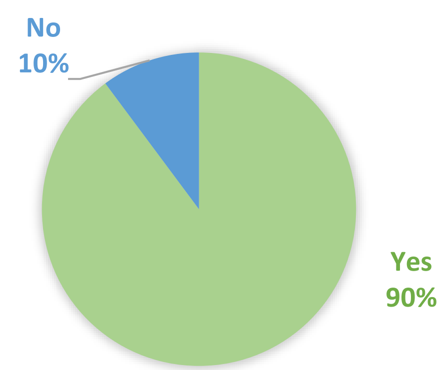
Appendix

Regional Climate Resiliency Survey

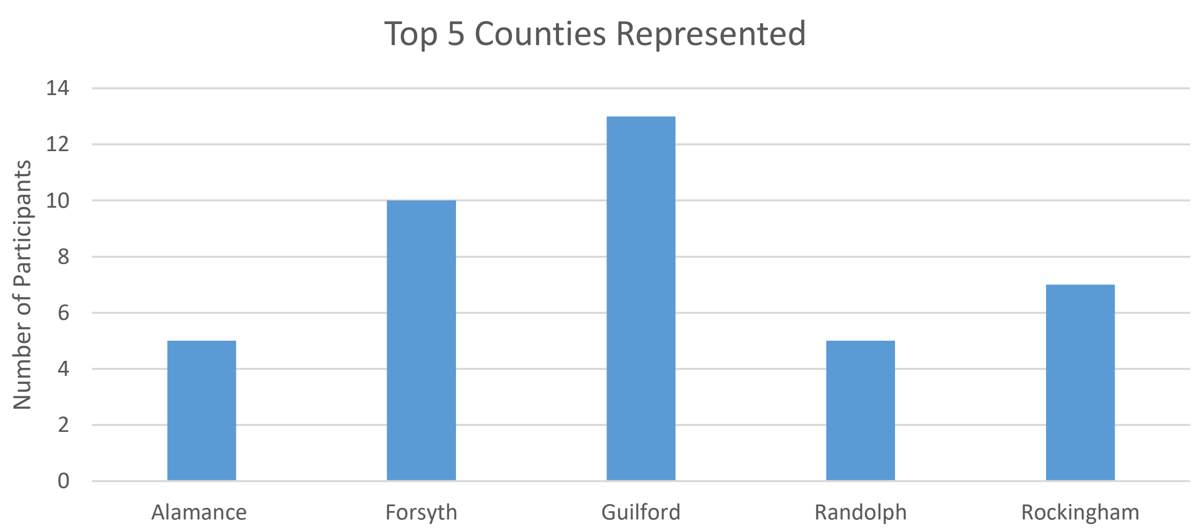
In an effort to gather input from a broad and diverse group of stakeholders, the Piedmont Triad Regional Council (PTRC) distributed a region-wide survey on climate-related issues. Survey questions were designed to evaluate the extent to which Piedmont Triad communities are currently being impacted by changes in climate, assess regional preparedness, discover any local best practices, and identify any gaps in available data or planning resources. The survey was made available online and distributed directly to local governments and agencies involved in water resource management, as well as across a wide range of professional listservs. In total, the survey received 59 responses. A summary of survey responses has been provided below. Responses were used to supplement stakeholder feedback that was gathered during PTRC's regional climate summits.

Respondent Demographics

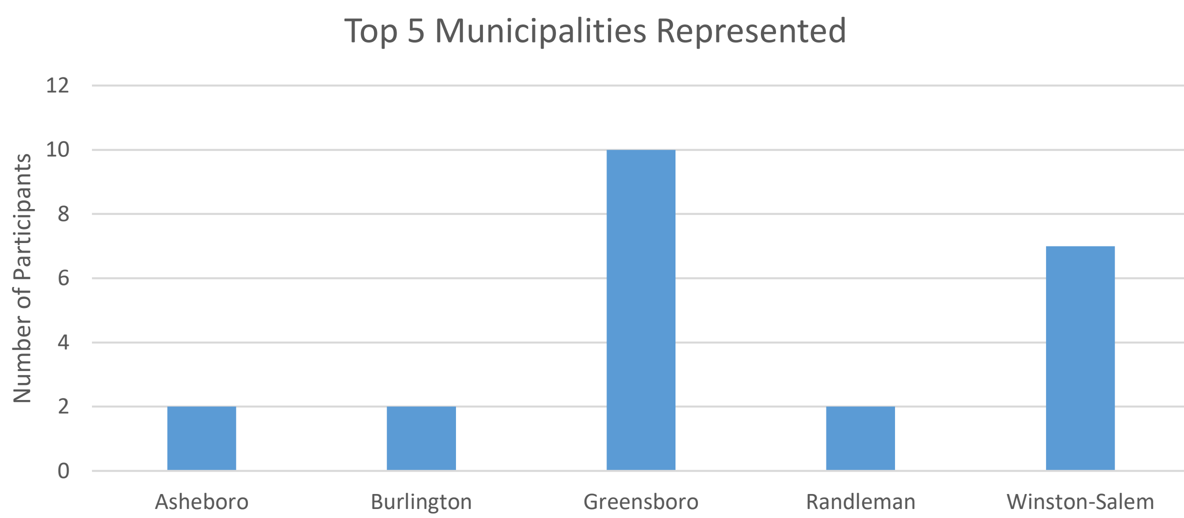
1. ***Do you live or work within the Piedmont Triad Region of North Carolina?***



