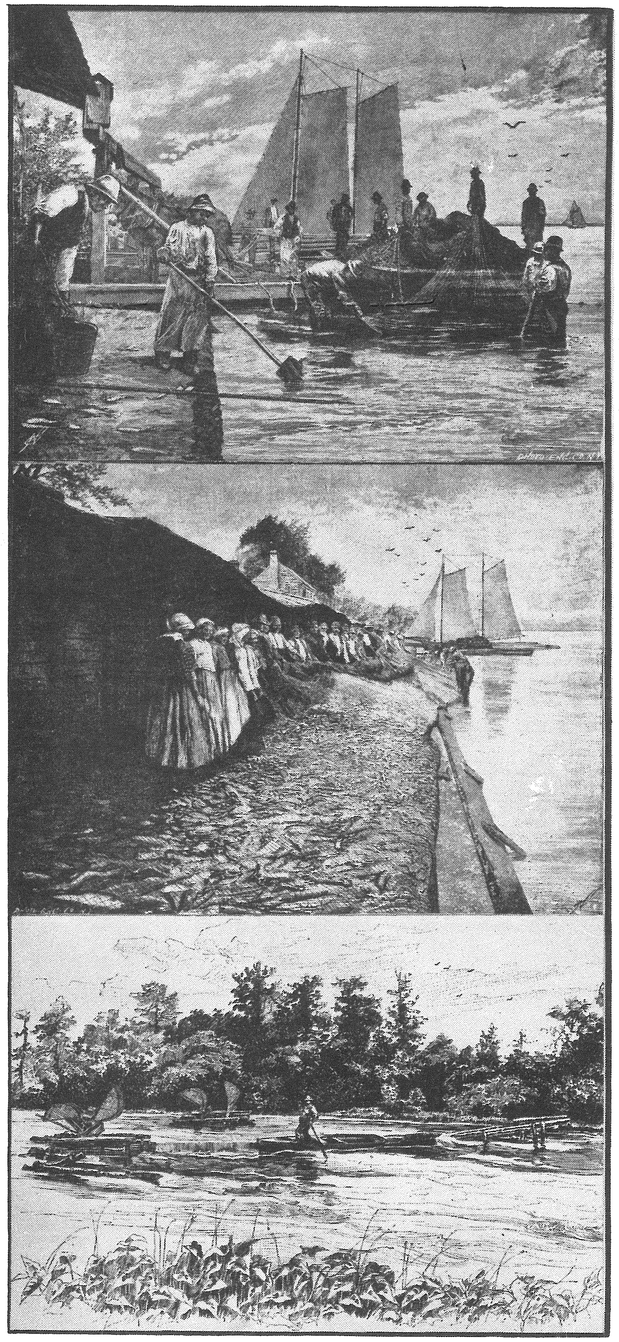
1988-1989 REPORT



ROANOKE RIVER WATER FLOW COMMITTEE

NOAA TECHNICAL MEMORANDUM NMFS-SEFC-256

ROANOKE RIVER WATER FLOW COMMITTEE REPORT FOR 1988 AND 1989

Edited by Roger A. Rulifson and Charles S. Manooch, III

April 1990

Sponsored by

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NOAA TECHNICAL MEMORANDUM NMFS-SEFC-256

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EXECUTIVE SUMMARY

A committee of 20 representatives of State and Federal agencies and university scientists was formed in 1988 to gather information on all resources of the lower Roanoke River watershed in North Carolina and to recommend a water flow regime that would be mutually beneficial to the resources and their users. The Committee has a combined record of experience on the ecology and fisheries of the Roanoke watershed and Albemarle Sound totaling over 200 years. The purpose of this Flow Report for 1988 and 1989 is to document hydrological events and reservoir operations for those years in context with field research efforts and observations on a number of watershed resources: striped bass, wildlife, agriculture, and timber. Following are summaries of the major sections contained in this report. Each is presented as a separate paragraph.

The water flow regime adopted by the Committee in 1988 is reviewed, in context with the hydrological conditions for 1988 and 1989. Roanoke River water flows were very different during the springs of the two years. During 1988, flows were typically very low from 1 March until 12 April. After this date, flows were generally within the upper and lower flow (in cubic feet per second, cfs) boundaries recommended by the Committee. Overall, 61.8 percent of the hourly flows were within the boundaries for the period 1 April - 15 June. Heavy spring rains during 1989 resulted in much higher flows compared with 1988. Approximately 41 percent of the hourly flows were within the recommended boundaries. For March, flows usually exceeded 10,000 cfs, and for several two to five-day periods ranged from 15,000 to 20,000 cfs. Flows were generally within the boundaries in April, greatly exceeded the upper boundary in May, and slightly exceeded the boundary in June. The Committee has also recommended that water flows not change more than 1,500 cfs during any hour from 1 April through 15 June. Flows during 1989 were more stable than in 1988.

Time series analyses presented in this report examine actual flows of the river during the 1988 and 1989 spring seasons. Two periods are analyzed: the entire March-June period of the original recommendation of the Committee, and the negotiated flow regime period, 1 April through 15 June. Both ARIMA analysis and autoregressive analysis were used, with the latter highlighting the role of hours of the day, days of the week, and months of the year during the period. Finally, both hourly flows and average daily flows were analyzed. The following represents a brief summary of the findings: for ARIMA models, there are large differences between the models for the same years but different time periods; for ARIMA models, there is a general similarity between models for the same time span but different years; for the autoregressive models of daily average flows, models of the same time span but different years are similar; for 1989, the autoregressive models are substantially different between the two time spans; for 1988, the autoregressive models are similar between time spans; for hourly data, all comparisons yield models which are similar in structure; and changes in the average daily flow during the period 1 April to 15 June, 1989, were random.

The Corps of Engineers, Wilmington District, was asked to prepare hypothetical scenarios of water releases from the Roanoke Rapids Dam had *a priori* knowledge been available to assist the process. Hypothetical flow models run by the Corps for the 1989 spring striped bass spawning period suggest that coordinating water releases using the negotiated flow regime target flows would have improved and stabilized hydrologic conditions downstream of Roanoke Rapids Dam during certain periods of 1989. However, the point must be made that these models were generated after the period in question. The Corps of Engineers did attempt to manage releases as close to the recommended flow regime as practicable, considering the frequency and intensity of watershed rainfall events.

The Committee offers a hypothetical guide, which may be followed if it is proven later that reservoir operational changes would be needed to regularly implement the recommended flow regime. The guide presents the position that it may be necessary to consider widening the reservoir water storage window, which is now positioned between 299.5 and 302.0 feet mean sea level. This assumption would apparently violate stated goals for flood control and power production. However, it may be possible to operate Kerr Reservoir for flood control and power generation as well as for the below-dam resources, including striped bass.

Water quality was monitored at several different stations by four separate studies during the springs of 1988 and 1989. Water quality of the Roanoke, Middle, and Cashie Rivers was generally better in 1988 than in 1989. Parameters monitored were water temperature, alkalinity, conductivity, color, suspended solids, biochemical oxygen demand, total organic carbon, soluble organic carbon, inorganic nitrogen, organic and ammonia nitrogen, total phosphate, sulfate, iron, manganese, sodium, zinc, arsenic, barium, aluminum, and other heavy metals.

A non-uniform probability stratified access point creel survey was used to estimate Roanoke River sport fishing effort and harvest for striped bass during the spawning seasons of 1988 and 1989, and to document the number of striped bass caught and released. In addition, fish were sampled for size (length and weight), sex, and age information for spawning stock biological characterization. An estimated total of 234,621 (1988) and 153,185 (1989) angler-hours of sport fishing was exerted during the spring. Approximately 100,000 (1988) and 46,600 (1989) angler-hours were directed to striped bass. Most of the effort in 1988 was exerted in the lower River and on the spawning grounds upstream, whereas in 1989 most of the effort was on the spawning grounds. Estimated harvest of striped bass was 16,657 fish in the spring of 1988; 8,753 in 1989. Total weights were estimated at 33,927 kg (74,796 pounds) in 1988, and 14,594 kg (32,174 pounds) in 1989. In addition, almost 9,000 striped bass were caught and released each year. The overall success rate for striped bass harvest was 0.075 fish (0.151 kg) per angler-hour in 1988, and 0.058 fish (0.096 kg) per angler-hour in 1989. Age composition of striped bass during the 1988 study revealed that most of the males were 3, 4, and 5 years old, while most females were 5, 6, 7, and 8 years old. Less than 3 percent of the females caught were less than 4 years old; 21 percent were age 8 or older.

Commercial fishermen landed 115,915 pounds of striped bass valued at $116,776 in North Carolina during 1988, and 100,830 pounds valued at $101,002 during 1989. Historically, most of the fish have been caught in the Albemarle Sound area by set gill nets and pound nets. From 1980-1989, 67 to 98 percent of the striped bass landed by commercial gear in the State came from the Albemarle Sound area.

Striped bass spawning activity, as reflected by egg deposition, occurred from mid-April through 2 June 1988. Peak spawning was of a prolonged nature from mid-May to late May. The estimated total number of eggs spawned was over two billion, the seventh highest total for the period of record starting in 1959. Egg viability was 89 percent, the best since 1972. Greatest egg viability was noted for the middle of the spawning season, at water temperatures of 20^{o} C and higher, and during times when surface water velocities were reduced. The majority of the eggs were between 20 and 28 hours old. In 1989, the spawning was during the last week in May. The estimated total number of eggs spawned was approximately 0.6 billion, the second lowest since 1959. Egg viability was only 42 percent. Greatest egg viabilities were at lower surface water velocities (40-60 cm/second). Most eggs were less than 10 hours old; 18.5 percent were between 20 and 28 hours old.

The relative success of juvenile striped bass recruitment to the forming year class is monitored by the Juvenile Abundance Index (JAI). For the years 1978-1987 the JAI has averaged about 0.8 young striped bass per trawl. The JAI for 1988 was 4.09 and 4.27 for 1989. These were the highest values since 1976, and represent the first time since 1976-1977 that two consecutive JAIs were greater than 1.0.

Sampling for phytoplankton, chlorophyll *a*, and zooplankton in the lower Roanoke River, delta, and western Albemarle Sound has been conducted since 1984 to gather information on the food chain available to support zooplankton prey for larval striped bass and other species. Chlorophyll *a* levels in the lower Roanoke River appear to be about what would be expected for a river-dominated, low salinity estuary in this region during the spring. Between 1985 and 1989, chlorophyll *a* concentrations in the lower Roanoke-western Albemarle Sound have ranged generally between 1 and 10 μg/L, with occasional higher values, within the 15-30 μg/L range. In every year since the Roanoke phytoplankton sampling began, species of diatoms and green algae have been the dominant taxa, together making up 80-90 percent of the total wet weight biomass (which has ranged between 0.5 and 2.0 mg/L). Higher chlorophyll *a* concentrations in the River are believed to develop following precipitation events. This could be interpreted as an indication that algae-rich waters in floodplain swamps are swept into the River when it rains.

Sampling for zooplankton in the lower River, delta, and western Albemarle Sound has been conducted since 1984 to document food availability for larval fishes. Overall, zooplankton abundance in the lower Roanoke watershed was much lower in 1988 compared with the two previous years. Over the season, zooplankton were in greatest numbers in the Cashie River and in the Roanoke just below Hamilton, NC. Copepods represented about 51 percent of the watershed zooplankton community, and cladocerans nearly 41 percent. Moderate flows prevailed in 1988, but reservoir discharge from March to mid-April was very low. Results of the zooplankton studies suggest that higher River flows, which inundate adjacent streams and floodplain are required in March and April to provide input of zooplankton to critical habitats. Zooplankton were more abundant in 1989 than they were in 1988. Cladocerans were most abundant (59 percent), followed by copepods (21.5 percent), and rotifers (9.9 percent).

Wildlife biologists reported that floodplain conditions during the spring of 1988 were much better for wild turkey and deer than they were during 1989. The floodplain was inundated by flood waters for most of the spring and summer months in 1989. The combined effect of flooding in 1987 and the floods of 1989 on both hunting and turkey populations has caused the harvest to decline. During flooded conditions, wild turkeys were displaced out of the lowground habitats. In addition to displacement, reproductive success was impacted as turkeys that were unable to locate their floodplain nesting sites did not nest that season. Deer did not fare much better in 1989. Extended flooding can adversely affect the number, condition, and survival of deer along the River. Flooded conditions in 1989 undoubtedly resulted in the displacement of pregnant does from normal home ranges as well as the decline in overall habitat available for rearing of fawns.

Although some water-related damage or problems were reported by agricultural and timber interests during the spring of 1988, conditions were far worse in 1989. Flooding resulted in delayed planting of soybeans and cotton, and prevented foresters from harvesting in the floodplain.

In conclusion, the Committee believes that spring flows during 1988 were more beneficial to downstream resources than were the water flows of 1989. Field observations and studies revealed that for striped bass, more anglers fished, more fish were caught, more eggs were spawned, water quality was better, and egg viability was much higher in 1988 than in 1989. However, the JAIs for the two years were about equal. This raises the question of what role stability in water discharge has on striped bass recruitment. Waters were more stable during the spring of 1989. The interaction of flow (i.e., times flows are within recommended boundaries) and stability needs to be studied. Early spring flooding, March through early April, appears to have had a positive impact on larval fish prey. Floodplain inundation in 1989 had a negative impact on wildlife, agriculture, and timber.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ROANOKE RIVER WATER FLOW COMMITTEE REPRESENTATIVES FOR 1989

Original Members (asterisk denotes individuals no longer serving):

Mr. Randall P. Cheek*, National Marine Fisheries Service
Mr. Mickey Clemmons*, N.C. Wildlife Resources Commission
Mr. Willard J. Cole, U.S. Fish and Wildlife Service
Mr. David Crawford*, N.C. Division of Water Resources
Mr. Tom Ellis, N.C. Department of Agriculture
Ms. L.K. "Mike" Gantt, U.S. Fish and Wildlife Service
Mr. Fred Harris, N.C. Wildlife Resources Commission
Dr. William W. Hassler, Professor Emeritus, N.C. State University
Mr. Lynn T. Henry, N.C. Division of Marine Fisheries
Dr. William T. Hogarth, N.C. Division of Marine Fisheries
Mr. Harrel B. Johnson, N.C. Division of Marine Fisheries
Mr. James W. (Pete) Kornegay, N.C. Wildlife Resources Commission
Dr. R. Wilson Laney, U.S. Fish and Wildlife Service
Dr. Charles S. Manooch, III, National Marine Fisheries Service
Dr. Robert J. Monroe, Professor Emeritus, N.C. State University
Mr. Anthony W. Mullis*, N.C. Wildlife Resources Commission
Dr. Thomas L. Quay, Professor Emeritus, N.C. State University
Dr. Roger A. Rulifson, East Carolina University
Ms. Sara E. Winslow, N.C. Division of Marine Fisheries
Dr. L.H. "Buddy" Zincone, Jr., East Carolina University

Replacement Members -

Mr. Larry Hardy (for R.P. Cheek), National Marine Fisheries Service
Mr. Thomas C. Fransen (for D. Crawford), N.C. Division of Water Resources
Mr. Kent W. Nelson (for A.W. Mullis), N.C. Wildlife Resources Commission

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Original Advisors to Committee:

Mr. Max Grimes, U.S. Army Corps of Engineers, Wilmington District
Mr. Jack D. Mitchell*, Virginia Power Company
Ms. Marsha E. Shepherd, East Carolina University

Replacement Advisors:

Mr. George McCabe (for J.D. Mitchell), Virginia Power Company

INTRODUCTION

The purpose of the Flow Report for 1988 and 1989 is to document hydrological events and reservoir operation in context with field research efforts and observations on a number of watershed resources: striped bass, wildlife, agriculture, and timber.

These annual reports are to inform the reader of the objectives, activities, data analyses, and recommendations of an ad hoc Committee formed in 1988 to investigate the improvement of Roanoke River water flows below Roanoke Rapids Dam for striped bass (*Morone saxatilis*) and other downstream resources. The Committee is composed of 20 representatives of State and Federal agencies and university scientists. Several advisors to the Committee provide expertise on areas of reservoir management, operation of dams for power production, and statistical analysis and interpretation. A list of Committee members and their affiliations has been provided.

The Committee has a combined record of experience on the ecology and fisheries of the Roanoke watershed and Albemarle Sound totaling over 200 years and is committed to the protection and recovery of the striped bass population. The purpose of the Committee is to gather information on all resources of the lower watershed and recommend a flow regime that will be mutually beneficial to these resources and their downstream users. Striped bass as a resource has received the most attention because of its great social and economic importance to this region and to our State; however, other resources such as wildlife, timber, and agriculture have been considered as well. The Committee recognizes the possibility that other factors such as water quality and overfishing may be contributing factors to a decline of the striped bass resource; however, the charge of the Committee was to examine only river flow.

The Committee's policy has been to examine Roanoke River flows in context with protection of wildlife and fishery resources irrespective of proposed or pending water use projects. This includes such projects as the National Wildlife Refuge plan by the U.S. Fish and Wildlife Service, the proposed water withdrawal from Lake Gaston by the City of Virginia Beach, and the proposed co-generation fossil fuel electrical generating facility in Martin County near Jamesville, NC.

A series of meetings held in 1988 resulted in the completion of a formal report that presented a detailed review and analysis of watershed hydrology and multi-use problems (Manooch and Rulifson 1989). All of the work presented in the document was endorsed by the full Committee. The U.S. Army Corps of Engineers, Wilmington District, participated in all meetings and endorsed the recommendations of the Committee.

DESCRIPTION OF THE WATERSHED

The Roanoke River, in northeastern North Carolina, flows through an extensive floodplain of national significance. This wetland area is considered to be the largest intact, and least disturbed, bottomland forest ecosystem remaining in the Mid-Atlantic Region (North Carolina Natural Heritage Program 1988). In addition to extensive mature bottomland hardwood and swamp forests, there are beaver ponds, blackwater streams, and oxbow lakes. Together, these habitats support a rich array of diverse and abundant wildlife species including waterfowl, fish deer, turkeys, otters, bobcats, herons, egrets, and migratory songbirds.

The Roanoke River in Virginia and North Carolina drains an area of 9,666 square miles (Moody et al. 1985), arising in the Blue Ridge Mountains of central Virginia and flowing east-southeast into north central North Carolina, where it empties into Albemarle Sound in the northeastern part of the State (Figure 1). Near the Virginia-North Carolina line, a series of dams was established between 1950 and 1963 for hydroelectric power and flood control from three reservoirs. These are the John H. Kerr Reservoir, Lake Gaston, and Roanoke Rapids Lake, upstream to downstream, respectively. The John H. Kerr Dam and Reservoir is operated by the U.S. Army Corps of Engineers for flood control, hydropower, low-flow regulation, recreation, water supply, and fish and wildlife. The dams at Lake Gaston and Roanoke Rapids Lake are owned and operated by Virginia Power Company and operated primarily for electric power generation. Below the dam at Roanoke Rapids, the river elevation drops from 50 feet at the dam to sea level as it enters Albemarle Sound. Downstream of the last dam (at Roanoke Rapids), the river meanders 137 miles through an extensive floodplain, approximately 70 air miles long and up to five miles wide, forming the border between Northampton and Halifax counties and Bertie and Martin counties.

The majority of the people in the Roanoke Valley live in the vicinity of the three reservoirs and in and around Roanoke Rapids and Weldon. Other major towns in North Carolina along the river's course include Halifax, Scotland Neck, Williamston, Jamesville, and Plymouth (Figure 2). The major industries are agriculture and forestry. The area consists of old plantations, some derived from the original royal grants, while "newer" ones are still over 100 years old. Very little population change has taken place within the basin area.

The river is no longer used for commerce as in earlier days. A drawbridge still exists across U.S. Highway 17 at Williamston but is seldom opened for barge traffic. In 1988, construction of a high-rise bridge to replace the existing structure was initiated. Floodplain development is limited primarily to the Plymouth area, probably due to the history of rampaging floods along the Roanoke River prior to construction of the reservoirs. In addition, a few residences are located on the adjacent river bluffs in the upper half of the river in North Carolina.

Detailed information on the hydrology and watershed resources was presented in the Committee's initial report (Manooch and Rulifson 1989). Resources included forestry, agriculture, soils, flood plain habitats, wildlife, and fisheries. The appendices to the 1989 report provided a listing of fauna and flora of the lower Roanoke River watershed.

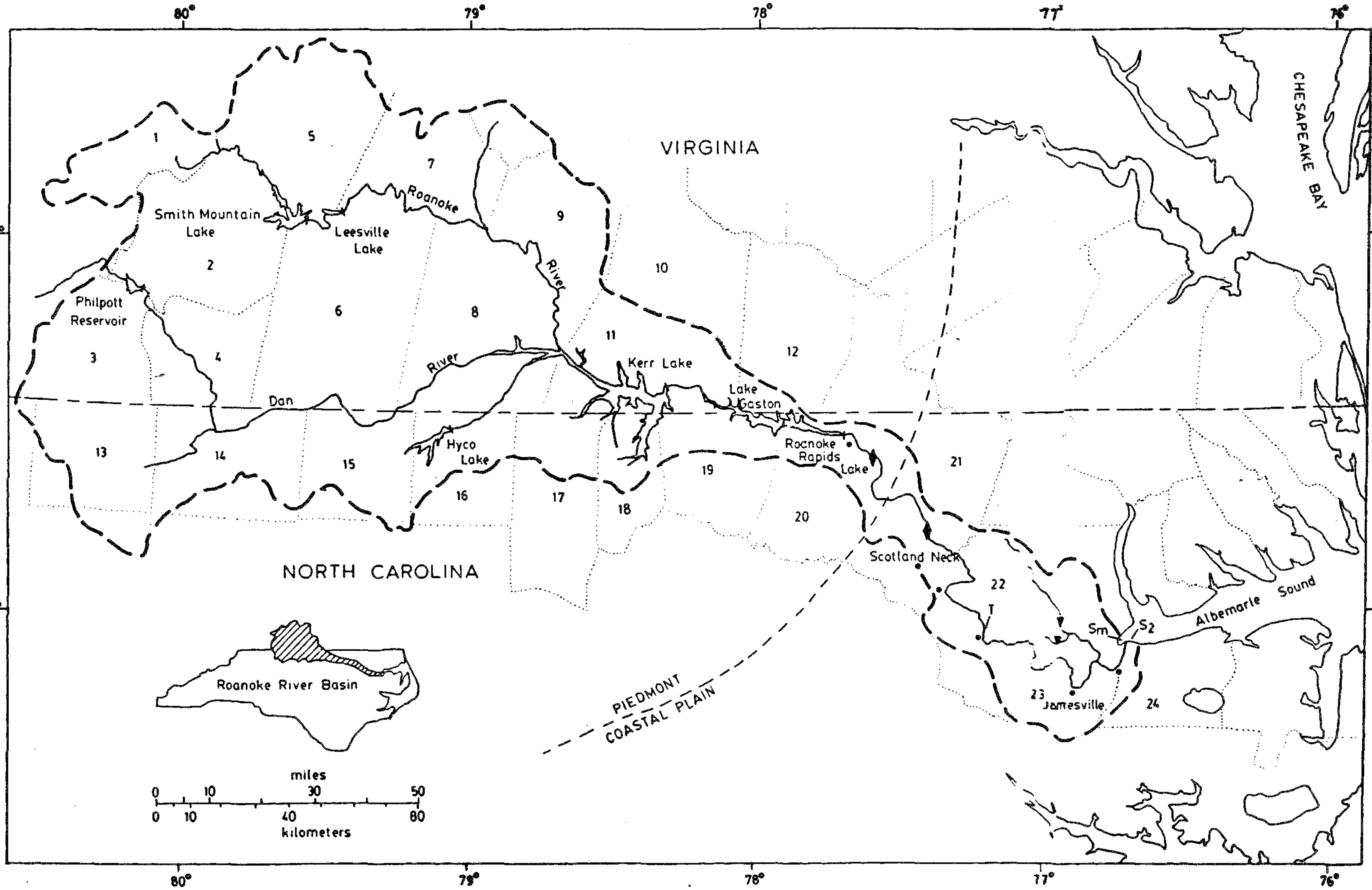


Figure 1. Drainage area of the Roanoke River Basin. Dashed line indicates approximate location of the Fall Line; diamonds=locations of USGS water quality and gaging stations; inverted triangle=USGS water quality station; T=upstream limit of tidal influence; S2=mean upstream intrusion limit of saltwater front (200 mg/L chloride); Sm=maximum upstream instrusion of saltwater front (Giese et al. 1979). Counties containing Roanoke watershed are enumerated.

List of Counties Enumerated in Figure 1.

1-12 (Virginia)

1. Roanoke
2. Franklin
3. Patrick
4. Henry
5. Bedford
6. Pittsylvania
7. Campbell
8. Halifax
9. Charlotte
10. Lunenburg
11. Mecklenburg
12. Brunswick

13-24 (North Carolina)

13. Stokes
14. Rockingham
15. Caswell
16. Person
17. Granville
18. Vance
19. Warren
20. Halifax
21. Northampton
22. Bertie
23. Martin
24. Washington

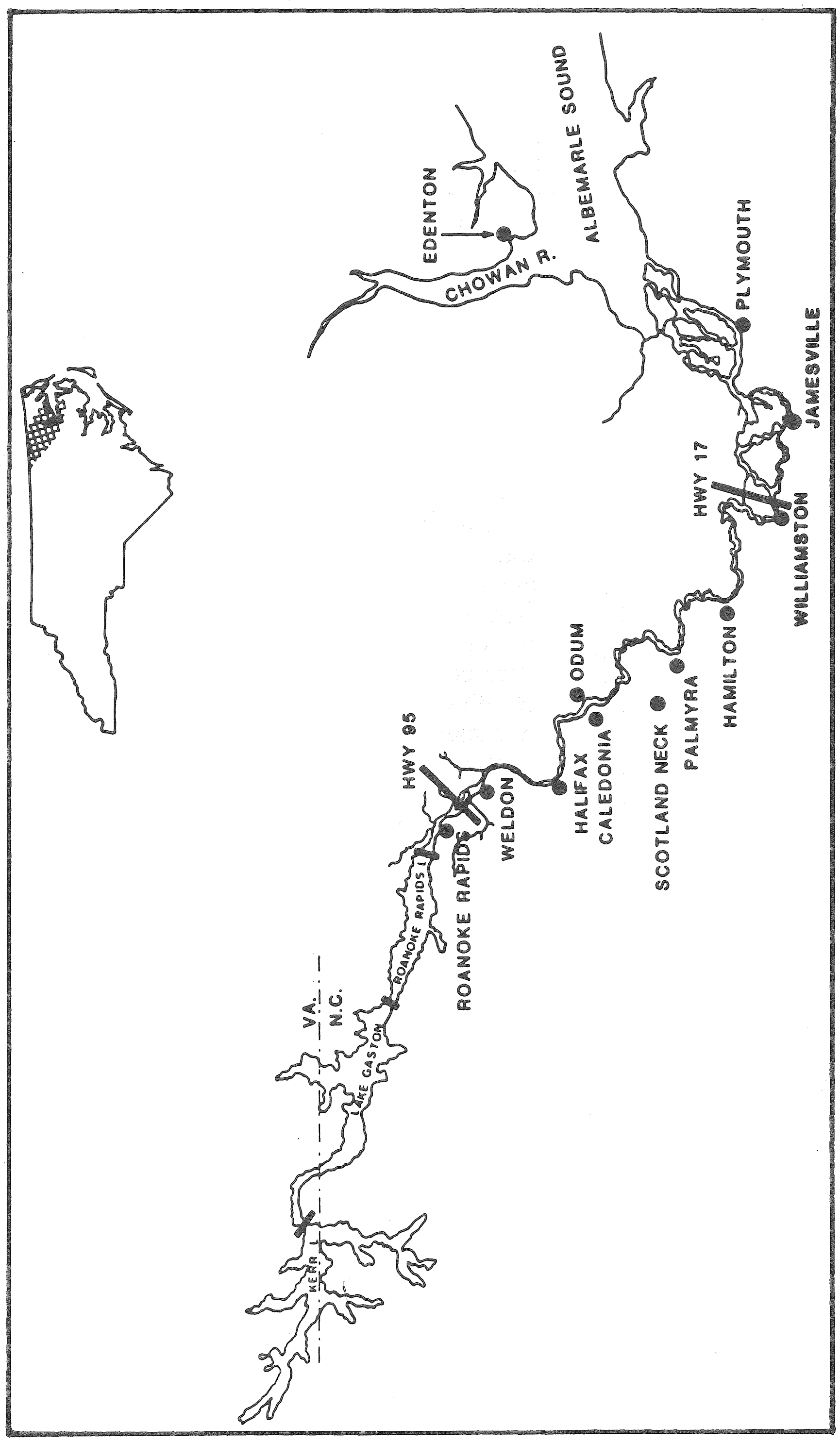


Figure 2. Lower Roanoke River watershed.

CHRONOLOGICAL RECORD OF WATERSHED EVENTS

1912-1950	Natural, unaltered river flow (database 1912 to August 1950).
1940	Hurricane moves through North Carolina, instigating an investigation by U.S. Army Corps of Engineers to determine need for flood control in Roanoke River Basin.
1942	Study by U.S. Health Service, August-September, requested by U.S. Army Corps of Engineers, to evaluate minimum flows required to dilute pollution at river mile (RM) 128-137 for a power diversion canal. Report submitted in 1943 suggested minimum flows of 500 cfs to 2,500 cfs depending on month.
1944	Passage of Flood Control Act by Congress, which authorized construction of Buggs Island (Kerr Reservoir).
1945-1950	Period of rapid growth of lower Roanoke River industries and subsequent need for hydroelectric power generation.
1946	Construction of Buggs Island (Kerr Reservoir) began in February at RM 179.
	U.S. Fish and Wildlife Service report on fishery and wildlife resources and minimum flows for striped bass spawning (House Document 650, 78th Congress, 2nd Session). Minimum flows approved by Federal Power Commission=2,000 cfs (10.8' stage). Not to exceed 75 days from 15 March-15 June each year at the recommendation of the N.C. Department of Conservation and Development.
	U.S. Fish and Wildlife Service continues river studies.
	Minimum daily flows of 2,000 cfs and mean monthly flows of 6,000-9,000 cfs during April and May will not be detrimental to striped bass spawning. An emergency 3-days of 15,000 cfs during the last week of April may be required to start fish upriver.
1947	N.C. Wildlife Resources Commission created as separate agency.
1948	Virginia Electric & Power Company applied to Federal Power Commission for license regarding future construction and operation of power facility at RM 137 (to become Roanoke Rapids Reservoir).
1950	Natural river flows first impacted by construction of Buggs Island (Kerr Reservoir) in August.
1951	Federal Power Commission issues license for construction of Roanoke Rapids Reservoir and sets minimum flow requirement of 2,500 cfs for navigation.
1952	Kerr Reservoir completed.
	First power is generated at Buggs Island in December. Report by U.S. Fish and Wildlife service, Office of River Basins. If 2,000 cfs minimum flow is not adequate for striped bass spawning as determined by N.C. Wildlife Resources Commission, increased minimum flows will be required.

1953 Public hearing held at Weldon, NC on 28 January by U.S. Army Corps of Engineers and N.C. Wildlife Resources Commission: "minimum flows as required are too low." U.S. Army Corps of Engineers holds meeting with Federal and State conservation agencies to discuss Roanoke River flows and striped bass spawning. It was suggested at this meeting that there be four days of 12,000 cfs (18' stage) water at Weldon to attract fish and maintain 2,000 cfs for spawning.

N.C. Wildlife Resources Commission conducts experiments in the spring to determine rates of survival for striped bass fry using different sources of river water.

State and Federal conservation agencies and U.S. Army Corps of Engineers hold a conference. The N.C. Wildlife Resources Commission recommends a minimum of 2,300 cfs (11' stage) from late March-late May, and a minimum stage of 15' (8,350 cfs) at all times during striped bass spawning.

1954 Several agencies join together to study dissolved oxygen, passage of striped bass fry through the lower river and recreational fishing at Weldon.

1955 Roanoke Rapids Reservoir completed.

Laboratory studies proved conclusively that constant motion was a physiological necessity for development of striped bass eggs.

Dr. W.W. Hassler begins long-term studies on egg abundance, juvenile abundance, exploitation, and migration of striped bass in the Roanoke River/Albemarle Sound.

North Carolina Congressman Herbert C. Bonner called a meeting on 2 May at Weldon, NC for all Federal and State agencies, industries and private citizens interested in the Roanoke River. A Steering Committee was formed at this meeting.

1955-1958 Roanoke River Steering Committee holds meetings.

1956 Dr. Hassler and other scientists study Roanoke River striped bass.

1959 The Roanoke River Steering Committee issues its report, 30 June: "The Roanoke River carries more water, by far, than any other river in North Carolina. The annual flow through the State averages about 8,500 cfs. With the construction of the John H. Kerr flood control and hydroelectric project by the Federal Government, river flow was consistently altered. Following completion of the Roanoke Rapids Hydroelectric Project in 1955, further re-regulation of river flows were effected so that now the river flow pattern downstream is largely determined either by the stipulated schedule of minimum discharges from the Roanoke Rapids Dam or by the demands for peak power on the Virginia Electric and Power Company's distribution system."

"The Roanoke River constitutes, by far, the most important spawning area for striped bass in North Carolina. Protection of the striped bass spawning in the Roanoke River should receive consideration equal to that given other primary uses of the water. The entire study area of the river -- including that section of the main stem at or below the industrial plants at Plymouth -- should contain water during the spawning season of such quantity as established for the maintenance of fish life."

"The 13-foot water stage at Weldon is the minimum at which fishing boats may pass from Weldon to River Mile 133. It is recommended each year for the 75-day period, April 2 through June 15, for the two-fold purpose of providing access of both fish and fishing boats to the vicinity of River Mile 133."

The N.C. Wildlife Resources Commission restated its position taken in 1953 that four days of 25' stage peak at Weldon during late March should be maintained to attract fish upriver.

The Roanoke River Steering Committee adopted the following schedule of instantaneous minimum flows at their meeting of 29 October.

Instantaneous minimum river discharges, as measured at the U.S. Geological Survey gage on the US 301 Highway Bridge near Weldon, not less than: 2,000 cfs (10.8') between 1 April and 25 April; 5,550 cfs (13') between 26 April and 4 May; 8,950 cfs (15') between 5 May and 20 May; and 5,550 cfs between 21 May and 15 June.

(This contradicted recommendations by others in that it did not provide adequate water in March-April to attract fish upriver).

The N.C. Wildlife Resources Commission, not satisfied by the Steering Committee findings and recommendations, issued a report by Fish and McCoy: "The N.C. Wildlife Resources Commission--the State agency now responsible for protection of the striped bass during their spawning activities--was not created until some time after the minimum flows of the Roanoke River below the John H. Kerr Dam had been established. Since the time of its inception, the Wildlife Resources Commission has vigorously contended that the Roanoke River minimum-flow schedule, as it pertains to striped bass, was woefully inadequate from a biological standpoint. The highest expectancy of survival for striped bass progeny would be provided at, or very close to, the average river condition which prevailed prior to the impoundment." Even the recommendations of this study conclude: "The foregoing recommendations are not advanced as providing optimum spawning conditions for the striped bass. They constitute what must be considered as <u>minimal</u> protection to the anadromous fishes of the Roanoke River."

