Chapter 1

The Importance of Hydrology

While Planet Earth is endowed with abundant water, the needs for water at specific times and places often exceed the available supplies. Efforts to utilize this precious resource often result in adverse social and environmental impacts, causing disruption of water supplies to downstream users, and the loss of aquatic habitats.

In addition to conflicts over water availability, the quality of water is often compromised. Use of water, as well as alteration of natural landscapes, can drastically affect the physical, chemical, and biological properties of water - what we call water quality.

The materials in this book focus on understanding water from a quantity and quality perspective in the hope that we might better utilize this resource – thus preserving and protecting our planet for today's occupants as well as tomorrow's.

1.1 A Brief History

Before we begin our study of water, let us reflect on how water has shaped our beliefs and values – just what is it about water that makes it so important to human societies?

Early human existence was a tug-of-war between feast and famine, and the weather was instrumental in affecting the availability of game, agricultural productivity, and catastrophic inundation. Accounts of floods and droughts have been handed down from the earliest prehistory - the flood of Noah which may be an account of the flooding associated with a breach between the Black and Mediterranean Seas. The seven plagues of Egypt, including droughts and floods, which prompted Moses to flee.

While the earliest forms of agriculture probably relied directly on rainfall, the great societies of Egypt, Mesopotamia, the Indus, and China were linked to irrigation. The ebb and flow of rivers allowed the water to flood and fertilize the land during the wet season, and then supply supplemental water during the dry season. The need to allocate scarce water supplies during droughts provided an impetus for water resources administration - leading to the establishment of modern civilization.

Knowledge of irrigation spread through the desert countries of North Africa and Southern Europe. The Romans built elaborate aqueducts to transport water over great distances. The elaborate irrigation and drainage systems of the Native Americans also developed hand-in-hand with an administration system that could resolve issues of communal work and rewards.

Water has also been used as a means of transportation, both along rivers as well as in the seas and oceans. The accounts of Ulysses in the Odyssey tell the travails associated primitive travel by ship. Earlier travel in canoes and small sailing craft helped primitive peoples spread across the tropical Pacific, as far as Hawaii and Easter Island in the east Pacific.

Many of the earliest writings are of a religious nature. Early religious documents, such as the *Bible* (Judeo-Christian), *Talmud* (Judaism), *Koran* (Islam), *Code of Manu* (Hindusim), *I-Ching* (Taosim), and the *Analects* (Confucianism), place great importance on water to society.

In the year 1086, twenty years after *William the Conqueror* had successfully invaded England, he authorized the inventory of all of his conquest. Included in this so-called *Doomsday Book*, or final accounting, are 6000 water mills that were used primarily for grinding wheat and other grains to make flour. By the seventeenth century, in France, there were over 60,000 water mills producing the flour used to make their daily bread. Even in early American history, the importance of water mills on local commerce can not be underemphasized. Many cities in the eastern U.S. were located in proximity to sites where water power could be used for grinding corn and grains, or for powering industries.

With the advent of the industrial age, reliance on hydropower as an abundant, cheap, and clean source of energy was widespread. First small, but then ever-larger, dams were built to harness the energy in water, culminating in the large dams of the twentieth century. As coal, and later nuclear energy, replaced hydropower, water was still needed to drive the steam turbines used to generate electricity.

Water was also used to remove wastes, such as human and animal wastes from cities. Industrial discharges of wastewater from mills and factories was as simple as constructing a ditch to the nearest river or stream. Unfor-

tunately, downstream water users were often left to bear the burden of polluted wastewater.

As recreation and environmental concerns increased during the late-nineteenth and twentieth-centuries, greater efforts were placed on maintaining instream water quality. Restrictions on discharges, as well as an emphasis on wastewater treatment, led to major improvements in stream water quality. These improvements were only for point-sources of discharge, however, and not for stormwater discharged from nonpoint sources.

American literature reflects the importance of water in American society. The writings of *Mark Twain* on the Mississippi River brought home the central role that water plays in commerce in nineteenth century America. The book *Silent Spring*, written by *Rachael Carson* in the 1950s, dramatized the plight of American birds due to the widespread application of pesticides, leading to strict controls on environmental toxins.

Carson's research relied upon *electron capture detector*, a technology developed by J.E. Lovelock, who later developed the *Gaia* hypothesis that Planet Earth is a self-regulating system with built-in checks and balances that controls the temperature and atmospheric gas composition. And finally, presidential candidate *Al Gore's* book, *Earth in the Balance*, outlines the challenges facing modern civilizations when confronted with resource management decisions.

Problems

1. Select a book to read on some aspect of water resources. Describe the setting, characters, and plot. Indicate how important the book was in terms of changing the way we think of water.

2. Select a video to watch on some aspect of water resources. Describe the setting, characters, and plot. Indicate how important the book was in terms of changing the way we think of water.

3. Religious literature often provides the earliest accounts of the role of water in human society. Search for references to water in religious literature (such as the Jewish Talmud, Christian Bible, Islamic Koran, Hindi Code of Manu, Confucian Analects, or other source), using either published or internet sources. Note the importance or role of water in the reference.