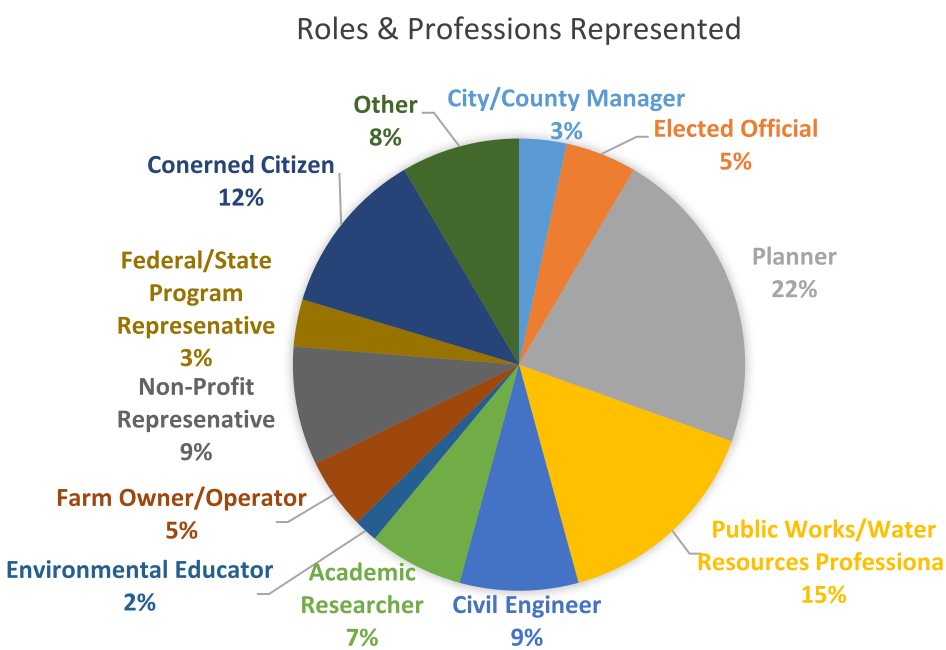
2. ***What County are you from or representing?***