1963 Lake Gaston is completed.

1970 Water shortage problems are projected for southeastern Virginia municipalities.

1971 Memorandum of Understanding signed by representatives of Virginia Electric and Power Company, U.S. Army Engineer District, Wilmington, Corps of Engineers, and N.C. Wildlife Resources Commission, which identifies reserved storage space in Kerr Reservoir between 299.5' and 302' for augmentation flow for striped bass spawning; 13' water stage as minimum during spawning; and that either party may terminate the agreement, and a revised Memorandum of Understanding has been approved by the Federal Power Commission.

1972-1987	Period of possible damaging river water flows to the striped bass resource.
1980	U.S. Army Corps of Engineers holds public meetings in Weldon, NC on 10 December, and in Clarksville, VA on 11 December. Public concerns were heard pertaining to Roanoke River water flows on wildlife, fisheries, recreation, timber, agriculture and other river industries. Also opposition to transfer of water out of Roanoke River watershed in North Carolina.
1983	Dr. R.A. Rulifson, East Carolina University, began studies on striped bass eggs and larvae in lower river and in western Albemarle Sound. These studies are ongoing as are the studies of Dr. Hassler, NCSU, the N.C. Division of Marine Fisheries and the N.C. Wildlife Resources Commission. Problems with year class strength and water flows.
1984	U.S. Army Corps of Engineers as directed by Congress prepared a Water Supply Study for Hampton Roads, VA. City of Virginia Beach, VA. applied for and received a permit from the U.S. Army Corps of Engineers to withdraw 60 MGD (93 cfs) from Lake Gaston (Lake Gaston Pipeline project).
1987	Judge W. Earl Britt, U.S. District Judge, Raleigh, NC, remanded the Corps, for further consideration on need of the Lake Gaston Pipeline project, and impacts on striped bass.
1988	U.S. Fish & Wildlife Service announces plans to establish a 30,000-acre National Wildlife Refuge in Halifax, Bertie, and Martin Counties.
	An ad hoc committee of State, Federal and university scientists formed to propose a flow regime for the Roanoke River that would benefit striped bass and other downstream resources and users.
	The 100th Congress of the United States approved H.R. 4124, which under Section 5, established a three-year study of striped bass in Albemarle Sound and Roanoke River. Congress found that the stock has been declining for some time and that "the reasons for the decline are thought to include fishing; other human activities and environmental factors, such as unsuitable water flow before, during, and after critical spawning periods; degradation of water quality..."
	The Virginia State Water Control Board publishes Planning Bulletin 339, "Roanoke Basin Water Supply Plan," which addresses total water demand, both existing and projected, and concludes that additional water withdrawals in the Virginia portion of the Basin will seriously limit the availability of water resources for future use in the lower Roanoke.
1989	Roanoke River Water Flow Committee publishes findings of one-year study and makes recommendations on flow conditions for March through June each year (Manooch and Rulifson 1989).
	Judge W. Earl Britt, U.S. District Judge, Raleigh, NC, held a hearing on 30 October to hear arguments concerning the Lake Gaston Pipeline lawsuit (State of North Carolina versus Hudson).
	The Roanoke National Wildlife Refuge was approved by North Carolina Governor James G. Martin.

Department of the Army, Corps of Engineers, Norfolk District published an "intent to prepare a draft environmental impact statement (DEIS) for a proposed coal-fired generating plant to be constructed by Virginia Power Co. in either Cumberland, Greensville, or Mecklenburg Co, Virginia."

State park tourist attendance in NC reached an all time high in 1989. Kerr Lake State Recreation Area, located in Vance and Warren counties, received second highest use with about 925,000 visitors.

One of the richest deposits of titanium on the East Coast was identified in an area bordering Interstate 95 from Petersburg, Va. to Bailey, NC. The titanium vein includes the Roanoke Rapids and Lake Gaston portion of the Roanoke watershed. The main environmental consideration is preventing muddy water from the mining process from entering the watershed.

1990 An 18-month permitting process for a proposed co-generation electrical power facility at Jamesville in Martin County was initiated on 3 January. The coal-fired plant will withdraw approximately 80 cfs (about 52 MGD) from the Roanoke River and return heated effluent.

On 2 February, Judge W. Earl Britt, U.S. District Judge, Raleigh, NC, upholds decision of the U.S. Army Corps of Engineers to issue a permit to the City of Virginia Beach, VA, to construct a water intake structure and pipeline in Lake Gaston to extend to Suffolk, VA, and to enter into a water storage reallocation contract for Kerr Reservoir on behalf of the United States with the City of Virginia Beach.

Roanoke River Water Flow Committee publishes an update on findings and makes recommendations on flow conditions (expected flows, upper and lower flow boundaries, and hourly variation in flows) for April through June each year (this document).

RECOMMENDED AND NEGOTIATED FLOW REGIMES

As part of the ongoing activities of the Flow Committee, a Recommendations Subcommittee was formed in 1988 to examine various aspects of Roanoke River flow and report back to the full Committee with suggestions on how flows might be changed in the spring. Also, the Subcommittee was asked to keep in mind the understanding that control of low flows and high flows, as well as moderation of hydropower peaking activity at Roanoke Rapids Dam, was necessary.

The Subcommittee recommended that Roanoke River flow be controlled between the historical 25 percent and 75 percent quartiles of the daily median flows between 1 March and 30 June each year; that is, between the 25 percent low median flow value (Q1) and 75 percent high flow value (Q3). The rationale for choosing median rather than daily averages, and quartiles rather than other levels, was described in detail in the original report (Manooch and Rulifson 1989). The pre-impoundment data (1912-1950) set of daily median values was used to develop these target values, which are presented in Table 1.

The original set of recommended flows from 1 March to 30 June was unacceptable to the U.S. Army Corps of Engineers because the time frame was not compatible with the guidelines mandated within the FERC license requirements agreed to by the Corps, Virginia Power, and the North Carolina Wildlife Resources Commission.

A second, "negotiated" set of target values was constructed that was acceptable to the Corps of Engineers, Wilmington District, and Virginia Power. The Negotiated Q1-Q3 Flow Regime involved a much shorter period of time than the original recommendations, but the time frame was now within the FERC license guidelines of 1 April to 15 June. The negotiated flow regime values are presented in Table 2. In addition to recommending minimum, maximum, and target flows, the Subcommittee recommended that the hourly variation in flow should not exceed 1,500 cfs.

The origination of these recommendations was a statistical analysis of how the flow related to measures of striped bass spawning success. Additional information was provided by time series analysis of pre-impoundment and post-impoundment flows, and generation of water surface profiles for specific reaches of the lower Roanoke River under various flow regimes using a water surface profile model developed by the Wilmington District Corps of Engineers. Details of these analyses, and presentation of the data sets used in the analyses, were presented in the formal report (Manooch and Rulifson 1989).

Table 1. Roanoke River flow data 1912 to 1950, in cfs (USGS data). Q_1 = 25 percent low flow value; Q_3 = 75 percent high flow value. These values represent the original recommendations of the Committee.

Week Number	Median	Q_1	Q_3	Approximate dates
0	8,577	6,127	11,175	1-7 March
1	9,799	7,543	16,029	8-14 March
2	9,090	6,973	14,429	15-21 March
3	8,930	6,626	14,300	22-28 March
4	8,333	6,681	14,186	29 March-April 4
5	8,476	6,379	13,171	5-11 April
6	8,539	6,810	14,029	12-18 April
7	7,821	5,703	10,800	19-25 April
8	7,260	5,357	9,327	26 April-2 May
9	6,470	4,829	9,200	3-9 May
10	6,213	4,410	9,490	10-16 May
11	5,896	4,431	9,759	17-23 May
12	5,854	4,329	9,329	24-30 May
13	5,450	3,983*	7,663	31 May-6 June
14	5,139	3,701	7,814	7-13 June
15	5,124	3,871*	7,301	14-20 June
16	4,447	3,394*	6,607	21-27 June
17	4,413	3,058*	6,173	28 June-4 July

* 4,000 cfs minimum tentatively agreed to at the Roanoke River Water Flow Committee meeting on 3 May 1988 in Greenville, NC.

Table 2. Negotiated (Q_1-Q_3) water flow regime (in cfs) for the Roanoke River below Roanoke Rapids Dam for the period 1 April to 15 June each year. These values represent the revised recommendations of the Committee after consultation and agreement with the U.S. Army Corps of Engineers - Wilmington District, and Virginia Power Company.

Dates	Expected Average Daily Flow	Lower Limit	Upper Limit
April 1-15	8,500	6,600	13,700
April 16-30	7,800	5,800	11,000
May 1-15	6,500	4,700	9,500
May 16-31	5,900	4,400	9,500
June 1-15	5,300	4,000	9,500

HYDROLOGY FOR 1988-89

Reservoir Operation 1988-89

David Crawford, Roger A. Rulifson, and Max B. Grimes

Background of Reservoir Operations

A basic understanding of reservoir operation is necessary before discussions of water releases from the reservoirs in 1988 and 1989 can be meaningful. A complete review of reservoir operation was presented in the first report (Manooch and Rulifson 1989) but is repeated again in this report to assist the reader.

The flow regime in the lower Roanoke River below Roanoke Rapids, North Carolina, is dictated by the releases from the Roanoke Rapids power plant. The release from the reservoir is dependent upon the release from Lake Gaston. These two reservoir projects have limited storage and therefore are driven by water releases from Kerr Reservoir. Water release is a function of the lake level in Kerr (as defined by the Rule Curve, Figure 3) and power demands or commitments to supply electrical power.

Kerr operation distributes higher winter run-off to the spring and more importantly decreases the peaks of flood events. The storage available at Kerr dictates the operation of all three reservoirs (Kerr, Gaston, Roanoke Rapids) on a weekly basis. That is, the storage available for release is known for any given point in time and a determination is made as to the amount of water available for power generation for the upcoming week. Forecasted higher flows or flood events will at times modify the release schedule. On an hourly basis, the operation of Roanoke Rapids power plant has control of water flow in the lower Roanoke River.

Flood control is accomplished by reserving the 1.2-million acre-feet storage space of the reservoir for containment of inflow during periods of excessive run-off from the upper watershed. Below the reservoir, the river need only carry the run-off entering the watershed downstream in addition to that amount released as part of flood control operations. As soon as downstream conditions permit, the excessive inflow is released from the storage space in the reservoir at the fastest rate possible but still maintaining the river within certain stages downstream. This procedure may result in prolonged flooding of downstream areas, with the flooding period much longer in duration than that observed under pre-impoundment conditions.

The potential for flood control varies with the seasons and in coordination with the two primary purposes of the project. This planned seasonal fluctuation in reservoir surface elevation is known as the "Rule Curve" for power generation (Figure 3). The surface water elevation of 300 feet is known as the "maximum power-pool elevation." During the usually wet months of December through February, a target water surface of 295.5 feet above sea level exists to provide maximum volume of floodwater storage space while maintaining sufficient height (head) for efficient power generation. Inflow conditions dictate the magnitude and duration of deviations from target elevations. Generally the Corps of Engineers operates the reservoir project to bring the lake elevation to the target elevation as quickly as possible, consistent with the flood control and power production directives. During March the surface elevation is raised so that by 1 April the water level is 301.5 feet and by 15 April the elevation is 302.0 feet. This elevation zone is to provide additional storage for flow augmentation during striped bass spawning activity from April into June. The normal upper target elevation for power operations is 299.5 from April to September. The elevation target is lowered from 299.5 to 295.5 during October and November to restore flood control storage.

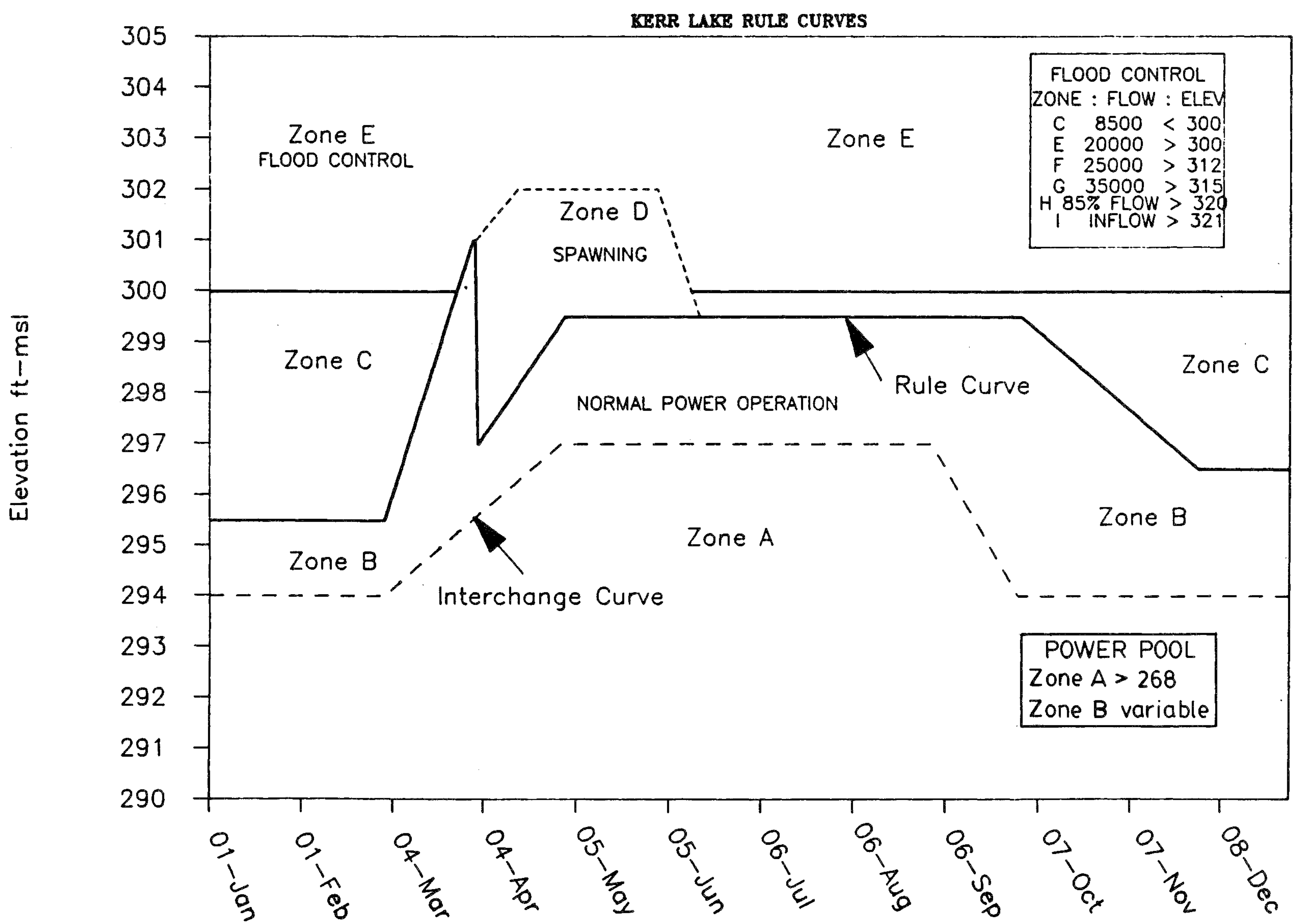


Figure 3. U.S. Army Corps of Engineers Rule Curve for John H. Kerr Reservoir. MSL=height (in feet) above mean sea level.

CLARIFICATION STATEMENT

Under "1988 Kerr Reservoir Operation," page 19

First paragraph: Mr. Max Grimes wishes to underscore his belief that during the spring of 1988 water releases were under the existing flow regime, however watershed precipitation conditions allowed the Corps of Engineers to release waters at rates within the guidelines being negotiated by the Committee.

Associated with specific elevation zones are maximum releases from Kerr powerhouse or dam. These zones are depicted in Figure 3. Zone "C," for example, is between elevations 295.5 and 300.0 from December through March. If the Kerr Lake elevation is within this zone, then the Corps would normally release 8,500 cfs. Zone "E" is between elevations 300.0 and 312.0; this is the first flood control zone (except during the striped bass spawning period). With lake levels in this zone, the Corps would normally release 20,000 cfs. Maximum recorded controlled releases below Roanoke Rapids Dam seldom exceed 35,000 cfs (equivalent to Zone "G," elevations 315 to 320 at Kerr). For 90 percent of the time and for most of the year, the flows are below 20,000 cfs (i.e., Kerr Lake elevations below or in Zone "E").

1988 Kerr Reservoir Operation

At a meeting held in Beaufort, NC, in April 1988, the early spawning activity of striped bass was discussed and Committee members asked the Corps and Virginia Power Company if they were willing to attempt regulation of flows in accordance with the guidelines under discussion at that time, but which had not been formally adopted. These two parties agreed that they could attempt to comply with this request within the existing flow regime. This trial flow regime was implemented on 12 April (see letter in Appendix 4 from H.W. Adams, Jr., of Virginia Power Company dated 6 March 1989). Formal adoption of the Flow Committee's recommendations was on 23 June 1988 (Manooch and Rulifson 1989).

Flow records for the first six months of 1988 clearly depict a regulation of flood events by Kerr Reservoir early in the year, followed by controlled water releases for striped bass spawning activity in the spring. On 21 January the inflow to Kerr Reservoir reached a peak of over 30,000 cfs (Figure 4). This storm resulted in the reservoir water level rising from 295.62 on 16 January to a peak elevation of 299.35 on 25 January. As this elevation exceeds the Rule Curve and is in Zone C (Figure 3), the Corps initiated release of flood waters to evacuate this storage. However, continuing moderately-high inflows and the release requirement of 8,500 cfs resulted in the Kerr Lake elevation remaining close to 299 feet throughout January and into March. This event proved beneficial in that it was relatively easy to store additional water to meet the spawning flow target elevation of 302 feet, which was reached by 23 April.

Flow augmentation (5,700 cfs) was initiated earlier than normal (12 April) when striped bass were observed spawning in the first two weeks in April (refer to section on egg abundance and viability). This initial spawning activity was one of the earliest on record, perhaps influenced by the drawdown/refill of Lake Gaston from December 1987 to February 1988. Lake level manipulation in Lake Gaston was accomplished in an attempt to control aquatic weeds, primarily *Brazilian elodea*. During the refilling process of Lake Gaston in March, minimum releases of about 2,000 cfs were generally maintained from Roanoke Rapids powerhouse until the flow augmentation releases of 5,700 cfs starting on 12 April.

In Kerr Reservoir, the spawning target elevation was maintained by moderate releases until 12 May, when higher releases began to augment river flows for spawning. Spawning flows were maintained until 30 May, when the reservoir reached the top of the power pool elevation 299.5. After 30 May, power operations resumed normal patterns of releases from Kerr Reservoir to meet power demands and conservation of power storage and daily rapid peaking changes from Roanoke Rapids. The last date on which striped bass eggs were found in the lower river was 2 June 1988 (Rulifson 1989).

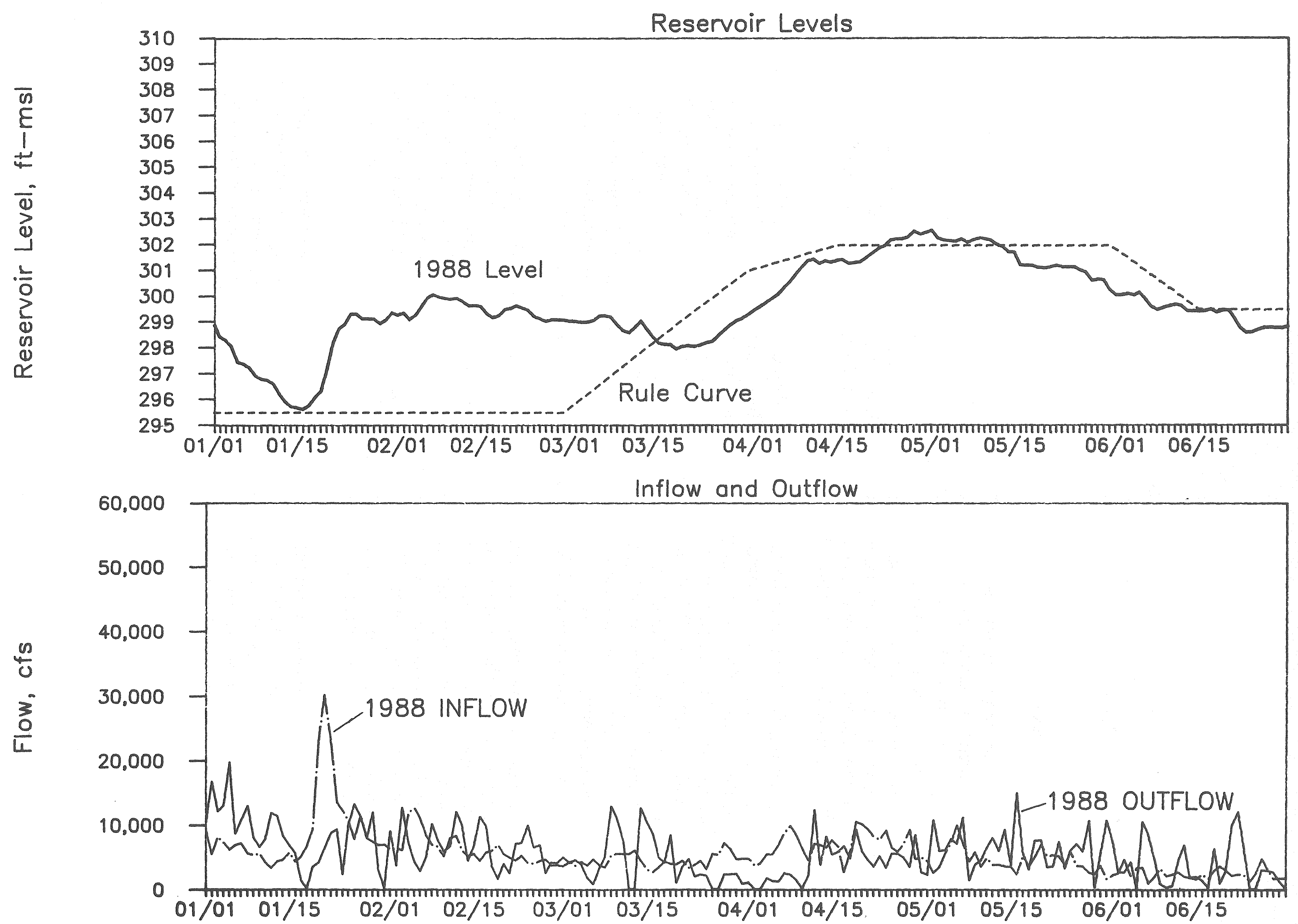


Figure 4. **Kerr Reservoir daily** elevations (feet above mean sea level) for 1988 and inflow and outflow in thousands of cubic feet per second (cfs).

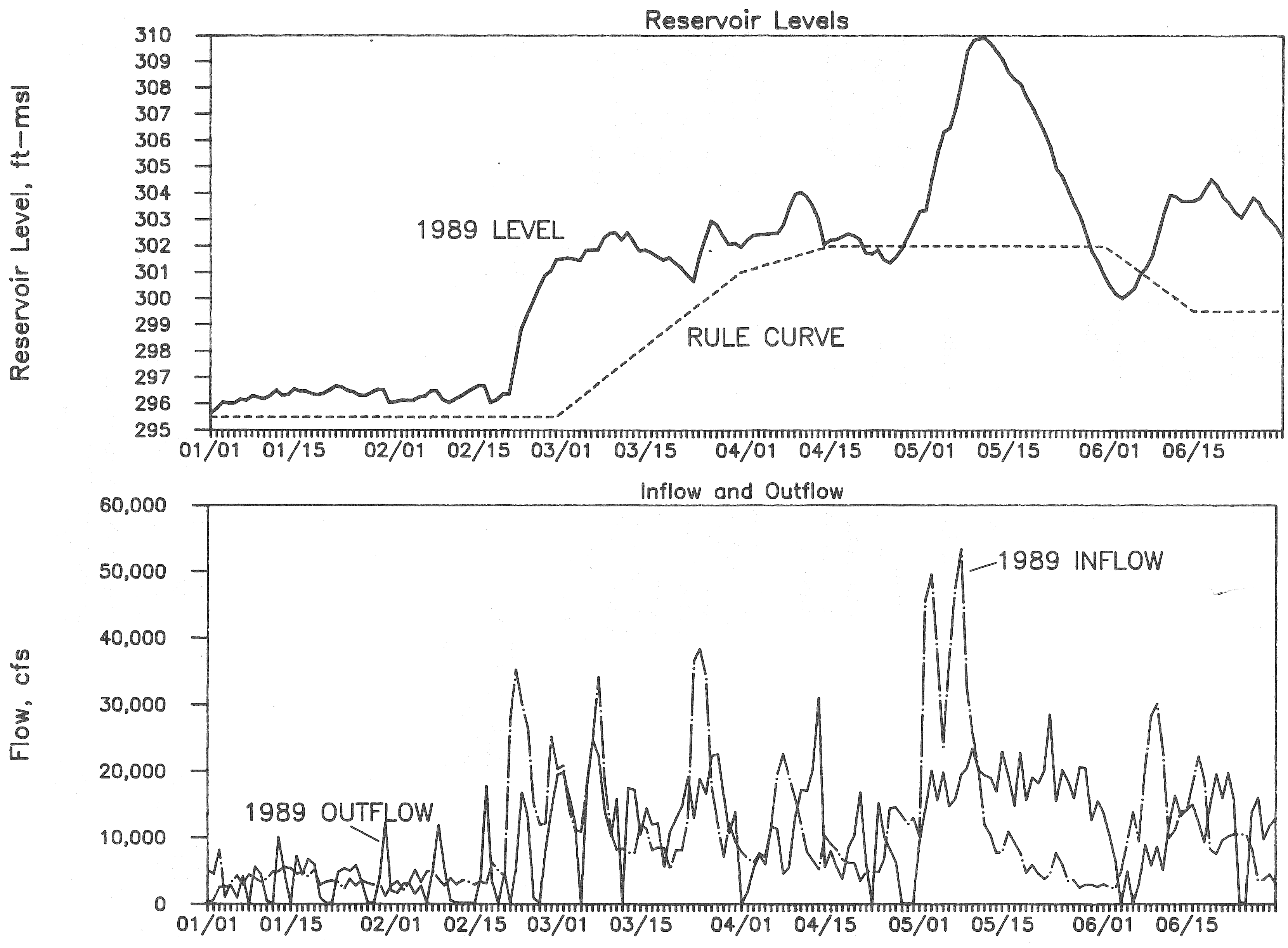


Figure 5. Kerr Reservoir daily elevations (feet above mean sea level) for 1989 and inflow and outflow in thousands of cubic feet per second (cfs).

1989 Kerr Reservoir Operation

A new interim operation plan (the negotiated flow regime) for striped bass releases was implemented during the spring of 1989. The schedule provided a step-down flow range from 1 April to 15 June which was designed to more closely represent pre-project conditions. At the beginning of the flow augmentation period on 1 April, storage was available in Kerr with the elevation near 302 feet msl. Greater than normal rainfall and heavy inflow to Kerr (Figure 5) forced deviations from the recommended plan during four blocks of time: 10-14 April and 2-29 May (20,000 cfs operation), and 1-2 June and 11-15 June (15,000 cfs operation). For the remainder of the days, releases were maintained as requested by the NC Wildlife Resources Commission (Manooch and Rulifson 1989, see request letter in Appendix) to ensure that sufficient storage would be available for the entire flow period. Elevations at Kerr ranged from 300.0 to 310.0 feet during the period 1 April to 15 June.

Hourly and Mean Flows

Charles S. Manooch, III and Marsha E. Shepherd.

Roanoke River water flows were very different during the springs of 1988 and 1989 (Figures 6 and 7; Appendix Table 1). During 1988 flows were typically very low (approximately 1,000 - 2,000 cfs) from 1 March until 12 April after which date flows were generally within the flow boundaries (Q1-Q3) until the end of May when water discharges increased and then became more erratic (Appendix Table 1).

Overall, 61.84% of the hourly flows were within the Q1-Q3 bounds for the negotiated period 1 April - 15 June during 1988 (Table 3). We believe this to be a very high percentage compared with most previous years. Only 7.89% of the hourly flows exceeded the Q3 values by date, whereas 30.26% were less than the Q1 values. The latter was primarily attributable to the very low flows which occurred during early April. The mean flow for the negotiated period was 5,669.3 cfs (s.d. = 2,922.7). Thirty-three of a possible 76 (43.42%) days had all hourly flows within the negotiated bounds. There was a period from 13 May - 30 May when all hourly flows were within the bounds, except on 16 May when flows were within the Q1-Q3 bounds only 79.17% of the time, and on 24 May when 91.67% of the values were within (Table 4).

Heavy spring rains during 1989 resulted in much higher flows compared with 1988 (Figure 7; Appendix Table 1). For the pre-negotiated period 1 March - 31 March, flows usually exceeded 10,000 cfs and for several two-to-five day periods ranged from 15,000 to 20,000 cfs. Flows during the negotiated period were usually within the Q1-Q3 bounds during April, exceeded the Q3 bounds in May, and slightly exceeded the Q3 bound in June.

For the negotiated period, 41.06% of the hourly flows were within the Q1-Q3 bounds for 1989 (Table 5). The overall high flow conditions are perhaps best realized by the fact that only 4.66% of the hourly recordings were less than Q1, whereas 54.28% exceeded Q3. The mean flow for the period was 13,712.6 cfs (s.d. = 5,931.5). Twenty of a possible 76 (26.32%) days had all hourly flows which most closely followed the recommendations of the Committee (Table 6). The reader can perhaps best grasp the contrast in flows between the two springs by viewing Figures 6 and 7 and by reading Tables 3 and 5. It is obvious that flows during the pre-negotiated period from 1 March to 31 March were very low during 1988 and relatively high during 1989 (Figures 6 and 7). It is also clear that flows more closely follow the Committee's guidelines in late April and May of 1988 and in April and June in 1989 (Tables 3 and 5).

The Committee has recommended that water flows not change more than 1,500 cfs during any hour from 1 April - 15 June each year (Manooch and Rulifson 1989). Flows during 1989 were more stable than they were in 1988 (Figures 8 and 9, Table 7). Flow stability in 1989

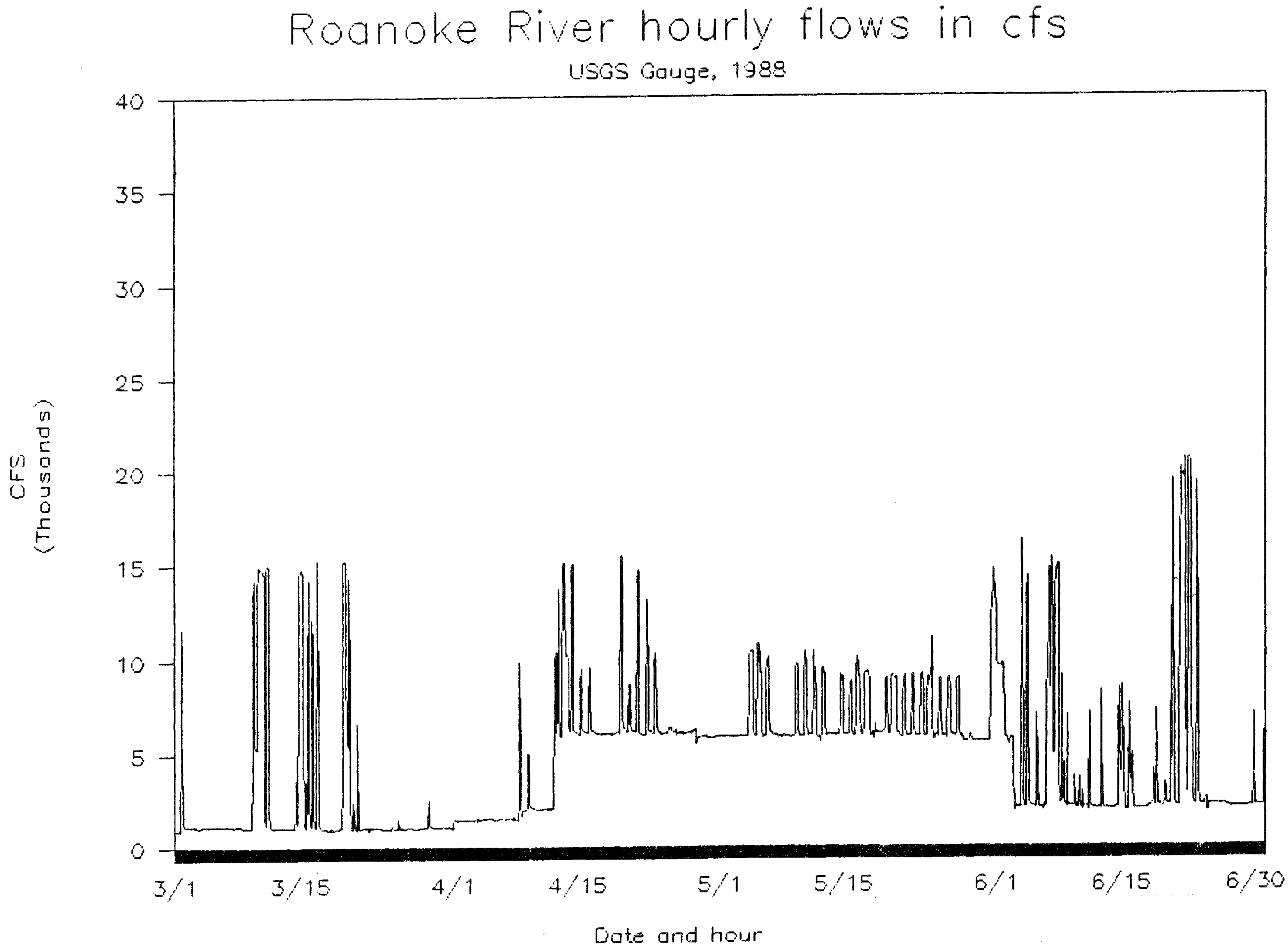


Figure 6. Hourly record of Roanoke River flows (cfs) downstream of the Roanoke Rapids Reservoir (USGS data), March through June 1988.