4. Many ancient civilizations derived great pleasure exploring their environment. Select an ancient civilization and describe how they conceptualized the hydrologic cycle.

5. There are many water resources engineering marvels from the ancient past. Pick one and describe its purpose and relevance to the society of its time.

1.2 The Role of Science

The early Greeks spent much time trying to understand the origin of rivers and streams. *Thales* (640-546 BCE) was an Ionian who popularized the belief that wind blew water into rocks along the coast, forcing water up through the rock under high pressure, where it eventually emerged in springs.

Later, *Plato* (427-347 BCE), an Athenian, argued that water was contained in a single underground cavern, and was pushed up into springs by underground forces. *Aristotle* (384-322 BCE), also an Athenian, disagreed with Plato, arguing that water vapor from the atmosphere and interior of the earth condensed directly in the soil, making it moist.

Seneca (4 BCE - 65 CE), a famous Roman senator, proved to the intellectuals of his day that precipitation that fell to the earth and infiltrated was not sufficient to supply all the water that was observed as streamflow. Even as late as *Kepler* (1571-1630), a German scientist renowned for his astronomy, showed that the earth digested salt water and excreted fresh water as waste.

It was not until *Perrault* (1608-1680), a French scientist, measured rainfall in the Seine River watershed during the period from 1668-70. His measurements showed the precipitation to be 520 mm, which was six times more than the river flow. This proved to a great many scientists that the source of water in rivers and streams is atmospheric precipitation falling on the soil.

To this day, however, there is still great dispute over the source of water in streams. Many argue that streamflow only results from overland flow during rainstorms. Others argue that while this may be true in urban areas where impervious surfaces dominate, the overland flow theory is not appropriate for forests and many agricultural areas. In these cases, streamflow results from infiltration, recharge, and subsequent exfiltration of water from ground water.

How Long Have People Been Tracking Precipitation?

"In his book *Meteorologica*, Aristotle (340 BCE) mentioned topics such as clouds, mist, rain, snow, etc, but not the measurement of precipitation. Measuring rain and keeping records of it was apparently still far off in the future.

"The earliest quantitative device for measuring rainfall seems to be credited to a king in Korea called King Sejong who lived from 1397 to 1450. One of his goals as king was to make his people literate, so not only did he invent a rain gauge, but more importantly, he invented a language and movable type for that language.

"He decided that instead of digging into the soil to check for moisture, it would be better to have a standardized container about 30 cm in depth and 14 cm in diameter that stood on a pillar to measure the rainfall. These containers were to help villagers determine their potential harvest and to give King Sejong a better idea of how much the farmers should be taxed!

So, these standard containers were distributed to each village. The rain gauge was invented in the fourth month of 1441, according to records."

"The tipping bucket rain gauge was invented by Christopher Wren in Europe around 1661 and used the standard of weight, or sometimes volume, of the liquid precipitation. This tipping bucket idea is still used in many of the automated electronic gauges today.

"In 1887, Mr. Cleveland Abbe wrote a manual on *Meteorological Apparatus and Methods* for the U.S. Army Signal Corps (agency responsible for U.S. weather observations at the time). In this booklet, Mr. Abbe described the standards for the weather gauges to be used by the U.S. Army Signal Corps. This standard 8-inch diameter gauge is still in use by many National Weather Service offices and cooperative weather observers across the United States and abroad." [1]

Flow Measurement: History

"Hydraulic structures existed before recorded history. Archeologists have found irrigation systems in Mesopotamia and check and diversion dams on the Arabian Peninsula dating to about 5800 BCE. The first water level records on the Nile River appeared about 3050 BCE. The Romans, even though they did not fully comprehend hydraulic principles relating to discharge, devised a method based on pipe areas in order to charge for water supplied to baths and private residences. *Hero*, a Greek of the first century ad, was the first to express the basis for flow measurement as we know it today. This important finding went unnoticed, however, for about 1500 years until *Leonardo da Vinci* extended the relationship to the continuity equation, but even da Vinci's work went unknown until his manuscripts were found in 1690. The German engineer, *Reinhard Woltman*, developed the spoke-vane current meter in 1790, a breakthrough for measuring velocities in rivers and canals. During the 18^{th} and 19^{th} centuries development and installation of weirs and flumes made flow measurements possible on irrigation canals, and gaging stations were constructed on many rivers to provide records of flows. New technology has provided various water measurement techniques, and stream flow data now can be accessed at over 4200 gaging stations in the United States." [2]

Problems

1. Select a scientist from the past who had some influence on changing how we think about water resources. Describe how they contributed to our modern understanding.

2. Describe how ancient cultures (e.g., Chinese, Egyptian, Persian, Babylonian, Mayan) described water resources. What was their *hydrologic cycle*?

3. Download maximum annual water levels from the so-called *Nilometer*. Summarize the source of the data and the types of behavior it displays.

1.3 Current Issues and Careers

Water is usually managed for both quantity and quality. Too much water - too little water, are both issues of *water quantity*. Flood control and drought protection are opposite ends of the water quantity spectrum. Dams, bridges, canals, revetments, harbors, etc., are all structures used to protect people and property from the vagarities of nature.