3. What municipality do you work in or represent?

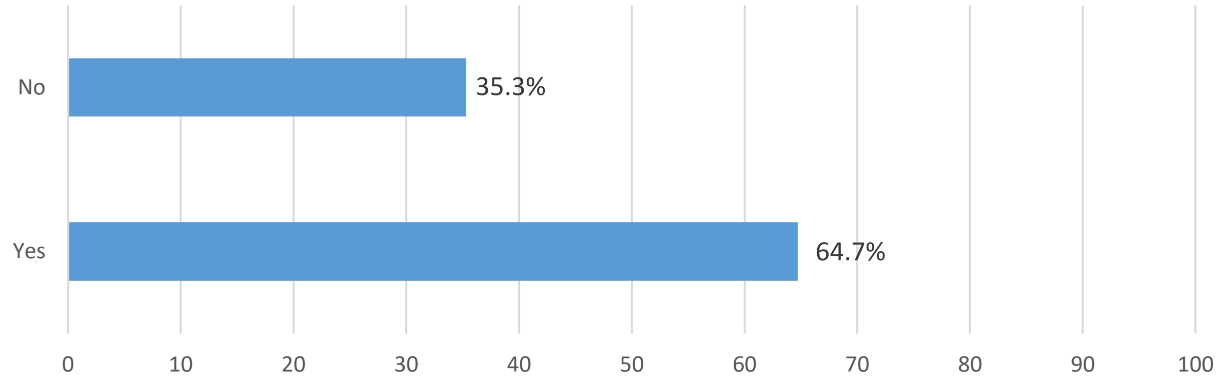


4. Which of the following best describes your role or profession?

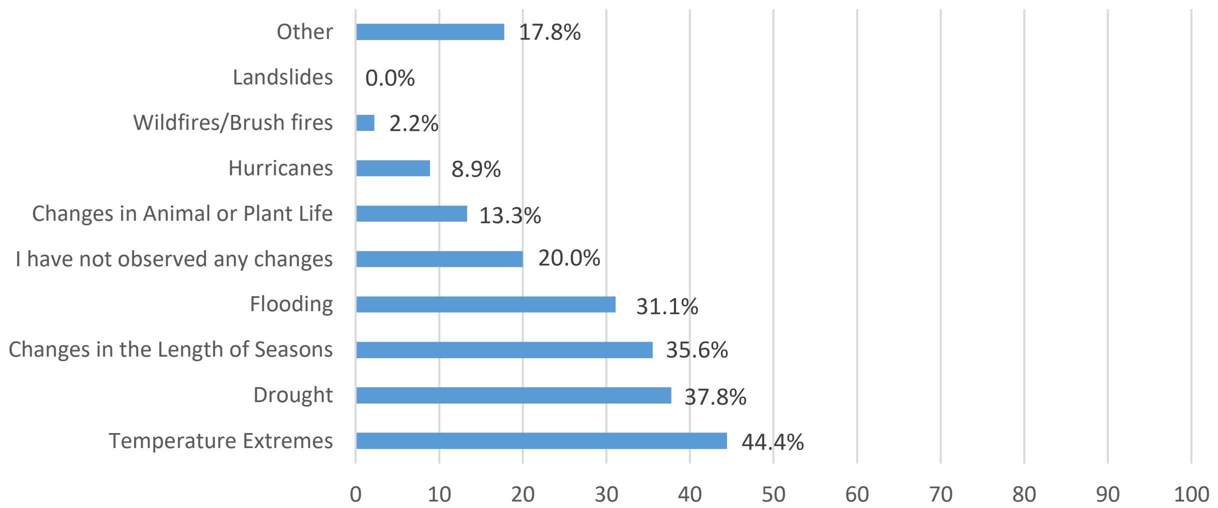


Existing Conditions

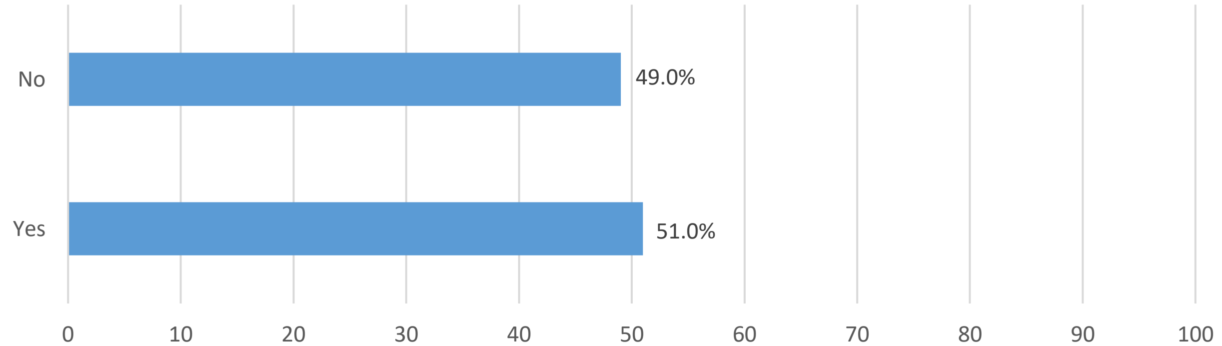
5. ***Have you observed any shifts in climate or extreme weather in recent years that has impacted you or your community's day-to-day operations?***



6. ***If so, which major weather event(s) has/have impacted how you or your community operates? (select all that apply)***