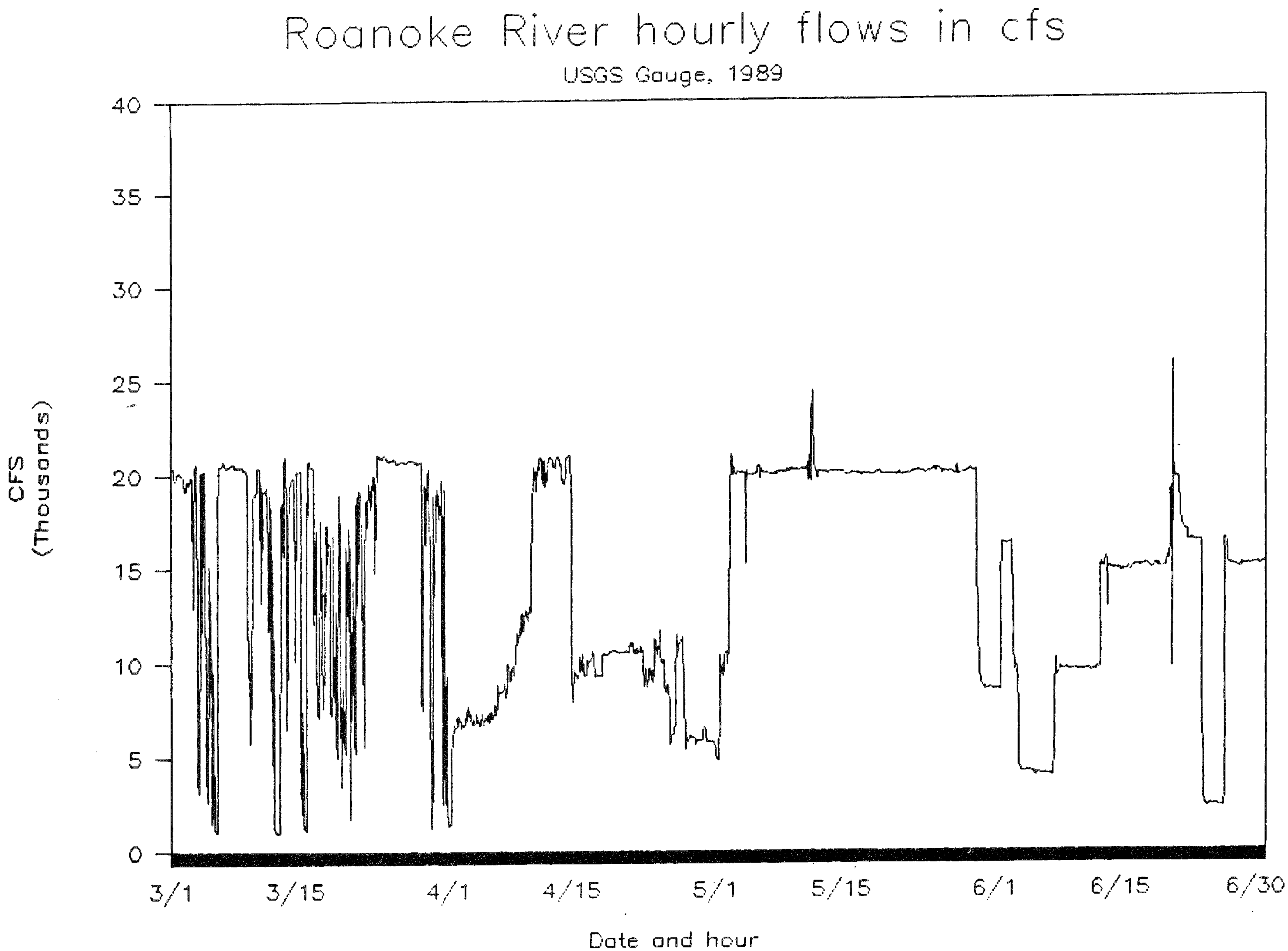


Figure 7. Hourly record of Roanoke River flows (cfs) downstream of the Roanoke Rapids Reservoir (USGS data), March through June 1989.

Table 3. Bi-weekly summaries of hourly flows of the Roanoke River below Roanoke Rapids dam for Spring 1988 using the flow regime guidelines in Table 2.

Week	Dates	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
1	1-15 April	360	313	86.94	38	10.56	9	2.50	3,412.37	3,216.76	268.704
2	16-30 April	360	2	0.56	346	96.11	12	3.33	6,505.63	1,518.39	223.782
3	1-15 May	360	.	.	316	87.78	44	12.22	6,767.89	1,542.82	213.866
4	16-31 May	384	.	.	364	94.79	20	5.21	7,035.50	1,859.83	245.858
5	1-15 June	360	237	65.83	64	17.78	59	16.39	4,534.19	3,787.60	682.194
	1 April-15 June	1,824	522	30.26	1,128	61.84	144	7.89	5,669.33	2,922.72	325.815

Table 4. Daily summaries of hourly flows of the Roanoke River below Roanoke Rapids dam for Spring 1988 using the flow regime guidelines in Table 2.

Month	Day	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
4	1	24	24	100.00	.	.	.	.	1,420.69	108.39	28.53
4	2	24	24	100.00	.	.	.	.	1,459.35	8.25	3.87
4	3	24	24	100.00	.	.	.	.	1,473.10	37.17	18.89
4	4	24	24	100.00	.	.	.	.	1,500.70	13.29	7.84
4	5	24	24	100.00	.	.	.	.	1,497.77	15.47	4.41
4	6	24	24	100.00	.	.	.	.	1,500.70	12.35	6.38
4	7	24	24	100.00	.	.	.	.	1,519.52	46.51	20.65
4	8	24	20	83.33	4	16.67	.	.	3,140.69	2,827.07	706.92
4	9	24	24	100.00	.	.	.	.	2,587.40	990.70	257.27
4	10	24	24	100.00	.	.	.	.	2,041.69	12.63	3.03
4	11	24	24	100.00	.	.	.	.	2,042.28	10.91	7.26
4	12	24	10	41.67	12	50.00	2	8.33	6,877.94	3,885.77	1,130.62
4	13	24	7	29.17	12	50.00	5	20.83	9,961.77	3,220.83	718.95
4	14	24	16	66.67	6	25.00	2	8.33	7,666.61	2,865.11	822.70
4	15	24	60	83.33	4	16.67	.	.	6,495.30	896.59	293.24
4	16	24	.	.	24	100.00	.	.	6,626.80	1,001.24	291.58
4	17	24	.	.	24	100.00	.	.	6,035.40	16.90	7.74
4	18	24	.	.	24	100.00	.	.	6,044.27	28.96	16.60
4	19	24	.	.	19	79.17	5	20.83	7,874.27	3,403.78	555.03
4	20	24	.	.	24	100.00	.	.	6,769.10	771.94	599.51
4	21	24	.	.	19	79.17	5	20.83	7,916.72	3,010.20	738.31
4	22	24	.	.	22	91.67	2	8.33	7,123.99	2,171.41	579.27
4	23	24	.	.	24	100.00	.	.	6,923.43	1,440.80	382.20
4	24	24	.	.	24	100.00	.	.	6,018.97	96.36	27.98
4	25	24	.	.	24	100.00	.	.	6,218.80	126.51	40.45

Table 4. (Continued)

Month	Day	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
4	26	24	.	.	24	100.00	.	.	6,115.42	62.59	25.63
4	27	24	.	.	24	100.00	.	.	6,112.07	56.57	24.48
4	28	24	2	8.33	22	91.67	.	.	5,977.83	277.00	51.58
4	29	24	.	.	24	100.00	.	.	5,878.50	36.48	10.92
4	30	24	.	.	24	100.00	.	.	5,858.88	30.15	5.44
5	1	24	.	.	24	100.00	.	.	5,898.08	16.97	5.47
5	2	24	.	.	24	100.00	.	.	5,884.98	14.07	4.36
5	3	24	.	.	24	100.00	.	.	5,936.39	10.74	4.38
5	4	24	.	.	13	54.17	11	45.83	8,133.74	2,124.85	386.60
5	5	24	.	.	13	54.17	11	45.83	8,315.02	2,188.47	451.88
5	6	24	.	.	18	75.00	6	25.00	7,387.67	1,723.74	347.31
5	7	24	.	.	24	100.00	.	.	5,927.73	53.86	21.95
5	8	24	.	.	24	100.00	.	.	5,895.95	34.59	14.22
5	9	24	.	.	18	75.00	6	25.00	7,146.12	1,717.97	310.64
5	10	24	.	.	18	75.00	6	25.00	7,210.78	1,850.01	394.24
5	11	24	.	.	21	87.50	3	12.50	7,126.08	1,695.43	383.29
5	12	24	.	.	23	95.83	1	4.17	6,979.51	1,588.36	319.52
5	13	24	.	.	24	100.00	.	.	5,977.22	74.08	37.65
5	14	24	.	.	24	100.00	.	.	6,924.32	1,373.45	281.24
5	15	24	.	.	24	100.00	.	.	6,774.75	1,139.25	245.25
5	16	24	.	.	19	79.17	5	20.83	7,859.15	1,691.07	355.58
5	17	24	.	.	24	100.00	.	.	7,921.52	1,566.48	283.60
5	18	24	.	.	24	100.00	.	.	6,050.60	143.07	85.79
5	19	24	.	.	24	100.00	.	.	6,845.30	1,158.67	227.20
5	20	24	.	.	24	100.00	.	.	7,840.49	1,420.15	275.41
5	21	24	.	.	24	100.00	.	.	6,882.84	1,319.29	281.62
5	22	24	.	.	24	100.00	.	.	6,730.56	1,332.22	289.91

Table 4. (Continued)

Month	Day	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
5	23	24	.	.	24	100.00	.	.	6,851.56	1,422.03	275.35
5	24	24	.	.	22	91.67	2	8.33	7,950.84	1,639.81	440.90
5	25	24	.	.	24	100.00	.	.	6,740.69	1,259.23	327.78
5	26	24	.	.	24	100.00	.	.	6,780.75	1,346.57	275.12
5	27	24	.	.	24	100.00	.	.	6,802.22	1,280.78	273.71
5	28	24	.	.	24	100.00	.	.	5,702.73	114.44	30.50
5	29	24	.	.	24	100.00	.	.	5,701.71	140.84	27.17
5	30	24	.	.	24	100.00	.	.	5,613.80	27.17	6.52
5	31	24	.	.	11	45.83	13	54.17	10,293.21	3,770.17	477.57
6	1	24	.	.	3	12.50	21	87.50	9,385.38	880.76	272.85
6	2	24	.	.	24	100.00	.	.	5,276.79	121.83	60.96
6	3	24	19	79.17	2	8.33	3	12.50	3,825.09	3,897.01	1,264.56
6	4	24	17	70.83	1	4.17	6	25.00	5,325.09	4,940.52	1,145.78
6	5	24	22	91.67	2	8.33	.	.	2,523.20	1,106.31	477.54
6	6	24	14	58.33	1	4.17	9	37.50	5,992.92	4,910.45	551.95
6	7	24	.	.	4	16.67	20	83.33	12,682.12	3,361.39	1,891.46
6	8	24	18	75.00	6	25.00	.	.	3,475.49	1,787.94	1,632.04
6	9	24	24	100.00	.	.	.	.	2,300.74	417.27	162.36
6	10	24	24	100.00	.	.	.	.	2,252.85	384.66	221.65
6	11	24	23	95.83	1	4.17	.	.	2,377.07	1,084.19	442.80
6	12	24	21	87.50	3	12.50	.	.	2,634.78	1,512.81	520.42
6	13	24	24	100.00	.	.	.	.	2,030.20	11.56	8.48
6	14	24	18	75.00	6	25.00	.	.	3,251.94	1,999.12	458.50
6	15	24	13	54.17	11	45.83	.	.	4,229.16	2,050.58	1,121.55

Table 5. Bi-weekly summaries of hourly flows of the Roanoke River below Roanoke Rapids dam for Spring 1989 using the flow regime guidelines in Table 2.

Week	Dates	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
1	1-15 April	360	23	6.39	228	63.33	109	30.28	11,889.15	5,889.40	231.739
2	16-30 April	360	30	8.33	316	87.78	14	3.89	8,973.54	1,968.04	143.013
3	1-15 May	360	.	.	17	4.72	343	95.28	18,889.73	3,665.90	151.506
4	16-31 May	384	.	.	41	10.68	343	89.32	18,678.50	3,636.49	51.107
5	1-15 June	360	32	8.89	147	40.83	181	50.28	9,800.90	4,253.79	121.552
	1 April-15 June	1,824	85	4.66	749	41.06	990	54.28	13,712.58	5,931.45	138.617

Table 6. Daily summaries of hourly flows of the Roanoke River below Roanoke Rapids dam for Spring 1989 using the flow regime guidelines in Table 2.

Month	Day	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
4	1	24	21	87.50	3	12.50	.	.	4,448.35	2,406.69	286.217
4	2	24	2	8.33	22	91.67	.	.	6,793.57	156.77	107.954
4	3	24	.	.	24	100.00	.	.	7,088.61	266.90	148.175
4	4	24	.	.	24	100.00	.	.	6,899.60	189.14	103.250
4	5	24	.	.	24	100.00	.	.	7,092.93	159.13	163.262
4	6	24	.	.	24	100.00	.	.	7,852.22	545.65	191.496
4	7	24	.	.	24	100.00	.	.	8,824.43	566.88	184.396
4	8	24	.	.	24	100.00	.	.	10,128.83	869.35	232.375
4	9	24	.	.	24	100.00	.	.	12,145.25	504.36	239.750
4	10	24	.	.	10	41.67	14	58.33	16,515.04	3,477.17	437.333
4	11	24	.	.	.	.	24	100.00	20,363.75	528.87	322.083
4	12	24	.	.	.	.	24	100.00	20,490.04	459.14	134.250
4	13	24	.	.	.	.	24	100.00	20,570.17	391.34	135.208
4	14	24	.	.	1	4.17	23	95.83	19,904.08	2,055.49	478.625
4	15	24	.	.	24	100.00	.	.	9,220.45	533.32	311.708
4	16	24	.	.	24	100.00	.	.	9,697.82	369.69	218.588
4	17	24	.	.	24	100.00	.	.	7,092.93	159.13	163.262
4	18	24	.	.	24	100.00	.	.	9,906.66	533.09	55.262
4	19	24	.	.	24	100.00	.	.	10,531.29	69.69	24.292
4	20	24	.	.	24	100.00	.	.	10,525.62	21.77	10.000
4	21	24	.	.	24	100.00	.	.	10,692.62	165.63	65.083
4	22	24	.	.	24	100.00	.	.	10,568.67	109.67	97.542
4	23	24	.	.	24	100.00	.	.	9,269.88	425.27	256.758
4	24	24	.	.	19	79.17	5	20.83	10,421.89	809.55	337.675
4	25	24	.	.	24	100.00	.	.	8,999.13	953.40	242.471

Table 6. (Continued)

Month	Day	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
4	26	24	3	12.50	19	79.17	2	8.33	7,503.16	2,175.92	326.046
4	27	24	3	12.50	14	58.33	7	29.17	8,961.67	2,436.83	300.117
4	28	24	5	20.83	19	79.17	.	.	5,927.15	129.81	39.287
4	29	24	.	.	24	100.00	.	.	5,992.87	255.07	48.238
4	30	24	19	79.17	5	20.83	.	.	5,766.84	81.72	26.138
5	1	24	.	.	17	70.83	7	29.17	7,356.97	2,331.35	391.354
5	2	24	.	.	.	.	24	100.00	14,400.44	4,530.63	581.325
5	3	24	.	.	.	.	24	100.00	20,073.17	83.91	51.958
5	4	24	.	.	.	.	24	100.00	19,785.00	996.54	427.083
5	5	24	.	.	.	.	24	100.00	20,073.67	170.53	47.958
5	6	24	.	.	.	.	24	100.00	20,051.21	97.52	53.958
5	7	24	.	.	.	.	24	100.00	20,011.00	28.31	20.000
5	8	24	.	.	.	.	24	100.00	20,083.08	42.71	24.042
5	9	24	.	.	.	.	24	100.00	20,183.79	34.76	22.167
5	10	24	.	.	.	.	24	100.00	20,198.00	23.74	20.000
5	11	24	.	.	.	.	24	100.00	20,850.75	1,253.82	526.708
5	12	24	.	.	.	.	24	100.00	20,109.50	179.63	70.167
5	13	24	.	.	.	.	24	100.00	20,079.00	44.57	18.000
5	14	24	.	.	.	.	24	100.00	20,085.00	9.80	4.000
5	15	24	.	.	.	.	24	100.00	20,005.33	64.22	13.875
5	16	24	.	.	.	.	24	100.00	20,019.08	33.49	13.958
5	17	24	.	.	.	.	24	100.00	19,969.38	48.24	27.917
5	18	24	.	.	.	.	24	100.00	19,987.33	42.07	17.833
5	19	24	.	.	.	.	24	100.00	20,025.04	50.92	13.917
5	20	24	.	.	.	.	24	100.00	19,955.67	22.63	13.708
5	21	24	.	.	.	.	24	100.00	19,965.50	50.56	21.875
5	22	24	.	.	.	.	24	100.00	20,005.13	41.81	15.833

Table 6. (Continued)

Month	Day	Total # Hours	#Hours $<Q_1$	% Hours $<Q_1$	# Hours (Q_1-Q_3)	% Hours (Q_1-Q_3)	# Hours $>Q_3$	% Hours $>Q_3$	Mean Flow	Std. Flow	Ave. Hr. Diff.
5	23	24	.	.	.	.	24	100.00	20,121.13	34.83	18.167
5	24	24	.	.	.	.	24	100.00	20,071.00	43.05	28.000
5	25	24	.	.	.	.	24	100.00	20,193.83	43.87	30.208
5	26	24	.	.	.	.	24	100.00	20,065.04	46.65	24.042
5	27	24	.	.	.	.	24	100.00	20,055.38	130.65	52.042
5	28	24	.	.	.	.	24	100.00	20,005.25	64.18	11.958
5	29	24	.	.	.	.	24	100.00	20,040.67	502.43	114.958
5	30	24	.	.	17	70.83	7	29.17	9,936.19	2,042.14	393.854
5	31	24	.	.	24	100.00	.	.	8,540.42	34.35	19.438
6	1	24	.	.	16	66.67	8	33.33	10,734.38	3,404.04	330.325
6	2	24	.	.	.	.	24	100.00	16,250.75	46.42	19.167
6	3	24	.	.	10	41.67	14	58.33	8,443.61	3,162.11	519.075
6	4	24	.	.	24	100.00	.	.	4,146.75	30.38	13.933
6	5	24	7	29.17	17	70.83	.	.	4,062.52	97.31	35.625
6	6	24	13	54.17	11	45.83	.	.	4,001.69	21.16	6.371
6	7	24	12	50.00	9	37.50	3	12.50	5,737.41	2,518.37	302.375
6	8	24	.	.	7	29.17	17	70.83	9,493.08	104.20	23.121
6	9	24	.	.	4	16.67	20	83.33	9,531.24	17.93	5.433
6	10	24	.	.	22	91.67	2	8.33	9,497.25	16.48	8.183
6	11	24	.	.	19	79.17	5	20.83	9,495.85	27.80	13.617
6	12	24	.	.	8	33.33	16	66.67	10,974.01	2,304.72	262.383
6	13	24	.	.	.	.	24	100.00	14,967.25	508.08	240.333
6	14	24	.	.	.	.	24	100.00	14,844.67	26.32	16.667
6	15	24	.	.	.	.	24	100.00	14,833.00	54.05	26.667

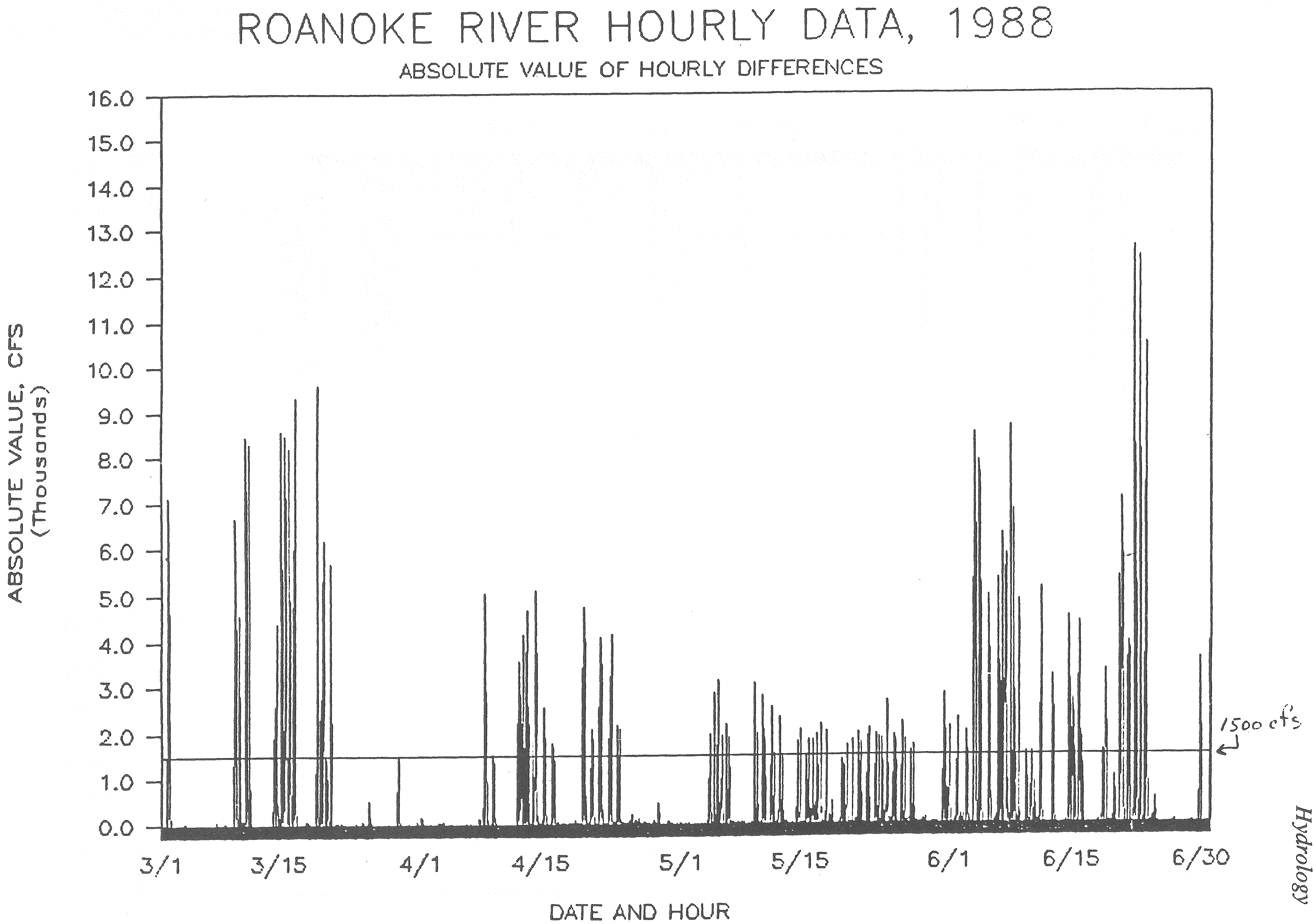


Figure 8. Hourly comparisons of differences in rate of Roanoke River flow (thousands of cfs) below the Roanoke Rapids Reservoir for March-June 1989 relative to the recommended change of 1,500 cfs/hour.

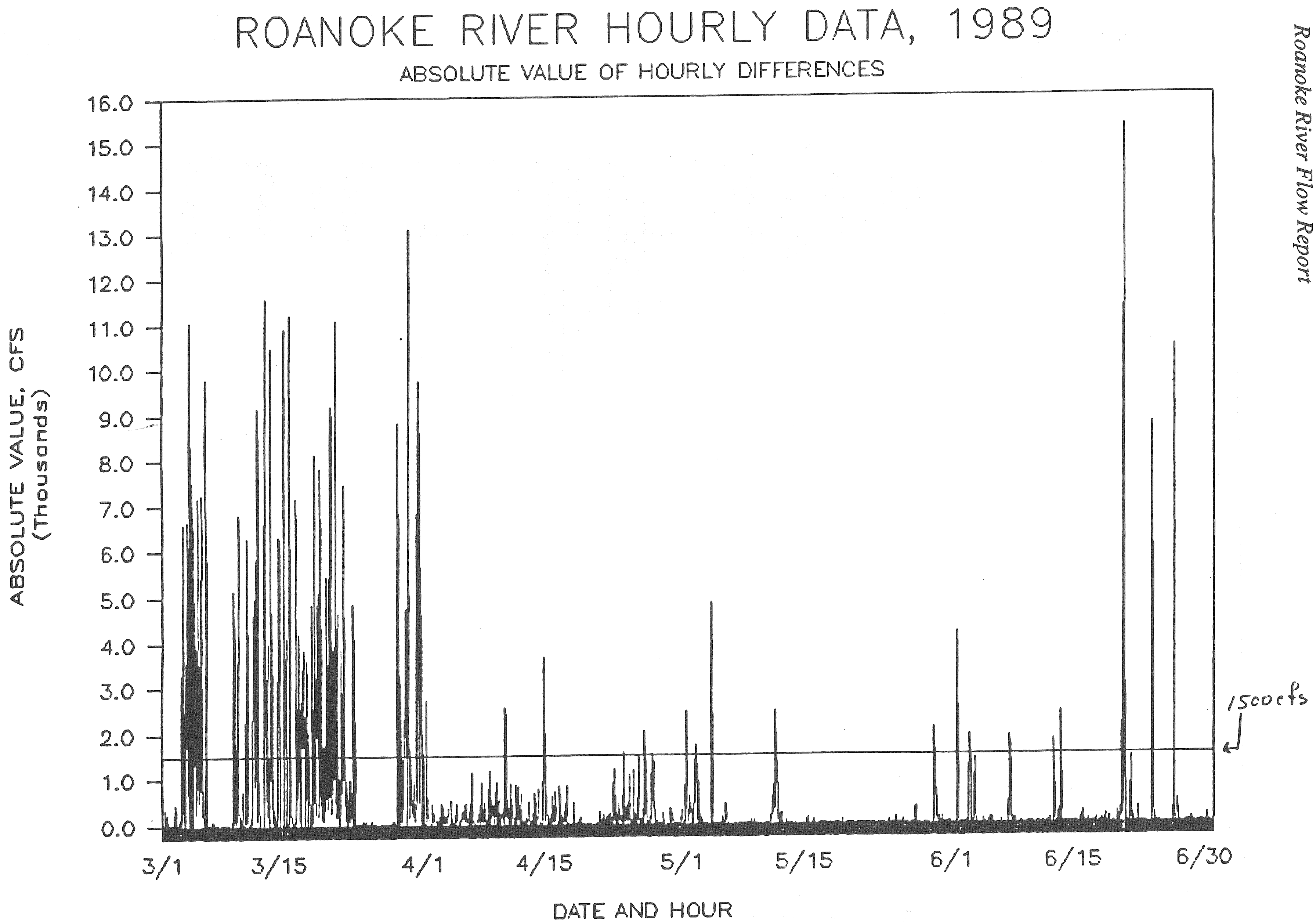


Figure 9. Hourly comparisons of differences in rate of Roanoke River flow (thousands of cfs) below the Roanoke Rapids Reservoir for March-June 1988 relative to the recommended change of 1,500 cfs/hour.

Table 7. Bi-weekly summaries of Roanoke River flow below Roanoke Rapids dam for Spring 1988 and 1989 concerning the amount of time during which the rate of flow change exceeded the recommended 1,500 cfs/hour value.

Week	Dates	Total # Hours	# Hours <=1,500	% Hours <=1,500	# Hours >1,500	% Hours >1,500
1988						
1	1-15 April	360	336	93.33	24	6.67
2	16-30 April	360	339	94.17	21	5.83
3	1-15 May	360	338	93.89	22	6.11
4	16-31 May	384	361	94.01	23	5.99
5	1-15 June	360	308	85.56	52	14.44
	1 April-15 June	1,824	1,682	92.21	142	7.79
1989						
1	1-15 April	360	352	97.78	8	2.22
2	16-30 April	360	356	98.89	4	1.11
3	1-15 May	360	355	98.61	5	1.39
4	16-31 May	384	381	99.22	3	0.78
5	1-15 June	360	352	97.78	8	2.22
	1 April-15 June	1,824	1,796	98.46	28	1.54

ERRATA SHEET

Please make these changes in your copy of the Flow Report. Subsequent printings of this document will be revised to correct these errors.

Errata as follows:

Page 36, Roanoke River Flow Time Series Analysis.

Summary, fourth paragraph, last sentence should read:

"During 1988, the coefficients for Tuesday and Wednesday and May were significantly different from zero for the March-June period, indicating persistent interdaily and intermonthly manipulation of river flows".

Page 39, first equation should read:

Flow(t)=2652 + 0.81 Flow(t-1).

Page 39, third equation should read:

Flow(t) = 1153 + 0.86 F(t-1) - 0.4 F(t-2) + 0.28F(t-3).

Page 43, first sentence should read:

"...,the estimated ARIMA model was (1-0.81B)F=2652."

Page 43, second equation should read:

Flow(t)=932 + 0.74Flow(t-1) - 0.2Flow(t-2) + 0.26Flow(t-3).

Page 44, fourth paragraph, fifth sentence should read:

"Also, the coefficient of the month of May is significantly greater than zero in 1988 indicating that the flow in May of 1988 was significantly higher than that of June."

Page 54, seventh paragraph should read:

Figure 12 compares the coefficients for the three-month period in 1988 and 1989. Again, the same general pattern is evident. The 1989 coefficients seem somewhat more negative in the early morning than those of 1988, however the 1988 coefficients are somewhat larger in the evening hours than the 1989 coefficients.

resulted from the US Army Corps of Engineers and Virginia Power Company adjusting their release schedules to follow recommended guidelines, and because May water releases were often near the 20,000 cfs powerhouse maximum. Average hourly differences in flow were less for every two-week interval during 1989 compared with 1988 (Tables 3 and 5). Approximately 92% of the hourly flow changes during 1988 were less than 1,500 cfs compared with 98.5% during 1989 (Table 7).

Roanoke River Flow Time Series Analysis

L.H. Zincone, Jr.

Summary

In contrast to the 1988 report (Manooch and Rulifson 1989), which concentrated on analyzing Roanoke River flows averaged over certain pre- and post-impoundment years, the time series analysis for this report examines actual flows of the Roanoke River during the 1988 and 1989 spring season. Two time periods are analyzed, the entire March-June period of the original recommendation of the Committee, and the negotiated flow regime period (1 April to 15 June). Both ARIMA analysis and autoregressive analysis were used, with the latter highlighting the role of hours of the day, days of the week, and months of the year during the period. Finally, both hourly flows and average daily flows were analyzed. The following represents a summary of the findings and conclusions.

ARIMA analysis of the 1989 river average daily flows using the entire three-month period yielded an autoregressive(1) model with a coefficient which was not significantly different from the coefficient of the model for the average bad year which is shown in last year's study. For the negotiated flow period, a one-period autoregressive model was estimated, the coefficient of which was not significantly different from one. Consequently, our conclusion is that the flow is represented best for the entire 1989 period by a one-period autoregressive model. On the other hand, changes in flow for the negotiated flow period were not significantly different from a random walk model. Therefore, day to day changes in average daily flow during the shorter negotiated period were random.

For 1988, a three-period autoregressive model was estimated for both the entire three-month period as well as the negotiated flow period. In general, the models were identical except that the 1988 model had somewhat smaller coefficients. All coefficients in both models were significantly different from zero.

Autoregression analysis, which specifically accounted for the days of the week and the months of the year, was performed on the average daily flow data for both years and both recommendation periods. For 1989, the model for the three-month period showed that certain weekday coefficients were significantly different from zero, indicating statistically meaningful interday flow variations. The month coefficients, however, were not significantly different from zero. For the shorter negotiated period, however, weekdays were not a source of significant variation. The lack of significance of the daily coefficients during the negotiated flow period indicates that the flows were smoothed out over the week, something which did not occur during the other times. During 1988, the coefficients for Tuesday and Wednesday and April were significantly different from zero, indicating persistent interdaily and intermonthly manipulation of river flows for both the March-June period and the negotiated flow period.

The final analysis involved autoregression performed on the hourly river flow data. Two different models were estimated for both years and time spans. The first model did not

specifically include the hours of the day, but rather captured the effect of differing hours in the autocorrelation of the residuals. When it was seen that neither the coefficients of the weekdays nor the months were significantly different from zero, it was decided to include the hours of the day specifically. Again in these models, monthly and daily coefficients were not significantly different from zero. Hourly coefficients, however, displayed a flow pattern which was statistically significant. Specifically, relative to the reference hour, 12 midnight to 1 am, the model indicated a significant reduction in flows during the early morning hours and a significant increase in flows during the late afternoon and evening hours. It should be noted that interdaily and intermonthly variation amounts to approximately two percent of the total variation measured in the hourly data. What this means, of course, is that variation among days and months is swamped by variation among hours within the days and months.

Finally, we examined the relative intradaily variability of the flows in the two years. To do this, the daily standard deviations were computed during the time period and the 1988 values subtracted from the 1989 values. The results appear in Figure 14, where a positive value indicates that the standard deviation for 1989 is larger. As can be seen from the figure, during the time period where the sampling station was finding the largest number of striped bass eggs, the intradaily variation in flows was smaller in 1989 than in 1988, even though the average flow was larger.

The following general conclusions can be made concerning these analyses:

1. For ARIMA models, there are large differences between the models for the same years but different time periods.
2. For ARIMA models, there is a general similarity between models for the same time span but different years.
3. For the autoregressive models of daily average flows, models of the same time span but different years are similar.
4. For 1989, the autoregressive models are substantially different between the two time spans.
5. For 1988, the autoregressive models are similar between time spans.
6. For hourly data, all comparisons yield models which are similar in structure.
7. Changes in the average daily flow during the period April 1 to June 15, 1989 were random.

Introduction

This section presents a statistical analysis of the 1988 and 1989 flows of the Roanoke River. The data, taken hourly at gage #02080500 approximately 2.8 miles downstream from the Roanoke Rapids dam, were furnished by Tom Fransen of the NC Department of Natural Resources and Community Development. The data began at midnight March 1 and ended at 11 PM, June 30. The remaining paragraphs of this introduction will outline the differences between this year's report and last year's and summarize the types of analysis reported in this chapter.

The primary purpose of the 1988 report was to characterize the average flows and compare pre-impoundment flows with post-impoundment flows. The post-impoundment flows were further divided into "good" and "bad" years, depending upon whether the Juvenile Abundance

Index was greater than or less than five. For each of these three subperiods, which omitted the years when the dams were under construction, daily flows were averaged over the entire time period for analysis. Put another way, the actual data modeled for last year's report were the average daily flows averaged over every year in the respective periods. In contrast, the data analyzed for this report is the actual daily average or hourly flows for the actual days in 1988 and 1989. We will refer to the hourly observations as "hourly data" and to the daily averages of the hourly observations as "daily data."

Thus, this year's report focuses on comparing actual 1988 and 1989 flows with each other and average flows of the good and bad post-impoundment years as defined in last year's report (Manooch and Rulifson 1989). The first task, then, was to build autoregressive integrated moving average (ARIMA) models as we did last year for the average flow. Once the ARIMA models are built for the actual 1988 and 1989 data, we can compare the structure of the models with the models for the intraperiod averages computed last year to see if 1989 and 1988 were more similar to bad or good post-impoundment years.

In addition to the ARIMA models, we built autoregressive models of the daily data which allow the specific inclusion of the effects of month and day of the week simultaneously with the autoregressive patterns. This should give us a better picture of the separate daily, monthly and other effects operating to form the overall pattern or the flow.

Because we have the hourly flows this year, additional analysis was performed on the hourly data. Specifically, the hourly flow was modeled first as a function of days of the week, months of the year, and the autoregressive component. Next the actual hours of the day were added to account specifically for intradaily patterns. All of this is reported below.