Careers in water quantity have historically been left to the engineering profession, with some opportunities for economists. Designs of engineering structures, and the ability to pay for these structures, have preoccupied the federal, state and local agencies since the beginning of the nation. In recent years, however, increasing attention is being placed on managing facilities, and providing initiatives for individuals to avoid building in flood-prone land, thus reducing the need for *structural remedies* to water resource problems.

Little legislation exists to regulate water quantity on the national scale. Regional compacts are usually negotiated at the state or local level to find an acceptable allocation of water between jurisdictions, primarily for periods of drought. Little national legislation exists related to the regulation of flooding, other than requirements related to building in the flood plain.

Unlike water quantity, the maintenance of water quality has a rigorous legal foundation, focusing on the protection of the quality of water supplies. We can divide modern water quality management into three categories; water supply, wastewater treatment, and the protection of aquatic habitats. Because each category has its own legislative history, issues and career opportunities are often uniquely defined within each category.

The first water quality category, water supply protection and augmentation, relates to the need of society for abundant sources of inexpensive water of acceptable quality. Surface water quality issues related to drinking water fall under the *Source Water Assessment and Protection* (SWAP) program, which is a part of *Safe Drinking Water Act*. A similar program for ground-water quality is the *Wellhead Protection Program* (WPP), which also falls under the Safe Drinking Water Act. These programs are intended to preserve and protect drinking water supplies so that chronic and acute exposures to hazardous contaminants are minimized.

In addition to water quality protection, new water supplies are routinely needed in growing communities for both municipal and industrial purposes. Reservoirs are one option for capturing excess streamflow during the winter months, and storing it for delivery during the drier summer months. Ground water is another resource that many communities are tapping whenever possible. Wastewater reuse is a potential source of new water for meeting the demands of growing communities.

[1] Taken from www.cocorahs.org

[2] by James F. Ruff, http://www.informaworld.com/10.1081/E-EWS2-120010345

Efforts are also underway to recharge excess surface water in ground-water aquifers. The intent is to avoid the need to construct surface-water reservoirs, and to use the subsurface as an underground reservoir to store excess streamflow until it is needed.

A second area is the treatment of municipal and industrial wastewater, as well as mitigating the effects of stormwater runoff from nonpoint sources, such as farms, homes, forests, etc. These programs fall under the Clean Water Act. Also included in this category is the cleanup of sites where hazardous and toxic wastes were discharged, primarily in the subsurface, during the years when such dumping was allowed. These programs fall under either CERCLA or RCRA.

The cleanup of current and historical contaminants is a challenge in this, and many other industrial and developing countries. Many poor countries are faced with the options of either destitute populations, or the discharge environmentally destructive compounds.

Nonpoint source issues related to stormwater runoff are manifested by erosion and sedimentation, as well as pathogens, heavy metals, herbicides, pesticides, and excessive nutrients.

While providing clean, abundant, and inexpensive water supplies is clearly linked to the cleanup of wastewater and the prevention of contamination, the poor linkages between the myriad federal water quality legislation makes integrating these programs difficult. One new tool for establishing linkages between these programs are watershed assessments, which inventories the watershed from the perspective of both point and nonpoint sources of pollution, as well as the importance of water supply protection.

Finally, a third category of issues is the protection of habitat of threatened and endangered species. The Georgia River Corridor Protection Act provides for limitations on riparian zone development along the larger rivers and streams in the state. Federal endangered species legislation is another controversial area of law related to protecting aquatic and terrestrial habitats.

Water Supply Legislation

Organic Act of 1897. Signed into law on June 4,1897, by President William McKinley for the purpose of timber production, watershed protection, and forest protection. The goal was to use federal lands to preserve wood and water supplies for the long-term benefit of the public. Of specific interest was "securing favorable conditions of water flows".

Weeks Act. Passed by the US Congress on March 1, 1911. It authorized the Secretary of Agriculture to "Examine, locate and recommend for purchase ... such lands within the watersheds of navigable streams as ... may be necessary to the regulation of flow of navigable streams ...". These lands were primarily in the eastern United States.

Flood Control Act of 1937. Signed into law by President Franklin D. Roosevelt on August 28, 1937, in response to major flooding throughout the United States in the 1930s, culminating with the *Super Flood* of January 1937, the greatest flood recorded on the lower Ohio River. The act provided funds for the initial construction of projects selected by the Chief of Engineers, including construction of floodwalls, levees, and revetments along Wolf River and Nonconnah Creek for protection of Memphis, TN, and modified the Yazoo River project.

Wilderness Act of 1964. Signed into law by President Lyndon B. Johnson on September 3, 1964. It created the legal definition of wilderness in the United States, and protected some nine million acres of federal land. The goal was to protect watersheds and clean-water supplies vital to downstream municipalities and agriculture, as well as habitats supporting diverse wildlife, including endangered species, while logging and oil and gas drilling are prohibited.

Wild and Scenic Rivers Act. Signed into law on October 2, 1968, by President Lyndon B. Johnson. Rivers are designated by the U.S. Congress or the Secretary of the Interior and are preserved in their free-flowing condition and are not dammed or otherwise impeded. A total of 156 rivers had wild and scenic status in 2004. Selected rivers are preserved for possessing outstandingly, remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values.