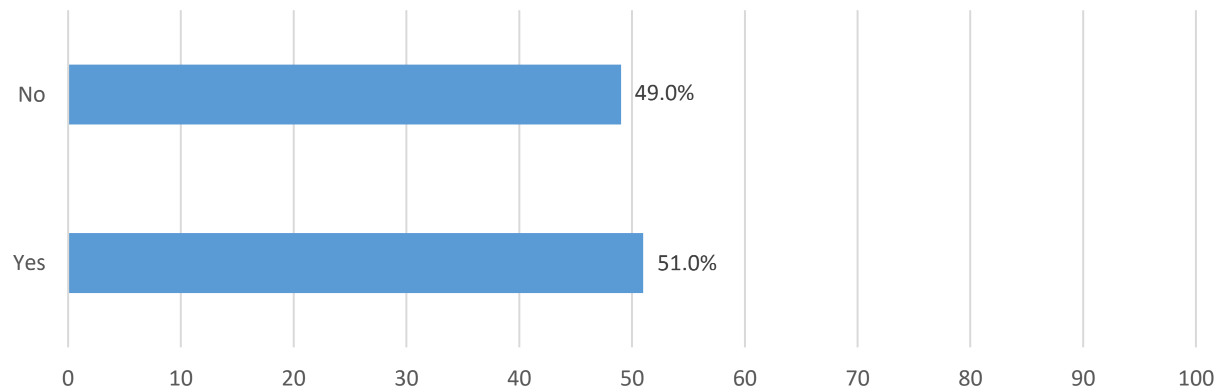
7. ***Have shifts in climate or extreme weather had any impact on your community or day-to-day operations?***



8. If so, what were the impacts?

- Sanitary sewer overflows and road closures due to more frequent flooding
- Restricted water use during drought
- Early blooming of plants
- Increased herbicide use due to rapid weed growth
- Limited outdoor activity due to extreme temperatures
- Increased water usage in summer months
- Health issues from inconsistent weather patterns

9. Have you or your organization taken steps to mitigate these impacts?



10. If so, what steps have been taken?

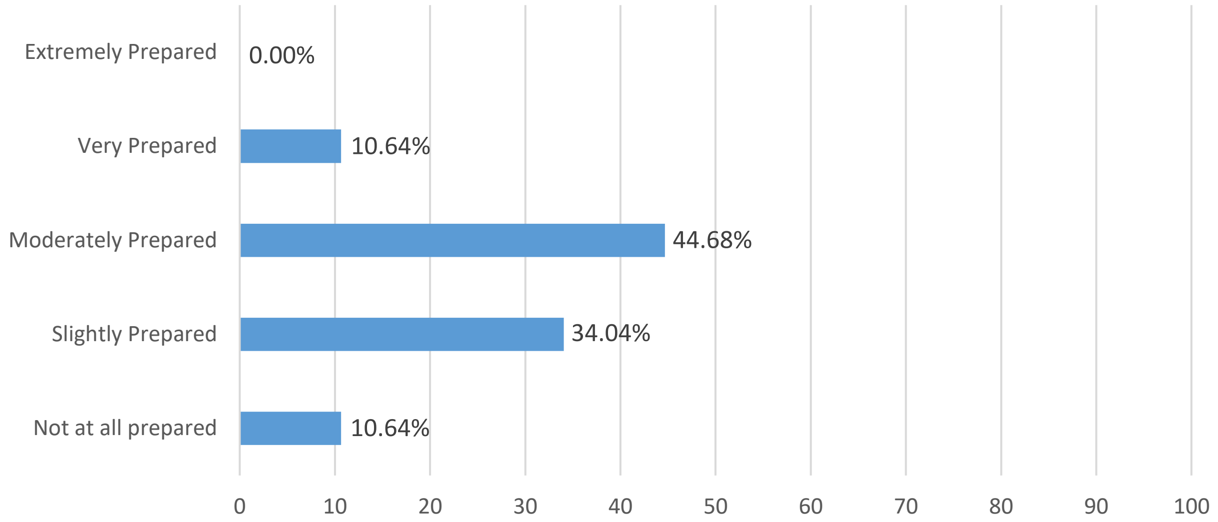
- Emergency operation plan review and updates
- Identification of alternative water sources (increasing the number of wells, as well emergency water connections with other communities)
- Implementation of water conservation programs and public outreach
- Infrastructure improvements
- Changes to local ordinances (water restrictions, preventing development in floodplain, etc)

11. Do you use certain asset management/planning tools or approaches that might be useful in evaluating risks associated with shifts in climate or extreme weather?