Two periods were analyzed: 1) the original flow recommendations of March through June stated in Table 1; and 2) the negotiated flow regime between 1 April and 15 June (Table 2). Results of each analysis will be compared.

Whenever any statistical phenomenon is described, there are always two dimensions - size and variation. Most of this year's report will concentrate on the size of the flows. However, the dimension of variability should not be overlooked. It has been shown that the amount of the flow plays a key role in how far up the river the fish come to spawn. In addition, since the water released from the dams is typically colder than that in the river, substantial variation in flows will cause ambient water temperature, a key variable in the biological processes of all fishes, to fluctuate, thereby changing behavior. Consequently, there is a comparison between the variability of the flow during the key subperiod when the fish were actually spawning this year and the same period last year.

ARIMA Analysis - Daily Average Flows

In the 1989 report (Manooch and Rulifson 1989), the committee reported on time series or ARIMA (autoregressive integrated moving average) models for the average daily flow from "good years" (juvenile abundance index > 5) and "bad years" (JAI <= 5) from the post-impoundment period. This section reports on ARIMA models based on the average daily flows during 1988 and 1989. In ARIMA analysis, a tentative model is identified from the auto- and partial autocorrelation functions, estimated and "fine tuned" until the model with the fewest number of parameters which randomizes the model residuals is found. Examination of the autocorrelation functions for the 1989 data indicated that an autoregressive model of order two should be the starting point for the analysis. This model was estimated as was an autoregressive model of order one. The latter model proved to be adequate in the sense that its residuals were white noise. Since the AR1 model is more parsimonious than the order two model and randomizes the residuals, we conclude that the correct model to characterize the 1989 flow is the AR1 model presented in Table 8.

Table 8 shows the result of the model estimation. The t-ratios for both the constant term 0and the AR(1) coefficient exceed the level required to reject the null hypothesis that the terms are zero at the five percent level. Autocorrelation analysis of the residuals showed that the residual autocorrelation function for this model was not significantly different from zero. The equation for this model is

Flow(t)=2562 + 0.81 Flow(t-1).

It should be noted that the model for the average bad year was

Flow(t)= 1560 + 0.84 Flow(t-1).

Note that the coefficients for flow(t-1) in both models are substantially identical, although the constant term, which reflects the over all average flow, is higher for 1989 than for the average of the bad years. This is to be expected since, because of the high rainfall, flows were generally higher than average during 1989.

A similar analysis performed on the 1988 data yielded the model

Flow(t) = 1153 + 0.86 F(t-1) + 1.4 F(t-2) + 0.28 F(t-3).

Attempts to reduce the number of parameters in this model resulted in model residuals which were not white noise. Consequently, one must conclude that the equation above is the most parsimonious adequate model to represent the 1988 flows. Clearly, the model is not the same as the model for the 1989 data. Nor is it the same as the model for the average bad year flow. Table 9 shows the details of the 1988 model. All t-ratios are well above the minimum necessary to reject the null hypothesis that the coefficients equal zero at the five percent level or above.

The results above were obtained from the data gathered from the original recommendations of the Committee extending from 1 March to 30 June in the respective years. The negotiated flow regime is in force only from 1 April to 15 June of each year. In order to determine whether the additional data in March and the last of June had any effect on the results, the ARIMA analysis was repeated using only the period between 1 April and 15 June of the respective years.

Table 10 shows the results of the ARIMA analysis for the 1 April to 15 June 1989 in the top panel and the 1988 results in the bottom panel. Again, we began by estimating an AR2 model, but found that the AR2 coefficient was not significantly different from zero. Dropping that coefficient yielded the model shown whose residuals are white noise. The constant term is not significantly different from zero but the AR1 coefficient is significantly different from zero. However, this coefficient is not significantly different from one. This is important, since if the coefficient were 1, the model would be referred to as a "random walk" model. That is, day to day changes would be random. (To test this hypothesis, the t statistic is (0.97-1)/0.03 = 1 which is not significant at the five percent level). Clearly, the model for the negotiated period is not significantly different from a random walk because 0.97 is not significantly different from one. Also, since the constant term is not significantly different from zero, the mean of this random walk is zero. Thus, the day to day changes inflow during the negotiated flow period were white noise.

Table 8. Results of the ARIMA model estimation for the period 1 March to 30 June, 1989.

Parameter	Estimate	Approx. Std. error	T ratio	Lag
MU	14477.6	1474.56	9.82	0
AR1,1	0.816784	0.0515988	15.83	1

Constant estimate	=	2652.53
Variance estimate	=	9645765
Std. error estimate	=	3105.76
AIC	=	2311.31
SBC	=	2316.92
Number of residuals	=	122

Table 9. Results of the ARIMA model estimation for the period 1 March to 30 June 1988.

Parameter	Estimate	Approx. Std. error	T ratio	Lag
MU	4391.91	674.517	6.51	0
AR1,1	0.860859	0.0885496	9.72	1
AR1,2	-0.403156	0.112785	-3.57	2
AR1,3	0.279635	0.0888751	3.15	3

Constant estimate	=	1153.59
Variance estimate	=	4277250
Std. error estimate	=	2068.15
AIC	=	2212.95
SBC	=	2224.17
Number of residuals	=	122

Table 10. Results of the ARIMA model estimation for the period 1 April to 15 June in 1989 (panel 1) and 1988 (panel 2)

1989 Results

Parameter	Estimate	Approx. Std. error	T ratio	Lag
MU	5188.67	2620.17	1.98	0
AR1,1	0.97314	0.0300839	32.35	1

Variance estimate = 6985002
Std.error estimate = 2642.92
AIC = 1415.36*
SBC = 1420.02*

1988 Results

Parameter	Estimate	Approx. Std. error	T ratio	Lag
MU	4627.75	930.13	4.98	0
AR1,1	0.740187	0.114695	6.45	1
AR1,2	-0.207394	0.141329	-1.47	2
AR1,3	0.265813	0.116749	2.28	3

Constant estimate = 932.004

Variance estimate = 3113250
Std. error estimate = 1764.44
AIC = 1355.86*
SBC = 1365.18*

Number of residuals = 76

Referring to the analysis for the entire three-month period, the estimated ARIMA model was (1-0.81B)F = 2562. The standard error of the coefficient was 0.05. Testing this coefficient against the null hypothesis that it is one yields a t ratio of -3.8 ((0.81-1)/0.05) indicating that the coefficient for the model for the entire period is significantly different from one. Therefore, the model for the entire period is not a random walk model. Thus, we conclude that, for 1989, changing the period did in fact make a difference in the model estimated. During the period of the negotiated flow regime, there is no interdaily pattern of average daily flows; however, during the entire period there is such a pattern.

For 1988, the model estimated from the entire period was

Flow(t) = 1153 + 0.86(Flow(t-1) -0.4 Flow (t-2) + 0.28 Flow (t-3).

As stated above, attempts to estimate a more parsimonious model by eliminating some lags resulted in residuals which were not white noise. Therefore, our conclusion was that the AR3 model was the appropriate model for describing the flows for the entire period in 1988.

The model estimated for the shorter negotiated period in 1988 was

Flow(t) = 4627 + 0.74 Flow(t-1) - 0.2 Flow(t-2) + 0.26 Flow(t-3).

Again, attempts to estimate a more parsimonious model were not successful in that the residuals of lower order models were not white noise. Our conclusion with respect to the shorter period in 1988 is that the structure of the models is the same in both years, but the coefficients are different. The appropriate statistics are shown in the bottom panel of Table 10.

Autoregression Analysis - Daily Average Flows

One way to combine the specific analysis of monthly and daily differences in mean values for different time periods and the autoregressive relationships analyzed in the second section of this report is to perform a regression analysis in which the autocorrelation of the residual terms is explicitly taken into account. Thus, consider the model

$$y = Bx + v$$

where y is an independent variable, B a vector of regression coefficients, x a vector of independent variables and v the residuals of that model which follow the autoregressive scheme

$$v(t) = a(t-1)e(t-1) + a(t-2)e(t-2)\ldots a(t-n)e(t-n)$$

where e(i) is a sequence of independent error terms with a mean of zero and a constant variance. Using ordinary least squares to estimate this model would result in unbiased regression coefficients, but their standard errors and significance measures would be subject to unknown bias. Consequently, estimating the above model must involve some explicit consideration of the autocorrelated residuals. We use SAS Proc Autoreg with the maximum likelihood option to estimate the model

$$flow(t) = f(day, month) + v(t).$$

This method "employ[s] a Gauss-Marquardt algorithm to . . . maximize the log likelihood. . . The relevant optimization is performed simultaneously for both the regression and the AR parameters." (SAS Institute 1985). Thus, the effect of day and month, measured as 0-1 dummy variables, can be seen explicitly as well as the autocorrelation pattern of the residuals. The models presented are the result of specifying that the autoregressive parameters be eliminated through a stepwise procedure so that only those autoregressive parameters which are significantly different from zero at the five percent level remain. Later we estimate autoregressive models which take account explicitly for the hours as well as the months and days.

Table 11 shows the results of the autoregression analysis of the mean daily flows from 1989. "Regular R-square" refers to what the R-square would have been using ordinary least squares estimation without considering the autocorrelation of the residuals. "Total R-square" shows the percentage of the variance explained when the autocorrelated residuals are modeled along with the effects of weekday and month.

The variables in the equation above consist of six dummy variables reflecting day of the week and three dummy variables reflecting the months from which the data are taken (two for the negotiated period, since March is eliminated from the data set). These variables for the days take on the value of 1 if the observation is taken from the particular day of the week listed for each variable and zero otherwise. Similarly, the three variables reflecting the months take on the value of one if the observation comes from the particular month and zero otherwise. If there are n categories for dummy variables, only (n-1) may be used in a regression, otherwise the X'X matrix is singular and the regression cannot be solved. Thus, the coefficients for the dummy variables reflect the relationship between the particular weekday and the level for Sunday or the particular month and the level for June. The coefficient for Tuesday, for example, is 2744, indicating that on the average Tuesday's flow was 2744 cubic feet/second greater than that on Sunday. Since the probability value for a larger t by chance is only 0.01, we can reject the null hypothesis that the coefficient for Tuesday is zero at the five percent level.

Perusal of Table 11 indicates that Tuesday, Wednesday, Thursday, and Friday all have flows that are significantly above that of Sunday at the five percent level or higher when all the data (March through June) are considered. All of the coefficients are positive, indicating that the flows on these days are higher than those on the Sundays. On the other hand, none of the coefficients for the months are significantly different from zero. This indicates that there was no significant difference in the monthly flows at the 5 percent level of significance. On the other hand, when the analysis is confined to the shorter, negotiated flow period, no coefficients were significantly different from zero. This indicates that the interdaily variation resulted primarily from the time period outside of the period from April 1 to June 15. These results are summarized in the bottom panel of Table 11.

Table 12 shows the results of the autoregression analysis for 1988. The results from the analysis of the entire period are shown in the top panel; those from the negotiated flow period are shown in the bottom panel. Several differences are apparent between the years for the entire period. First, only the coefficients for Tuesday and Wednesday are significantly different from zero for 1988, whereas in 1989 the coefficients for Tuesday through Friday were significant. Also, the coefficient of the month of April is significantly greater than zero in 1988 indicating that the flow in April of 1988 was significantly higher than that of June. Finally, one additional significant autoregressive coefficient at lag 3 is present in 1988 which does not appear in the analysis for 1989. The results are quite similar for the negotiated period, with the exception that no monthly coefficients are significantly different from zero in the negotiated period.

In looking at the average daily flow, we can conclude that most of the interdaily variation is the result of the data outside of the time in which the negotiated flow regime was in force. The reason for this conclusion is that no daily coefficients in the model from the short period were significantly different from zero. Secondly, for the long period, 1989 shows more daily variation than 1988, but since the May, 1988 coefficient was significantly greater than zero, intermonthly variation over the long period in 1988 was more pronounced than in 1989.

Table 11. Results of autoregression analysis on the 1989 average daily flows (cfs) of the Roanoke River below the Roanoke Rapids reservoir for the original recommendation period (1 March to 30 June, top panel) and the negotiated period (1 April to 15 June, bottom panel).

Original Recommendation Period

Reg RSQ 0.1888 Total RSQ 0.7439
Durbin-Watson 1.9373

Variable	B value	Std. error	T ratio	Prob.
INTERCPT	10582.5259	1767.91274	5.986	0.0001
MON	1369.5817	748.17667	1.831	0.0699
TUES	2744.7590	1064.62524	2.578	0.0113
WED	2953.2788	1201.51856	2.458	0.0155
THURS	3363.7130	1199.25578	2.805	0.0060
FRI	3456.9441	1064.66578	3.247	0.0015
SAT	1260.3786	739.10997	1.705	0.0910
MAR	3606.1084	2258.07368	1.597	0.1131
APR	-926.5447	2172.72206	-0.426	0.6706
MAY	3325.9949	2099.21434	1.584	0.1160
A(1)	-0.939254	0.09434026	-9.956	0.0001
A(2)	0.2290016	0.09316268	2.458	0.0155

Negotiated Period

SSE	429698444	DFE	65
MSE	6610745	Root MSE	2571.137
SBC	1446.674	AIC	1421.036
Reg RSQ	0.0891	Total RSQ	0.8329

Durbin-Watson 1.9904

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	12307.4178	3085.91134	3.988	0.0002
MON	1	635.6564	787.60137	0.807	0.4226
TUES	1	843.8272	1110.14079	0.760	0.4499
WED	1	1220.3731	1258.59651	0.970	0.3358
THURS	1	1932.3371	1264.21382	1.528	0.1312
FRI	1	2006.5213	1107.14673	1.812	0.0746
SAT	1	162.4006	760.60015	0.214	0.8316
APR	1	-666.1814	3248.76488	-0.205	0.8382
MAY	1	496.3187	2596.77975	0.191	0.8490
A(1)	1	-1.10413	0.1219204	-9.056	0.0001
A(2)	1	0.2349426	0.1205026	1.950	0.0555

Table 12. Results of autoregression analysis on the 1988 average daily flows (cfs) of the Roanoke River below the Roanoke Rapids reservoir for the original recommendation period (1 March to 30 June, top panel) and the negotiated period (1 April to 15 June, bottom panel).

Original Recommendation Period

Reg RSQ 0.1975 Total RSQ 0.6083
Durbin-Watson 2.0211

Variable	Value	Std. error	T ratio	Prob.
INTERCPT	3339	939	3.552	0.0006
MON	442.9	551	0.802	0.4240
TUES	103.8	742.903	2.832	0.0055
WED	193	734.68	2.639	0.0095
THURS	1353	734.989	1.841	0.0683
FRI	409	750.670	0.545	0.5869
SAT	410	559.00510	0.734	0.4647
MAR	-1809	1139.25206	-1.589	0.1151
APR	725	1133.876	0.640	0.5236
MAY	2297	1062.7524	2.162	0.0328
A(1)	-0.74	0.09326549	-8.031	0.0001
A(2)	0.3	0.1115108	3.510	0.0007
A(3)	-0.23	0.09452207	-2.497	0.0140

Negotiated Period

SSE	183056987	DFE	66
MSE	2773591	Root MSE	1665.41
SBC	1376.31	AIC	1353.003
Reg RSQ	0.2106	Total RSQ	0.5744
Durbin-Watson	1.9439		

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	3832.50047	1131.35058	3.388	0.0012
MON	1	476.38058	546.81685	0.871	0.3868
TUES	1	2308.76643	687.03230	3.360	0.0013
WED	1	1682.21477	749.20619	2.245	0.0281
THURS	1	1129.33083	755.93943	1.494	0.1400
FRI	1	708.49751	692.00716	1.024	0.3097
SAT	1	577.87459	554.20425	1.043	0.3009
APR	1	131.77263	1284.34217	0.103	0.9186
MAY	1	1704.46468	1175.80771	1.450	0.1519
A(1)	1	-0.644414	0.09437592	-6.828	0.0001

Autoregression Analysis - Hourly Flows

Table 13 shows the autoregressive analysis for the 1989 hourly flow data for March through June. In this analysis, the monthly and daily variations were accounted for using dummy variables while the hourly effect was allowed to interact with the autoregressive effects. Since the observations were hourly, the autoregressive coefficients reflect any hourly patterns which might be present. Interestingly enough, in this formulation, all the separate effects of the days and the months disappear. In terms of the relationships between the hours, the present flow is related significantly with the flows 1, 2, 3, 7, 8, 11, 14, and 20 hours in the past. The relationships are negative for lags 3, 11, and 20 and positive for the remaining lags.

It should be noted that for the daily data, the total sum of squares is approximately 3 billion, while for the hourly data it is 104 billion. Thus, approximately 98 percent of the variation in the hourly data is eliminated by averaging the flows over a 24 hour period. It is therefore not surprising that the monthly and daily coefficients are not significantly different from zero.

Table 14 shows the same analysis for the full 1988 period. Substantially the same conclusions hold except that the autoregressive structure does not contain exactly the same lags.

Table 15 shows the results of the autoregression analysis for hourly flows in 1989 when the hours are specifically included. Again, no monthly or daily coefficients are significantly different from zero. However, several hourly coefficients are significantly different from zero, indicating that the mean flows at these hours are either above or below the mean flow at midnight. Specifically, the flow is less than that of the midnight hour from one to six AM and greater than the midnight hour from 7 until 11 PM. In addition, there are remaining autocorrelations at lags 1 through three, 7, 8, 13, 14, and 20. The autocorrelation at lags 2, 8, and 14 is positive, indicating a positive relationship between flow in the current hour and river flow two, eight and fourteen hours earlier. The autocorrelation coefficients for the remaining lags are negative, indicating a negative relationship between present flow and river flow at those lags.

Table 16 shows the results of the full autoregression on the 1988 hourly data. Again, no monthly or daily coefficients were significantly different from zero. The hourly coefficients were negative for the hours one through four AM and positive for 6 through 11 PM. This is precisely the same pattern shown for 1989. The significant autoregressive coefficients are similar to the pattern shown in 1989.

Since the full autoregressive models give the most detail about the subpatterns which make up the overall pattern of the flows, we will compare these models in detail with the models for the negotiated flow period from 1 April to 15 June of each year. Tables 17 and 18 below give the details for the full autoregression models for the shortened period.

Perusal of Table 17 shows that, like the autoregressive equation for the longer period, no coefficients representing days of the week or months of the year are significantly different from zero in the negotiated period analysis. Thus, the intradaily variation continues to dominate the interdaily variation. Continuing on, the coefficients for the hours of 1 to 3 AM are significant for the negotiated period, whereas the coefficients for 1-6 AM were significant when the model was estimated from the entire three-month data set. However, the models are alike in that the coefficients of the early morning hours are negative. In both equations, the coefficients for the hours 7 to 11 PM are significantly positive, indicating that river flow in these hours is significantly higher than river flow at midnight.

Table 13. Autoregression analysis of the 1989 hourly flow data for the Roanoke River below the Roanoke Rapids dam (March through June).

Reg RSQ 0.0042 Total RSQ 0.9568
Durbin-Watson 1.9966

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	14205.6296	1620.22781	8.768	0.0001
MON	1	-101.1651	272.94721	-0.371	0.7109
TUES	1	-30.6470	347.30003	-0.088	0.9297
WED	1	-10.8952	378.27876	-0.029	0.9770
THURS	1	-40.8397	377.17082	-0.108	0.9138
FRI	1	449.5819	346.93602	1.296	0.1951
SAT	1	-272.6643	266.52020	-1.023	0.3064
MAR	1	777.2021	1784.25993	0.436	0.6632
APR	1	-195.5829	1504.15522	-0.130	0.8966
MAY	1	195.0007	1140.24048	0.171	0.8642
A(1)	1	-1.22611	0.0183662	-66.759	0.0001
A(2)	1	0.3644413	0.02841172	12.827	0.0001
A(3)	1	-0.0680361	0.01989195	-3.420	0.0006
A(7)	1	-0.113799	0.01922658	-5.919	0.0001
A(8)	1	0.1040602	0.02006174	5.187	0.0001
A(11)	1	-0.0426212	0.01213255	-3.513	0.0004
A(14)	1	0.04495622	0.01057301	4.252	0.0001
A(20)	1	-0.0452166	0.007228499	-6.255	0.0001

Table 14. Autoregression analysis of the 1988 hourly flow data for the Roanoke River below the Roanoke Rapids dam (March through June).

Reg RSQ	0.0059	Total RSQ	0.9220
Durbin-Watson	2.0097		

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	4406.32833	732.867494	6.012	0.0001
MON	1	281.21515	214.766479	1.309	0.1905
TUES	1	285.63572	275.305548	1.038	0.2996
WED	1	-10.24840	301.249249	-0.034	0.9729
THURS	1	183.72165	302.271286	0.608	0.5434
FRI	1	-215.08764	277.962567	-0.774	0.4391
SAT	1	4.39435	218.512694	0.020	0.9840
MAR	1	-1178.07630	978.892967	-1.203	0.2289
APR	1	355.62489	887.078577	0.401	0.6885
MAY	1	1368.26069	748.254048	1.829	0.0676
A(1)	1	-1.30487	0.01847568	-70.626	0.0001
A(2)	1	0.4674761	0.02948909	15.853	0.0001
A(3)	1	-0.0708684	0.02098398	-3.377	0.0007
A(6)	1	0.04137029	0.0136689	3.027	0.0025
A(8)	1	-0.0926334	0.02320625	-3.992	0.0001
A(9)	1	0.09310824	0.03002394	3.101	0.0019
A(10)	1	-0.0536803	0.01986725	-2.702	0.0069
A(14)	1	-0.0276169	0.009137263	-3.022	0.0025
A(18)	1	0.02605138	0.01009816	2.580	0.0099
A(21)	1	-0.0531393	0.01351069	-3.933	0.0001
A(23)	1	-0.0484985	0.02197948	-2.207	0.0274
A(24)	1	0.06678328	0.01780114	3.752	0.0002

Table 15. Full autoregression analysis of the 1989 hourly flow data (March through June)

Maximum likelihood estimates

SSE	4381002298	DFE	2887
MSE	1517493	Root MSE	1231.866
SBC	50271.73	AIC	50026.47
Reg RSQ	0.0310	Total RSQ	0.9579
Durbin-Watson	1.9900		

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	14420.6869	1614.76015	8.931	0.0001
MON	1	-126.6871	271.43057	-0.467	0.6407
TUES	1	-60.6186	345.45231	-0.175	0.8607
WED	1	-44.4093	376.27151	-0.118	0.9061
THURS	1	-73.2342	375.16251	-0.195	0.8452
FRI	1	442.3402	345.09652	1.282	0.2000
SAT	1	-297.9736	265.12662	-1.124	0.2612
MAR	1	256.7454	1787.25335	0.144	0.8858
APR	1	-567.6187	1499.70918	-0.378	0.7051
MAY	1	50.1789	1136.17387	0.044	0.9648
ONE	1	-362.4479	118.54126	-3.058	0.0023
TWO	1	-630.2469	183.72164	-3.430	0.0006
THREE	1	-781.6576	226.77114	-3.447	0.0006
FOUR	1	-832.3879	258.70449	-3.218	0.0013
FIVE	1	-737.1341	283.52899	-2.600	0.0094
SIX	1	-592.0131	300.80089	-1.968	0.0491
SEVEN	1	-355.8970	312.71097	-1.138	0.2552
EIGHT	1	214.6664	323.96440	0.663	0.5076
NINE	1	255.8416	332.53029	0.769	0.4417
TEN	1	15.4731	337.13274	0.046	0.9634
ELEV	1	361.2491	339.10665	1.065	0.2868
TWELVE	1	453.4150	340.15857	1.333	0.1827
THIRTN	1	580.9293	339.06820	1.713	0.0868
FOURTN	1	415.5881	337.05043	1.233	0.2177
FIFTN	1	215.9681	332.39573	0.650	0.5159
SIXTN	1	57.0444	323.77251	0.176	0.8602
SEVTN	1	-16.5187	312.46161	-0.053	0.9578
EIGHTN	1	283.3913	300.49475	0.943	0.3457
NINTN	1	620.9651	283.14283	2.193	0.0284
TWENTY	1	820.2132	258.23792	3.176	0.0015
TWONE	1	766.3155	226.19957	3.388	0.0007
TWO2	1	569.2212	182.96576	3.111	0.0019
TWO3	1	304.8676	117.28647	2.599	0.0094
A(1)	1	-1.21638	0.01846166	-65.887	0.0001
A(2)	1	0.3595501	0.02843572	12.644	0.0001
A(3)	1	-0.0765518	0.01992517	-3.842	0.0001
A(7)	1	-0.114314	0.01918534	-5.958	0.0001
A(8)	1	0.09264955	0.01881247	4.925	0.0001
A(13)	1	-0.0540223	0.01890545	-2.857	0.0043
A(14)	1	0.06908646	0.01867408	3.700	0.0002
A(20)	1	-0.0421028	0.007338102	-5.738	0.0001

Table 16. Full autoregression analysis of the 1988 hourly flow data (March through June).

Maximum likelihood estimates

SSE	3069188205	DFE	2884
MSE	1064212	Root MSE	1031.607
SBC	49253.16	AIC	48989.95
Reg RSQ	0.0316	Total RSQ	0.9239
Durbin-Watson	2.0055		

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	4386.12491	746.124223	5.879	0.0001
MON	1	286.20995	214.318445	1.335	0.1818
TUES	1	260.08024	274.617089	0.947	0.3437
WED	1	-29.91557	300.426343	-0.100	0.9207
THURS	1	178.20788	301.482323	0.591	0.5545
FRI	1	-222.41665	277.265691	-0.802	0.4225
SAT	1	1.64151	217.997284	0.008	0.9940
MAR	1	-1412.07971	961.232252	-1.469	0.1419
APR	1	226.92754	873.597660	0.260	0.7951
MAY	1	1311.57417	740.542380	1.771	0.0766
ONE	1	-434.34190	107.271107	-4.049	0.0001
TWO	1	-502.58420	177.249894	-2.835	0.0046
THREE	1	-517.04762	228.295322	-2.265	0.0236
FOUR	1	-562.01558	265.312441	-2.118	0.0342
FIVE	1	-515.01976	290.238238	-1.774	0.0761
SIX	1	-437.38762	305.296530	-1.433	0.1521
SEVEN	1	-380.07624	312.096788	-1.218	0.2234
EIGHT	1	-170.23060	313.673781	-0.543	0.5874
NINE	1	-81.72888	314.168579	-0.260	0.7948
TEN	1	87.06838	314.112091	0.277	0.7817
ELEV	1	165.72417	314.102204	0.528	0.5978
TWELVE	1	75.95043	314.103985	0.242	0.8090
THIRTN	1	114.17640	314.094785	0.364	0.7163
FOURTN	1	160.90025	314.099843	0.512	0.6085
FIFTN	1	96.68162	314.146699	0.308	0.7583
SIXTN	1	226.53863	313.635370	0.722	0.4702
SEVTN	1	514.72528	312.037364	1.650	0.0991
EIGHTN	1	706.81088	305.188377	2.316	0.0206
NINTN	1	875.19572	290.074420	3.017	0.0026
TWENTY	1	1004.58054	265.086924	3.790	0.0002
TWONE	1	1232.85016	228.009547	5.407	0.0001
TWO2	1	1186.42539	176.886714	6.707	0.0001
TWO3	1	500.39175	106.686854	4.690	0.0001
A(1)	1	-1.29744	0.01852195	-70.049	0.0001
A(2)	1	0.46053	0.02949871	15.612	0.0001
A(3)	1	-0.069974	0.02101825	-3.329	0.0009
A(6)	1	0.0367277	0.01376183	2.669	0.0077
A(8)	1	-0.0885116	0.02322461	-3.811	0.0001
A(9)	1	0.08500263	0.0300179	2.832	0.0047
A(10)	1	-0.0488128	0.01993568	-2.449	0.0144
A(14)	1	-0.0328291	0.009295744	-3.532	0.0004
A(18)	1	0.02871413	0.01018487	2.819	0.0048
A(21)	1	-0.0629416	0.01112828	-5.656	0.0001
A(24)	1	0.03392881	0.008964751	3.785	0.0002

Table 17. Full autoregression analysis of the 1989 hourly flow data for the negotiated period (1 April to 15 June).

Maximum likelihood estimates

SSE	218000453	DFE	1739
MSE	125359.7	Root MSE	354.0617
SBC	26133.69	AIC	25930.85
Reg RSQ	0.0323	Total RSQ	0.9965
Durbin-Watson	2.0083		

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	13424.5755	2164.15687	6.203	0.0001
MON	1	10.4833	97.30910	0.108	0.9142
TUES	1	-129.3824	123.72512	-1.046	0.2958
WED	1	-30.6638	136.13931	-0.225	0.8218
THURS	1	17.6681	137.19363	0.129	0.8975
FRI	1	44.3636	125.48592	0.354	0.7237
SAT	1	-85.6983	97.31285	-0.881	0.3786
APR	1	165.0741	492.53120	0.335	0.7375
MAY	1	71.5964	349.88839	0.205	0.8379
ONE	1	-93.5272	42.60709	-2.195	0.0283
TWO	1	-154.7131	67.90791	-2.278	0.0228
THREE	1	-181.4062	87.70068	-2.068	0.0387
FOUR	1	-201.3908	103.82107	-1.940	0.0526
FIVE	1	-219.8828	116.85259	-1.882	0.0600
SIX	1	-226.6120	127.31063	-1.780	0.0753
SEVEN	1	-192.3132	135.63024	-1.418	0.1564
EIGHT	1	-148.6662	142.16213	-1.046	0.2958
NINE	1	-166.0097	147.10421	-1.129	0.2593
TEN	1	-251.9936	150.57809	-1.674	0.0944
ELEV	1	-154.8681	152.65255	-1.015	0.3105
TWELVE	1	-99.6571	153.34614	-0.650	0.5159
THIRTN	1	-49.4666	152.63614	-0.324	0.7459
FOURTN	1	-85.6820	150.54506	-0.569	0.5693
FIFTN	1	-57.9913	147.05391	-0.394	0.6934
SIXTN	1	-50.7739	142.09329	-0.357	0.7209
SEVTN	1	33.2553	135.54073	0.245	0.8062
EIGHTN	1	182.9454	127.19616	1.438	0.1505
NINTN	1	313.5402	116.70593	2.687	0.0073
TWENTY	1	358.0261	103.62923	3.455	0.0006
TWONE	1	348.6826	87.43731	3.988	0.0001
TWO2	1	280.1987	67.51133	4.150	0.0001
TWO3	1	145.7671	41.86950	3.481	0.0005
A(1)	1	-1.3637	0.0236942	-57.554	0.0001
A(2)	1	0.3259354	0.0317815	10.256	0.0001
A(4)	1	0.03875303	0.01585116	2.445	0.0146
A(13)	1	-0.00432896	0.009049315	-0.478	0.6324
A(18)	1	0.007006727	0.007065421	0.992	0.3215

Table 18. Full autoregression analysis of the 1988 hourly flow
11 data for the negotiated period (1 April to 15 June).

Maximum likelihood estimates

SSE	1195463844	DFE	1733
MSE	689823.3	Root MSE	830.556
SBC	29198.43	AIC	28962.69
Reg RSQ	0.0572	Total RSQ	0.9202
Durbin-Watson	1.9900		

Variable	DF	B value	Std. error	T ratio	Approx. prob.
INTERCPT	1	5043.73224	864.501234	5.834	0.0001
MON	1	355.84401	214.227391	1.661	0.0969
TUES	1	189.83275	278.616392	0.681	0.4957
WED	1	-535.10282	312.029365	-1.715	0.0865
THURS	1	-424.55849	312.921434	-1.357	0.1750
FRI	1	-231.24621	286.416424	-0.807	0.4196
SAT	1	-92.54159	221.520001	-0.418	0.6762
APR	1	165.08500	915.829076	0.180	0.8570
MAY	1	758.96596	707.152369	1.073	0.2833
ONE	1	-448.12234	111.260375	-4.028	0.0001
TWO	1	-483.18251	180.216019	-2.681	0.0074
THREE	1	-499.93882	228.545149	-2.187	0.0288
FOUR	1	-511.11266	262.429874	-1.948	0.0516
FIVE	1	-513.73462	286.655375	-1.792	0.0733
SIX	1	-504.34510	300.353374	-1.679	0.0933
SEVEN	1	-393.79824	304.209254	-1.294	0.1957
EIGHT	1	-128.57107	302.792400	-0.425	0.6712
NINE	1	159.43611	302.981035	0.526	0.5988
TEN	1	447.53315	301.993631	1.482	0.1385
ELEV	1	407.49150	298.606367	1.365	0.1725
TWELVE	1	357.58018	296.580957	1.206	0.2281
THIRTN	1	456.46646	298.621968	1.529	0.1266
FOURTN	1	415.98829	301.983649	1.378	0.1685
FIFTN	1	460.25576	302.907163	1.519	0.1288
SIXTN	1	635.38946	302.690997	2.099	0.0359
SEVTN	1	875.69866	304.068871	2.880	0.0040
EIGHTN	1	1046.89686	300.109087	3.488	0.0005
NINTN	1	1132.79519	286.298857	3.957	0.0001
TWENTY	1	1119.26373	261.954353	4.273	0.0001
TWONE	1	1232.26489	227.919793	5.407	0.0001
TWO2	1	1187.97044	179.437506	6.621	0.0001
TWO3	1	474.40553	110.018839	4.312	0.0001
A(1)	1	-1.26112	0.02357723	-53.489	0.0001
A(2)	1	0.471475	0.03682123	12.804	0.0001
A(3)	1	-0.135828	0.02866526	-4.738	0.0001
A(5)	1	0.05456614	0.01747626	3.122	0.0018
A(8)	1	-0.11825	0.0256218	-4.615	0.0001
A(9)	1	0.1233307	0.02797282	4.409	0.0001
A(11)	1	-0.0803032	0.01595271	-5.034	0.0001
A(16)	1	-0.0531715	0.02383796	-2.231	0.0258
A(17)	1	0.06914671	0.02389234	2.894	0.0039
A(22)	1	-0.120951	0.02360733	-5.123	0.0001
A(23)	1	0.08474331	0.0226602	3.740	0.0002

Finally, there is some difference in the autoregressive structure of the residuals. Interestingly enough, there are no lags common to both models except lags 1 and 2, which have opposite signs in the two models.

Turning to the 1988 models, again no monthly or daily coefficients are significant. The coefficients for hours 1 to 3 AM are significant for the negotiated period whereas the hours 1 to 4 AM (Table 14) are significant for the entire three-month period. These are quite similar results. As for the evening hours, the coefficients from 6 to 11 PM are significantly positive when the entire data set is considered, but this time period begins an hour later, at 7 PM when the model is estimated from the negotiated flow period only. As for the autocorrelation structure, the significant lags for both equations are similar in both structure and sign.

In summary, we conclude that the full autoregressive models show more differences between the two recommendation periods in 1989 than in 1988. Thus, the relevant models to consider, when analyzing for policy purposes, would be those estimated from the negotiated flow period.

Figures 10 through 13 summarize what has been found by the full autoregressive analysis concerning hourly flow differences. We have found that approximately 95 percent of the variation in the hourly data is eliminated when the data are averaged to form the daily data. Hence, when analyzing the hourly data, the intradaily variation overwhelms the interdaily variation, so the terms reflecting daily and monthly differences in flow are not significantly different from zero. The only significant coefficients are those which reflect different hours of the day and those which reflect the autoregressive pattern.