Water Quality Legislation

Soil Conservation and Domestic Allotment Act. Passed on April 27, 1935, that allowed the government to pay farmers to reduce production so as to conserve soil and prevent erosion. The act was intended to conserve soil in the High Plains by planting trees and native grass - soil that created the huge dust bowls during the 1930s. Soil conservation in the Deep South was also targeted. Three years after the Act was adopted, soil erosion had dropped 65 percent.

Clean Water Act. Passed in 1972 and regulates discharges to "navigable waters". The act introduced a permit system for regulating point sources of pollution, and created a new requirement for technology-based standards for these discharges.

Safe Drinking Water Act. Passed in 1974. Prior to the 1970s the protection of basic air and water supplies was a matter mainly left to each state. During the 1970s, responsibility for clean air and water to shifted to the federal government. Discovery of organic contamination in public drinking water and the lack of enforceable, national standards persuaded congress to take action. The act applies to public water systems, but does not cover private wells or bottled water.

Resource Conservation and Recovery Act. Enacted in 1976. It is the principal law governing the disposal of solid waste and hazardous wastes. Congress enacted the law to address the increasing problems from these wastes, setting national goals for protecting human health and the environment.

Comprehensive Environmental Response, Compensation, and Liability Act. (CERCLA or Superfund) was passed in 1980 to clean up abandoned hazardous waste sites. The act provides authority to clean up releases or threatened releases of hazardous substances that may endanger public health or the environment. The law authorized the Environmental Protection Agency (EPA) to identify parties responsible for contamination of sites and compel the parties to clean up the sites. Where responsible parties cannot be found, the Agency is authorized to clean up sites itself, using a special trust fund.

Habitat Protection Legislation

National Environmental Policies Act. Enacted in 1970 to establish a national policy promoting the enhancement of the environment and also established the President's Council on Environmental Quality (CEQ). NEPA's most significant effect was to set up procedural requirements for all federal government agencies to prepare Environmental Assessments (EAs) and Environmental Impact Statements (EISs). EAs and EISs contain statements of the environmental effects of proposed federal agency actions.

Endangered Species Act. Passed in 1973 to protect critically imperiled species from extinction as a "consequence of economic growth and development untempered by adequate concern and conservation". The act) is the most wide-ranging of the dozens of United States environmental laws passed in the 1970s. The stated purpose of the Endangered Species Act is to protect species and also "the ecosystems upon which they depend".

Swampbuster Provisions. Passed in 1985 as a provision of the Food Security Act to discourage the conversion of wetlands to cropland use. Producers converting a wetland area to cropland lose eligibility for several federal farm program benefits.

Federal Agencies

Federal agencies with water interests include:

Geological Survey. Agency with offices in each state that monitor streamflow, ground-water levels, and water quality.

Environmental Protection Agency. Agency with nine regions in the nation, plus research facilities around the U.S., devoted to the regulatory oversite of water quality programs.

Army Corps of Engineers. Agency divided into watershed-based districts that focuses on managing water resources infrastructure.

Bureau of Reclamation. Agency that focuses on managing water resources in the western U.S.

Fish and Wildlife Service. Agency that inventories and manages aquatic habitats.

Forest Service. Manages forest land for water, timber production, recreation, grazing, and habitat.

Bureau of Land Management. Manages grazing lands for water, timber production, recreation, grazing, and habitat.

Bureau of Indian Affairs. Agency that administers and manages 55.7 million acres of land held in trust by the United States for Native Americans in the United States, Native American Tribes, and Alaska Natives.

National Oceanographic and Atmospheric Administration. A scientific agency within the U.S. Department of Commerce that focuses on the conditions of the oceans and the atmosphere. NOAA warns of dangerous weather, charts seas and skies, guides the use and protection of ocean and coastal resources, and conducts research to improve understanding and stewardship of the environment.

Natural Resources Conservation Service. Agency within the U.S. Department of Agriculture that provides technical assistance to farmers and other private landowners and managers. Its mission is to improve, protect, and conserve natural resources on private lands through a cooperative partnership with local and state agencies. While its primary focus has been agricultural lands, it has made many technical contributions to soil surveying, classification and water quality improvement.

Agricultural Research Service. The principal research agency of the U.S. Department of Agriculture (USDA). ARS is one of four agencies in USDA's Research, Education, and Economics (REE) mission area. ARS is charged with extending the Nation's scientific knowledge with programs in agriculture, human nutrition, food safety, natural resources, the environment, library and information services, and other topics affecting the American people on a daily basis.

Georgia State Agencies

State agencies with water interests include:

Department of Natural Resources. Primary agency responsible for managing and regulating natural resources, composed of:

- Environmental Protection Division.
- Pollution Prevention Assistance Division.
- Coastal Resources Division.
- Wildlife Resources Division.
- Georgia Geologic Survey.

Georgia Soil and Water Conservation Commission. Responsible for assisting landowners with water and soil conservation.