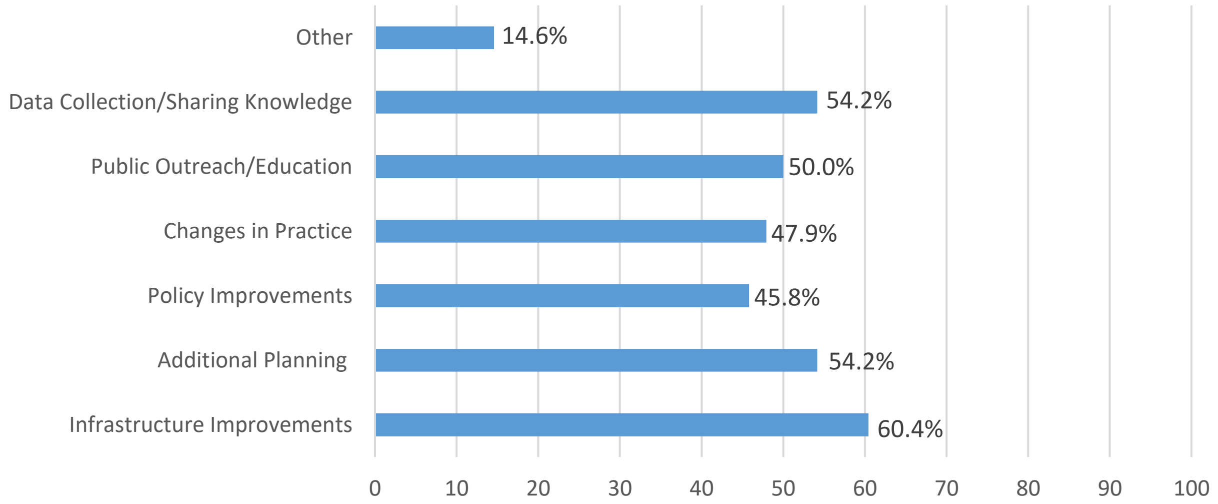
- GIS mapping of prone areas
- Long-range water supply plans
- Storm modeling
- Convergence of Climate-Health-Vulnerabilities
- Carolinas Precipitation Patterns and Probabilities Atlas
- VCAPS (Vulnerability, Consequences, and Adaptation Planning Scenarios)

Regional Preparedness

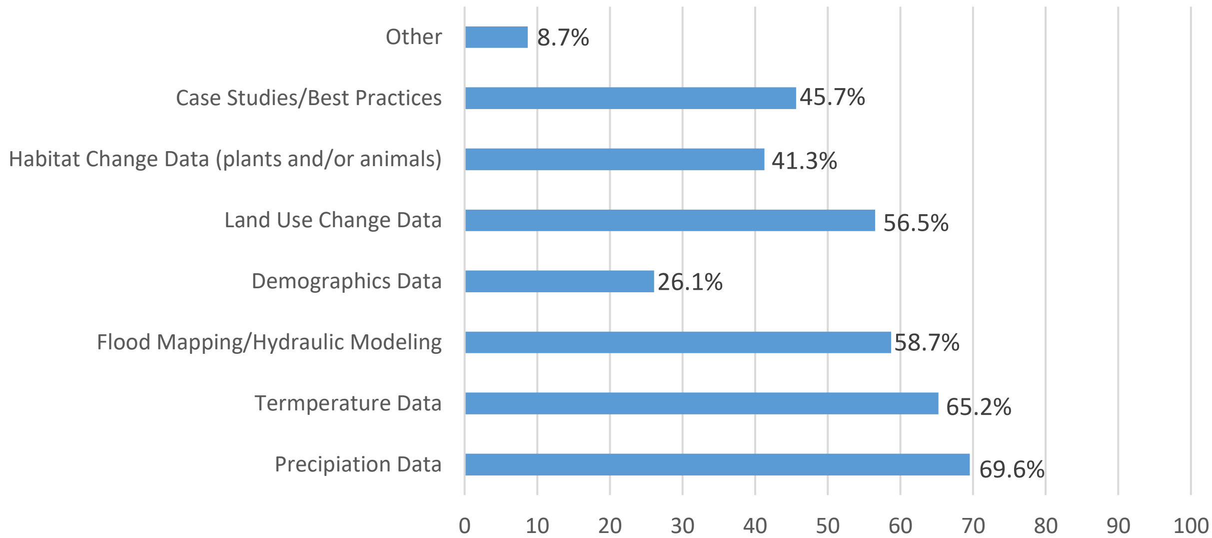
12. How prepared do you think the region is to deal with changing weather patterns?



13. Which actions would most benefit the Piedmont Triad in preparing for changes in weather patterns?



14. Which data or tools would be most valuable to you in addressing changing weather patterns in the Piedmont Triad (select all that apply)



Piedmont Triad Climate Summits

The PTRC held interactive workshop sessions during both days of the 2018 Piedmont Triad Climate Resiliency Summits. Attendees were divided into 5-7 small groups and asked to discuss a number of different questions. Each group worked to identify strengths, opportunities, aspirations and results (SOAR) to assess how well the region is prepared to mitigate impacts associated with climate change and extreme weather. A SOAR analysis is a strategic planning tool that focuses on current strengths and establishes a vision of the future for developing strategic goals. The purpose of these workshop sessions was to engage stakeholders and representatives from across the region on climate issues, identify local best practices and resources, and set goals for the future of climate resiliency planning efforts. The summits also acted as a networking opportunity aimed to increase regional connectivity between agriculture, water resource, and climate professionals. Below is a summary of the workshops results from both days of the summit. Monday's session focused on agriculture, natural resources, stormwater, and flood preparedness while Tuesday's session focused on water supply, wastewater, and drought.

