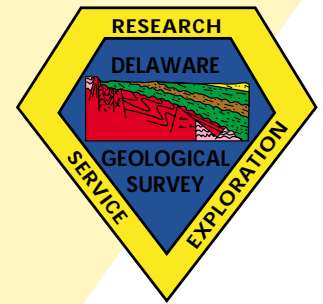


First State Geology

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The Drought and Flood of 1999

By John H. Talley

Water, too little followed by too much, was the focus of attention during the summer of 1999. Agricultural and water-supply droughts were followed by the 100- to 500-year floods caused by Hurricane Floyd on September 15-16.

Precursors of the drought conditions occurred during the summer and fall of 1998. For the six-month period July through December 1998, deficit precipitation (amount below the long term average) ranged from 7.20 inches at Greenwood to 10.49 inches at Wilmington with a statewide average of 8.46 inches. The figure showing cumulative precipitation at Wilmington's Porter Reservoir over a longer period of time (January 1998–October 1999) illustrates the 13-month-long deficit following a surplus and the return to a surplus starting with Hurricane Floyd in September 1999.

The below normal precipitation and associated lack of recharge during the deficit period resulted in near record low groundwater levels throughout Delaware. In addition, streamflows were significantly below normal across Delaware with record and near-record lows established on Brandywine, Red Clay, and White Clay creeks, and the Christina River, all of which are used for public water supplies in northern New Castle County. Relatively low streamflows were caused by a combination of below normal rainfall and a decrease in the amount of ground water available to support adequate baseflow or fair weather flow. Review of preliminary streamflow data indicates that record low daily mean streamflows were established on 14 days on Brandywine Creek, 30 days on Red Clay Creek, and 19 days on White Clay Creek from late July through mid August 1999. During the first two weeks of August 1999, the average daily streamflows for seven consecutive days on Brandywine and Red Clay creeks had a recurrence interval of 50 to 75 years. Tables and graphs showing precipitation and

streamflow data can be seen on the DGS web site at

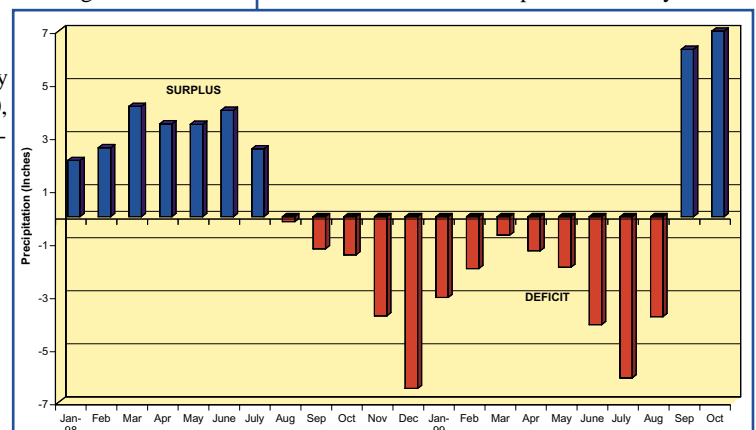
<http://www.udel.edu/dgs/drought.html>.

Daily mean streamflows on White Clay Creek at United Water Delaware's surface water treatment plant at Stanton were greater than the amount of water being withdrawn from the stream until July 26. Daily mean streamflows from July 27 through August 20, a period of 25 consecutive days, were less than the amount of water being withdrawn by the company to meet demands. The shortfall was made up by pumping water from White Clay Creek during periods of high tide. On August 2, salt levels from the influx of tidal waters resulted in increasing chloride

and sodium levels. In order to manage chloride levels water was released from Hoopes Reservoir at an average rate of about 5 million gallons per day (mgd) between August 4 and August 20 when increased streamflows

associated with rainfall pushed the salt front downstream.

The City of Newark, which normally relies on surface water from White Clay Creek to meet a significant portion of its water demands, was required to discontinue use of its surface water plant for 56 days



Cumulative precipitation January 1998 through October 31, 1999, Porter Reservoir, Wilmington, Del.

between June 29 and September 14 because of low streamflows. Water demands were met by utilizing wells and through purchase of water from other utilities.