Georgia Forestry Commission. Responsible for assisting landowners with forest management and protection.

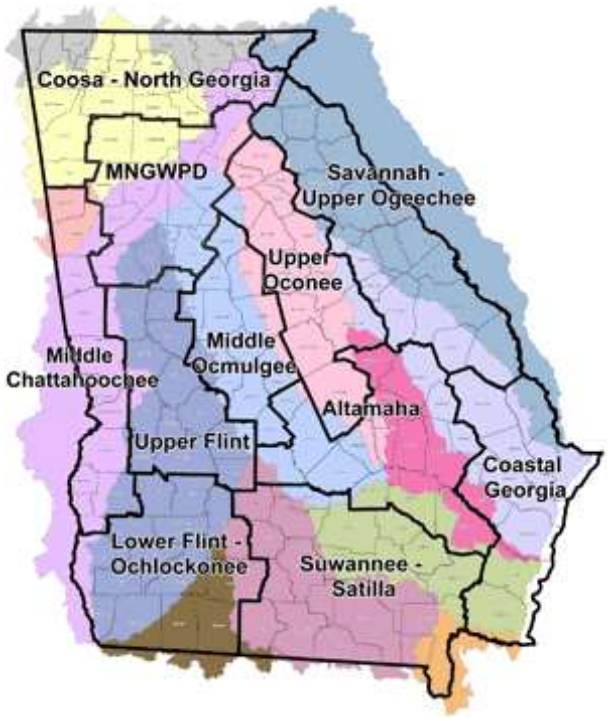

Figure 1.1: Map showing Georgia Regional Water Planning Councils.

Georgia Water Management

The Georgia Comprehensive Statewide Water Management Plan was adopted by the General Assembly in 2008. It provides for:

- The Georgia Environmental Protection Division to conduct water resource assessments to determine how much water there is in Georgia and how much pollution the waterways can handle before water quality is unacceptably degraded;
- The creation of regional water planning councils (shown in Figure 1.1) to prepare recommended water development and conservation plans to characterize the water needs for each region as those needs relate to the needs of adjacent regions and the preferred management practices to use in each region to close any "gap" between water capacities and water needs;
- Regional water planning guidance, including the development by major water use stakeholders of a Water Conservation Implementation Plan; and,
- Water quality and water supply permitting decisions to be made by EPD in accordance with the state water plan.

University of Georgia Resources

UGA Water Resources Faculty. The UGA Water Resources Faculty is an informal group of faculty who meet several times each year to discuss water resource issues and opportunities. The faculty has grown over time from an initial group of three in 1993 to over 100 faculty from ten different academic units. The primary means of communication amongst the group is a water resources listserve that also includes staff, students, and water resources professionals with an interest in water resources. The listserve is supplemented by a website[3], that summarizes UGA activities related to water resources. While never formalized, the Water Resources Faculty have found that meeting and sharing information using the listserve and website helps to coordinate research, teaching, and outreach.

The UGA Water Faculty, at the behest of then-Provost Karen Holbrook in 2001, prepared a white paper (*A Proposal to Form a Water Resources Faculty at the University of Georgia*,[4] which is referred to as the Keeler Report after the primary author, Professor Andrew "Andy" Keeler, who was then a professor within the Department of Agricultural and Environmental Economics, College of Agricultural and Environmental Sciences. The Keeler Report, the result of discussions amongst twelve UGA faculty, established the rationale for a formal Water Faculty, including better internal and external teaching, research, and outreach coordination. The faculty would also provide greater visibility to the university and individual faculty. The report summarized the ongoing strengths in water resources at UGA, including 1) Measuring, Assessing, and Modifying Water Resources; 2) Aquatic Ecosystems; and 3) Human Systems, Technology and Policy.

The Keeler Report finished by recommending a number of "Next Steps", including providing resources for: 1) A full-time faculty director to devise and implement programs to achieve the goals of the faculty; 2) A Faculty Advisory Board to represent faculty interests and provide guidance; and 3) Staff to enhance internal and external communications, survey and catalog faculty activities and expertise, design and maintain a web site, and identify and help capitalize on funding opportunities. While the report represented the consensus of the water faculty, resources were not available at the time to implement the recommendations.

Institutes, Centers, and Laboratories. Within UGA, colleges, schools, and departments are devoted directly or indirectly to various aspects of water resources investigations, management, policy, and development. Additionally, many institutes, centers, and laboratories are also directly or indirectly engaged in water science, including, but not limited to:

- River Basin Center
- Carl Vinson Institute of Government
- Center for Applied Isotope Studies
- Marine Education Center and Aquarium
- Center for Remote Sensing and Mapping Science
- Center for Archeological Sciences
- Marine Institute on Sapelo Island
- Savannah River Ecology Laboratory
- Watershed Assessment Laboratory
- Environmental Process Control Laboratory
- Chemical Analysis Laboratory
- National Environmentally Sound Production Agriculture Laboratory (NESPAL)