Workshop Results

Monday, May 14th: Agriculture & Natural Resources + Stormwater & Flooding

According to the results of the first day's workshop, the region is doing a great deal to protect our agricultural land and natural resources, mitigate stormwater runoff and prevent flooding. Some of our strengths include stormwater runoff regulations, regional educational workshops, government involvement, change in citizen behavior and regional cooperation. It was decided that our greatest assets in the Piedmont Triad are location, county wide programs, forest services, and state agencies. In addition to all of the positive feedback, we also received a long list of improvements that farmers and natural resource managers could make to better prepare for the impacts of climate change. Some communities do appear to be more at-risk than others, and these include rural and low-income areas as well as downstream communities. Results showed that four barriers need to be overcome in order to be better prepared for the shifting climate. Primarily, the region needs to build consensus around climate related issues and effective solutions, simplify the scientific information, and convey this information to the public in a way that is effective in raising awareness and promoting action. As a result of these lists of both strengths and improvements, some future regional goals were laid out. The group agreed that there is a need for more policy improvements to protect farmers and natural resources. Goals with immediate impact need to be prioritized by updating development ordinances and ensuring that policy makers are aware of these programs. For more information and the final results of this workshop, see the discussion below.

Strengths

1. As a region, what are we doing well to protect our agricultural land and natural resources and mitigate stormwater runoff and flooding?
    - State level involvement on water resources
    - Strong stormwater runoff regulations
    - Local watershed planning
    - Regional coordination by PTRC
    - Regional cooperation
    - PTRC's Stormwater SMART program (local boards addressing stormwater impacts)
    - Environmental Education and training opportunities
    - Voluntary Agricultural Districts
    - Several existing BMPs on agricultural land
    - Local government involvement
    - Use of green growth strategies are increasing
    - Environmental stewardship is increasing
    - County Soil & Water buffer protection programs

2. What are some of the Piedmont Triad's greatest assets or resources when it comes to protecting agricultural land and natural resources and mitigating stormwater runoff and flooding?
    - Location (less drastic changes in climate and extreme weather projected in the Piedmont Triad)
    - County-wide programs like Soil & Water, Cooperative Ext, etc.
    - NC Forest Service
    - State Agencies (Department of Environmental Quality, Wildlife Resources Commission, etc.)

3. What are some local success stories or best practices from your community?
    - UNC Charlotte conducted a study that examined the correlation between water quality and costs
    - Increasing number of ordinances in place for low impact development (LID)
    - The NC Forest Service worked to restore the long leaf pine using prescribed burn techniques in coordination with the NC Wildlife Resources Commission, US Department of Defense, and the Nature Conservancy

Opportunities

1. Where do you think farmers and natural resource managers could make improvements to better prepare for the impacts of climate change?/ In what ways could stormwater or floodplain managers be better prepared to address these anticipated changes in precipitation and storm frequency?
    - Focus more on soil health
    - Increase the use of cover crops

- Improve riparian buffers & increase no till farming practices
- Help reduce costs to farmers
- Lessen clear cutting
- Increase the conservation of non-developed land/Prevent conversion of farmland
- Increase utilities in rural/agricultural areas to increase business opportunities and increase educational opportunities
- Expand regional cooperation to improve pedestrian infrastructure & transit options
- Promote local food
- Expand education & awareness of different profit models
- Communicate economic value of green/open space
- More long-range planning efforts are needed

2. Are there communities within the region that are more at-risk than others?
    - Rural & low income areas
    - Downstream communities
    - There is a need to model locations of additional vulnerable communities

3. What should be the focus of future regional efforts to improve climate resiliency?
    - Build consensus on climate issues and proposed solutions
    - Bring existing development up to current standards, rather than just focusing on regulating new development
    - Additional policy improvements to protect farmers and natural resources

4. Are there any barriers that need to be overcome in order to be better prepared for a shifting climate?
    - Simplifying/filtering existing information and resources
    - Consensus building
    - Improving communication/messaging
    - Increasing awareness of climate related issues