Considering all four figures at once, an immediate similarity is that, no matter what year nor what time period, the coefficients for the early morning hours are significantly negative and those for the early and late evening are significantly positive. This suggests, of course, an increase in the flow (relative to the midnight hour) commencing about 6 or 7 PM and a reduction beginning about 1 AM in the morning. This would agree with the pattern of electricity usage which is observed in warm weather months: electricity usage peaks in the late afternoon.

Considering Figures 10 and 11 specifically, we observe they have the same general shape. However, the coefficients estimated from the entire data set in 1989 are generally much larger than those estimated from the negotiated period. This indicates that during the negotiated period the intradaily variation was smaller than during the period as a whole. In contrast, the overall pattern is still there in 1988, as shown in Figure 11, but the size difference in the coefficients is not as noticeable.

Figure 12 compares the coefficients for the three-month period in 1988 and 1989. Again, the same general pattern is evident. The 1988 coefficients seem somewhat more negative in the early morning than those of 1989, however the 1989 coefficients are somewhat larger in the evening hours than the 1988 coefficients.

Finally, Figure 13 compares the coefficients of the negotiated periods for both years. Again, the same general pattern appears throughout the day, however, the coefficients for 1989 are smaller (more negative) in the early morning and larger in the evening.

Two conclusions come from this analysis. 1) For 1989, the flow during the negotiated period, from 1 April to 15 June, was less variable than for the period as a whole. This is because the early morning coefficients were less negative and the late evening coefficients were less positive relative to midnight. In 1988, the differences in the time period made little difference in the magnitude of the coefficients. 2) The biggest difference between 1988 and 1989 is found in comparisons of the negotiated periods, supporting the prior conclusion illustrated in Figure 13.

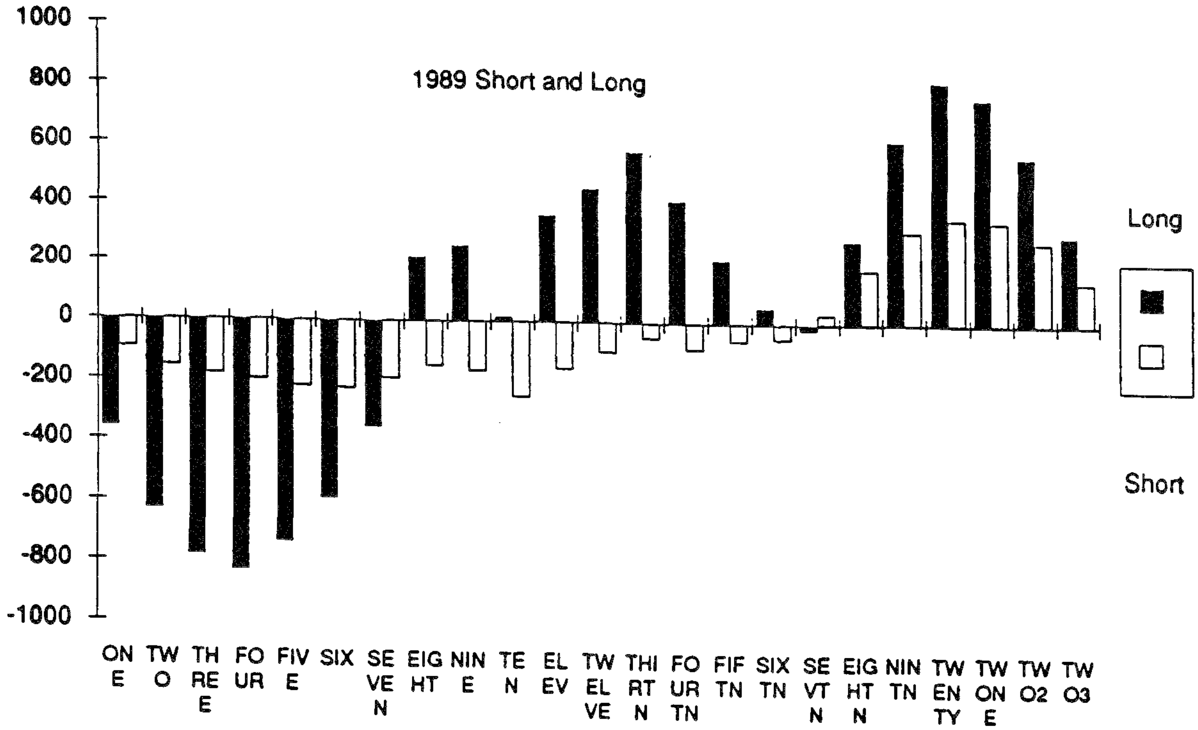


Figure 10. Comparison of hourly coefficients for the negotiated period (short) and the original recommendation period (long, March-June) using the 1989 data set.

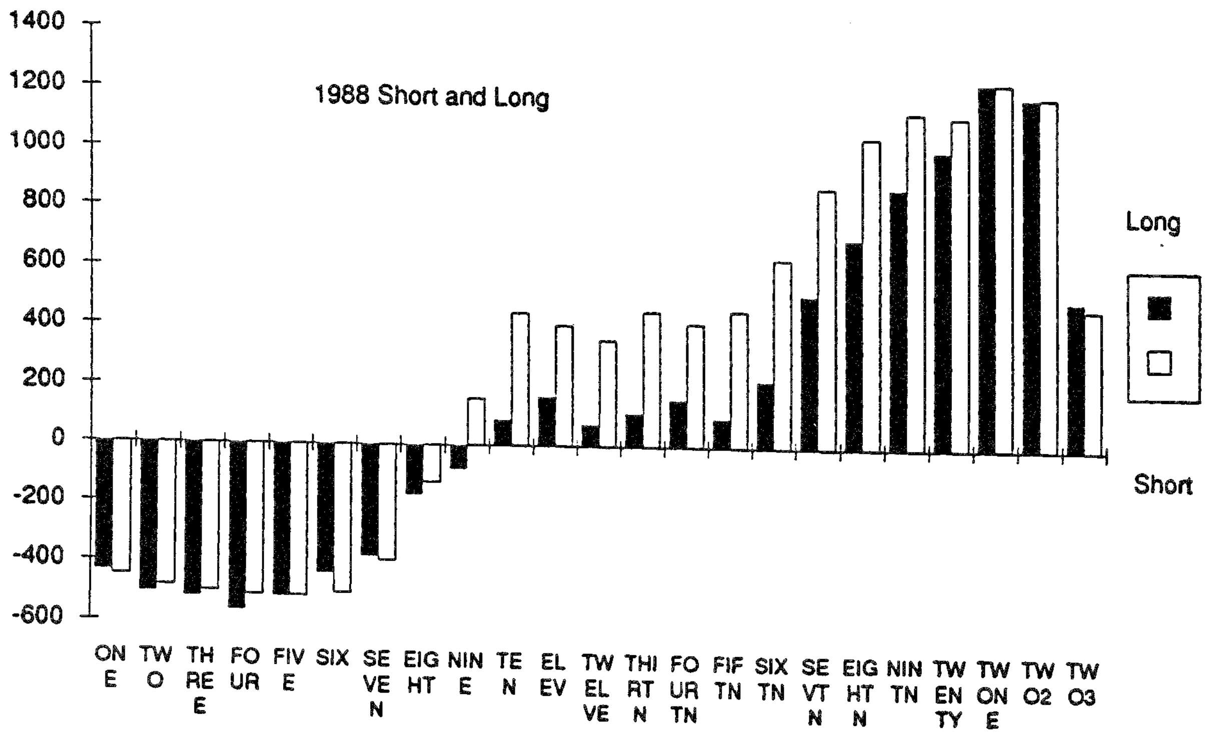


Figure 11. **Comparison of hourly coefficients for the negotiated period (short) and the original recommendation period (long, March-June) using the 1988 data set.**

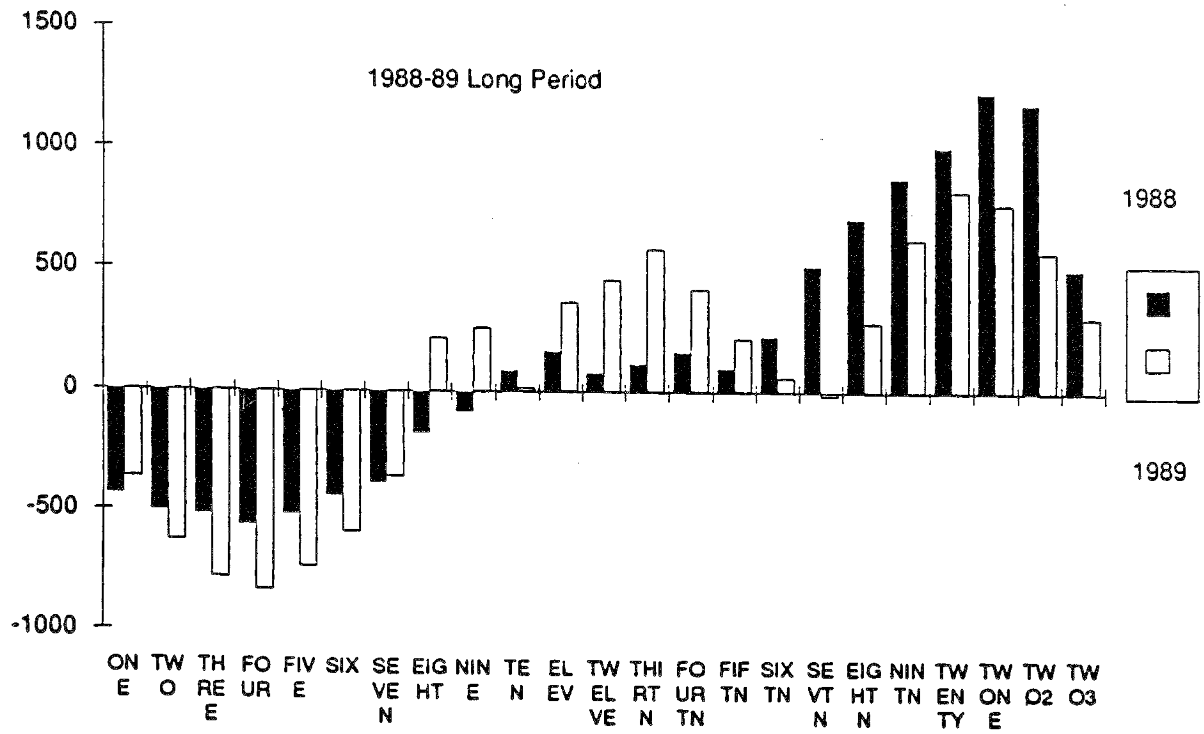


Figure 12. **Comparison of hourly coefficients for 1988 and 1989 river flows for the original recommendation period (long, March-June).**

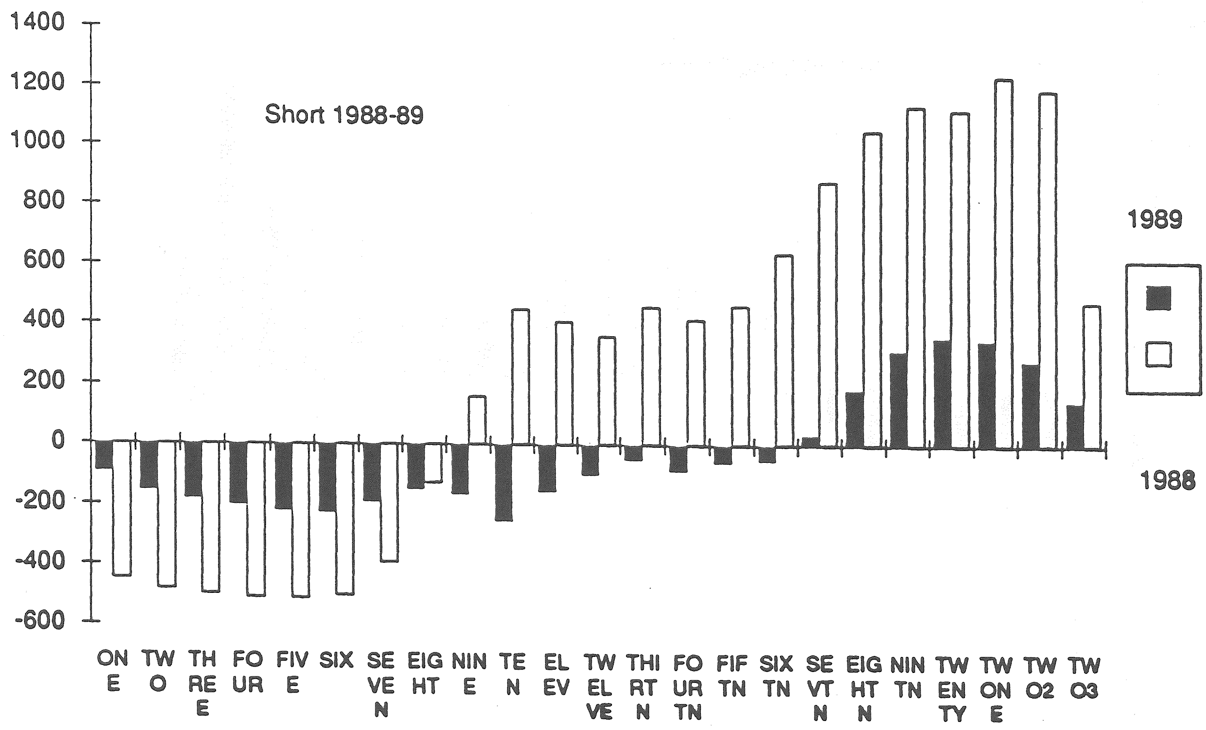


Figure 13. Comparison of hourly coefficients for 1988 and 1989 river flows for the negotiated period (short, 1 April to 15 June).

Graphical Analysis of Variability

Figure 14 shows a comparative analysis of the daily variability of the flow over the 1 March to 30 June time period. The graph was constructed by calculating, for each day in the period, the standard deviation of the hourly data for each year. The standard deviation for 1988 was then subtracted from the standard deviation for 1989 by day. Thus, each bar represents the difference, for that particular day, between the standard deviation in 1989 and that in 1988. A positive result indicates that on a particular day the flow was more variable in 1989 than in 1988; conversely, a negative result indicates the daily value was more variable in 1988 than in 1989.

Also indicated on the graph are the approximate limits of the spawning period as shown in the egg sampling data. Clearly, every single day in this critical period during 1989 was less variable than the corresponding day in 1988. Indeed, after approximately 1 May, practically all of the flows in 1989 were less variable than those on the corresponding days in 1988.

Other Hydrological Considerations:

1989 Reservoir Operation in Hindsight

Roger A. Rulifson and Max B. Grimes

The Roanoke River Water Flow Committee held a meeting at East Carolina University in July 1989 to review the hydrological and biological events that occurred during the first half of 1989. Prior to the meeting, the Corps of Engineers, Wilmington District, was asked to prepare hypothetical scenarios of water releases from the Roanoke Rapids Reservoir had *a priori* knowledge been available to assist in the process. Max Grimes of the Wilmington District created two hypothetical models for discussion at the meeting.

Figure 15 depicts a hypothetical water release schedule designated as "perfect operation." The top panel (a) indicates how the Kerr Lake elevation might have differed from the observed, and the lower panel (b) indicates what the Corps considers a perfect release schedule under the limitations of the negotiated Q1-Q3 boundaries. Initially, water releases from Roanoke Rapids Reservoir would have matched the first Q3 (upper) boundary from 1 April to 16 April. This release schedule would have resulted in the absence of flooding actually observed from 11 April to 15 April (Figure 15b) and a Kerr Lake elevation below the Rule Curve target (Figure 15a). During the second two-week flow period beginning 15 April, flows would have been reduced at 1,500 cfs per hour to the next Q3 (upper boundary) level until 22 April, at which time Kerr elevation would have fallen below 300.0 feet msl (Figure 15b). At that point, water release would have adjusted to the Q1 (lower boundary)limit in an attempt to preserve water storage in Kerr for discharge through the remainder of the negotiated flow period. However, the high inflows of early May due to increased run-off necessitated abandoning the Q1-Q3 boundary limitations and implementing flood control procedures. A return to the Q3 boundary around 26 May would have reduced the downstream flooding event by several days without affecting evacuation of Kerr flood storage. The Q3 flow limit would have represented the rate of discharge through 9 June, at which time elevation in Kerr would have exceeded the Rule Curve and water evacuation procedures take effect.

The second hypothetical scenario uses the target flows established as part of the negotiated flow regime (Table 2). Initial moderate water releases in early April (Figure 16) would have resulted in releases slightly above the Q3 limit from 11 April to 15 April, but would have reduced the amount of flooding downstream from that actually observed during that period

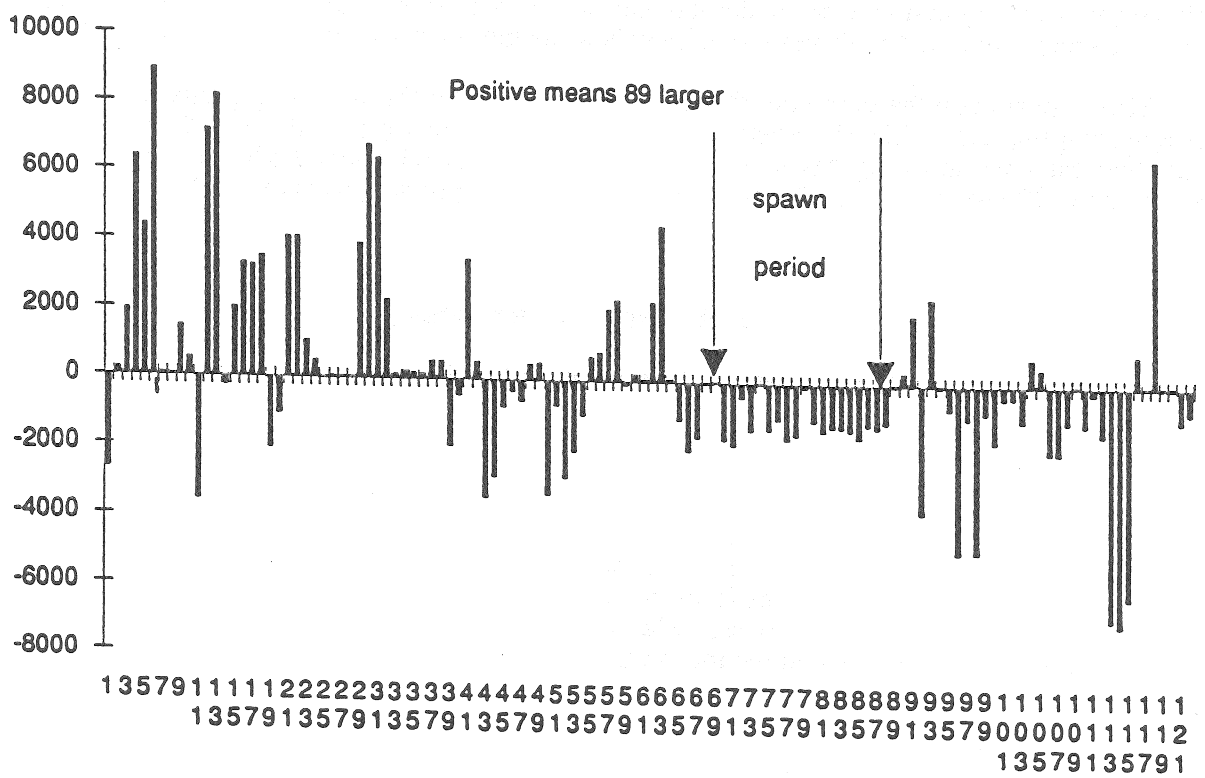


Figure 14. Comparison of the standard deviations in flows by date for 1988 and 1989. Positive values means that flow instability on that date in 1989 was greater.

(Figure 16b). Following target flows during this time would have resulted in Kerr elevations closer to the Rule Curve (Figure 16a). Again, around 15 April flows would have been reduced to the second set of target flows of the negotiated flow regime, resulting in more moderate and stable flows than that actually observed in 1989 (Figure 16b), and Kerr Reservoir levels closely approximating the Rule Curve (Figure 16a). The flooding event during May precludes the use of target flows during the three-week period. At the end of May, water releases reduced to the target flow for the period would have resulted in lower moderate and stable flows compared to the actual flow patterns recorded; Kerr elevation would have remained closer to the Rule Curve (Figure 16a).

In summary, hypothetical flow models run by the Corps for the 1989 spring spawning period suggests that coordinating water releases using the negotiated flow regime target flows would have improved and stabilized hydrologic conditions downstream of Roanoke Rapids Dam during certain periods of 1989. However, the point must be made that these models were generated after the period in question; the Corps of Engineers did make a good faith attempt at managing flow releases as close to the negotiated flow regime as practicable given that future rainfall in the watershed is not as predictable as one might wish.

Other Hydrological Considerations:

Kerr Lake Flow Guides

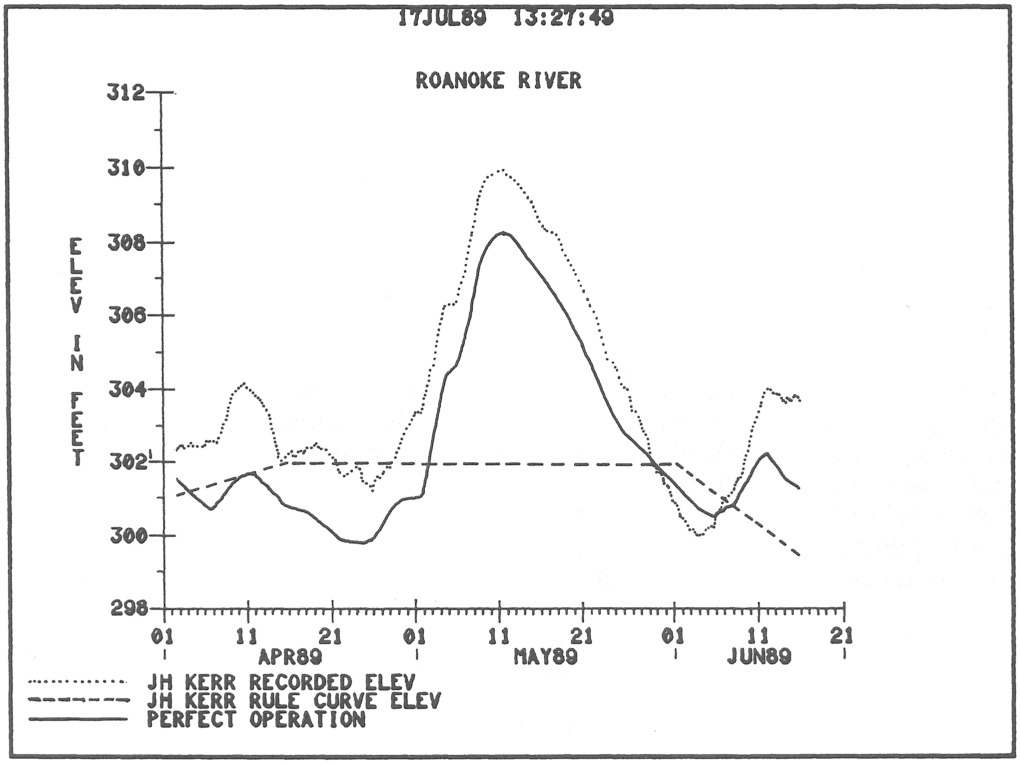
David Crawford

To begin a meaningful discussion on the likelihood of achieving the recommended flow regime for most years, it is necessary to take a look at Kerr Project operation. This is not to say that the Kerr operation is flawed, but only that the negotiated flow regime has added another possible constraint.

To meet the flow regime targets, it may be necessary to consider that the storage window is wider than elevations 299.5 to 302.0 feet above sea level. This assumption would apparently violate stated goals for flood control (> elevation 302.0 feet) and power production (< elevation 299.5 feet). However, it may be possible to operate Kerr for flood control and power as well as for striped bass. Several examples of a hypothetical operation are given below which, naturally, raise more questions than are answered. The purpose of this hypothesis is to at least bring operational or Rule Curve changes into the discussion. Granted, such changes would require major review by the Corps, possibly even an Environmental Impact Statement and congressional action.

The operations of Kerr in 1988 and 1989 provide examples of a good flow year (1988) for the combined downstream resource and a relatively bad year for the resources (1989, because of the numerous high flow days). To perform an analysis on what could have been, an operational guideline with respect to flow regime needs to be established. This guideline does not, at the present, consider the impact upon power production (which may be positive as well as negative), or impact upon recreational facilities at Kerr Lake. Nor does the assumed guide address flood control impact, although some comments are given below.

What is the objective of instituting a regimented flow regime? In my opinion it is to provide a river flow that provides all life stages of the striped bass a good opportunity to thrive, supports quality wildlife habitat, and provides good growth and harvest conditions for row crop agriculture and timber. This objective implies a target flow somewhere around the expected flow. As nature is not so obliging, the recommended [negotiated] flow regime also tries to bracket the target flow by providing a minimum flow and maximum flow. This range is the



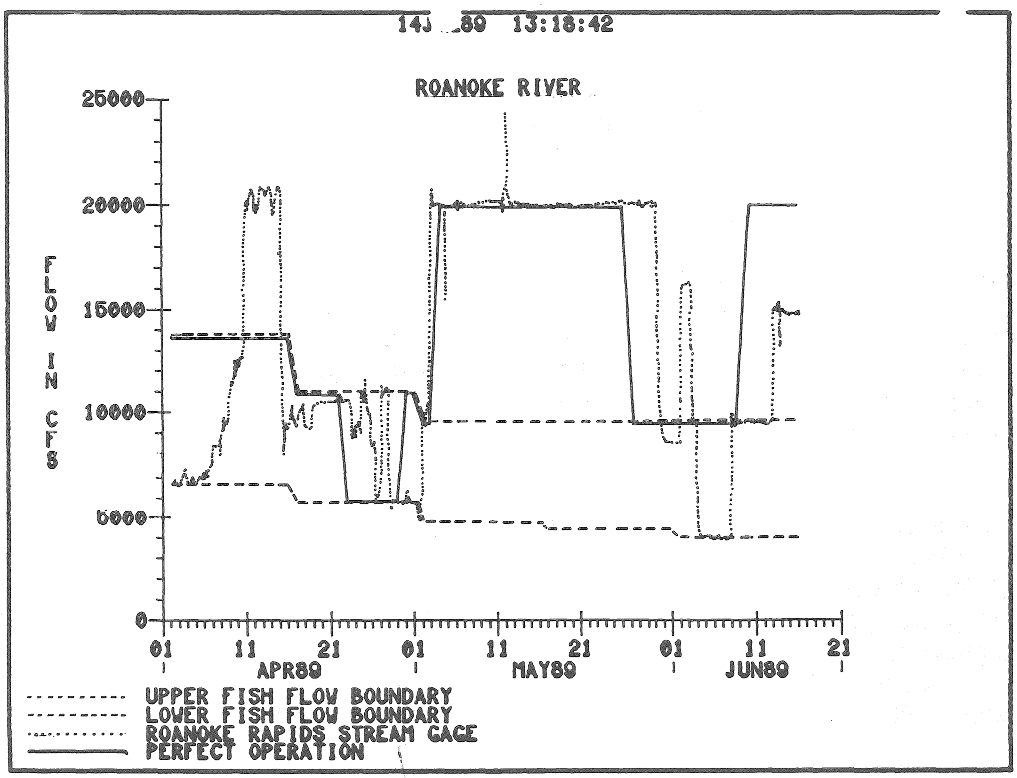
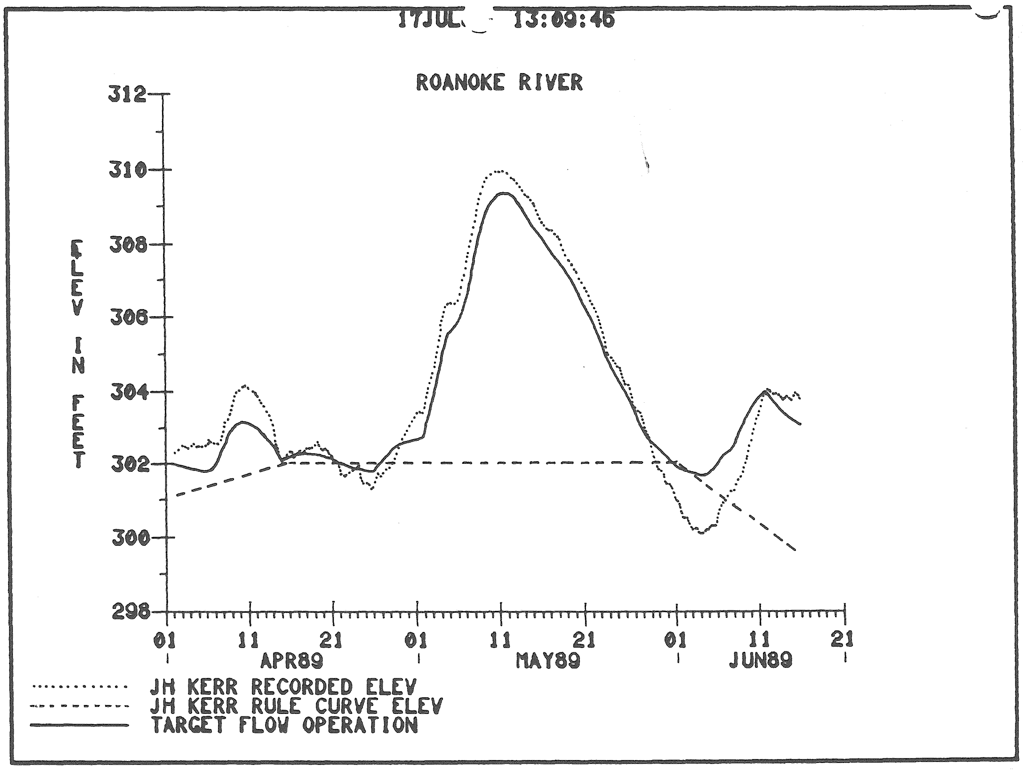


Figure 15. U.S. Army Corps of Engineers, Wilmington District, modeling of 1988 Kerr Reservoir water releases under a "perfect operation" scenario showing (a) hypothetical changes in Kerr surface water elevation relative to the Rule Curve and observed values, and (b) river flow downstream of Roanoke Rapids Dam relative to the Q1-Q3 bounds and observed values.



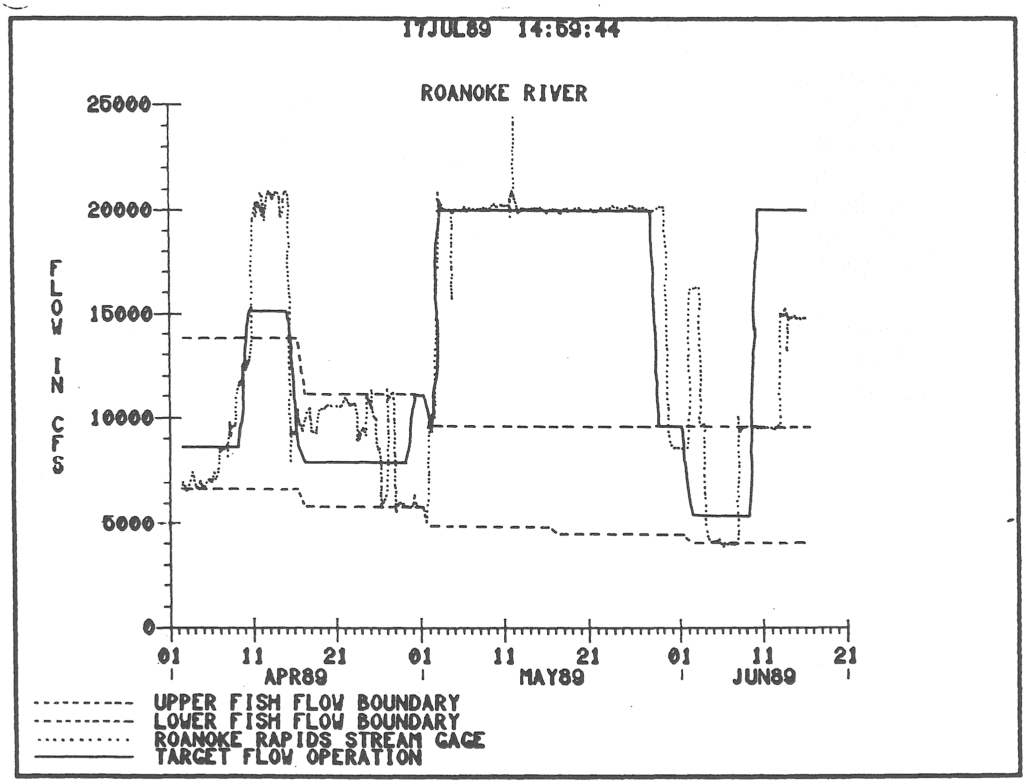


Figure 16. U.S. Army Corps of Engineers, Wilmington District, modeling of 1989 Kerr Reservoir water releases under a "target flow operation" scenario showing (a) hypothetical changes in Kerr surface water elevation relative to the Rule Curve and observed values, and (b) river flow downstream of Roanoke Rapids dam relative to the Q1-Q3 bounds and observed values.

critical parameter in this discussion, as it is the maximum and minimum values which need to be considered with respect to the operation of Kerr, especially when Kerr Lake level is out of the 299.5 - 302.0 feet elevation window. Therefore, given that Kerr Lake can provide considerable control to flow and assuming that the 299.5 - 302.0 elevation window can be adjusted, a hypothetical guide would be:

Example Flow Guide for the lower Roanoke River

Kerr Lake level (ft.)	April	May	June
<300	minimum	minimum	minimum
300<EL<302	expected	expected	maximum
302<EL<305	maximum	maximum	maximum
EL>305	flood control	flood control	flood control

This guide follows the recommended flow regime, with the minimum, expected, and maximum values tied to the time of year. The flow guide would release control back to normal operation if Kerr level rises above elevation 305. It assumes that April and May are more important than June for meeting target flows and also that they have a lower flood risk than June (hence, the change to maximum flow in June if Kerr Lake exceeds 300 feet msl).

Figures 17 and 18 provide results of applying the above flow guide to operations for years 1988 and 1989, respectively. The adjustment to flow at Roanoke Rapids and elevation of Kerr is given in part (a) and (b), respectively. These adjustments were made by storing water at Kerr or releasing water from Kerr to modify the recorded flow at Roanoke Rapids to give the guide flow and noting the change in storage needed. Obviously, this is a simplification of the actual operation, but it does provide a useful tool in gaining an insight into the possibilities for operational change at Kerr to meet a flow regime objective or constraint.

Reexamination of the 1988 flow release schedules using the flow guide is as follows. Release of water at the minimum (6000 cfs) in early April results in drawdown of Kerr rather than filling of the reservoir as was actually observed. In 1988, a flow regime was under discussion, so the old agreement was in place, which called for release no sooner than 15 April. At this time, the Corps of Engineers was attempting to store water to allow for augmentation flow releases during striped bass spawning activity. The effects upon striped bass spawning of providing augmentation flow beginning the first half of April (in addition to other flow effects) requires review by appropriate fishery specialists. For the remainder of April, river flows are close to the expected flows and are higher and more stable than that actually observed. For May and June, the guide flows are lower but more stable than those actually observed (Figure 17a).