In addition to adverse effects on public



Photographs looking upstream White Clay Creek near the Hale-Byrnes house, about a half-mile downstream from the confluence with Red Clay Creek. The left photo was taken during the early stages of the flood with the passing of Hurricane Floyd on September 16. Note the height of the water relative to the tops of the gateposts which are shown in the photo on the right taken on the following day after flooding had receded.

water supplies, the drought also had a severe impact on the agricultural community. Total precipitation for the period May through August ranged from 4.66 inches below normal at New Castle to 6.91 inches below normal at Dover with the least amount of rainfall in Kent and Sussex counties. The Delaware Department of Agriculture estimated that the impact to the agricultural community was a 50 percent loss in corn production and a 30 percent loss in soybean production.

Acting on the advice of the Drought Advisory Committee, Governor Carper declared a statewide drought warning July 23 and called for voluntary conservation measures. The continuing precipitation deficit culminated in the Governor's declaration of a drought emergency on August 5 whereby mandatory water use restrictions were imposed in northern New Castle County. This area is primarily dependent on surface water supplies in contrast to the rest of the state where ground water is the principal source.

As in 1995, the citizens and industry in New Castle County responded positively to voluntary and mandatory restrictions that enabled us to get through a critical hydrologic period. Daily water demands decreased from 89 mgd on July 19 to an average of 67 mgd between August 7 and August 20. Precise measurements of stream flows and ground-water levels contributed significantly to the management of water supplies.

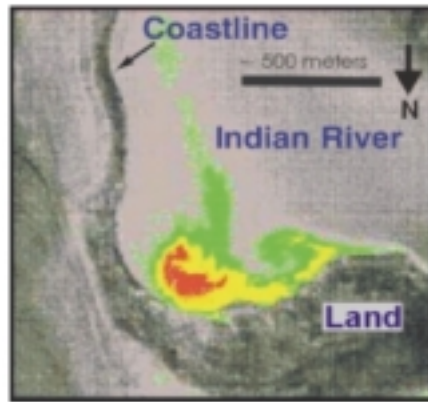
The stressed public water supply situation was alleviated somewhat by precipitation associated with the remnants of Hurricane Dennis in early September, and Governor Carper rescinded the drought emergency and mandatory restrictions on September 5 and replaced it with a drought warning with voluntary restrictions. The drought of 1999 essentially ended on September 15-16 when Hurricane Floyd dumped between 4.44 inches and 9.75 inches across the state with the largest amount of precipitation falling in northern Delaware. Flooding caused extensive property damage throughout Delaware. The Delaware Emergency Management Agency estimated damage to be about 11.5 million dollars statewide. Northern New Castle County was hit especially hard as the flows on Christina River at Coochs Bridge and White Clay Creek near Newark were classified by the U.S. Geological Survey as having 500-year recurrence intervals and flows on Red Clay Creek at Wooddale and Brandywine Creek at Wilmington having 100-year recurrence intervals. A significant amount of ground-water recharge was associated with Hurricane Floyd. Water levels in several shallow water-table observation wells rose into the normal and above normal range.

Delaware has now entered into the time of year when water use and evapotranspiration

decline substantially. Accordingly, it is unlikely that a water-supply drought will occur at least until the spring or summer of 2000. The DGS will continue to monitor and analyze all ground-water indicators, especially ground-water conditions into the spring of 2000 to determine the adequacy of supplies when we will again enter the high-use summer season.

Thermal Image of Ground-Water Discharge

By Thomas E. McKenna



This image is from the aerial thermal-infrared radiometer survey conducted over the Inland Bays in March 1999 as part of the EPA-funded CISNet Project (see Winter 1999 and Summer 1999 issues of *First State Geology*). The image was taken from an altitude of 5400 feet over the Indian River, 1.6 miles downstream from the Millsboro Pond dam. The difference in water temperature from the gray to red colors is about 7° Celsius and represents warmer ground water (red) discharging into cooler surface water (gray). Locating these areas is an integral part of our ongoing effort in the CISNet project to estimate nutrient (nitrogen and phosphorus) inputs to the Inland Bays via ground-water discharge.