<u>Aspirations</u>

1. Considering the strengths and opportunities listed, what are some goals for the region or your community moving forward?
    - Limit development in rural areas
    - Incentivize infill development & mitigation of development impacts
    - Increase green space
    - Increase the amount of resources and funding available to small farmers
    - Provide incentives to larger farms to be more sustainable
    - Increase funding for Cooperative Extension and Soil & Water agents to provide high quality education to farmers
    - Have more cooperative agreements between developers & downstream farmers to use stormwater as an asset
    - Improve overall sense of community & shared responsibility
    - Continue education and advance education programs

- Establish common ground between urban & rural areas to form partnerships
- Continue to rethink how land planning & econoomic development works from the ground up with citizens
- Promote trail connections between communities and develop funding
- Promote land preservation in perpetuity
- Increase public benefits & programs with public and private partners

2. How should these goals be prioritized?
    - Goals with most the immediate impact should be prioritized first

3. What strategic initiatives would support these goals?
    - Update development ordinances
    - Make policy makers aware of these programs

Results

1. How can we tangibly define climate resiliency in terms of natural resource protection and stormwater and flood management?
    - Rate of vegetation adaption
    - Protection/survival of existing species
    - Flexibility/Ability to adapt programs and policies
    - From a forestry standpoint, plan plantings that are more tolerant to drought & flooding
    - Increase bio-diversity on farms and w/ natural resources (both planned and native/non-disturbed areas)
    - Less property/land loss and FEMA claims, larger percent of people utilizing recommendations, recognizing the need & having the mind-set. For stormwater, lower cost from high water events & fewer sewer overflows.
    - By incorporating the value of open space
    - By sustaining water supply levels and quality during variable weather
    - The number of rain gardens/recapture systems
    - The number of active farms/farmland
    - Soil rehabilitation acres/the amount of active soil
    - By increasing the use of SNAP benefits at farmers markets
    - By getting young people excited about farming as a viable business

2. What resources are needed in order to achieve our resiliency goals?
    - Funding
    - There is plenty of data available. Now we need to focus on implementing strategies to improve climate resilience.
    - We need to quantify the benefits of green infrastructure for developers

3. What meaningful measures would indicate that we are on track in terms of meeting our goals?
    - Removing impaired waters from the 303(d) impaired waters list

Tuesday, May 15th: Water Supply/Wastewater/Drought Summary

The results from day two on water supply were similar to those from the previous day of workshops. A lot of strengths were discussed within the region and state to ensure there is enough clean water for the future. Some strengths include existing interbasin transfers, infrastructure improvements, education and outreach efforts, planning, and economic potential. For water management, the Triad's greatest assets include an established interconnected system, strong availability of professionals, and the USGS Water Watch. These assets may be utilized in order to ensure water security for our area in the future. Once again, there are also some challenges presented in this case based on precipitation and water availability in our area. Some of these include better economic analysis, a need for updated treatment technology, especially to address emerging contaminants, and additional regional planning. Particular areas of the Triad that were concluded to be more at risk are urban and expanding areas, areas with nutrient overload, and areas with smaller water systems and no reservoirs. In order to begin preparing for a climate shift, there are a few barriers that need to be overcome including a current lack of regulations, public perception of climate change, funding and education. Considering the strengths and barriers that were discussed, many realistic goals for the Piedmont were laid out during this workshop. The region aims to increase the amount of reclaimed water, proactive stormwater controls, protection of headwaters, and planning for rural areas. It was concluded that resources should primarily be focused in infrastructure upgrades, education of the public, planning, regionalization of wastewater treatment, and additional stormwater utility fees. For more information on strategic initiatives and the final results of this workshop, see the discussion below.

Strengths

1. What are we doing well within the region (or as a state) to ensure that there is enough clean water to meet the needs of future generations?
    - Learning lessons from previous droughts
    - Recognizing that we need to do better
    - Strong interconnectivity between regions & towns (interbasin transfers)
    - Improving infrastructure as a state
    - PTRWA Randleman Reservoir providing water to Triad Region
    - Public education, outreach, and training opportunities on water issues
    - Economic potential
    - Sharing of tools for long-term planning & management
    - Planning ahead with water supply projects
    - Rebuilding of Salem Lake
    - Available capacity (water surplus)
    - Proactive watershed protections
    - Extended buffers (particularly at Randleman Reservoir)

2. What are some of the Piedmont Triad's greatest assets or resources in terms of water management?
    - Established interconnected system
    - Strong availability of investigative scientist and professionals (university/state/federal)
    - USGS Water Watch – real-time info on groundwater levels

