Drought in the South: Planning for a Water-Wise Future

BILL SUBLETTE

Last year, the Southeast was in the grip of its worst drought on record. At one point, more than a quarter of the region was covered by "exceptional" drought, the National Weather Service's worst category; streams went dry, reservoirs shrunk, lawns turned brown. Almost every community responded by encouraging or mandating conservation measures for businesses and residents. In desperation, some officials rushed to build more reservoirs, eyed rivers in neighboring states, or simply prayed for rain.

Although a combination of more rainfall in 2008 and water conservation appears to have alleviated the acute symptoms in some areas, the Southeast is still in a bad drought. Atlanta is touting the fact that it used 20% less water this June than in June 2007 — but Lake Lanier is lower than it was at this time last year. In North Carolina, 54% of the public water systems have water restrictions in place, up from 12% last year, and Falls Lake, which supplies water for most of Raleigh and Wake County, is just one foot below normal compared to four feet last year — but dozens of streams in the fast-growing western part of the state are setting record low flows.[1]

In fact, a majority of streams in the Southeast monitored by the U.S. Geological Service in mid-August were gauged at 25% or less of their 30-year average flow for that time period.[2] Groundwater levels are still lower than normal — especially in southwest Georgia, parts of North Carolina, the Hampton Roads area of Virginia, and Memphis.[3] Despite consistent reminders from the National Weather Service and others that long-term drought conditions persist and may worsen, water-use restrictions this summer were lessened or lifted in many cities across the region.

Lack of rain is not the only factor for the looming crisis in the historically water-rich South. Population growth has exploded in recent decades, and perhaps more significantly, localities have largely failed to assess the impacts of growth on water resources or to guide development accordingly. Confounding matters, scientists believe global warming is changing the intensity, duration and location of weather systems, from droughts to hurricanes, which will directly impact the availability of clean water for human and ecosystem needs.

We can no longer count on having all the water we want, when we want it, where we want it. In the past, water management has focused on extending water supply. But reservoirs and interbasin pipelines can no longer be the region's first choice for water management. Such projects don't address long-term needs, are exorbitantly expensive, and wreak havoc on aquatic ecosystems. Furthermore, any new supply would be outstripped by ever-growing demand if current sprawl patterns and water-use trends continue.

We need to rethink how we think about water. It is not a commodity we can produce on demand; rather, it is a publicly owned natural resource that requires wise stewardship to ensure long-term sustainability. It's time we focus on better management and reducing demand, not on overextending supply.

Southern Environmental Law Center

SELC is a nonprofit, nonpartisan advocacy organization dedicated to safeguarding the natural resources and special places in Alabama, Georgia, North Carolina, South Carolina, Tennessee and Virginia. Using the power of the law, we work with more than 100 partner groups, we protect rivers and wetlands, air quality, wildife habitat, coastal resources, native forests, and rural landscapes.

Challenges and Problems

Population Growth and Development

More land was lost to development in the Southeast in recent decades than in any other region. Moreover, the Southeast is the fastest sprawling region per capita in the U.S. Based on best available data, between 1982 and 1997, SELC's six-state region developed 60,645,000 acres, compared to the next highest, the eastern Midwest at 37,772,000 acres.[4] The total U.S. population grew by 15.6% and saw a 33.9% increase in acres lost, while the Southeast's population grew by 21.4%, and saw a 54.7% increase in acres lost.[5]

CHARLES SHOFFNER

New development in the mountain community of Waynesboro, VA.

More development means greater demand for water, but it impacts water availability in other ways as well. Headwater streams in the mountains and foothills — which feed rivers like the Tennessee, James, Chattahoochee, Alabama and others that millions of people rely on — are increasingly degraded or destroyed by residential, commercial and road building. Streams are being piped, channelized and moved to make room for development. Wetlands — essential for absorbing flood waters, filtering pollutants, and providing wildlife habitat — are being destroyed at a fast clip in the South. In the 1990s, almost half of wetlands loss was attributed to development; wetlands conversion was greatest in the South.[6]

Development in the South mostly defies the traditional patterns of establishing communities around available sources of water. Much of the region's growth has occurred in the Piedmont, which has relatively little available groundwater and where the streams hold relatively low volumes of water.[7] As a striking example, Atlanta has the distinction of being the largest metro area in the U.S. in the smallest watershed. Roughly 3.5 million people in metro Atlanta depend on a 1,000 square mile watershed. That compares to cities such as Charlotte, where about 1.1 million people depend on a 2,100 square mile watershed.[8]

Much like the South's sprawling development patterns have ignored the natural constraints of watersheds, the region has largely overlooked the limits of its water resources, as illustrated by comparing water-use trends in the region to the rest of the U.S. From 1990 to 2000, water use in SELC's region increased 21.5% (from 40,614 million gallons per day [mgd] to 49,342 mgd[9]), while our population grew 18.5% (from 26.8 million to 31.8 million). Water use in the rest of the U.S. decreased by 0.4%, while population increased by 12.3%.[10] In 2000, average per capita water use in the South was 1,553 gallons per day, a 2.5% increase from 1990, while per capita water use in the rest of the U.S. was 1,168 gallons per day, an 11.3% *decrease*.[11]