Figure 17b shows the effects of guide flows upon Kerr elevation. Note that the elevation, although lower than that actually recorded in 1988, remains within the 299.5 - 302 window from mid-April to mid-June, then crosses over the recorded level, ending higher and nearer the Rule Curve.

The spring of 1989 was very wet, with Kerr Reservoir providing essential flood control. It was not a good year, however, for regulating river flow for striped bass spawning activity because of the need to release, for long periods, 20,000 cfs (as dictated by operational rules).

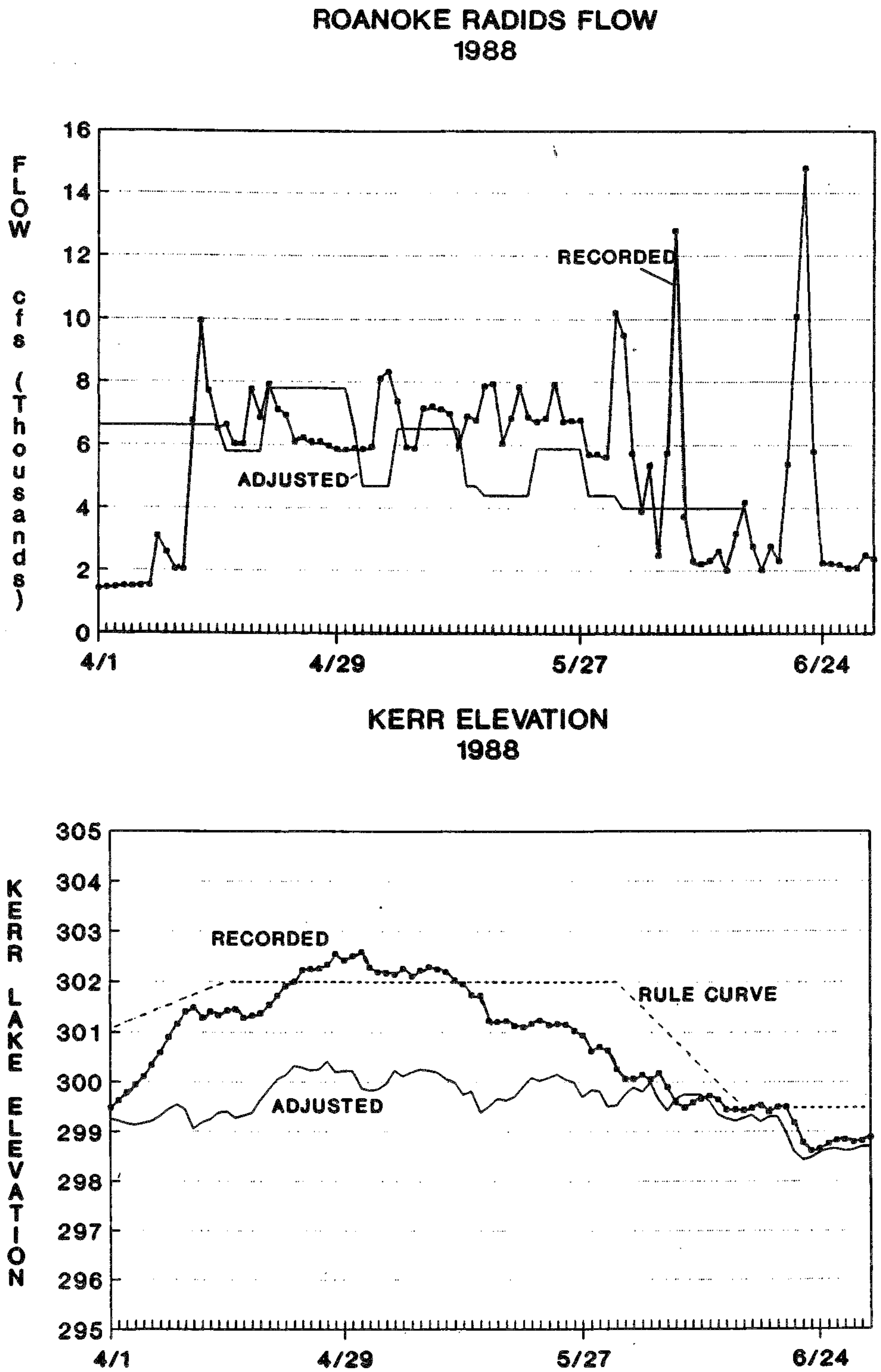


Figure 17. Actual recorded flow (cfs) and hypothetical flow of the Roanoke River (a), and the actual and hypothetical Kerr elevation levels (b), for 1988 based on the "flow guide" method of reservoir management.

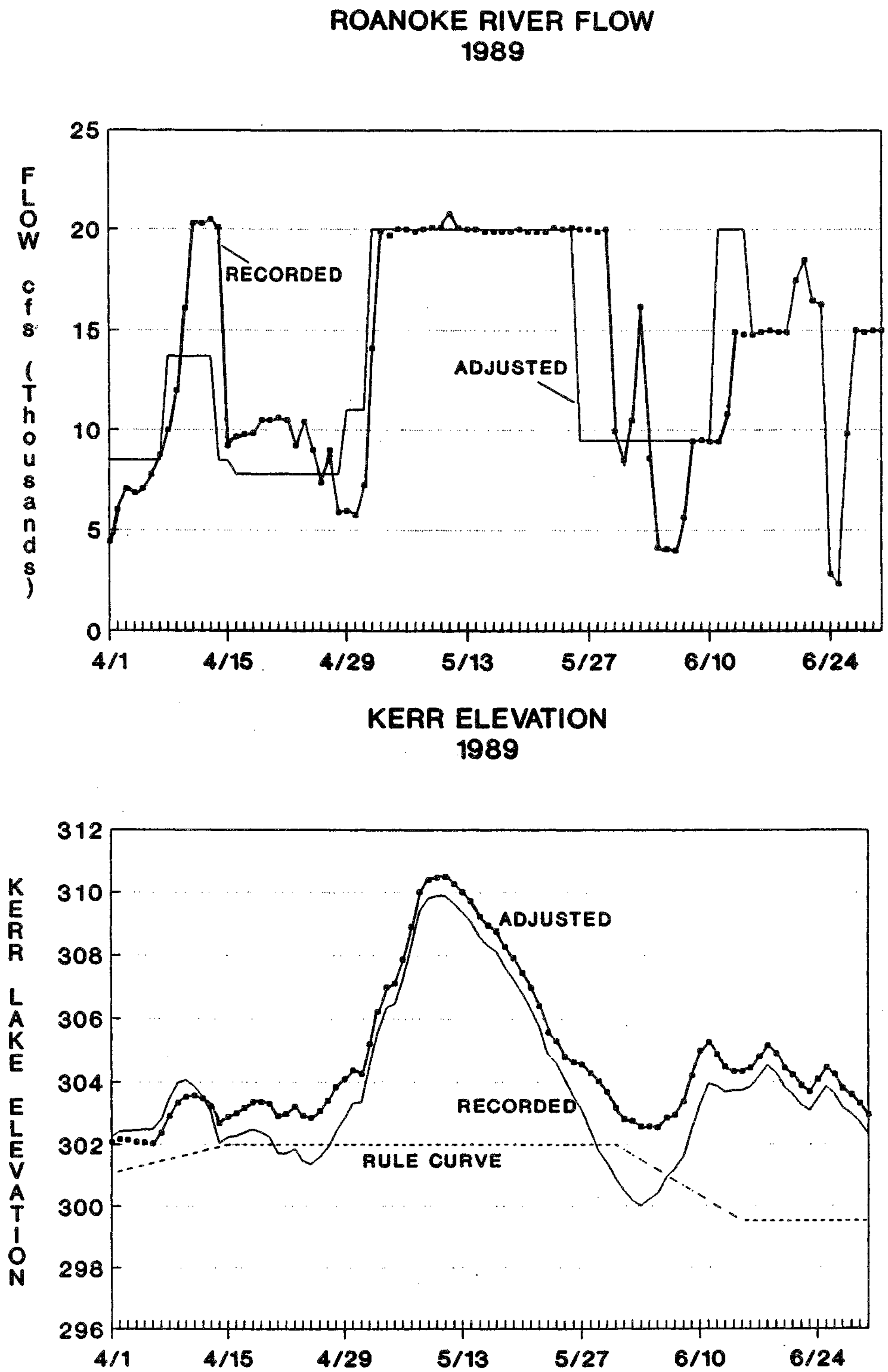


Figure 18. Actual recorded flow (cfs) and hypothetical flow of the Roanoke River (a), and the actual and hypothetical Kerr elevation levels (b), for 1989 based on the "flow guide" method of reservoir management.

However, the flow guide hypothesized above and used for 1988 was again applied to 1989 resulting in the adjusted flow at Roanoke Rapids depicted in Figure 18a and modified Kerr elevation in Figure 18b.

The net result of the modifications to flood control by assuming the flow guide controls operation up to elevation 305 is an additional one foot of water in the reservoir (Figure 16b). On Memorial Day, the elevation could have been at least two feet higher, thus bringing in the question of impact to recreation, obviously an important consideration in the Corp's operation of Kerr. River flow below Roanoke Rapids (Figure 16a) is not changed significantly in May and early June except for being more stable. In April, however, a major flood peak is eliminated - an event which would be expected to be controlled given the objective behind the maximum values provided by the recommended flow regime.

This flow guide analysis could be recreated for all years on record to determine the average effect upon Kerr elevation as well as effects during flood and drought years. Multi-year simulation is also needed to determine the effect upon hydropower operation, not only during April through June but also for the summer months. The hypothetical flow guide may result in higher or lower reservoir elevations at the end of the striped bass spawning season, and this would affect power production. Economic impacts of controlled peaking operation at Roanoke Rapids also requires consideration.

The flood risk associated with this hypothetical flow guide may not be raised substantially, given the relative occurrence of peak inflows for April and May and the results presented for 1989. The operation during 1989 shows a willingness on the part of the Corps to maintain Kerr Reservoir above the Rule Curve (around elevation 304) and provide releases (if averaged) not far removed from the maximum suggested by the negotiated flow regime, but substantially below the 20,000 cfs discharge during April and May.

13

WATER QUALITY OF THE LOWER ROANOKE RIVER, 1988-1989

Roger A. Rulifson

Water quality monitoring in 1988 and 1989 was conducted at several locations by four separate studies. The Roanoke River downstream of the striped bass spawning grounds at Weldon was monitored every four hours for basic water quality information from mid-April through early June as part of a striped bass egg production and viability study (Rulifson 1989; Rulifson, in preparation). The lower river, delta, and Batchelor Bay were monitored for basic water quality on an alternate day basis at selected stations as part of a study concerning abundance and timing of phytoplankton, zooplankton, and larval striped bass in downstream areas (Rulifson, Stanley, and Cooper, in preparation). In addition, water samples were collected weekly in 1988 for intensive water quality analyses of nutrients and metals at upstream and downstream locations (Rulifson et al. 1990).

Spring 1988

In 1988, water quality of the lower Roanoke River was monitored every four hours from 14 April to 8 June at River Mile (RM) 105, known as Pollock's Ferry, which is approximately 24 miles downstream of Weldon, NC (Figure 19). The station corresponded to the site selected for monitoring striped bass spawning activity in the spring of 1988 (Rulifson 1989).

Water quality samples were also collected within the Roanoke delta at sites designated Station 6 (Middle River), Station 7 (above Weyerhaeuser on the Roanoke mainstem), Station 10 (mainstem just upstream of the Highway 45 bridge), and Station 8 (Cashie River). Stations in the delta were sampled weekly. Complete methodology and the resultant data base were presented in Rulifson et al. 1990. A summary of the results was presented in Manooch and Rulifson (1989).

Two factors resulted in rather stable river flow at Pollock's Ferry during the 1988 study: moderate input of runoff from the watershed, and the attempt by the Corps of Engineers and Virginia Power to regulate downstream flow as per the guidelines of the negotiated flow regime, which at the time was still being discussed. The water quality information obtained by the Rulifson et al. (1990) study therefore represented good baseline data on the results of moderating flows downstream of hydropower projects.

Water quality of the Roanoke, Middle, and Cashie Rivers was generally good during the 1988 striped bass spawning season. Some changes in water quality between the upstream and downstream sites were apparent, but there were no significant diel variations in water quality at Pollock's Ferry, nor vertical variations in the water column at Stations 7 and 10 in the lower Roanoke River. This could be attributed to the moderation of hydropower releases at Roanoke Rapids Dam during the study.

At Pollock's Ferry, water temperature was 13° C on 14 April and increased to 24° C by the end of May. The in-situ pH ranged from 6.7 to 7.9. The lowest pH value of 6.7 was observed on 17 May. Dissolved oxygen values remained above 5.0 mg/L throughout the study.

At the delta stations, water temperatures ranged from a low of 11.0° C on 14 April to a high of 24.0°C on 9 June. Levels of dissolved oxygen dropped below 5 mg/L in late April and

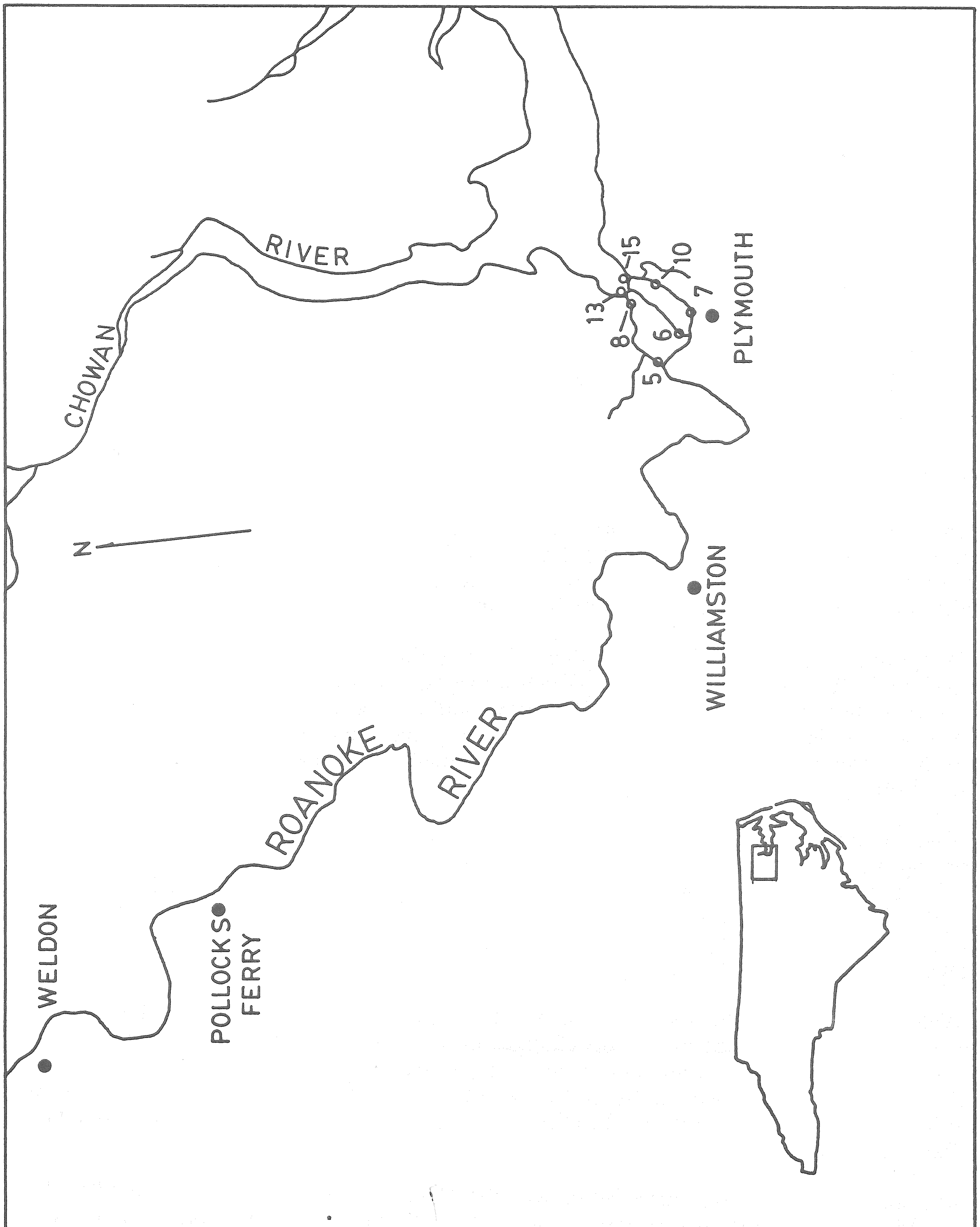


Figure 19. Map of the lower Roanoke River and western Albemarle Sound depicting water quality monitoring stations for 1988.

early May. Decreasing dissolved oxygen concentration with depth was evident at several stations. Salinity remained consistently below 1.0 ppt at all stations throughout the study. Values of pH usually remained above 7.0.

Low alkalinities recorded in 1988 indicate that waters of the lower Roanoke watershed are soft and poorly buffered. Little variation in alkalinity was evident among sampling sites, averaging about 26 mg/L (as $CaCO_3$) for all stations of the Roanoke and Middle Rivers. However, the Cashie River alkalinity averaged slightly lower at 22 mg/L (as $CaCO_3$).

Conductivity averaged 100 umhos at Pollocks Ferry and in the Cashie and Roanoke Rivers, except for the area near Highway 45 bridge, which averaged 125 umhos. This portion of the river is below Weyerhaeuser's pulp mill and the Plymouth wastewater treatment plant.

Color of the Roanoke River water increased with distance downstream. Delta waters averaged about 50 color units, more than twice the color found upstream at Pollocks Ferry. This difference could be due to swamp land drainage and/or color from pulpmill discharge. Pulp mill effluent probably contributed to the consistently higher color (57 color units) at the Highway 45 bridge. A peak in color values on 10 May corresponded to a large rainfall event in the lower watershed on 4-6 May, but no directed sampling efforts were conducted to confirm the relationship.

Suspended material in the water column was quantified by measuring turbidity and total suspended solids (TSS). Increased turbidity and TSS values are often associated with storm events and subsequent runoff and increased river flow. Turbidity ranged from 12 ntu at Pollocks Ferry to 22 ntu in the Cashie River. Middle River turbidity averaged 20 ntu, and lower Roanoke Stations 7 and 10 averaged 15 ntu and 17 ntu, respectively. The low turbidity values of the Rulifson et al. (1990) study indicated the relative stability of river flow.

Average TSS values were also low for the Roanoke in 1988, ranging from 13.8 mg/L at Pollocks Ferry to a high of 24.8 mg/L in the Cashie River. The volatile fraction of the suspended solids (VSS) ranged between 15 and 20 percent of the TSS. These turbidity and suspended solid concentrations are typical for eastern North Carolina rivers.

The biochemical oxygen demand (BOD) is a function of the type and amount of carbonaceous material present in the water. Overall, BOD values were low at all locations and averaged about 1 mg/L. A general decline in BOD values was evident during mid-May, but increased toward the end of the study. This trend corresponded with a rainfall event during 4-6 May, but no confirming data were collected.

Carbon content of Roanoke water, quantified by analyzing total (TOC) and soluble (SOC) organic fractions, increased with distance downstream. TOC at Pollocks Ferry averaged 5.6 mg/L, doubling in concentration downstream to 13.2 mg/L at Station 6 and 11.0 mg/L at Station 7. About half (3.3 mg/L) of the TOC content at Pollocks Ferry was SOC. The Cashie River had the highest average TOC concentration at 21.7 mg/L; about 76 percent (16.5 mg/L) of the total was SOC.

Concentrations of inorganic nitrogen in the lower Roanoke watershed increased with distance downstream. At Pollocks Ferry, the ammonia nitrogen (NH_3-N) concentration averaged 0.063 mg/L and the nitrate/nitrite (NO_3/NO_2-n) concentration averaged 0.142 mg/L. Downstream, total inorganic nitrogen increased by almost 50 percent at Stations 6 and 7, averaging about 0.2 mg/L. Total inorganic nitrogen increased to 0.32 mg/L at the Highway 45 bridge. The Cashie River had lower inorganic nitrogen concentrations, averaging 0.08 mg/L NH_3-N and 0.16 mg/L NO_3/NO_2-N. Only trace quantities of NO_2-N, averaging 0.006 mg/L, were found at all locations during the study.

Total organic and ammonia nitrogen, known as total Kjeldahl nitrogen (TKN), also increased in the Roanoke with distance downstream. At Pollock's Ferry, waters had an average TKN of 0.34 mg/L, of which 0.28 mg/L was organic nitrogen. Higher TKN values were found downstream at Stations 6 and 7, averaging about 0.45 mg/L; organic nitrogen concentration rose slightly to 0.35 mg/L. For the Roanoke mainstem, TKN was consistently highest below Weyerhaeuser at Station 10 with an average of 0.62 mg/L; organic nitrogen was 0.47 mg/L. The Cashie River exhibited a similar organic nitrogen concentration of 0.46 mg/L.

Average total phosphate (TPO_4) concentrations did not vary significantly among stations but exhibited a tendency to increase with distance downstream later in the season. Pollock's Ferry was the lowest with an average of 0.14 mg/L, while the lower Roanoke, Middle, and Cashie Rivers ranged from 0.15 to 0.17 mg/L. Orthophosphorus increased from an average of 0.05 mg/L at Pollock's Ferry to 0.08 mg/L in the Middle River. Highest average orthophosphorus was 0.09 mg/L at the Highway 45 bridge.

Generally, sulfate (SO_4) concentrations were similar throughout the study site, averaging about 10 mg/L. The Cashie River, averaging 6.7 mg/L, was the exception. However, from 26 April through the remainder of the study, Station 10 below Weyerhaeuser and Plymouth exhibited consistently higher values compared to upstream stations. The sulfate concentrations were similar to those reported for the Neuse River by Harned (1980).

In 1988, all metals concentrations in the Roanoke, Middle, and Cashie Rivers were below the North Carolina criteria for freshwater except for iron, manganese, and a single cadmium measurement of 16 ug/L at Station 15 (Batchelor Bay) on 31 May.

Iron concentrations increased with distance downstream. Pollock's Ferry values averaged 0.644 mg/L, which is below the 1976 USEPA criteria of 1.0 mg/L for protection of freshwater aquatic life (USEPA 1976). However, iron concentrations doubled downstream: averages ranged from 1.072 mg/L at Station 10 to 1.510 mg/L in the Cashie River. No seasonal changes were evident.

Manganese concentrations also increased with distance downstream, averaging 0.05 mg/L at Pollock's Ferry, 0.081 mg/L above Weyerhaeuser, and 0.085 at the Highway 45 bridge. Highest values of 0.119 mg/L occurred in the Cashie River. A seasonal increase in manganese was evident in the Cashie River, but the cause was undetermined. The USEPA criteria for manganese is 0.1 mg/L for protection of aquatic life.

Sodium exhibited no seasonal trends, averaging about 9,100 ug/L. Station 10 below Weyerhaeuser and Plymouth consistently was highest in sodium concentrations, averaging 13,926 ug/L.

Zinc concentrations were highest in the Middle (34 ug/L) and Cashie (28 ug/L) Rivers, and lower at the other sites. Several relatively high values were observed at several delta sites (up to 97 ug/L), the origin of which was not determined. Within the Roanoke River, an increase in zinc values was observed in mid-May, followed by a general decline.

Arsenic and selenium analyses on samples from mid-April to mid-May 1988 showed no detectable concentrations. Analyses on these elements were discontinued on the sixth week of the Rulifson et al. (1990) study due to budgetary constraints.

Several metals exhibited temporal variation in concentration. Total aluminum concentrations increased in May and were most noticeable in the Middle and Cashie Rivers, where concentrations peaked at 2.7 mg/L and 2.0 mg/L, respectively. Iron, manganese, barium, TSS and

VSS concentrations followed the temporal trend of aluminum. The Roanoke larval striped bass study conducted in 1985 found similarly high total aluminum concentrations (Rulifson et al. 1986a).

Although no intensive water quality data base exists prior to the Rulifson et al. (1986a) study, the authors of the 1988 study believed that the 1988 water quality information represented an initial "optimal flow" data base for a number of water quality parameters. Rulifson et al. (1990) pointed out that this data base includes only the spring and does not consider summer months, when operation of hydropower facilities typically results in extremely low flow rates just above the minimum guidelines (1,000 to 2,000 cfs).

Spring 1989

Patterns of water release from Roanoke Rapids Reservoir were described previously. Changes in several water quality parameters were apparent at Barnhill's Landing (Figure 2) during the striped bass egg production study.

Reduction in water release during the latter part of April resulted in a lowering of river stage (Figure 20) and slowing of surface water velocity (Figure 21). Water temperatures increased (Figure 22). Just prior to the sudden increase in discharge on 2 May, a drop in surface water pH and reduction in secchi visibility was noted (Figures 23 and 24). At first glance, these phenomena did not fit the overall pattern throughout the study. However, upon closer inspection, changes in these two parameters reflected a rainfall event in the lower watershed, which caused a drop in river pH and increased turbidity. Several hours later, Virginia Power Company began releasing waters at the maximum rate, which caused a sudden shift in pH, reduction in turbidity, and reduced water temperatures.

During the three-week period of high reservoir discharge, secchi disk visibility, pH, and water velocities all remained high until the end of May and early June, when reservoir releases were reduced to pre-spawning levels. These conditions of high stable flows resulted in water temperatures gradually rising from 15^oC to 18^oC (Figure 22). Once water temperatures reached 18^o C, peak spawning activity occurred but much later in the season than that reported in Hassler's annual reports.

There were three spills in the lower River documented during 1989, all originating from the Weyerhaeuser Plant at Plymouth, NC:

1. On 20 April 1989, 3,000 gallons of sodium hypochlorite were spilled directly into the River. A total of 244 fish were "officially counted as killed": crappie, bluegill, pumpkinseed, largemouth bass, and assorted other species. Cost of investigation and replacement by WRC was $731.00.

2. On 20 July 1989, Several million gallons of "untreated plant wastes" spilled into Welch Creek. No dead fish were observed due to very heavy rains. Investigation costs to WRC totalled $323.92.

3. On 17 September 1989, 2.5 million gallons of "untreated plant wastes" and 2,000 gallons of sodium hydroxide spilled into Welch Creek. A total of 26,211 fish were officially counted as killed: catfish, bluegill, largemouth bass, crappie, pumpkinseed, etc. Investigative and replacement costs to WRC were $19,568.

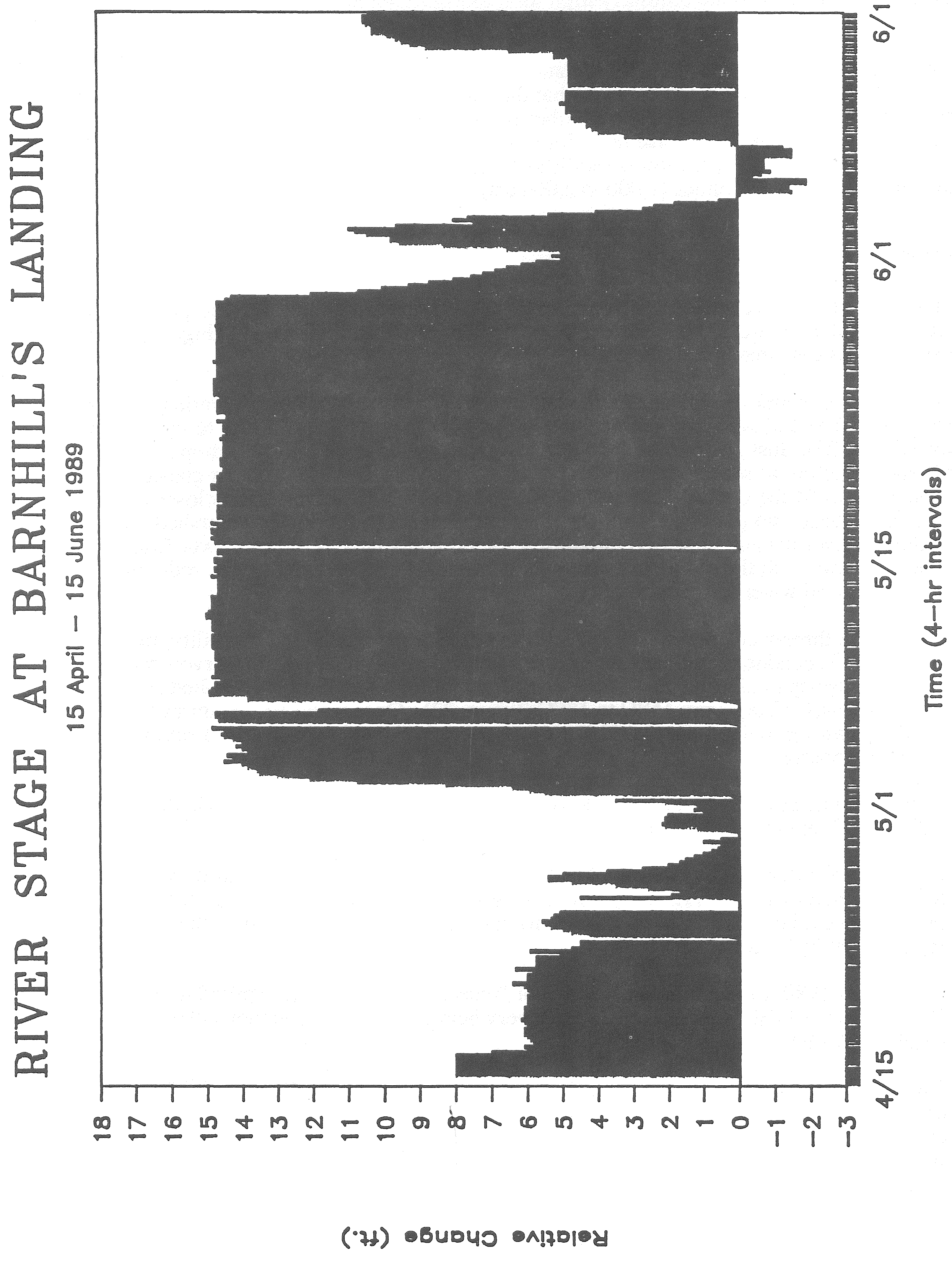


Figure 20. Relative change in stage of the Roanoke River at Barnhill's Landing (RM 117) from 15 April to 15 June 1989.

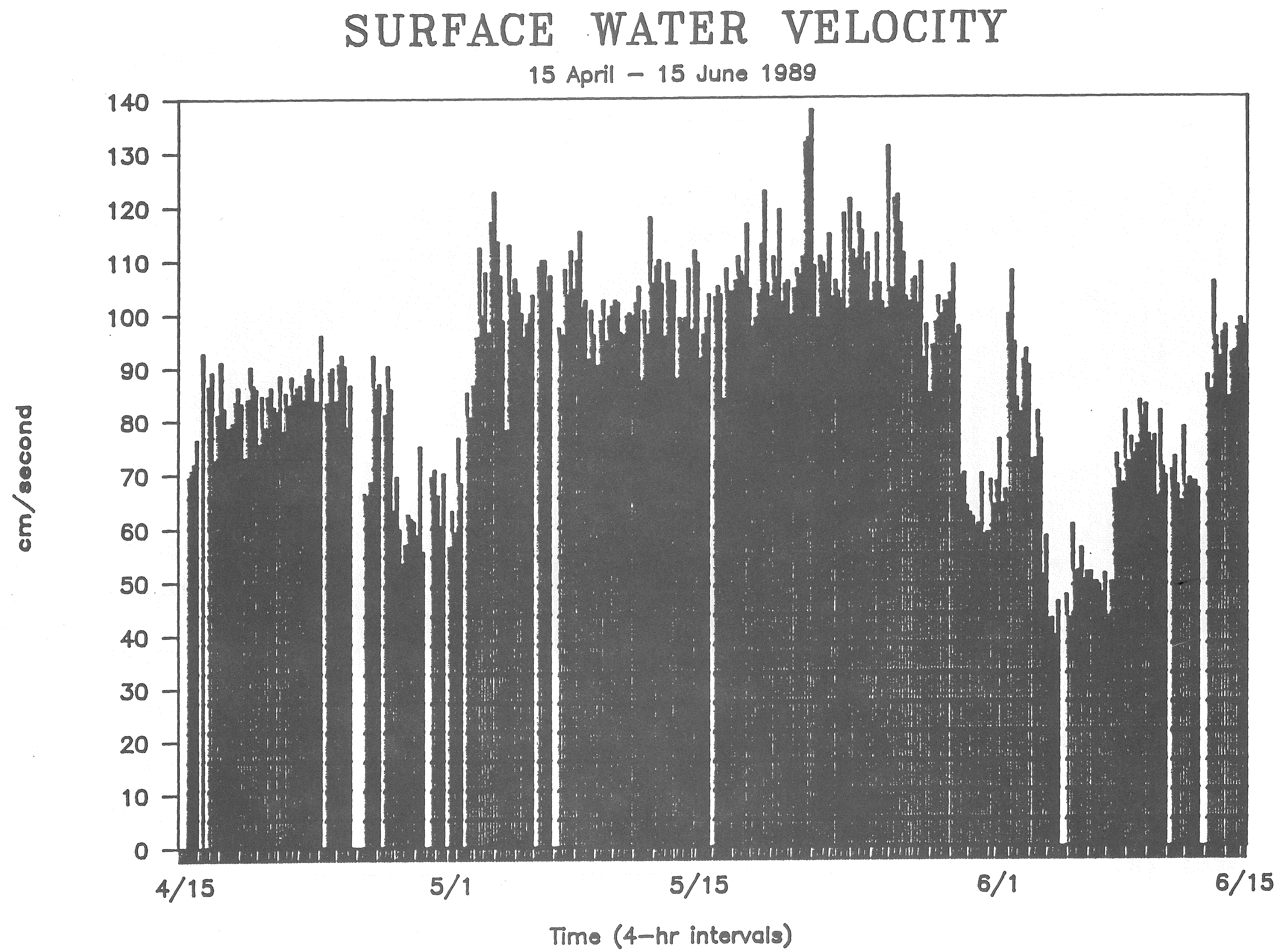


Figure 21. Surface water velocity (cm/second) of the Roanoke River at Barnhill's Landing (RM 117) from 15 April to 15 June 1989.