[3] http://www.uga.edu/water
[4] http://www.hydrology.uga.edu/keeler.pdf

- Natural Resources Spatial Analysis Laboratory
- Environmental Analysis Laboratory
- Geomorphology Laboratory
- LTER - Georgia Coastal Ecosystems
- LTER Coweeta Hydrologic Laboratory
- Faculty of Engineering
- CSREES Regional Program
- Sea-Grant Program
- Southern Regional Forestry Program

Undergraduate Certificate in Water Resources. The Undergraduate Certificate in Water Resources[5] was approved in 2002, and graduated its first students the following year. The undergraduate certificate is administered by the UGA Water Resources Faculty, and the program is directed by Todd Rasmussen and Jenny Yearwood. The Water Resources Certificate Program prepares students for related careers in water science and management. Protecting the long-term ecologic health of our aquatic systems is an important national goal. Yet our society has ever-increasing demands for inexpensive supplies of high-quality water. The Program provides a common curriculum to meet the educational needs of the next generation of water resource scientists and managers. Many of the courses provide hands-on experiences to learn about water resources in both laboratory and outdoor settings. The purpose of the program is to train students to manage our scarce water resources for the maximum benefit of the world's population, while at the same time preserving the ecologic integrity of our aquatic resources.

Graduate Certificate in Water Resources. The UGA Water Resources Faculty is currently pursuing the submission of a degree proposal for a Graduate Certificate in Water Resources. The purpose of the graduate certificate is to establish a program of study that fulfills the needs of water resource professionals. The program is intended to provide incentives and structure for graduate students in water-related fields to broaden and strengthen their education in the area of water resources. While earning a graduate degree in a specific discipline related to water resources, students in the certificate program will be introduced to other disciplines that are equally essential to creating and maintaining healthy water systems. Students who earn a Graduate Water Resources Certificate will acquire an improved understanding of the biophysical, social, and institutional aspects of terrestrial and aquatic systems. This greater knowledge base and enhanced skill set will strengthen graduates credentials for professional employment and enable greater multidisciplinary communication among future water resource professionals.

Georgia Water Resources Conference. The Georgia Water Resources Conference has been held biennially since 1989, as a collaborative gathering of people interested in Georgias water resources.[6]. This collaborative conference has led to the advancement of water science and management in the state by providing a neutral and open forum for diverse perspectives to be presented and discussed.

[5]http://www.uga.edu/water/certificate.htm
[6]http://www.ce.gatech.edu/research/gwri/

Since its inception, the goal of the Georgia Water Resources Conference has been to provide an open forum for the discussion of current water policies, research, projects, and management in Georgia. Papers on topics related to water policies, legislation, research, on-going studies, technical innovations, issues and concerns, current situation and trends, new approaches, management programs, data and information, education, public participation, institutional and financial arrangements, history, culture, future needs and solutions, and other topics related to water management have been encouraged and actively solicited.

Georgia Cooperative Extension Program. As a land grant university, UGA maintains faculty in every county through the Cooperative Extension Service. While these agents have traditionally worked with agriculture, many of the current demands, especially in urban areas, are related to natural resources and the environment. Agents routinely receive water resource related training from UGA faculty and then distribute this knowledge to the local community through county meetings and programs, local newspaper and radio shows, and through Master Gardeners, 4-H students, and other volunteers. Agents have proven to be particularly helpful in assisting local communities with stormwater and water conservation education programs. Many states (e.g., Wisconsin, Oregon, North Carolina) have implemented the concept of using *Watershed Agents* to implement water resource programs at the local level. While UGA has discussed this (and temporarily had one watershed agent in the Upper Oconee Watershed), lack of resources has prevented implementation of this program.

Problems

1. Select a state or federal law. In 30 words or less, discuss the intent of the legislation with respect to water resources.
2. Select a state or federal agency. In 30 words or less, discuss their mission and role with respect to water resources.
3. Describe an academic program related to water resources at the University of Georgia. Identify and describe the faculty there that are involved in water resources. Indicate what kind of teaching, research, or extension activities they are involved with.
4. Select an important piece of water resources legislation. Indicate the reasons for the legislation. Also indicate which agencies are involved in implementing the legislation.

1.4 Water Reading List

These are some books of direct relevance to understanding the subject of water resources. They are generally written for the non-technical audience, and should be an easy read. Abstracts are supplied by the author, publisher, or reviewer.

A Civil Action by Jonathan Harr.

This riveting work of legal reportage is at once the story of an emotionally explosive lawsuit and a searing expose of the American legal system. When young lawyer Jan Schlichtman initiates a civil suit against two of the nation's largest corporations who stand accused of the deaths of children in a Massachusetts suburb, he finds himself locked in an epic struggle that costs him his home, his reputation, and very nearly his sanity.

Cadillac Desert by Mark Reisner.

The story of the American West is the story of a relentless quest for a precious resource: Water. It is a tale of rivers diverted and dammed, of political corruption and intrigue, of billion-dollar battles over water rights, of ecologic and economic disaster. In Cadillac Desert, Marc Reisner writes of ht earliest settlers, lured by the promise of paradise, and o f the ruthless tactics employed by Los Angeles politicians and business interests to ensure the city's growth. He documents the bitter rivalry between two government giants, the Bureau of Reclamation and the U.S. Army Corps of Engineers, in the competition to transform the West.