Earth Science Week 1999

During Earth Science Week 1999, DGS was fortunate to have as a visitor Dr. Charles G. Groat, the recently appointed director of the U.S. Geological Survey. On October 12 he met with DGS staff and other University of Delaware staff and faculty associated with the geosciences and presented a lecture, "Advancing the Geosciences: Do We Thrive or Just Survive?"

His lecture was followed on October 13 with a talk by DGS Director Robert R. Jordan on "Geology, Dams, and Waters of the Delaware." Dr. Gregory J. Retallack, a lead-

ing expert on paleosols from the University of Oregon, was invited to present a short course in paleosols to those of us working on the rocks recovered from the continuously cored Potomac Formation (see *First State Geology*, Summer 1999). As his visit coincided with Earth Science week, we scheduled him for three lectures on October 14: "Recognizing Paleosols," "Factors in Soil Formation," and, jointly sponsored with the Department of Geology for their seminar series, "World's Greatest Midlife Crisis: the Permian-Triassic Extinctions on Land in Antarctica."

Other activities during the week were tours of the DGS Building and displays set up for the occasion in the building's lobby.

Palynology, Ages, and Paleoenvironments of Delaware's Surficial Sedimentary Deposits

The geologically youngest (Pliocene–Quaternary) sedimentary deposits that occur at or near the surface of the Atlantic Coastal Plain of Delaware are of considerable economic importance to the state. They form the topographic features of most of the state and are prolific sources of ground water, aggregate for construction and road-building, and sand for beach nourishment.

These sediments were deposited in non-marine environments; therefore, they lack the types of fossils that have been used to interpret the ages of the older marine rocks that are below them. Fossil pollen and spores, however, have been recovered from samples of the deposits from many geologic exposures and drill holes in the state. Recently published Delaware Geological Survey Report of Investigations No. 58, "The Pliocene and Quaternary Deposits of Delaware: Palynology, Ages, and Paleoenvironments" by Johan J. Groot and Robert R. Jordan, presents data derived during many years of study of these microscopic plant remains by Dr. Groot and provides information about the geologic history of the deposits which have been studied for many years by Dr. Jordan. The 36-page report establishes the geologic framework for the deposits, which is fundamental to the investigation of their ground water and mineral resources.

The ages of the surficial deposits range from as old as 3–5 million years to within the last 10,000 years. Because the ice ages occurred during this period of time, the climate of Delaware varied significantly. Paleoclimates ranged from cold (36°F mean annual temperature) to warm temperate (59°F). Delaware's mean annual temperature now is about 55°F.

Past geologic environments interpreted from the plant microfossil record include fluvial (river), estuary, marsh, and bog. Present elevations of ancient estuarine deposits indicate that sea levels during one or more interglacial times of the past were more than 40 feet higher than they are today.

Copies of the report may be obtained from the Delaware Geological Survey on the Newark campus or by calling 831-2833. The report can also be viewed from the DGS web site at <http://www.udel.edu/dgs/pub/RI158.pdf>.

Palynological Studies to Continue at DGS

In Delaware, palynology is an important means of determining the ages and paleoenvironments of non-marine sedimentary rocks. Analysis of fossil pollen and spores has been an important part of many DGS projects, including geologic mapping of surface sediments and well-to-well correlation of subsurface aquifer units.

The DGS has been fortunate in the past several years to benefit from the palynological expertise of two volunteer retirees, DGS's founder and first director Dr. Johan J. Groot, and Dr. Ralph Orlansky. Dr. Orlansky remains active in his studies of Cretaceous pollen and spores. With the publication of DGS Report of Investigations No. 58 that summarizes many years of his work, Dr. Groot has decided to give up most of his research activities and hand over his microscope and project data to our newest staff member Dr. Peter P. McLaughlin. With help from both Drs. Groot and Orlansky, Pete is learning this new specialty and will add palynology studies to his ongoing research in stratigraphy and foraminiferal micropaleontology.