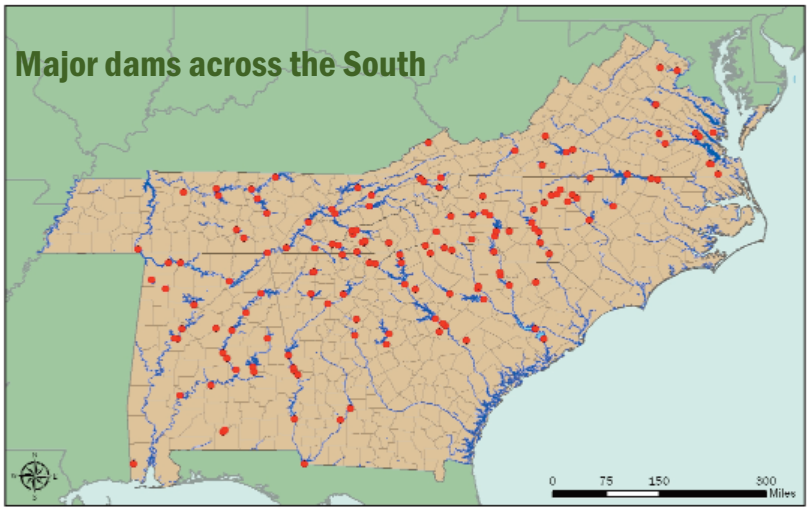
Water Quality

Development also impacts water quality, putting a premium on the availability of clean water for public use and aquatic habitat. When land is cleared, muddy runoff pollutes nearby streams that feed into public water supplies. Stormwater from roads, rooftops and other hard surfaces carries pollutants into storm sewers and streams. A city block generates roughly nine times more runoff than a wooded area the same size.[12]

During rain storms, high volumes of gushing water can erode stream banks, adding still more sediment to the water, filling in reservoirs and harming aquatic habitat. The U.S. Environmental Protection Agency has identified sediment as the most widespread pollutant in the nation's rivers and streams, affecting aquatic habitat, drinking water treatment processes, and recreational uses of rivers, lakes, and estuaries.[13]

Water Lost to Impervious Surface
Billions gallons/year

Atlanta, GA	56.9 – 132.8
Charlotte, NC	13.5 – 31.5
Greensboro, NC	6.7 – 15.7
Greenville, SC	12.7 – 29.5
Nashville, TN	17.3 – 40.5
Raleigh-Durham, NC	9.4 – 21.9
Washington DC	23.8 – 55.6



These 148 dams hold impoundments of 1 square mile or greater designated as either drinking water supply, hydrolelectric power, or both. This map does not show the tens of thousands of other impoundments that are smaller or used for other purposes, such as agriculture. Source: ESRI (2007); National Inventory of Dams (2005)

In times of drought, with less water in the streams, mud and other pollution becomes more concentrated, stressing fish and other aquatic species and making it more difficult and expensive for utilities to treat water for safe public consumption.

Groundwater

Hard surfaces prevent water from seeping into the ground to recharge aquifers, further disrupting the natural hydrological cycle. According to one analysis, the amount of groundwater infiltration lost due to impervious surfaces in Atlanta each year between 1982 and 1997 ranged from 56.9 billion to 132.8 billion gallons.[14] Atlanta's "losses" in 1997 amounted to enough water to supply the average daily household needs of 1.5 million to 3.6 million people for a year. By comparison, Dallas lost between 6.2 billion to 14.4 billion gallons annually during the same period.

In addition to being a major source of drinking water and other public uses in the coastal plain, groundwater is essential for recharging surface waters. While winter and spring rains in early 2008 have topped off many of our reservoirs, groundwater sources are still well below normal and without their recharge, streams and rivers that feed the reservoirs will quickly dry up.

Water Use and Loss

Water may be withdrawn, used for any number of purposes, and quickly returned to its source. Depending on the use, however, water often evaporates, takes years to return to the original source, or is returned to a different river basin or a different area of the same basin, disrupting the natural system from which it was withdrawn. Public water supply systems, which provide water for homes, offices, schools, etc., account for a significant loss of water. Whether it is lost to leaky pipes, runs off the pavement into nearby streams, or infiltrates the ground after being sprinkled on lawns, publicly supplied water has been removed from its original stream, which impacts aquatic systems and downstream users.

The electric power sector withdraws and uses a tremendous amount of water; thermoelectric plants, including nuclear and coal-fired facilities with steam-driven turbine generators, withdrew 37,890 mgd in 2000, more than three times the amount used by public drinking water utilities, agriculture, industry and domestic well-water combined.[15] Some of the water used for cooling processes evaporates as steam, which means it is lost to the river from which it came.