3. What are some local success stories or best practices from your community?
    - OWASA reusing water, as well as conducting a supply vs demand study
    - When Greensboro & Winston-Salem faced a water shortage due to drought, they were able to obtain an emergency permit because the Fed., state, & local partners collaborated in a time of need
    - West Wake is reclaiming water
    - Winston-Salem is gaining additional water source
    - Greensboro, Winston-Salem, Reidsville have an intake interconnection
    - Mega-site preparation
    - Available funding sources (CDBG & Revolving Loan Fund)

<u>Opportunities</u>

1. Based on the precipitation and water availability data presented today, what are our greatest anticipated challenges in terms of water security and wastewater treatment? How can we reframe these as opportunities?
    - Getting more concrete data on water availability
    - Using different materials in new piping
    - Upgrading utility systems to prevent loss (20% sometimes lost to leaks)
    - Making infrastructure last longer (new & existing)
    - Reaching vulnerable populations before disaster arises
    - Lack of surface and groundwater monitoring
    - Economic analysis of planning scenarios
    - The ability to assemble
    - Need for updated treatment technology (emerging contaminants)
    - Keeping up maintenance & operation of systems
        - Limited resources, regulatory challenges & new rules, infrastructure deterioration, capacity expansion
    - Asset management (especially buried assets)
    - Wastewater to the east of High Point is close to capacity
    - Headwaters of Cape Fear limits expansion of WWTP options & regulation
    - Need for additional regional planning
    - Improving cyber security
    - Interbasin transfer with Charlotte

2. Are there particular areas of the Triad (watersheds) that may be more at risk than others?
    - Urban & expanding areas
    - Areas with impoundments, nutrient overload
    - High residential growth areas have water quantity concerns. High commercial growth areas have water quality concerns
    - Smaller towns/systems that do not have reservoirs

3. Are there any barriers that need to be overcome in order to begin preparing for these anticipated shifts in climate?
    - Lack of regulations
    - Public perception
    - Educating decision makers so that they can make fact-based decisions
    - Uncertainty
    - Money/Available resources (including staff)
    - Politics
    - Education

Aspirations

1. Considering the strengths and opportunities you just discussed, what are some realistic goals or steps that local communities could begin taking to improve water security and wastewater facilities?
    - Better access to information across departments & divisions
    - Better use of technology
    - More comprehensive planning and having those plans taken seriously (especially in rural areas)
    - Economic analysis to give cost metric implications to decision makers
    - Better support of high ESG rating companies
    - Maintaining forest cover
    - Protecting headwaters
    - More proactive in stormwater controls (next generation controls)
    - Assess existing structures
    - Reclaim water
        - Policies & programs to incentivize with funding for collaboration and planning
        - Industries & universities may be able to be customers outside direct service area
        - Legislation or local system to use direct & indirect re-use
        - Chatham Park incorporating purple pipe into residential development
        - Durham & Cary could share how much they have saved from water reuse
    - Assess future demands
    - Better water conservation notices
    - Improving wastewater capacity and developing new treatment technology

2. Where should resources primarily be focused?
    - Stormwater utility fees for rural communities
    - Infrastructure upgrades
    - Planning (seek planning grants/loans)
    - Regionalization of wastewater/water treatment
    - Educating the public

3. What strategic initiatives (projects, programs, etc) could help support these goals?
    - Conservation easements
    - Riparian buffers
    - Regional planning

Results

1. How can we tangibly define resiliency in terms of water supply? How about for wastewater treatment?
    - Lower per capita use of water
    - Number of drought emergencies
    - Retrospective analysis of previous unexpected storm events compared to future events
    - Cost of treatment to meet current/future demand & regulations
    - Supply vs demand projections (if supply > demand)
    - Emergency water supplies as backups
    - System capacity & pull size
    - Discharges to streams & decreasing water levels
    - Amount of flooding

2. What meaningful measures would indicate that we are on track to achieving our goal of improving water security and wastewater treatment?
    - Higher rate of implementation (follow through)
    - Land use cover
    - Conservation methods
    - Surface and groundwater levels
    - Delisting impaired waters
    - Flattening loss of water (unaccounted)
    - Flattening demand (system & use)
    - Expanding storage for large rain events
    - Look at improving report of water use outside water supply areas
    - Require collaboration between economic development, land planning & utilities (use & expansion)

3. What resources are needed to support the goals, next steps, or strategic initiatives that were discussed under “aspirations”?
    - Regulations for agricultural practices and forestry
    - More data to refer to and compare
    - Make data accessible
    - Money, especially smaller communities
    - Legislative support
    - Enforcement of regulations
    - Educated planners & the newest technology
    - Education
    - Better regional connectivity