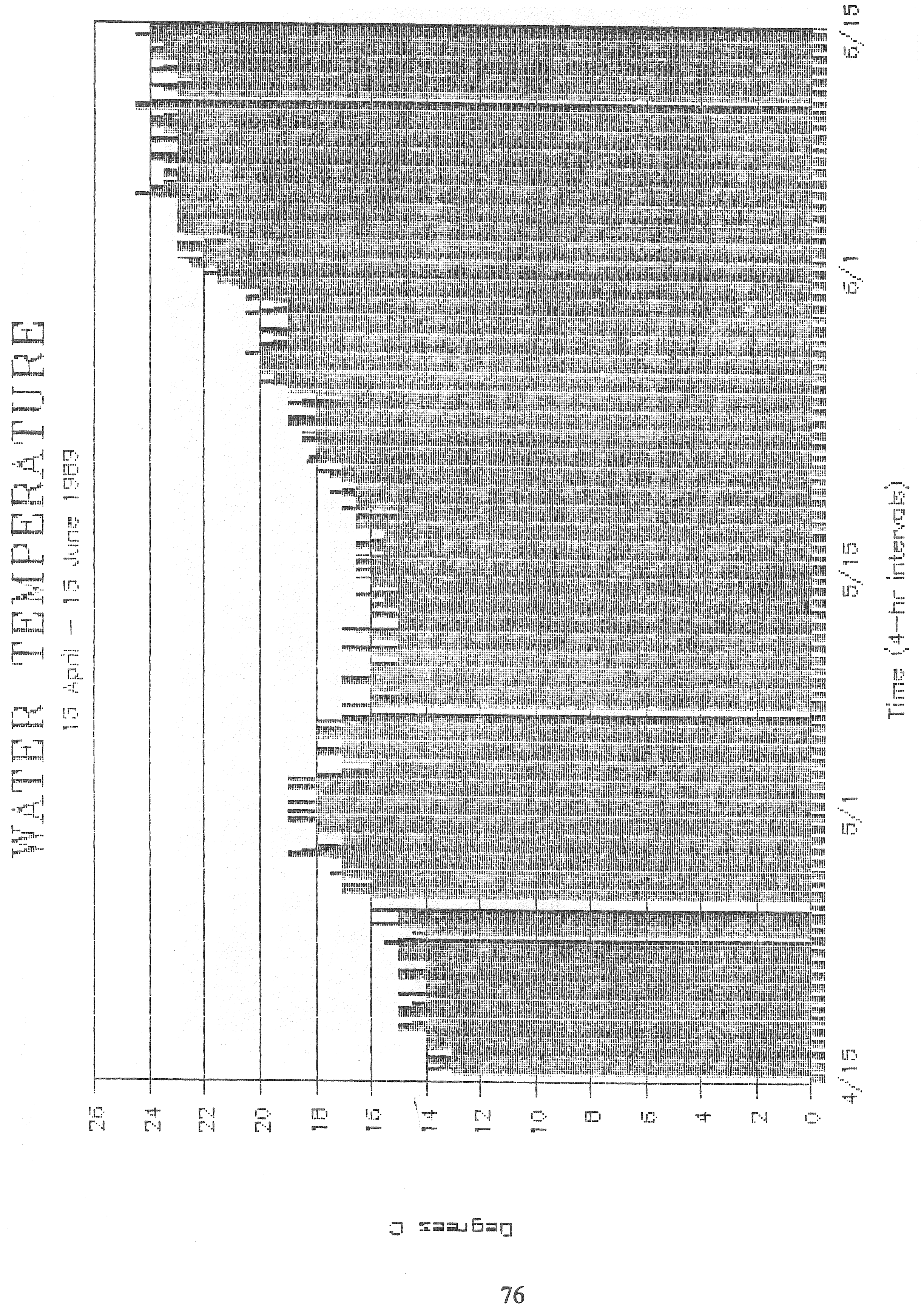


Figure 22. Surface water temperature (C) of the Roanoke River at Barnhill's Landing (RM 117) from 15 April to 15 June 1989.

14

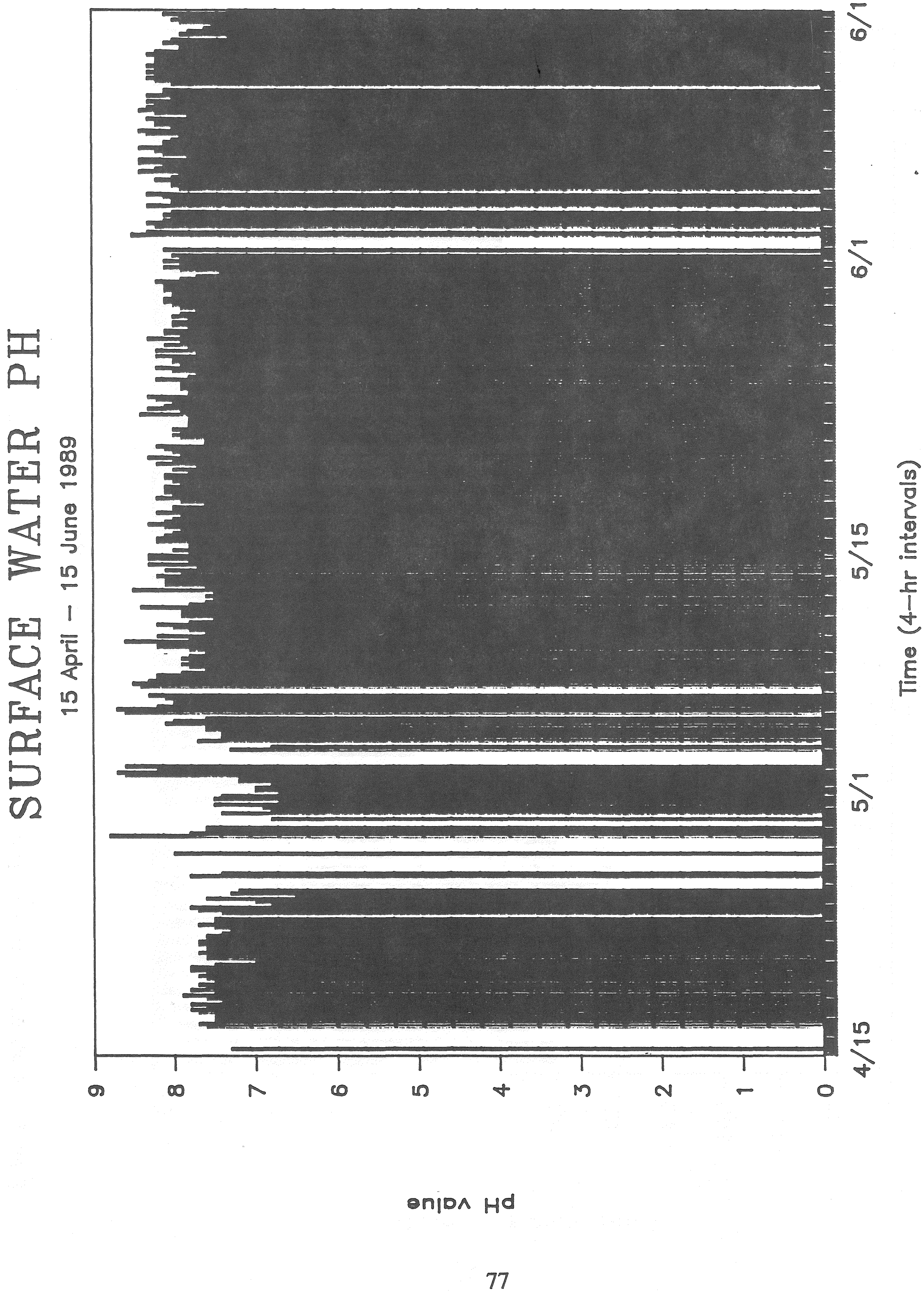


Figure 23. Surface water pH of the Roanoke River at Barnhill's Landing (RM 117) from 15 April to 15 June 1989.

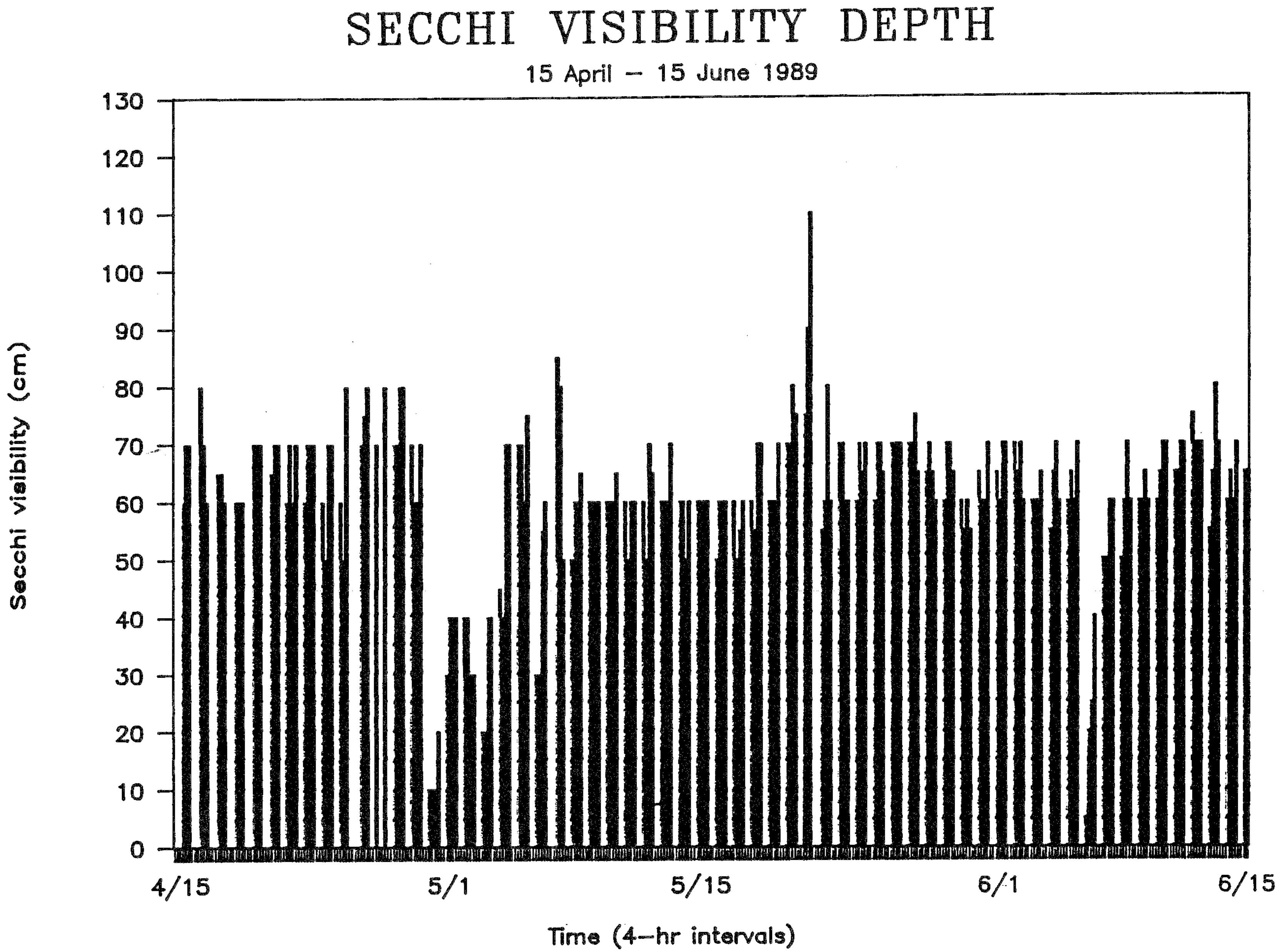


Figure 24. Secchi visibility depth (cm) of the Roanoke River at Barnhill's Landing (RM 117) from 15 April to 15 June 1989.

STRIPED BASS

Age Composition (1988) and Sport Harvest (1988-1989) of Striped Bass from the Roanoke River

Kent L. Nelson and Anthony W. Mullis

Methods

A non-uniform probability stratified access point creel survey was used to estimate sport fishing effort and harvest of striped bass, largemouth bass (*Micropterus salmoides*), and other species from Roanoke River during the striped bass spawning seasons of 1988 and 1989. The number of striped bass released by sport anglers was also estimated. The creel survey was designed by the NC State University Institute of Statistics and will be conducted at least through 1990.

The creel survey was conducted throughout the unimpounded reach of the Roanoke River from the Roanoke Rapids Lake Dam downstream to the river's mouth at Albemarle Sound comprising a surface area of approximately 3,016 ha (Fish 1968). The river was divided into 3 zones with the upper 2 zones (I and II) comprising the segment designated as inland waters (Figure 25). The lower zone (III) is designated as joint waters under the combined jurisdiction of the North Carolina Wildlife Resources Commission (WRC) and the North Carolina Division of Marine Fisheries (DMF). The creel survey was conducted from 28 March - 19 June in 1988 and 27 March - 18 June in 1989. These 12 weeks were divided into 6 two-week periods. The creel survey was stratified with respect to type of day, i.e. weekday or weekend (defined as all Fridays, Saturdays, Sundays, and Memorial Day), zone, and period. Probabilities of sampling the respective stratifications were assigned based on anticipated total fishing effort.

Two creel clerks interviewed anglers returning from fishing trips at selected boating access areas to provide data necessary to calculate catch per unit of effort. Probabilities of sampling (interviewing) at each respective access area were assigned based on its anticipated use by striped bass anglers relative to the others. Probabilities of sampling within each zone during each period were assigned based on migration patterns of spawning striped bass. Data collected from each fishing party interviewed included date and time of the interview, time fished, number in the party, species fished for, catch of striped bass, largemouth bass and other species, and the county of residence of the anglers. All data were recorded on an interview form.

Total fishing effort was estimated from counts of empty boat trailers at boating access areas along the river. Counts were made on two weekdays and two weekend days per week. The end of the river at which the trailer counts began were selected randomly, and the times of day during which trailers were counted were selected based on probabilities of anticipated fishing activity. The trailer counts and relevant data were recorded on field sample sheets.

In 1989, procedures were modified slightly to improve accuracy of estimates for total fishing pressure. Trailer counts in 1989 were adjusted to eliminate non-sport fishermen, which included commercial and recreational net fishermen, hunters, and recreational boaters. Data were adjusted based on the proportion of sport fishermen observed by the creel clerk within each zone by period and day of the week. In addition, in 1989 one minor access area was deleted from the trailer counts and one added (Plymouth), where trailer counts were made for the last few weeks of the sample period.

Total length in millimeters, weight in kilograms, and sex were recorded and a scale sample was collected from each striped bass harvested by interviewed anglers. Scales were

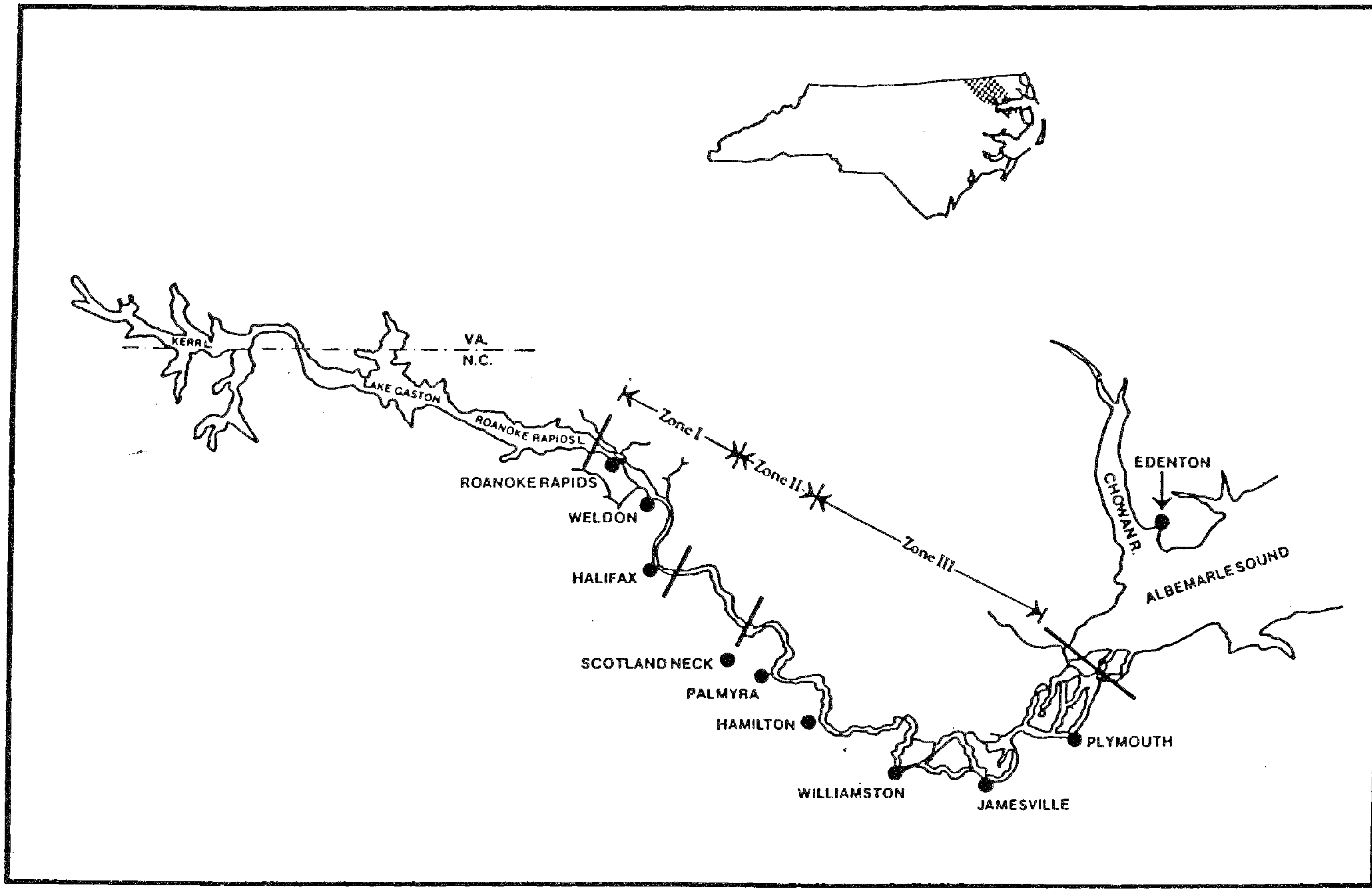


Figure 25. Map of the Roanoke River and vicinity depicting the three study zones for the striped bass creel survey in 1988 and 1989.

removed from the left side of the fish below the lateral line near the end of the depressed pectoral fin. Scales were examined at 33x magnification on a Micro Design Model 995 microfiche reader, and ages were determined by counting annuli.

Estimates of fishing effort and catch of striped bass and other species were compiled by the NC State University Institute of Statistics. The number of fish caught in 1988 in each age class by sex and the average size were compared to previous data to evaluate changes in the age composition of the spawning striped bass population.

Results

An estimated total of 234,621 (1988) and 153,185 (1989) angler-hours of sport fishing effort was exerted by Roanoke River anglers during the spring. Most of the effort occurred in Zone III: 70 percent (1988) and 66 percent (1989) (Figure 25). Nineteen percent (1988) and 28 percent (1989) of the effort occurred in Zone I, while 11 percent (1988) and 6 percent (1989) was found in Zone II.

Approximately 100,000 (1988) and 46,600 (1989) angler-hours of recreational fishing effort were directed specifically for striped bass (Table 19). Most of the striped bass effort in 1988 was exerted in the lower river (Zone III) and in the vicinity of the spawning grounds (Zone I). In 1989, however, most effort (78 percent) was concentrated in Zone I. Effort for striped bass peaked in 1988 during period 4 (9-22 May), at and slightly after the peak of striped bass spawning activity. In 1989, greatest effort occurred in about equal proportions between 10 April and 21 May (periods 2-4).

Largemouth bass anglers exerted an additional 21,067 (1988) and 31,272 (1989) angler-hours of effort (Table 19). Effort for largemouth bass was concentrated in the lower portion of the river. Largemouth bass fishing pressure was relatively evenly distributed over the study period in 1988 and peaked during period 6. Greater variability was found in effort for largemouth bass per period during 1989.

Fishermen seeking other species, primarily catfish (*Ictalurus* spp.), sunfish (*Lepomis* spp.), and white perch (*Morone americana*) exerted about 112,000 (1988) and 64,000 (1989) hours of sport fishing effort. Most effort for other species was exerted in the lower portion of the river, and it was distributed throughout the study period.

Estimated harvest of striped bass from the Roanoke River was 16,657 fish in the spring of 1988 and 8,753 in 1989. Total weights harvested were estimated at 33,927 kg (74,796 lb) in 1988 and 14,594 kg (32,174 lb) in 1989 (Table 20). The number of fish harvested was highest in Zone I during 1988 and 1989. Most of the estimated harvest by weight in 1988 occurred in Zone I (45 percent) and III (50 percent), while in 1989 most weight was taken in Zone I (96 percent). Almost 9,000 striped bass were caught and released, primarily in Zone I, in both 1988 and 1989. As a result, the total catch was highest in Zone I: 65 percent (1988) and 98 percent (1989).

Striped bass harvest and the number of striped bass released was highest during period 4 in 1988 and period 3 in 1989 (Table 21). Estimated striper catch was higher during the periods prior to the spawning peak than after it. The catch fell to very low levels in late May and June.

The overall success rate for striped bass harvest by sport fishermen was 0.075 fish and 0.151 kg per angler hour in 1988 and 0.058 fish and 0.096 kg per hour in 1989. Harvest rates were greatest in Zone I during both years with anglers harvesting 0.200 fish and 0.341 kg per hour in 1988 and 0.189 fish and 0.313 kg per hour in 1989. Striped bass were caught and released at the rate of 0.170 (1988) and 0.191 (1989) fish per angler-hour in Zone I.

Table 19. Fishing effort (angler-hours) exerted specifically for striped bass, largemouth bass, and other species on Roanoke River in spring 1988-1989 by zone and period (2-week intervals beginning 28 March in 1988 and 27 March in 1989).

Zone or period	Angler-hours by species					
	Striped bass		Largemouth bass		Other species	
	1988	1989	1988	1989	1988	1989
Zone						
I	40,151	36,542	885	286	2,986	6,690
II	18,381	2,913	380	151	7,204	5,064
III	41,449	7,110	19,802	30,834	101,762	52,371
Period						
1	17,897	685	3,538	1,861	15,590	3,436
2	18,850	13,208	2,017	7,679	25,368	13,155
3	17,014	11,925	3,644	4,837	10,822	24,773
4	38,498	11,694	2,214	8,224	20,070	6,862
5	5,833	4,795	2,194	6,846	14,031	7,961
6	1,889	4,259	7,460	1,824	26,071	7,937
Total	99,981	46,566	21,067	31,272	111,952	64,126

Table 20. Estimated catch of striped bass from Roanoke River in spring, 1988-1989 by zone. Standard errors are in parentheses.

	Harvested					
	Number		Weight (kg)		Number Released	
Zone	1988	1989	1988	1989	1988	1989
I	8,827 (2,660)	8,473 (2,404)	15,355 (4,542)	14,085 (3,938)	7,682 (3,242)	8,590 (2,282)
II	929 (377)	153 (73)	1,746 (694)	427 (188)	501 (242)	48 (45)
III	6,901 (6,987)	127 (59)	16,826 (17,465)	82 (34)	715 (612)	28 (30)
Total	16,657 (9,736)	8,753 (2,355)	33,927 (21,861)	14,594 (3,891)	8,898 (4,040)	8,666 (2,312)

Table 21. Estimated catch of striped bass from Roanoke River in spring 1988-1989 by period (2-week intervals beginning 28 March in 1988 and 27 March in 1989).

	Harvested					
	Number		Weight (kg)		Number Released	
Period	1988	1989	1988	1989	1988	1989
1	1,233	99	1,754	38	375	0
2	2,485	2,207	4,287	3,490	1,224	2,024
3	2,333	3,331	4,739	5,384	1,896	3,245
4	10,097	2,097	22,340	3,948	4,782	2,285
5	294	827	430	1,357	621	948
6	215	192	377	377	0	164
Total	16,657	8,753	33,927	14,594	8,898	8,666

15

An estimated 4,338 largemouth bass weighing 2,542 kg (5,604 lb) were harvested by sport anglers in 1988 and 5,023 fish weighing 4,288 kg (9,453 lb) were harvested in 1989. Most of the largemouth bass harvest occurred in Zone III. Sport anglers also harvested over 475,000 (1988) and 124,000 (1989) fish of other species weighing about 133,000 kg (1988) and 50,000 kg (1989). Almost all fish of other species were caught in Zone III.

More people from Halifax County fished in the Roanoke River in the spring of 1988 and 1989 than from any other county (Table 22). Relatively few of the fishing parties interviewed were residents of counties which border the downstream portion of Roanoke River. Approximately one-third of the people who fish in the Roanoke River in the spring do not live in a county adjacent to it.

Scale samples were collected from 934 angler-caught striped bass in the spring of 1988. The ages of 912 of these were successfully determined. A total of 699 (77 percent) of the aged fish were males, and 213 (23 percent) were females (Table 23).

Age composition of striped bass examined during the 1988 study revealed most of the males were 3, 4, and 5 years old while most of the females were 5, 6, 7, and 8 years old. Few males over 8 years of age were caught and few females were over 9 years old. The youngest fish caught were 2 years old and were primarily males. Less than 3 percent of the females caught were less than 4 years old.

While the numbers of fish caught from Zones II and III are low, the age composition of the 1988 catch from these zones was somewhat younger than that of Zone I (Table 24). Unlike in Zones I and II, clerks examined many more female striped bass than males in Zone III.

Discussion

The adjusting of trailer counts in 1989 to eliminate non-sport fishermen has likely increased the accuracy of estimates of fishing effort and harvest. Most of the boaters on the Roanoke River during the creel period are sport fishermen. Estimates were reduced slightly, but to an undetermined degree, in comparison to 1988 figures as a function of this adjustment. An estimated 77.8 (1988) and 50.8 (1989) angler-hours of sport fishing effort were exerted per hectare on the Roanoke River during the 12-week period of the study. Only 3.82 angler-hours of sport fishing effort were exerted per hectare per year on adjacent Albemarle Sound in the late 1970's (Mullis and Guier 1982). Albemarle Sound is an open water system with a relatively high proportion of area that is devoid of fish concentrating cover, while anadromous fish species are concentrated in the Roanoke River while on their spawning migrations.

Hassler et al. (1981) estimated the sport harvest of striped bass from Roanoke River to be as high as 65,399 fish in 1971, but not less than 15,000 fish per year prior to 1981. However, the downward trend in harvest had been identified by 1981, and a series of regulation changes designed to reduce the harvest of striped bass began that year. The regulation changes included the prohibition of special devices (e.g. bow nets) for catching striped bass in 1981, reduction of the daily creel limit from 25 to 8 fish in 1981 and further to 3 fish in 1985, and increasing the size limit (recorded as total fish length) from 305 mm (12 in.) to 406 mm (16 in.) in 1982. The estimated harvest ranged from about 4,000 to 7,000 fish from 1981 through 1984 (Hassler and Taylor 1984, 1986a). In 1985, the estimated harvest of 3,499 fish was the lowest on record (Hassler and Taylor 1986b), but a steady increase over the next 2 years brought harvest to over 10,000 fish in 1987 (W.W. Hassler, N.C. State University, pers. commun.). Hassler's estimates and those generated in this study are not directly comparable because different methods of estimation were used. While estimated harvest of 16,657 fish in 1988 represented an increase in comparison to recent years, the 1989 harvest is within the range observed since 1986.

Table 22. County residency composition (%) of anglers interviewed during the spring 1988-1989 Roanoke River creel survey.

County or area	Percent 1988	Percent 1989
Bertie	4	3
Halifax	33	41
Martin	10	5
Northampton	16	15
Washington	3	2
Other NC counties	33	32
Nonstate resident	1	2

Table 23. Mean total lengths (mm) and weights (kg) and number of male and female striped bass by age caught by Roanoke River anglers interviewed during spring 1988.

	Males				Females			
Age	Number	%	Mean length	Mean weight	Number	%	Mean length	Mean weight
2	91	13	414	0.80	1	< 1	391	0.60
3	144	21	445	0.99	5	2	463	1.00
4	205	29	490	1.36	20	9	511	1.60
5	157	22	510	1.59	30	14	542	1.86
6	61	9	580	2.21	55	26	593	2.51
7	33	5	599	2.39	57	27	633	3.19
8		4	1 634	2.70	29	14	659	3.42
9	2	< 1	636	2.80	9	4	675	3.90
10	0				2	1	786	6.55
11	2	< 1	812	6.05	3	1	811	7.03
12	0				1	< 1	796	6.40
13	0				1	< 1	831	8.60
Total	699				213			

Table 24. Numbers of male and female striped bass by age caught by interviewed anglers from each zone of Roanoke River in spring 1988.

	Zone I		Zone II		Zone III	
Age	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
2	72 (11)	1 (<1)	19 (31)	0 (0)	0 (0)	0 (0)
3	130 (21)	4 (2)	13 (21)	1 (4)	1 (33)	0 (0)
4	189 (30)	16 (9)	14 (23)	3 (13)	2 (67)	1 (8)
5	149 (24)	24 (14)	8 (13)	4 (18)	0 (0)	2 (17)
6	58 (9)	45 (25)	3 (5)	6 (26)	0 (0)	4 (33)
7	29 (5)	49 (28)	4 (6)	4 (17)	0 (0)	3 (25)
8	3 (<1)	24 (14)	1 (2)	3 (13)	0 (0)	2 (17)
9	2 (<1)	9 (5)	0 (0)	0 (0)	0 (0)	0 (0)
10	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)
11	2 (<1)	2 (1)	0 (0)	1 (4)	0 (0)	0 (0)
12	0 (0)	0 (0)	0 (0)	1 (4)	0 (0)	0 (0)
13	0 (0)	1 (<1)	0 (0)	0 (0)	0 (0)	0 (0)
Total	634	177	62	23	3	12

Estimates of the number of striped bass caught and released are not available for the period before restrictive regulations were imposed. It is assumed that most of the striped bass released were either under the legal size limit or in excess of the daily creel limit. This assumption is based on conversations with anglers during interviews and the lack of traditional voluntary catch and release practices in this fishery. If this assumption is correct, the large number of released fish indicates the regulations are impacting on the harvest.

Mullis and Guier (1982) reported the Albemarle Sound commercial fishery was the largest harvester of striped bass from the system by a relatively large margin. In 1988, 49,347 kg (108,791 lb) of striped bass were harvested by the commercial fishery in Albemarle Sound (this document). The almost 34,000 kg of striped bass harvested by river sport fishermen in 1988 was about 68 percent of the commercial harvest from the sound.

In 1988, most of the striped bass harvest occurred in Zone I (53 percent) and Zone III (41 percent), while in 1989, 97 percent occurred in Zone I. The preponderance of those released in 1988 (86 percent) and 1989 (99 percent) were caught in Zone I which encompassed the traditional spawning grounds. The mid-point of the striped bass spawning season generally occurs around 11-13 May each year (Hassler et al. 1981), with the spawning peak in 1988 on 10 May (this document). During 1988 and 1989, the majority of striped bass harvested and released occurred between early April (period 2) and the latter part of May (period 4). During 1988, most of the striped bass catch (61 percent) and effort (38 percent) occurred between 9-22 May.

Study results confirmed biologists' suspicions that the largemouth bass fishery is of a considerable magnitude in the lower reach (Zone III) of the Roanoke River. Effort for largemouth bass peaked during different periods during 1988 and 1989 (Table 19).

Approximately half of the anglers interviewed were residents of counties that bordered the river in the vicinity of the traditional spawning area. However, about a third of the interviewed fishermen were not residents of counties that bordered any portion of the Roanoke River. This indicates that the striped bass fishery is not merely of local interest, and that anglers are drawn from considerable distances to participate in it.

Scofield (1931) concluded that the age of striped bass could be accurately determined in the first 8-10 years using scale analysis. However, Humphries and Kornegay (1985) reported the presence of false annuli and other checks made the use of scales for determining the age of Albemarle Sound-Roanoke River striped bass difficult and time consuming. They also evaluated several bony structures from striped bass in this population to determine their feasibility for use in age studies and concluded otoliths were easier to read than scales and provided similar age estimates. However, collection of otoliths is time consuming and requires mutilation of the fish, a procedure not well tolerated by fishermen in a hurry to return home. Therefore, scales were collected for aging purposes from striped bass examined in the creel survey.

While ages could be assigned to most (912) of the 934 striped bass from which scales were collected in 1988, the difficulties in reading scales reported by Humphries and Kornegay (1985) likely led to reduced accuracy of the readings. A subsample of approximately 10 percent of the scales aged in this study were also read by the co-author (Kornegay) of that earlier report. Agreement on the ages assigned independently to the same scale samples by Kornegay and Mullis was only 44 percent. However most discrepancies were of only 1 year, and agreement of assigned ages plus or minus 1 year was 90 percent. The proportions of discrepancies that were 1 year higher or lower, respectively, than the ages assigned by this author were about equal (24 percent versus 21 percent). Therefore the ages assigned in this study were considered acceptable for use in determining the age composition of the striped bass sport harvest.

The mean lengths of striped bass caught by sport anglers from the Roanoke River in 1988 are somewhat smaller than those caught by a variety of sport and commercial gears in the mid 1960's and early 1980's when corrected for the discrepancies of fork length vs. total length (Table 25). Virtually all sources agree that the length of female striped bass at given ages is larger than that of males. The mean weight of striped bass caught by sport anglers in 1988 is equal to the 1.8 kg (3.9 lb.) average weight of stripers collected in a Roanoke River fish kill in 1963 (Smith and Bayless 1963).

The age composition of the striped bass sport harvest should not be considered representative of the age composition of the spawning population. Under the restrictive sport fishing regulations now in effect, anglers tend to cull their catches in favor of larger fish which tends to bias estimates of age composition toward older age classes. However, changes in the age structure of the harvest may reflect similar changes in the spawning stock.

A much wider distribution of age classes of striped bass, particularly males, was examined in 1988 than in previous studies (Table 25). The age composition of both males and females was clearly shifted toward older fish in 1988. The reason for this is not clear. Sampling gear used in the earlier studies may not have adequately sampled older, larger fish.

The age composition of female striped bass in the spawning population is more important than that of males. The percentage of spawning stock females age 8 and older is considered a criterion for restored stock status in the current draft of the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Striped Bass Management Plan (Richkus and Perra 1989). The ASMFC believes that 10 percent of the striped bass spawning stock females should be age 8 and older. Approximately 21 percent of the females caught in 1988 were age 8 and older (Table 23). In the early 1960's, Trent and Hassler (1968) estimated that only about 10 percent of the females collected from the Roanoke River in the spawning season were in those age categories. However, many of those fish were caught by gears, particularly gill nets, which are very size selective. This probably introduced a substantial, but unknown, amount of bias into the estimation of age composition. In 1981, Harriss et al. (1985) found that 14 percent of the females were ages 8, 9, and 10, but, again, collection gear could have biased these results (Table 25). In 1985 and 1987, the proportion of age 8 and older females was negligible (Winslow and Harriss 1986, Winslow and Henry 1988). However, many of the fish examined in these studies, and all of them in 1985, were obtained from commercial fishermen from the lower Roanoke River. The commercial gears used to catch these fish may have been selective against larger and older fish.