Hydroelectric facilities — dams and reservoirs — are also a tremendous source of water loss. Generally, water in reservoirs evaporates more quickly than water in a free-flowing stream. For example, Lake Lanier in northern Georgia loses about 28.3 mgd more to evaporation than does the free-flowing Chattahoochee River, enough water to serve 170,000 people.[16] In 1995, hydropower in Alabama, Georgia, North Carolina and Tennessee lost 34.5 gallons per kilowatt-hour of electricity — enough to supply the Atlanta metropolitan region, including the city and its 16-county area, for nearly six years — compared to 18.27 gallons/kWh nationally.[17]

	Southeast	Percent Increase from 1990	Rest of U.S.	Percent Increase from 1990
Water Use 2000	49,342 mgd	21.5	295,685 mgd	(0.4)
Population 2000	31.8 million	18.5	253.2 million	12.3
Per Capita Use 2000	1,553 gal/day	2.5	1,168 gal/day	(11.3)

The energy sector adds immense stress to river systems during the warmer months, which in the South can be half the year. More electricity is needed for air conditioning, meaning more water withdrawn from rivers, while warm temperatures accelerate evaporation from impoundments. Compounding this is the tremendous amount of energy needed to clean water for discharging, and to move it from one place to another, which in turn results in increased water needed

RON SHERMAN

Miller Steam coal-fired power plant on the Black Warrior River, AL.

to produce the energy. This cycle results in lower water levels in our rivers, streams and aquifers. The warmer months also mean increased irrigation for crops and landscaping, filling of pools and other uses. Yet, spring and summer are when aquatic species most need a healthy river system, with clean and plentiful water flows necessary for fish migration and spawning. The more water we lose, the more stress we put on these species, and the more vulnerable our water sources are to drought.

Lack of Planning

Despite these troubling trends, states in the South have largely failed to plan sufficiently for long-term, comprehensive, sustainable water use. While some have a statewide plan, they either lack regulatory mechanisms for meaningful action or, in the case of Georgia's newly adopted plan, place undue focus on building more impoundments and seeking interbasin transfers. Planning activities in each of SELC's six states are described below.

Alabama

The state Office of Water Resources is charged with issuing Certificates of Use to water users, but it has little ability to regulate or condition these certificates. The agency does have authority to manage water use if it declares a certain geographic area to be a "capacity stress" area — which it has never done, not even during the dire drought conditions of 2007. It is also legally separate from the Alabama Department of Environmental Management, which results in a lack of coordination between the agency in charge of water quantity and the one regulating pollution. The only other significant laws on water management in Alabama are local bills prohibiting water transfers from the Tennessee River basin to any county that is not adjoining the Tennessee River.

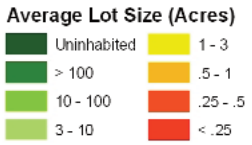
There is hope, however. This year, the legislature established a permanent committee charged with providing yearly recommendations on water issues beginning in 2009. Although the scope of the committee's work is unclear, the goal seems to be the creation of a statewide water plan. The committee has pledged to have an open and transparent process in which all stakeholders will be allowed to participate.

Georgia

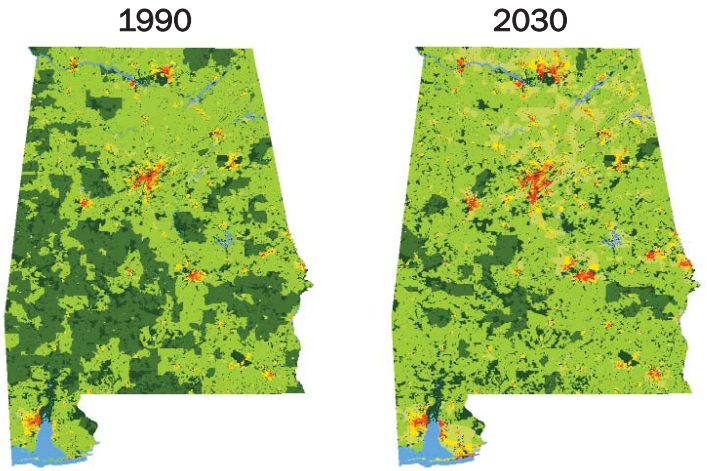
In 2002, a study committee provided water management recommendations to the legislature, but it took until this year for the state to act, finally adopting its first comprehensive statewide plan. While an important step, the plan falls far short of implementing meaningful strategies to manage water sustainably, consisting instead of recommendations for future rules about water conservation, interbasin transfers, and other management tools. The plan does call for water resource assessments to be conducted over the next three years, which the Environmental Protection Division is beginning this summer. It also creates a mechanism for regional planning, but the planning entities are based on geo-political boundaries, not watershed boundaries, which is likely to make regional solutions more difficult.