As an important part of his training, Pete attended a week-long short-course, "Introduction to Pollen Analysis," at the University College London from November 29 to December 3, 1999. This workshop examined the application of pollen studies to geological problems, focusing on Quaternary-age (1.8 million-year and younger) sediments. Basic concepts and pollen identification were treated in practical exercises, and recent geological applications were highlighted in lectures and discussions. Workshop participants included scientists from England, Scotland, USA, Norway, and Slovenia. The knowledge gained in this course will be applied to ground-water recharge mapping and surface geology mapping in Kent and Sussex counties and the geology and hydrology of the Potomac Formation in New Castle County.

Paleosol Short Course

Paleosols, soils preserved in the rock record, are an important topic in the study of

sedimentary rocks. We recognized many paleosols in cores of the Potomac Formation recovered from the continuously-cored hole near New Castle, Del. (see *First State Geology*, Summer 1999).

Potomac Formation aquifers supply most of the ground water used in New Castle County. Identification of specific aquifer sand bodies and their correlation between wells can be difficult owing to the nature of the non-marine sediments comprising the bulk of this formation. A sound understanding of the paleosols in the formation will help unlock the depositional history of this unit and improve our ability to recognize stratigraphic sequences. Well-to-well correlation of these stratigraphic sequences is the first step toward understanding the lateral and vertical continuity of the aquifer sands.

To help us understand the details of these paleosols, we arranged for Dr. Gregory J. Retallack, a leading expert on paleosols from the University of Oregon, to visit DGS in October. He presented a two-day short course on the subject to a group of scientists including personnel from the DGS, University of Delaware Department of Geology, the Delaware Department of Natural Resources and Environmental Control, and consulting geologists. After the workshop, he examined the New Castle cores with a team of DGS staff members and was able to recognize over 100 paleosols in the 415 feet of the Potomac section that was cored.

With this information, our plans are to establish the geophysical log signatures of paleosols through comparisons of the cores and geophysical logs taken in the hole. By correlating the geophysical log from this corehole with geophysical logs of other wells, stratigraphic sequences within the Potomac Formation can be defined. This will result in a better understanding of the heterogeneity of aquifers, a critical factor for realistic ground-water modeling.

Geologic History and Hydrogeology of the Great Cypress Swamp

By A. Scott Andres and C. Scott Howard

During the latest part of the Quaternary Period, the youngest period of Earth history, the environment of the Great Cypress Swamp (GCS) area in southeastern Sussex County, Del., gradually changed from (1) a coastal, temperate-climate, fluvial-estuary-lagoon system, to (2) a fresh-water, cold-climate taiga to boreal forest system, to (3) a fresh-water, temperate-climate, forested swamp and bog system. This overall pattern of change revealed by GCS sediments deposited over

the past 22,000 years can be described as natural eutrophication. The sediments comprise a mappable geologic unit that we refer to as the Great Cypress Swamp formation. The unit extends well beyond the current boundaries of the GCS.

Human activities such as timbering, log mining, ditching, and cultivation have dramatically changed the environment of the GCS. From a hydrogeologic perspective, artificial drainage significantly lowered the water table, and drainage has been redirected from the Pocomoke River watershed to the Indian River watershed. Additionally, sedimentation and erosional processes are very different between the ditched northern portion of the GCS and the relatively undrained southern portion. These drainage modifications have reduced the size of the GCS significantly.

Experiments with water control structures (WCS) in the GCS indicate that swamp hydrology can be restored in much of the intensively ditched portions of the GCS by raising the spillway elevation of WCSs near a proposed 80-acre wetlands mitigation bank site. The effects of restoring swamp hydrology on water quality and vegetation are uncertain.

The DGS research is part of the Delaware Natural Heritage Program project "Management, Conservation, and Restoration Recommendations for the Great Cypress Swamp."

Visuals may be viewed at the following DGS web sites:

- Orthophotoquad of the Great Cypress and Burnt swamps areas,
<http://www.udel.edu/dgs/graphics/webortho.jpg>
- North-south geologic cross section,
<http://www.udel.edu/dgs/graphics/gcsns.jpg>
- West-east geologic cross section,
<http://www.udel.edu/dgs/graphics/gcsew.jpg>

Scott Howard to South Carolina Geological Survey

Staff member C. Scott Howard is leaving the DGS for a position at the South Carolina Geological Survey (SCGS) in Columbia, South Carolina. Scott began working as a student assistant for the DGS in 1991 while completing his Ph.D. at the University of Delaware Department of Geology. He has been employed as a professional staff member of the DGS since 1997.