Future Eaters: An Ecological History of the Australasian Lands and People by Tim Flannery.

In this illustrated ecological history, acclaimed scientist and historian Flannery follows the environment of the islands through the age of dinosaurs to the age of mammals and the arrival of humans, to the European colonizers and industrial society. Penetrating, gripping, and provocative, this book combines natural history, anthropology, and ecology on an epic scale.

Rising Tide: The Great Mississippi Flood of 1927 and How It Changed America by John M. Barry.

This gripping account of the mammoth flooding of 1927 that devastated Mississippi and Louisiana and sent political shock waves to Washington is a brilliant match of scholarship and investigative journalism. [Jason Berry]

Rivers for Life: Managing Water for People and Nature by Sandra Postel and Brian Richter.

Rivers for Life is a clarion call to society for the need to balance human demands with the needs of our world;s rivers, the arterial system of life on this planet. The authors describe the vanguard movement to restore rivers and to reconnect rivers with their flood plains, portraying the under-appreciated life support services our rivers perform, their ecological function, and the threats to riverine ecosystems.

Water Wars: Drought, Flood, Folly, and the Politics of Thirst by Diane Raines Ward.

This is a wonderful book, a wake-up call of startling clarity and insight, with a flood of facts and anecdotes that place the abstract into riveting human perspective. I will never turn on the rap again without thinking about where water comes from and where it goes. [Ken Burns, producer and director of the Civil War, Baseball, and Jazz documentaries]

Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters by Robert Glennon.

This book is a timely and much needed wake-up call concerning the all-too-frequent pollution and misuse of the groundwater tables that America relies upon for fresh drinking water. Consisting of a selection of anecdotes about how the Santa Cruz River in Tucson went dry, the rampant greed in Tampa Bay, watershed initiatives concerning Massachusetts' Ipswitch River Basin, and a great deal more, Water Follies is a clarion warning and very strongly recommended contribution for Environmental Studies reference collections. [Midwest Book Review]

Unquenchable: America's Water Crisis and What To Do About It by Robert Glennon.

Robert Glennon captures the irony - and tragedy - of Americas water crisis in a book that is both frightening and wickedly comical. From manufactured snow for tourists in Atlanta to trillions of gallons of water flushed down the toilet each year. Unquenchable reveals the heady extravagances and everyday inefficiencies that are sucking the nation dry.

Confluence of a River, The Environment, Politics, and the Fate of All Humanity by Nathaniel Tripp.

Tripp, author of Father, Soldier, Son (1997), has long been fascinated by the flow of water: I could find more in the swamp down below the high school than I ever could in the classrooms. And he has spent some of his happiest days on the Connecticut River, paddling its waterways with his sons, investigating Atlantic salmon restoration, and visiting its broad, glittering reservoirs. Each chapter in this slender volume discusses a specific watershed of the Connecticut, which divides Vermont and New Hampshire, with the exception of a side trip to northern Quebec. Tripp is a knowledgeable guide, whether discussing the dwarf wedge mussel or hydroelectric politics. The state of our rivers is grim, to be sure, but one person, argues Tripp, can make a difference. Much like the beginnings of a river itself: The river begins as all rivers do, with a drop of rain, a wisp of fog. [Rebecca Maksel]

Dam Break in Georgia: Sadness and Joy at Toccoa Falls by Kenneth Neill Foster, K. Neill Foster.

A true story about the flooding disaster of Toccoa Falls College on November 6, 1977. A moving story telling of the horror and subsequent victory, and of the people involved. Kelly Barnes Dam, located above the Toccoa Falls Bible College near Toccoa, Georgia, failed in the early morning hours of November 6, 1977. The campus was inundated within minutes. One dormitory had 8 ft of water on the ground floor. A trailer park associated with the college was destroyed as 10 ft of water rushed through it. Thirty-nine deaths and $2.8 million in damages occurred during this flash flood.

Encounters with the Archdruid by John McPhee.

Born in 1915, the mountaineer and outdoorsman David Brower has arguably been the single most influential American environmentalist in the last half of the 20^{th} century; even his erstwhile foes at the Department of the Interior grudgingly credit him with having nearly single-handedly halted the construction of a dam in the heart of the Grand Canyon, and he has converted thousands, even millions, of his compatriots to the preservationist cause through his work with the Sierra

Club, Friends of the Earth, and other organizations. [Gregory McNamee]

The Founding Fish by John McPhee.

In his newest (after Annals), McPhee leads readers out to the river-pole and lures in hand-to angle for American shad. McPhee knows where the fish are running, so to speak, and he opens with a tall tale about his long vigil with a giant roe shad on the line. Night falls, a crowd gathers on a nearby bridge to watch and still the fish refuses to roll over; however embellished, it's a comic story. He then probes the natural history of the shad, known as *Alosa sapidissima* and traces the fish's storied place in American history and economics. The shad manages to turn up, at least in legend, at George Washington's camp at Valley Forge; it waylaid Confederate General Pickett in the defense of Richmond and hastened the end of the Civil War; it even played a minor role in John Wilkes Booth's murder of Lincoln. McPhee consults specialists like a fish behaviorist, an anatomist of fishes and a zooarcheologist who studies 18th-century trash pits to see whether Washington indeed ate shad at Mount Vernon. The author studies under a master shad dart maker and in an appendix gives recipes, too. McPhee reaffirms his stature as a bold American original. His prose is rugged, straightforward and unassuming, and can be just as witty. This book sings like anglers' lines cast on the water. It runs with the wisdom of ocean-going shad. [Publishers Weekly]

The Control of Nature by John McPhee.