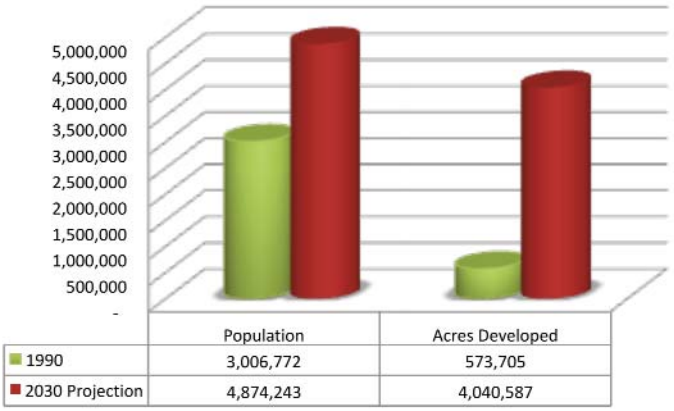
The ineffectual nature of Georgia's water plan is most apparent when contrasted with other bills that passed this year, including one that streamlines construction of reservoirs. While such projects can be components of water management, they should not

Southeast Population Vs. Acres Developed*



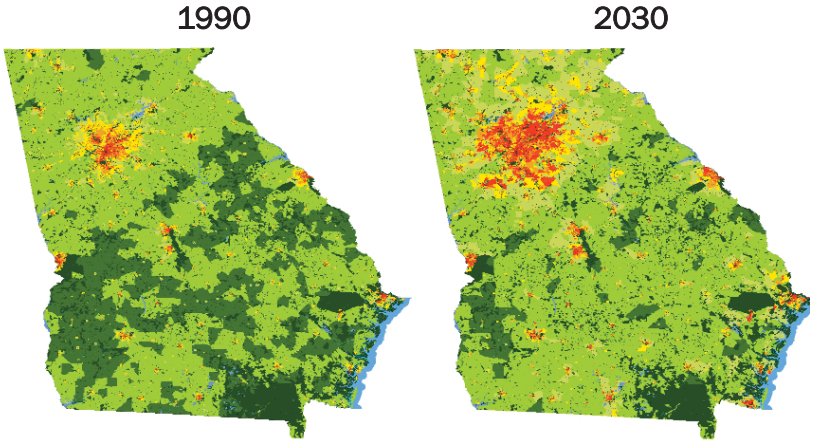
Alabama

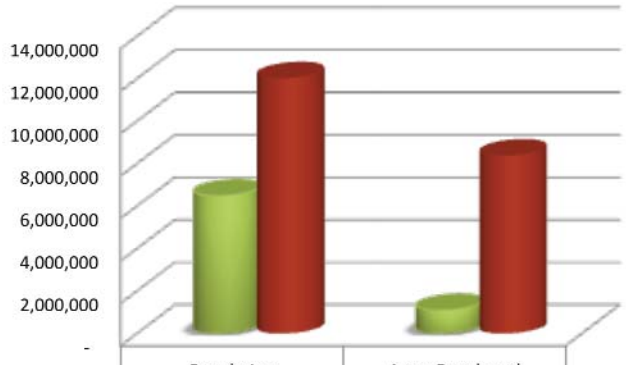




	Population	Acres Developed
1990	3,006,772	573,705
2030 Projection	4,874,243	4,040,587