During his tenure he has contributed significantly to a number of projects covering diverse subjects; these include geologic and hydrologic mapping, ground-water quality, aquifer characterization, and database and geographic information systems. This range of experience is testament to his broad knowledge of geologic sciences, willingness to learn, and professional skills.

Scott's new responsibilities at the SCGS include geologic mapping in the Piedmont, which was the subject of his M.S. and Ph.D. research, and he will also be working on development of a computer-aided cartography system. We at the DGS wish him success in his new position.

Publications Recent DGS Publications Report of Investigations

No. 58, The Pliocene and Quaternary Deposits of Delaware: Palynology, Ages, and Paleoenvironments: Johan J. Groot and Robert R. Jordan, 1999, 36 p.

Other Publications by DGS Staff

Robert R. Jordan, 1999, The East Coast Petroleum Province: Science and Society:

Northeastern Geology and Environmental Science, v. 21, p. 139–141; Citation for William S. Condit, George V. Cohee Public Service Award: Northeastern Geology and Environmental Science, v. 21, p. 208–209.

T. E. McKenna, S. J. Baxter, R. D. Catchings, M. R. Goldman, and **R. N. Benson**, 1999, Investigation of shallow-depth faults in the Atlantic Coastal Plain of Delaware, USA: EOS, v. 80, no. 46, p. 1050-1051.

Staff Notes Presentations

At the 1999 Fall Meeting of the American Geophysical Union in San Francisco, December 17: **Thomas E. McKenna, Stefanie J. Baxter,** and **Richard N. Benson** with Rufus D. Catchings and Mark R. Goldman, U.S. Geological Survey, "Investigation of Shallow-Depth Faults in the Atlantic Coastal Plain of Delaware, USA."

T. E. McKenna and **A. S. Andres** with W. J. Ullman, K. C. Wong, and J. R. Scudlark of the University of Delaware College of Marine Studies, J. A. Madsen of the University of Delaware Department of Geology, and D. E. Krantz of the U. S. Geological Survey prepared a series of posters intended for the general public that describes the CISNet project (see Winter 1999 issue of *First State Geology*) which were displayed during Coast Day, October 4, at the College of Marine Studies, Lewes, and at the DGS during Earth Science Week, October 11–15.

T. E. McKenna, "Thermal-Imaging of Ground-Water Discharge to the Inland Bays," to the Citizen Monitor Subcommittee of the Center for the Inland Bays, October 21, Lewes.

William S. Schenck, "Delaware Earth

Science Information Center On-line," North American Cartographic Information Society, Williamsburg, Va., October 22; with **Margaret O. Plank**, "Delaware Geology," Delaware Nature Society, Ashland Nature Center, Wilmington, November 4.

John H. Talley, "New Castle County Water Supply and the Drought of 1999," to current events class at the Academy of Lifelong Learning, University of Delaware, September 14; "Aquifers and Water Resources in the Coastal Plain of Delaware" and panel moderator for "Well Drilling and Well Development Methods for Constructing Irrigation Wells" at the Delaware-Maryland Irrigation Conference, Denton, Md., December 8.

Service and Awards

Congratulations to the following staff members on anniversaries of their years of service with the University of Delaware: **Roland E. Bounds, A. Scott Andres, Mary F. Sullivan,** and **Stefanie J. Baxter** for 20, 15, 10, and 5 years, respectively.

Roland E. Bounds hosted and presided over The Friends of Mineralogy, Pennsylvania Chapter Symposium, at the Delaware Geological Survey Building, Newark, November 5.

Peter P. McLaughlin offered a workshop on "Rocks, Minerals, Fossils and What Geologists Do" for an Elbert-Palmer Elementary School sixth-grade science class, Wilmington, November 9.

William S. Schenck conducted a workshop for teachers sponsored by Ashland Nature Center. It consisted of a tour of the Delaware Geological Survey facilities and presentation of educational materials and programs available from the DGS.

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