Master how-it-works writer John McPhee has instructed his readers in the arcana of how oranges are commercially graded, how mountains form, how canoes are built and oceans crossed. In The Control of Nature he turns his attention once more to geology and the human struggle against nature. In one sketch, he explores the U.S. Army Corps of Engineers' unrealized plan to divert the flow of the Mississippi River into a tributary, the Atchafalaya, for flood control; in another, he looks at the ingenious ways in which an Icelandic engineer saved a southern harbor on that island from being destroyed by a lava flow; in a third, he examines a complex scheme to protect Los Angeles from boulders ejected from mountains by compression and tectonic movement. As always, McPhee combines a deep knowledge of his subject with a narrative approach that is wholly accessible; you may not have thought you were interested in earthquakes and flood control, but he gently leads you to take a passionate concern in such matters.

When the Rivers Run Dry by Fred Pearce.

Veteran science writer Pearce (Turning Up the Heat) makes a stron - and scary - case that a worldwide water shortage is the most fearful looming environmental crisis. With a drumbeat of facts both horrific (thousands of wells in India and Bangladesh are poisoned by fluoride and arsenic) and fascinating (it takes 20 tons of water to make one pound of coffee), the former New Scientist news editor documents a "kind of cataclysm" already affecting many of the world's great rivers. The Rio Grande is drying up before it reaches the Gulf of Mexico; the Nile has been dammed to a trickle; reservoirs behind ill-conceived dams sacrifice millions of gallons of water to evaporation, while wetlands and floodplains downriver dry up as water flow dwindles. In India, villagers lacking access to clean water for irrigation and drinking are sinking tube wells hundreds of feet down, plundering underground supplies far faster than rainfall can replace themthe same fate facing the Ogallala aquifer of the American Midwest. The news, recounted with a scientist's relentless accumulation of observable fact, is grim. [Publishers Weekly]

Guns, Germs, and Steel: The Fates of Human Societies by Jared Diamond.

Explaining what William McNeill called The Rise of the West has become the central problem in the study of global history. In Guns, Germs, and Steel Jared Diamond presents the biologist's answer: geography, demography, and ecological happenstance. Diamond evenhandedly reviews human history on every continent since the Ice Age at a rate that emphasizes only the broadest movements of peoples and ideas. Yet his survey is binocular: one eye has the rather distant vision of the evolutionary biologist, while the other eye - and his heart - belongs to the people of New Guinea, where he has done field work for more than 30 years. [Amazon.com]

Collapse: How Societies Choose to Fail or Succeed by Jared Diamond.

This book is the glass-half-empty follow-up to his Pulitzer Prize-winning Guns, Germs, and Steel. While Guns, Germs, and Steel explained the geographic and environmental reasons why some human populations have flourished, Collapse uses the same factors to examine why ancient societies, including the Anasazi of the American Southwest and the Viking colonies of Greenland, as well as modern ones such as Rwanda, have fallen apart. Not every collapse has an environmental origin, but an eco-meltdown is often the main catalyst, he argues, particularly when combined with society's response to (or disregard for) the coming disaster. Still, right from the outset of Collapse, the author makes clear that this is not a mere environmentalist's diatribe. He begins by setting the book's main question in the small communities of present-day Montana as they face a decline in living standards and a depletion of natural resources. Once-vital mines now leak toxins into the soil, while prion diseases infect some deer and elk and older hydroelectric dams have become decrepit. On all these issues, and particularly with the hot-button topic of logging and wildfires, Diamond writes with equanimity. [Jennifer Buckendorff]

A.D. New Orleans after the Deluge by Josh Neufeld.

A graphic history of hurricane Katrina in New Orleans and the aftermath. The author traces the experiences of five different groups of people as they decide to stay or evacuate, the storm, and trying to start life over after the storm.

The Two-mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future by Richard B. Alley.

The Long Summer: How Climate Changed Civilization by Brian M. Fagan

Pompeii by Robert Harris.

Salmon by Geoff Meggs.

Salmon Country: A History of the Pacific Salmon by Robert H. Busch.

Angle of Repose by Wallace Stegner.

The River Why by David James Duncan.

Monkey Wrench Gang by Edward Abbey.

The Swamp: The Everglades, Florida, and the Politics of Paradise by Michael Grunwald.

Wetland Drainage, Restoration, and Repair by Thomas R. Biebighauser.

The Great Lakes Water Wars by Peter Annin.

Cool It: The Skeiptical Environmentalists Guide to Global Warming by Bjorn Lomborg.

Swimming in Circles: Aquaculture and the End of Wild Oceans by Paul Molyneaux.