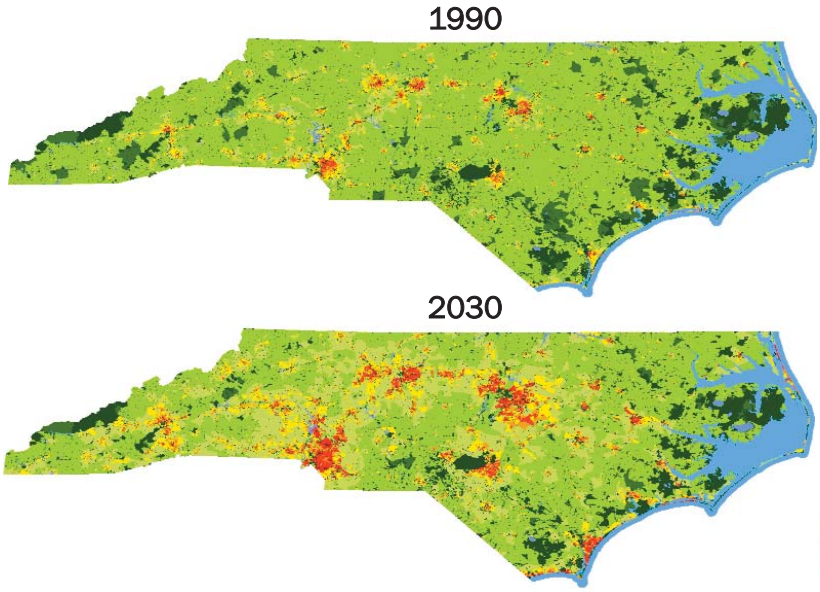
Georgia

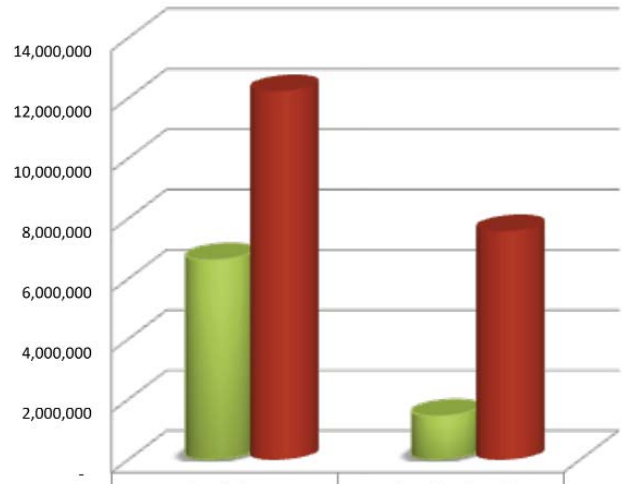




	Population	Acres Developed
1990	6,478,216	1,084,912
2030 Projection	12,017,838	8,379,602

North Carolina

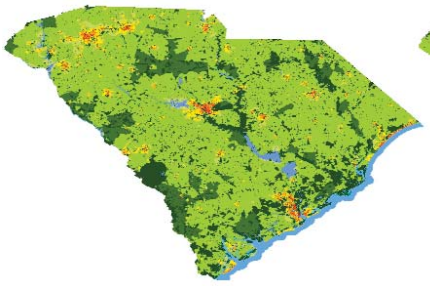




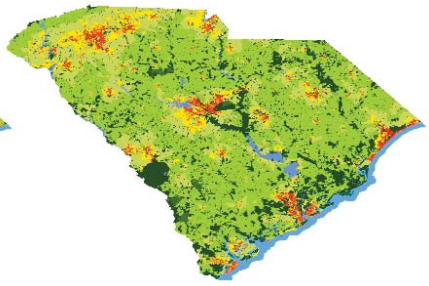
	Population	Acres Developed
1990	6,628,637	1,448,366
2030 Projection	12,227,739	7,582,646

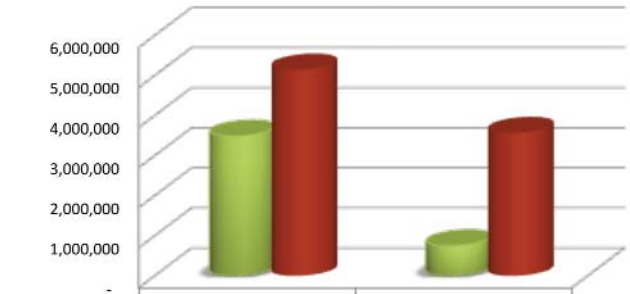
South Carolina

1990



2030

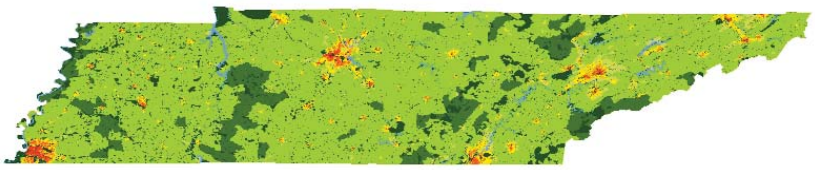




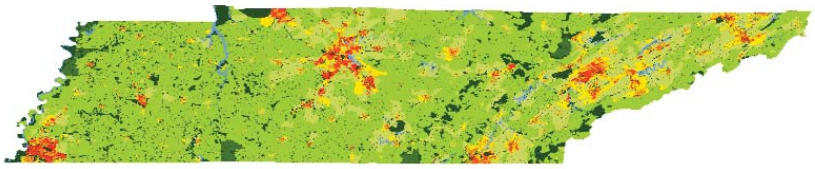
	Population	Acres Developed
1990	3,486,703	747,517
2030 Projection	5,148,569	3,569,478

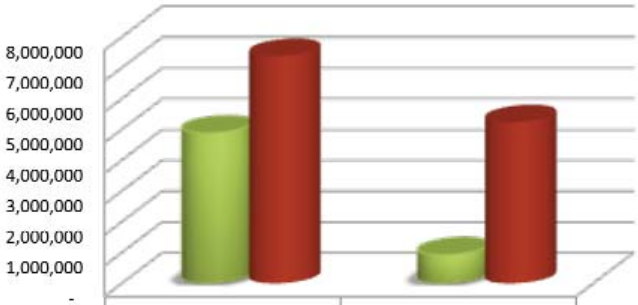
Tennessee

1990



2030

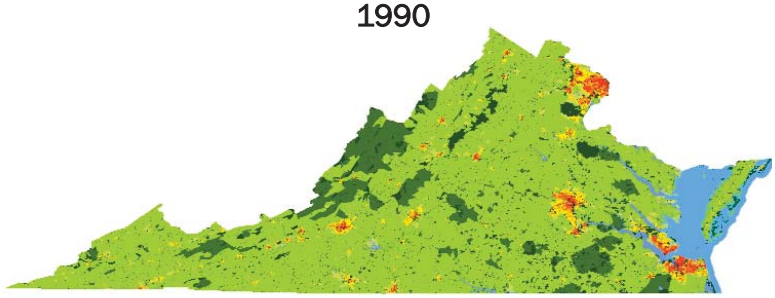




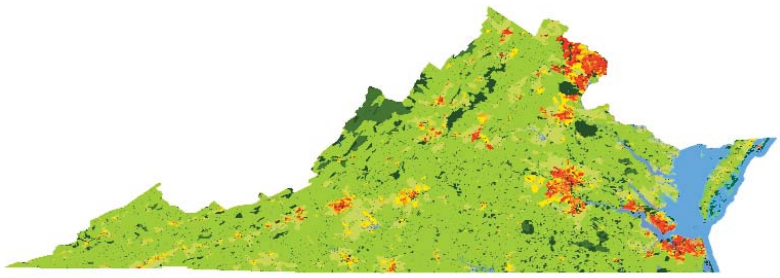
	Population	Acres Developed
1990	4,877,185	920,775
2030 Projection	7,380,634	5,228,088

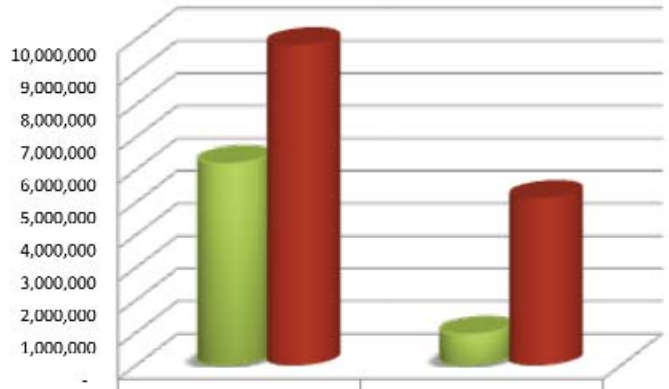
Virginia

1990



2030





	Population	Acres Developed
1990	6,187,358	954,187
2030 Projection	9,825,019	5,133,330

* The data displayed in the housing density maps was created by researchers at the University of Wisconsin's SILVIS lab, which is a well respected authority of landscape ecology and spatio-temporal modeling of growth and development. According to the authors' own metadata, "the maps and data were designed for strategic decision making and for the visualization of housing growth patterns over large areas." However, this data is not appropriate for analysis at the county level or smaller. These maps support the findings of this paper; that the southeast is growing not only in population, but in land consumption as well, as much of the southeast is changing from rural to suburban housing densities along an ever expanding urban fringe. The metadata also mentions that future projections (through 2030) are considered conservative ones, since they are based on a linear projection of population and land cover change from 1990-2000, and rates from 2000-2010 could increase the slope of that linear projection. Like any growth projection, only the future can affirm the saliency of their findings, but in the short term these results serve as an important window to what the southeast will look like by 2030, given holding 1990-2000 growth constant for 30 years. (http://silvis.forest.wisc.edu/Library/HousingData.asp)

RON SHERMAN

The Chattahoochee River flowing toward the Atlanta skyline.

be given preferential treatment over more cost-effective tools such as conservation and efficiency. Another bill forbids local governments from adopting conservation measures more strict than state policies without getting permission from the state first. Yet state policies are confusing and unenforceable; for example, one limits outdoor watering to 25 minutes per day, by hand. Lastly, the legislature passed a resolution calling for reexamination of Georgia's border with Tennessee, with the far-fetched and legally questionable goal of tapping the Tennessee River to pipe water to metro Atlanta.

North Carolina

North Carolina has a state plan that is primarily a report on water use without management mandates. Recognizing the need for statewide water managment, the legislature last year initiated a study of water allocation options to help develop a comprehensive water management strategy that addresses water resources in times of scarcity and times of plenty. The study is currently being conducted by academic consultants, with recommendations to the General Assembly anticipated in 2009. The study will not immediately address the ongoing drought currently gripping North Carolina. As of August 12, more than one-third of the state was in extreme or exceptional drought — the most severe categories. Drought legislation passed this summer requires the state to evaluate local drought plans and to reject those that fail to meet basic requirements. While this is a positive step, it remains to be seen whether the local plans or the approval process are strong enough to protect North Carolina's water resources for the long term.

South Carolina

An existing state plan primarily serves as a guideline and repository for studies and reports on water use, with no binding resource management directives. For example, although large water withdrawals must be reported, South Carolina lacks a permitting program to regulate surface and groundwater withdrawals, a serious failing in terms of wisely managing water in the public interest. The state does have a few specific water policies on the books, including a permitting program for interbasin transfers over a certain volume, which requires an assessment of the impacts on the sending and receiving streams, and the authority to declare drought areas within which regulators can limit withdrawals and take other actions.

In 2004, the state identified establishment of a withdrawal permitting program as a top priority. Following last year's drought, the legislature appointed a task force, which included SELC, to make recommendations for a bill, proposed this year. Contention over the issue of minimum in-stream flows stopped passage of the measure, though it will likely be brought back next year.

Tennessee

Tennessee has no statewide water resources plan or requirements for local planning. Several bills were introduced in the 2008 legislature that would have created the framework to start such planning, but all were dropped in the face of the state's budget crisis.

BARRY SULKIN

Muddy runoff from construction upstream turns a Tennessee stream brown.

Governor Bredesen and others have said they plan to revive the effort next year. In the meantime, both the Department of Environment and Conservation and the Wildlife Resources Agency are convening study groups of experts and citizens to examine ways to protect in-stream flow while meeting increasing human needs for water. In 2000, Tennessee did pass a law — aimed largely at a feared water grab by metro Atlanta — requiring permits for interbasin withdrawals and analysis of impacts to the sending and receiving streams.

Virginia

In 2003, following a major drought period, the state passed the Water Supply Planning Act requiring development of a comprehensive statewide water-supply planning process to ensure adequate and safe drinking water, protect other beneficial uses of Virginia's waters, and promote incentives for alternative water sources. First, communities must submit local or regional water supply plans that include information on existing water sources, use, resource conditions, projected demand, management actions, and potential supply alternatives, including conservation.

LYNDA RICHARDSON

Kayakers enjoy sunset on the Rappahannock River, VA.

Local plans for communities of 35,000 or more are due beginning this November. Regional plans — of two or more localities — are due in 2011. Once these plans are assembled, Virginia will develop a statewide plan outlining needs and potential alternatives for at least 30 years into the future. Virginia took an important step in setting up this process, but it will have taken a decade or more before any real action might occur.

Planning for a Water-Wise Future for the South

Natural Stream Flows

The most important step towards sustaining water resources for humans and aquatic life is maintaining natural stream flows. This includes assuring minimum and maximum flow levels, as well as duration, seasonality, timing and intensity of water flows according to each stream's natural conditions. Natural flows protect aquatic habitat, and they bring economic benefits as well. Rivers with natural flows usually have better water quality, which means lower treatment costs for drinking water. In addition, many communities rely on naturally flowing rivers to support fishing, boating, and other outdoor tourism activities.

Natural flows are affected when water is removed from or added to a stream, river, lake or wetland. As described above, human influence in the South has caused flow conditions to fluctuate well outside their natural range. Dams and impoundments, water intakes and discharges, interbasin transfers, channelization of streams, filling wetlands, depletion of groundwater, paving over open space — all cause major disruptions in the hydrological cycle, with adverse consequences for human use, the economy and aquatic life.

Solutions — SELC's Clean Water Program

The Southern Environmental Law Center, in tandem with scores of public interest groups, is working at all levels of government in our six-state region to promote cost-effective, sustainable water management tools. Among our goals is to advocate for more incentives for water conservation and efficiency for all users, ensure that development is appropriately planned according to water availability, strengthen drought-related regulations, and secure comprehensive resource management plans and policies that prioritize watershed health. Our aim is to restore and protect water quality and healthy streams while ensuring ample clean water for future generations. Here are highlights of our work:

Regionally

- As Alabama, Georgia and Florida continue their years-long fight over future water allocations in the two major river basins they share, SELC is assisting river groups in Georgia and Alabama to ensure that long-term water quality, in-stream flows, and healthy aquatic habitat remain front-and-center

priorities. We have submitted legal filings supporting that position and continue to analyze the various proposals put forth by the states and by federal agencies.

- SELC is challenging the NC Environmental Management Commission's approval of a transfer of 20 million gallons of water per day from the Catawba and Yadkin rivers to communities near Charlotte. The transfer would exacerbate drought conditions in both watersheds and accelerate growth and water quality problems in the sensitive ecosystems of the Rocky River. In a related case, the U.S. Supreme Court has agreed to hear a complaint filed by South Carolina regarding the transfer and equitable apportionment of water in the Catawba River.

Alabama

- SELC was a lead organization in developing the 2007 Alabama Water Agenda, which outlined the top threats to water quality in the state and recommendations for addressing them. We pushed for a water study committee, which the Alabama legislature has now created; over the next year we will advocate for sound water management before the committee.
- We are representing river groups to defend the Birmingham regional stormwater management agency, which has taken strong measures to protect the Cahaba and Black Warrior rivers, against business interests seeking to do little more than minimally required.

Georgia

- SELC is a lead partner in the 167-member Georgia Water Coalition, which is made up of diverse groups whose shared goal is sustainable management of state waters as a public resource. We aim to improve the water plan approved this year and discourage the state from pursuing destructive and costly alternatives like damming the Flint River or siphoning water from neighboring Tennessee.
- This year, SELC helped to pass several water conservation bills and defeat a bill that would have given the Department of Transportation immunity from all water quality laws.

North Carolina

- In 2006, we won a comprehensive state court ruling overturning three state permits that would have allowed increased discharges of stormwater and other pollution into Goose Creek, a tributary of

LYNDA RICHARDSON

the Rocky River near Charlotte; the ruling sets a precedent for stronger stormwater regulations across the state. In the Triangle, we are pushing for improved measures to protect water quality in Jordan Lake, a major drinking water reservoir, from sewage treatment plant discharges and stormwater runoff.

- The ongoing development boom in the mountains poses severe threats to water quality, including the headwaters for many of the state's major rivers. We are pursuing a multi-county strategy to discourage steep-slope development and other unwise growth trends.
- SELC worked to pass drought legislation in 2008 and will be strongly advocating a comprehensive water management policy in 2009.

South Carolina

- Upstream water withdrawals in North Carolina and Georgia are threatening South Carolina's major rivers, including the Catawba, Pee Dee, and Savannah. SELC is promoting legislation in the General Assembly designed to preserve adequate flow levels in the state's waters.
- SELC is in court fighting attempts by the would-be developer of the 4,600-acre Green Diamond project along the Congaree River near Columbia to overturn federal flood maps prohibiting development in this area. The project would turn the unpopulated farmland and forest into a New Orleans-style city behind the levees, disrupting the natural ecology of the floodplain and raising flood risks for those living across the river.

Tennessee

- SELC is at the forefront of efforts to change the way the Department of Transportation plans and builds roads, with a primary goal being to protect

water quality in the state's streams and rivers. Our advocacy helped convince the agency to reroute portions of the southern section of the Nashville Loop highway to avoid certain waters, and this year we helped defeat legislative proposals that would have allowed highways that are partly funded by private companies to circumvent normal planning processes and undermine environmental review requirements.

Virginia

- For ten years, SELC has litigated to stop a massive, unnecessary reservoir proposed by the fast-growing Newport News region that would cause the single greatest authorized loss of wetlands in Virginia under the 35-year-old Clean Water Act, and set a dangerous precedent for similarly ill-planned reservoirs. We are currently challenging a Corps of Engineers' permit, which reverses the agency's own previous decision to reject the project based on findings that it would have unacceptable impacts and is not needed.
- In Charlottesville and Albemarle County, where SELC's regional headquarters are based, we are deeply engaged in assisting citizens and public officials to determine the best means to meet future drinking water needs, control stormwater runoff to the Rivanna River watershed, and rein in sprawling development.

Endnotes

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2 USGS; http://water.usgs.gov/waterwatch/.

3 USGS; http://groundwaterwatch.usgs.gov/Net/OGWNetwork.asp?ncd=rtn.

4 Natural Resources Conservation Service (NRCS); http://www.nrcs.gov/technical/ NRI/1997/summary_report/table1.html. NRCS has indicated an update of this data is forthcoming in 2008.

5 *Ibid.*

6 NRCS Strategic Plan, June 2003; http://www.nrcs.usda.gov/about/spa/documents/2003_Strategic_Plan_Update.pdf. The last year for which this data was available was 1997.

7 James E. Kundell, PhD., University of Georgia Carl Vinson Institute of Government; and personal interview, June 2008.

8 *Ibid.*

9 USGS; http://water.usgs.gov/watuse/.

10 *Ibid.*

11 *Ibid.*

12 U.S. Environmental Protection Agency (EPA) Office of Wetlands, Oceans & Watersheds; http://www.watershed-assistance.net/resources/files/wiseco_web.pdf.

13 Bent, G.C., et al; "A synopsis of technical issues for monitoring sediment in highway and urban runoff," USGS Open File Report; Number: 00-497 (2001); http://ma.water.usgs.gov/fhwa/NDAMSP1.html.

14 "Paving our Way to Water Shortages," *American Rivers*, Natural Resources Defense Council, Smart Growth America (2002); http://www.americanrivers.org/site/DocServer/PavingOurWayToWaterShortages.pdf?docID=164.

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17 Torcellini, P., N. Long, and R. Judkoff; National Renewable Energy Laboratory, DOE; "Consumptive Water Use for U.S. Power Generation," December 2003. Numbers based on DOE study of the 120 largest hydroelectric facilities in the U.S. (1995 is latest data available; no data available for South Carolina or Virginia). To arrive at "State Loss (mgd)," each state's Average Gallons Consumed Per Kilowatt Hour (NREL) was multiplied by each state's volume of hydroelectric energy produced (USGS 1995).

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