Protection of female striped bass from fishing pressure appears to be important in restoring populations with the objective of increasing the number of females in the older age classes. An estimated 24 percent, or almost 4,000 of the striped bass harvested by the Roanoke River sport fishery in 1988 were females. Few of the females caught were less than 508 mm TL (20 in.) long and most were more than 559 mm (22 in.) long. Almost 60 percent of the females harvested were between 559 mm (22 in.) and 686 mm (27 in.) in total length. Only 13 percent of the males harvested were in this length range, with almost all of the rest being less than 559 mm (22 in.) in total length. A protected slot length limit that prohibits the harvest of striped bass in the 559 to 686 mm range from the Roanoke River would provide a high degree of protection to female fish. If harvest was limited to fish outside of this length range, most of them would be males. Anglers would still be permitted to retain a trophy fish of over 686 mm (about 4 kg or 9 lbs in weight). The current minimum size limit protects primarily male striped bass when applied to the spawning population in the river with little protection for female fish. An increase in the daily creel limit of 1 or 2 additional fish would tend to make such a regulation more acceptable to sport fishermen. No minimum size limit and the elimination of harvest of fish between 559 and 686 mm would effect a shift in the sex ratio of the harvest toward males. This protected slot limit should be coupled with a quota on the Albemarle Sound commercial fishery to establish parity between the respective fisheries.

Table 25. Comparison of mean lengths (mm) (fork lengths adjusted to total lengths) and percent composition of sex by age class of striped bass collected from Roanoke River.

Males

Age	1963-1965 Trent & Hassler (1968) %	Length	1981 Harriss et al. (1985) %	Length	1985 Winslow & Harriss (1986) %	Length	1987 Winslow & Henry (1988) %	Length	1988 Present Study %	Length
1			1	292						
2	4	382	63	403	73	394	64	440	13	414
3	70	450	27	474	25	468	29	514	21	445
4	21	495	8	513	1	476	6	552	29	490
5	4	533					2	617	22	510
6	<1	585	1	634					9	580
7	1	628							5	599
8	<1	666							1	634
9	<1	855							<1	636
10										
11									<1	812
12										
13										

Females

Age	1963-1965 Trent & Hassler (1968) %	Length	1981 Harriss et al. (1985) %	Length	1985 Winslow & Harriss (1986) %	Length	1987 Winslow & Henry (1988) %	Length	1988 Present Study %	Length
1										
2			2	402	28	394	25	425	<1	391
3	7	492			42	492	15	539	2	463
4	53	543	25	620	6	555	40	586	9	511
5	24	574	31	631	19	637	14	654	14	542
6	7	636	22	665			1	718	26	593
7	6	688	7	681	5	762	3	817	27	633
8	4	709	6	724			1	842	14	659
9	2	762	5	802					4	675
10	2	780	2	839					1	786
11	1	804							1	811
12	1	1,011							<1	796
13	<1	948							<1	831

Conclusions

1) Sport fishing regulations are having an impact on the striped bass harvest.

2) The 1988 striped bass sport harvest was composed of relatively more fish in older age groups than in samples collected by other researchers in the 1960's and early 1980's.

3) The sex ratio of the sport harvest may be shifted toward males by removing the minimum size limit and prohibiting the harvest of fish between 559 mm and 686 mm in total length.

Commercial and Recreational Landings of Striped Bass in Albemarle Sound, 1988-89

Lynn T. Henry and Sara E. Winslow

Commercial fishermen landed 115,915 pounds of striped bass valued at $116,776 in North Carolina during 1988, and 100,830 pounds valued at $101,002 during 1989 (Table 26). Historically, most of the fish have been caught in the Albemarle Sound area by set gill nets and pound nets. From 1980 to 1989, 67 to 98% of the striped bass landed by commercial gear in the State came from the Albemarle Sound area (Table 26). The remaining small percentages were caught in the Atlantic Ocean, and other riverine-estuarine systems, such as the Neuse-Pamlico.

A multitude of fishing regulations (refer to Table 33) imposed by the NCWRC and NCDMF since the mid-1970s has complicated efforts to assess the striped bass resource in North Carolina. For instance, a once thriving commercial fishery, which had operated in the Roanoke River since colonial times, has been eliminated. In Albemarle Sound, commercial fishermen have seen restrictions placed on types and sizes of gear, fishing locations, minimum size limits, and closed seasons. The latter was imposed in 1984 and is clearly reflected in Table 27. In recent years, most of the fish have been caught in November and December, and from January through April. Recreational fishermen have also been restricted. Daily creel limits have been reduced from 25 fish to 8 fish in 1980, and from 8 fish to 3 fish in 1985. During the fall of 1989, NCDMF instituted the first recreational season closure on striped bass harvest for North Carolina's internal coastal waters in an effort to further protect the 1988 year class from excessive harvest.

The recreational striped bass harvest in Albemarle Sound has not been evaluated since the NCWRC conducted a sport fishery survey during 1977-1980 (Mullis and Guier 1982). NCDMF is planning to re-implement an Albemarle Sound recreational creel survey during 1990 to gain harvest information from this fishery. The study design will be similar to the earlier NCWRC survey.

Past harvest estimates, from the Albemarle Sound and Roanoke River recreational fisheries and recent commercial landing levels, suggest that commercial and recreational interests may be harvesting approximately equal poundage. Albemarle Sound recreational harvest estimates made by Hassler et al. (1981) from 1967 to 1973 indicate that the best striped bass fishing occurs from October through April, with the greatest catches occurring during October and November.

Table 26. Commercial harvest of striped bass in North Carolina, 1980-89 (data from M.W. Street, NC Division of Marine Fisheries).

Year	Statewide Pounds	Statewide Value	Albemarle Sound area (including Roanoke R.) Pounds	Albemarle Sound area (including Roanoke R.) Value	Percent of total landings
1980	472,503	435,479	376,510	318,054	79.7
1981	417,324	451,824	333,484	325,315	79.9
1982	338,310	531,470	228,004	316,222	67.4
1983	361,275	491,491	288,742	323,281	79.9
1984	512,896	452,002	475,640	381,378	92.7
1985	279,940	229,586	269,671	219,925	96.3
1986	188,992	189,859	172,683	171,220	91.4
1987	262,221	262,542	228,861	228,312	87.3
1988	115,915	116,776	108,791	109,364	93.9
1989	100,830	101,002	99,291	99,300	98.4

Table 27. Commercial landings (pounds) of striped bass by month in the Albemarle Sound area (including Roanoke River), 1980-1989 (data from M.W. Street, NC Division of Marine Fisheries).

Month	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
JAN		17,083	33,470	15,344	97,507	54,096	34,875	28,565	13,972	7,913
FEB		8,845	22,048	17,009	31,953	23,887	12,125	68,513	9,098	5,560
MAR		20,736	36,289	29,847	14,452	30,677	36,196	38,158	20,297	14,795
APR		27,324	50,884	27,689	28,547	38,965	0	56,074	9,807	8,701
MAY		18,675	23,007	21,167	12,718	24,289	0	0	0	0
JUN		15,772	8,878	1,970	10,995	0	0	0	0	0
JUL	12,098	11,437	7,457	1,089	6,187	0	0	0	0	0
AUG	13,214	13,149	8,007	850	0	0	0	0	0	0
SEP	25,948	41,745	9,594	5,800	0	0	0	0	0	0
OCT	82,977	76,860	13,269	69,026	93,499	0	0	0	0	0
NOV	94,622	64,359	5,964	23,294	129,425	27,662	48,444	26,544	43,955	62,322
DEC	33,295	17,299	9,137	75,657	50,357	70,095	41,043	11,007	11,662	0
Total		333,484	228,004	288,742	475,640	269,671	172,683	228,861	108,791	99,291

Restrictions on fishing have been imposed because of the expressed public concern for the decline of striped bass in the State. Although the two commissions generally represent separate constituencies, they realize that management of the stock must be a shared responsibility. A management plan for the species is being developed by the State agencies.

Both Commissions and agencies face unique problems as the plan is moved forward. The Wildlife Resources Commission must evaluate the impacts of fishing on the spawning grounds, something that is not permitted in any other state on the east coast, and the Division of Marine Fisheries must manage controversial gill net and pound net commercial fisheries that operate in Albemarle Sound. These gear catch a variety of finfish, not just striped bass (i.e., white perch, yellow perch, white catfish, channel catfish, bullheads, shad, herring, flounder, and sciaenids). Elimination of catches of other fishes would be an economic disaster to local fishermen and their families. The Division of Marine Fisheries is testing fyke nets as an alternative fishing technique (Henry 1989).

The State agencies are working closely with the Atlantic States Marine Fisheries Commission (ASMFC), which is a board of representatives of the Atlantic coastal states chartered for the purpose of managing interjurisdictional fishery resources, including striped bass. North Carolina is striving to adopt mangement options that complement the intent of the ASMFC coastwide management plan for striped bass.

Egg Production and Viability

Roger A. Rulifson

Spring 1988

In 1988, sampling for striped bass eggs was conducted at the Pollock's Ferry Hunting Club at River Mile 105, approximately 24 miles below Weldon, NC (Figure 26). Details of the study were described by Rulifson (1989). Briefly, eggs were collected in a manner similar to that described by Dr. Hassler's annual reports. Samples were taken six times daily at four-hour intervals by sampling with paired 10-inch diameter nets of 500-um mesh netting from a small boat for five minutes. River stage (relative), water temperature, dissolved oxygen, conductivity, pH, total dissolved solids, and water velocity were recorded for each sample. Depth of secchi disk visibility was noted for all samples taken during daylight hours. For each sample, all eggs were examined in the laboratory for viability and stage of development.

Striped bass spawning activity, as reflected by egg deposition, occurred from mid-April through 2 June 1988. Peak spawning was of a prolonged nature from mid-May to late May.

In 1988, the estimated number of eggs produced was 2,082,130,728 from a total of 20,144 eggs collected in surface tows. Although sampling was initiated on 10 April, eggs were first collected in surface nets on 12 April. Spawning activity prior to this date was unknown. Spawning activity continued at a low level until 11 May, which was the major spawning peak of the season representing 31 percent of the eggs produced. From 11 May through 24 May, the major portion of eggs were produced in one large peak and three minor peaks: 11-12 May, 15-16 May, 20 May, and 24-25 May. Less than two percent of the total egg production occurred after 25 May. No eggs were collected in surface nets after 2 June, and sampling was terminated on 7 June (Figure 27).

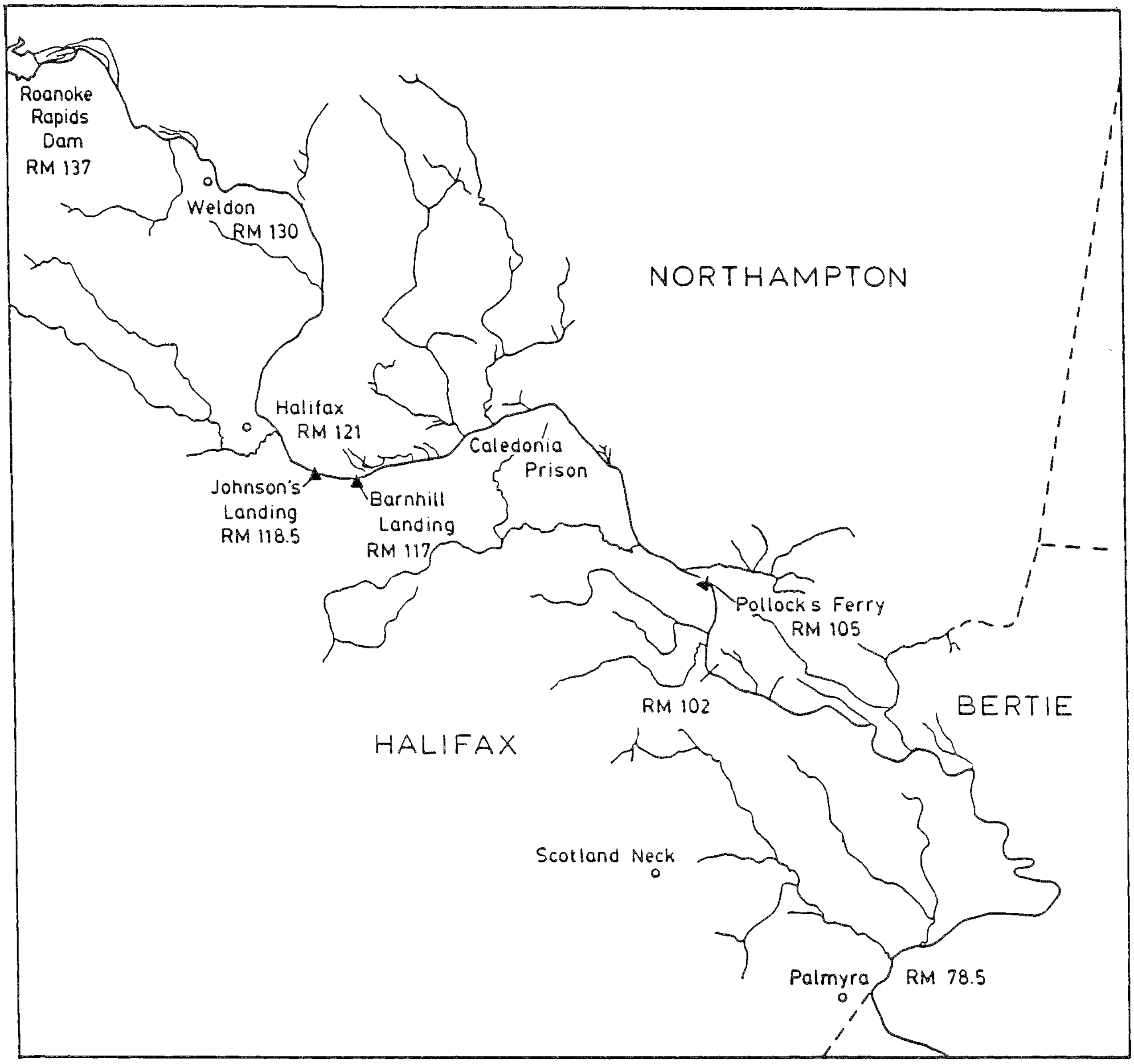


Figure 26. Roanoke River watershed downstream of Roanoke Rapids Reservoir showing the historical sampling stations for striped bass eggs: Palmyra (1959-60), Halifax (1961-74), Barnhill's Landing (1975-81), Johnson's Landing (1982-87), and Pollocks Ferry (1988).

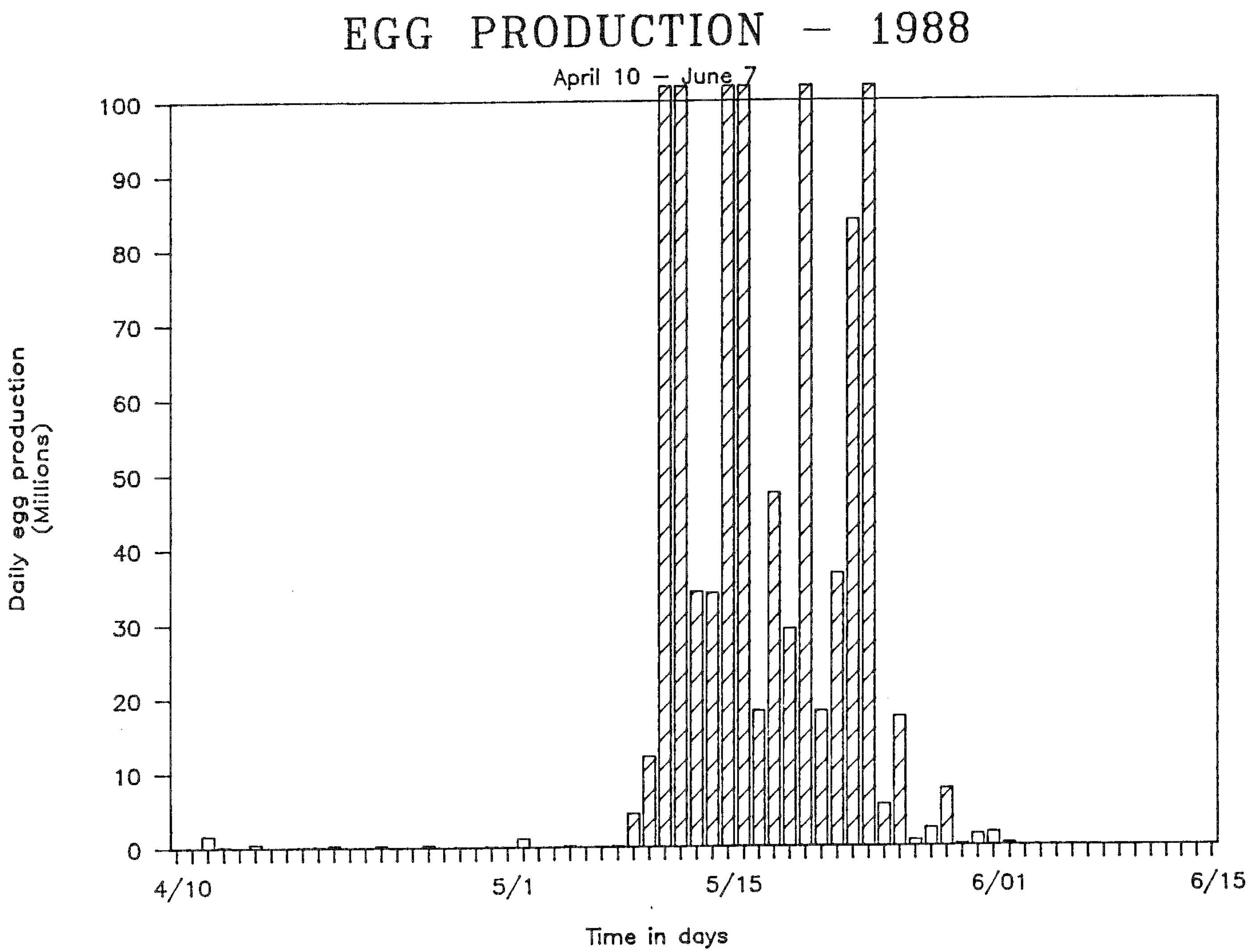


Figure 27. Estimated daily production of striped bass eggs in the Roanoke River based on samples collected at Pollocks Ferry, NC, in 1988.

The estimated total egg production for 1988 was the seventh highest for the period of record starting in 1959 and, with the exception of 1986, represented the greatest production estimate since 1975 (Table 28).

Viability of striped bass eggs in 1988 was estimated at 89 percent, ranking tenth for the period of record but representing the best viability estimate since 1972. Eggs collected in April and early May had low viability, but the percentage increased dramatically during peak spawning activity. Viability declined late in the spawning season.

Stage of development was noted for 9,557 viable eggs caught in all nets. The majority of the eggs (71.8 percent) were between 20 and 28 hours old. Fewer than one percent were less than 10 hours old. Nearly 13 percent exhibited development between 10 and 18 hours old, and 14 percent were staged at 30 to 38 hours of development. Only six eggs were close to hatching (over 40 hours old).

Major egg production was observed just after water temperatures reached 18^{o} C (Figure 28). Most eggs (79 percent) were collected at water temperatures ranging between 18 and 21.9^{o} C. An additional 16 percent were collected at temperatures of 22.0 to 23.9^{o} C. Greatest viability was observed at temperatures of 20.0^{o} C and higher.

Surface water velocities at Pollock's Ferry in 1988 never deviated more than about 40 cm/second during the study, resulting in essentially all eggs (99.5 percent) collected at velocities between 60.0 and 99.9 cm/second. Although most eggs were caught in a range between 80.0 and 99.9 cm/second, greatest viability was evident at the lower range of water velocities (Table 29).

The relatively small variability in water velocities reflected the manner in which water was released from the Roanoke Rapids Dam during spawning activity. From mid-April through the end of May, Virginia Power Company regulated on-demand water release to stay between approximately 5,800 and 10,000 cfs. This cyclical pattern of peak power production resulted in river height fluctuations of four feet at the sampling station.

Levels of dissolved oxygen remained above 5.0 mg/L throughout the study. About 85 percent of striped bass eggs were collected in waters with dissolved oxygen values of 6.0 to 7.9 mg/L (Table 29).

Acidity of the waters at Pollock's Ferry remained near 7.0 throughout much of the study. Approximately 67 percent of striped bass eggs were collected in waters of pH 7.00 to 7.24. Only eight percent of the eggs were caught at pH values less than 7.0 (Table 29).

Spring 1989

In 1989, sampling for striped bass eggs was conducted at Barnhill's Landing at RM 117, which was the location of Hassler's egg studies from 1975-1981 (Figure 24). The methodology was virtually the same as that described above for spring 1988.

In 1989, the striped bass spawning period, as reflected by egg deposition, was from mid-April to 12 June. Peak spawning was the last week in May.

The estimated total number of eggs spawned by striped bass in 1989 was 637,919,162 from a total of 4,722 eggs collected in surface samples. Eggs were observed in surface nets on 14 April, the first day of sampling. Spawning activity prior to this date was undetermined.

Table 28. Historical reproduction information on the Roanoke/Albemarle bass population (from Hassler and Taylor 1986[b], except as otherwise noted).

Year	Number of eggs spawned	Percent egg viability	Number of fish in spawning migration	Juvenile abundance index NCSU	Juvenile abundance index NCDMF
1955				3.27	
1956			239,489	19.14	
1957			173,289	5.71	
1958			251,280	0.15	
1959	300,000,000[a]		448,292	23.86	
1960	740,000,000	92.88	418,062	5.93	
1961	2,065,232,519	79.74	310,135	10.33	
1962	1,088,076,294	86.22	148,260	7.86	
1963	918,652,436	79.94	157,246	4.80	
1964	1,285,351,276	95.77	251,906	3.14	
1965	823,522,540	95.91	310,003	10.08	
1966	1,821,385,754	94.51	277,397	3.48	
1967	1,333,312,869	96.20	174,286	23.39	
1968	1,483,102,338	86.20	317,474	6.59	
1969	3,229,715,526	89.86	200,259	2.99	
1970	1,464,841,490	89.23	421,571	12.45	
1971	2,833,119,620	80.81	441,823	2.86	
1972	4,932,000,707	90.51	507,145	2.52	
1973	1,501,498,887	87.21	402,593	1.95	
1974	2,163,239,468	87.31	433,213	5.52	
1975	2,193,008,096	55.69	337,024	10.80	
1976	1,496,768,659	50.73	277,630	10.52	
1977	1,775,957,318	52.72	347,584	3.63	
1978	1,691,227,585	37.72	354,152	0.59	
1979	1,613,382,382	43.62	313,736	0.55	
1980	870,322,832	43.39	100,192	0.46	
1981	344,364,065	73.70	34,032	0.09	
1982	1,698,888,853	71.93	70,650	3.80	0.61[d]
1983	1,352,611,202	33.29	69,771	0.84	0.42[e]
1984	703,879,559	22.73	59,890	0.36	0.00[e]
1985[b]	600,562,645[b]	72.21[b]	32,937[b]	1.24[b]	0.32[f]
1986[b]	2,279,071,483[b]	51.10[b]	61,656[b]	0.14[b]	0.11[g]
1987[b]	1,382,496,006[b]	42.87[b]	91,738[b]	0.06[b]	0.30[h]
1988	2,082,130,728[c]	89.00[c]			4.09[i]
1989	637,919,162[c]	41.80[c]			4.27[d]

[a]Partial season data only.
[b]Personal communication, W.W. Hassler, N.C. State University, Raleigh, NC.
[c]Personal communication, R.A. Rulifson, East Carolina University, Greenville, NC.
[d]Personal communication, Lynn Henry, N.C. Division of Marine Fishries, Elizabeth City, NC.
[e]Winslow, et al. (1985).
[f]Winslow and Henry (1986).
[g]Winslow and Henry (1988).
[h]Winslow and Henry (1989).
[i]Henry and Winslow (1990).

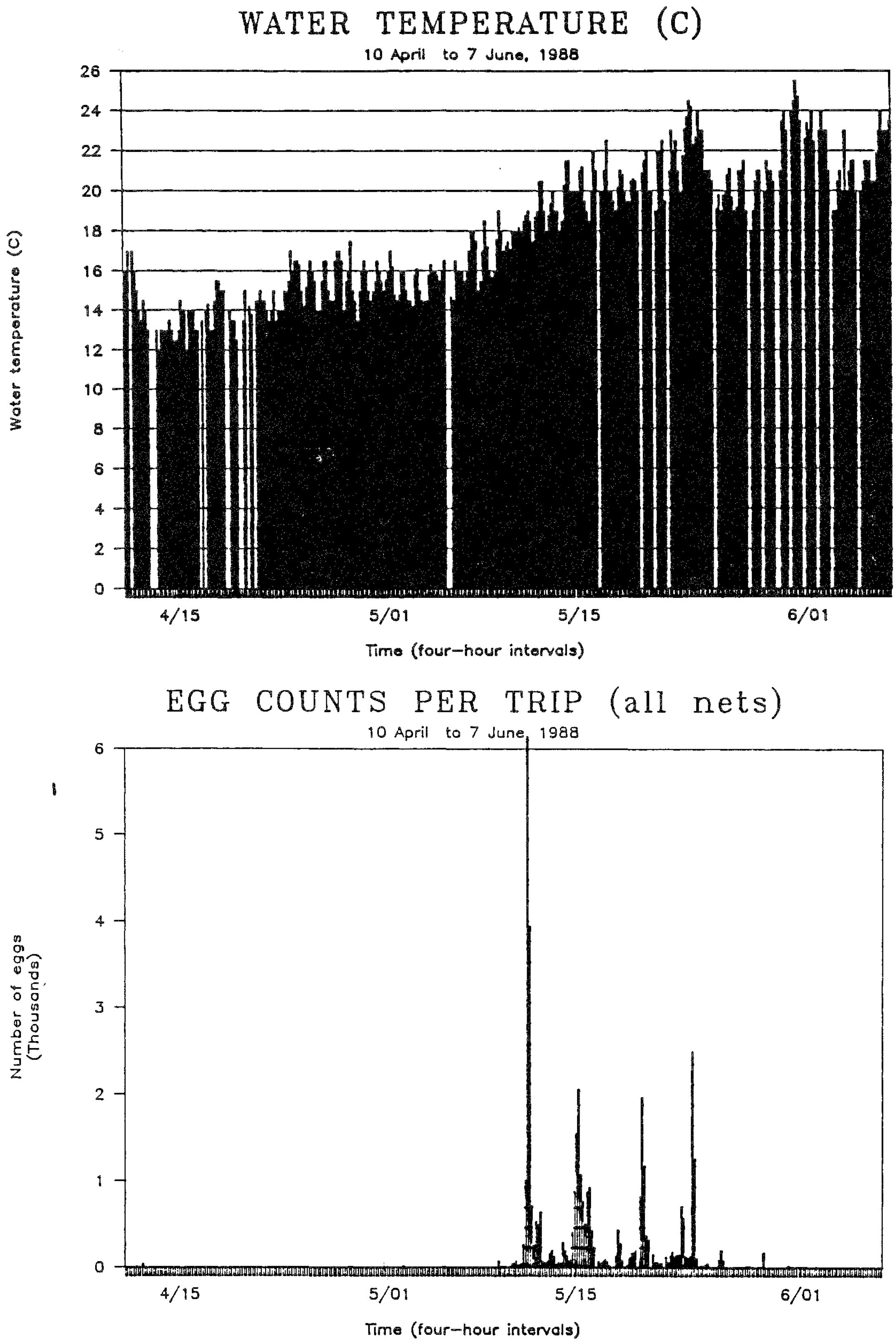


Figure 28. Number of striped bass eggs collected in all nets during each trip, and corresponding water temperatures (°C), at Pollocks Ferry, NC, in 1988.

Table 29. APES striped bass egg production and viability studies, Roanoke River, NC.

Parameter	1988	1989
No. of trips completed	90%	94%
No. of eggs collected (surface nets only)	20,144	4,722
Egg production (estimated)	2,082,000,000	637,900,000
Egg viability	89%	42%
Diurnal periodicity	1000-1800 hrs (63%)	2200-1000 hrs (82%)
Temperature (C)	18-22 C (79%)	18-22 C (88%)
pH values	7.0-7.5 (67%)	7.75+ (99%)
Dissolved oxygen (mg/L)	6.0-7.9 (85%)	7.0-8.9 (99%)
Water velocities (cm/second)	60-100 (99.5%)	100-120 (58%) 60-80 (21%)
Spawning period	mid-April to 2 June	mid-April to 12 June
No. of days that river flow was within Q_1-Q_3 bounds	53 of 76 (69%)	33 of 76 (43%)

Initially, we anticipated that major spawning activity, and perhaps peak activity for the season, would occur at the end of April. Water temperatures had reached 18° C and numbers of eggs in nets increased steadily from 28 April to 2 May (Figure 29). However, major water release from Roanoke Rapids Dam dropped water temperatures below 18° C and spawning activity ceased until mid-May, when water temperatures rose above 18° C. Peak spawning activity was delayed until the last week in May, and continued into early June. Eggs were collected through 12 June, and sampling was terminated on 15 June.

The estimated total egg production for 1989 was 637,919,162, which was the second lowest estimate on record. In 1985, Hassler estimated egg production at 600,562,645 for the season (Table 28).

Egg viability in 1989 was estimated at 41.80 percent, which was similar to that estimated in 1987 (42.87 percent) by Hassler. Although this viability estimate is the fourth lowest on record, it is similar to over one-third (12 of 31) of viability estimates of less than 50 percent (Table 29). No seasonal pattern in viability was apparent.

Stage of development was recorded for 4,237 viable eggs collected in all nets. Most eggs (76.7 percent) were less than 10 hours post-spawn. About 4.7 percent of the eggs were between 10 and 18 hours old, and 18.5 percent were between 20 and 28 hours in development. Less than one percent of the eggs were older than 30 hours.

Similar to 1988, the major spawning activity occurred after water temperatures reached 18° C. Water temperatures reached this level at two times during the study: at the end of April, and again from mid-May to the end of the study in June. The two week period in between had water temperatures dipping as low as 15° C caused by maximum reservoir discharge of 20,000 cfs. It is interesting to note that once discharge rates reached 20,000 cfs, variability in the discharge rate was virtually undetectable and allowed water temperatures to increase gradually to 18° C. At the end of May, water temperatures increased several degrees rather suddenly due to the sudden drop in reservoir discharge.

Almost 88 percent of all eggs were collected at temperatures between 18.0 and 21.9° C (Table 29). Only three percent were collected at temperatures below 18° C, and eight percent were taken at temperatures of 22° C or higher. No trend in viability as a function of water temperature was evident.

Surface water velocities at Barnhill's Landing in 1989 (Figure 21) reflected the drastic changes in reservoir discharge (Figure 7). Water velocity ranged from a low of almost 40 cm/second in June to a high of nearly 140 cm/second in mid to late May (Figure 21). Approximately 58 percent of all striped bass eggs were spawned at surface water velocities between 100 and 120 cm/second. An additional 21 percent were found in waters flowing 60 to 80 cm/second (Table 29). Greatest egg viability (52 percent) occurred at the lowest water velocities recorded (40.0 - 59.9 cm/second).

Levels of dissolved oxygen remained at 7.0 mg/L and higher throughout the study. Nearly 99 percent of the eggs were collected at 7.0-8.9 mg/L of dissolved oxygen.

In 1989, Roanoke waters flowing past Barnhill's Landing were of pH 7.0 and greater. Over 99 percent of the eggs were collected in waters of pH 7.75 or greater (Table 29).

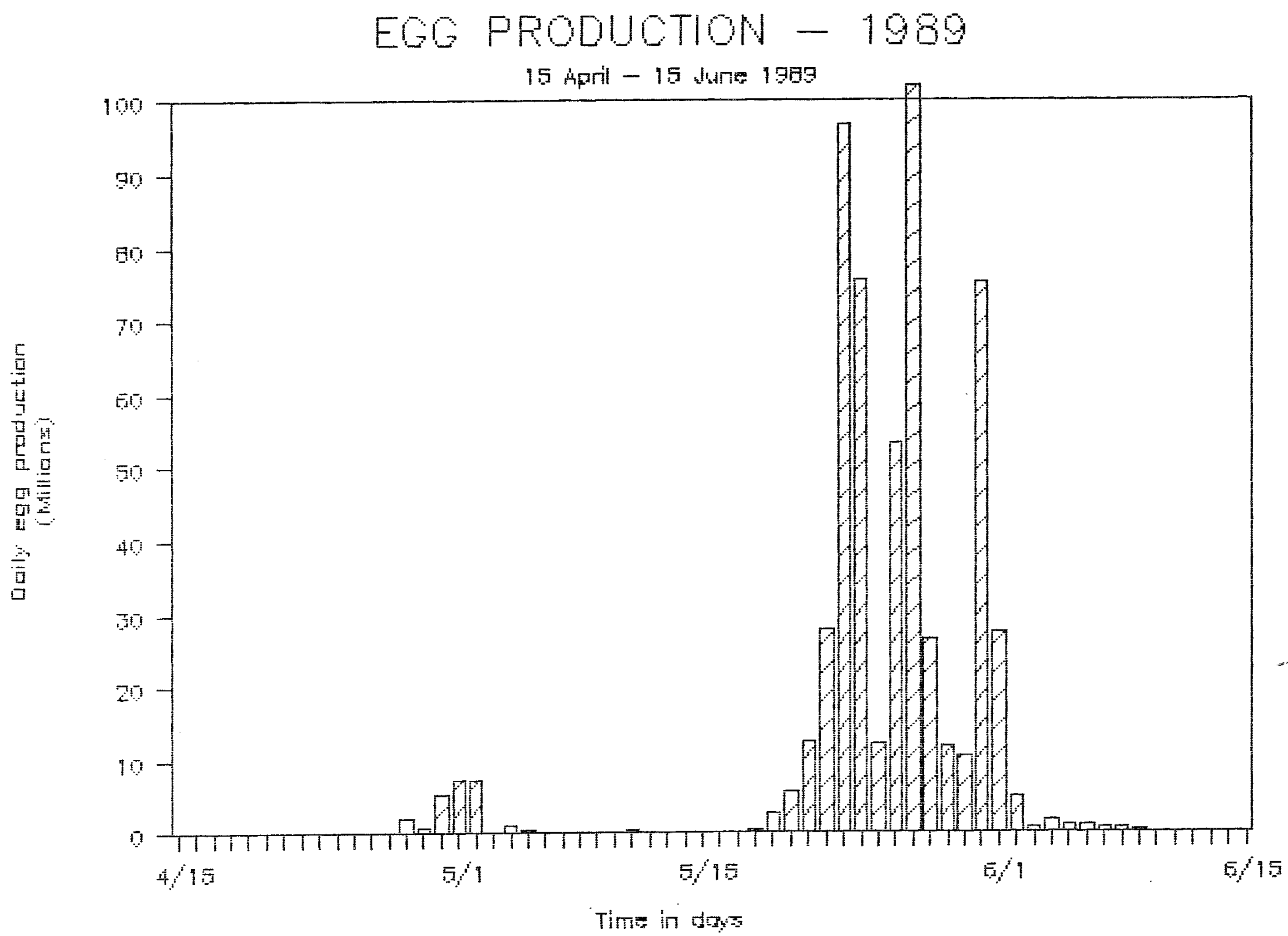


Figure 29. Estimated daily production of striped bass eggs in the Roanoke River based on samples collected at Pollocks Ferry, NC, in 1989.

Juvenile Abundance Index of Young-of-Year Striped Bass, 1988-89

Lynn T. Henry and Sara E. Winslow

The relative success of juvenile striped bass recruitment to the forming year class is monitored by the Juvenile Abundance Index (JAI), which is simply the number of young striped bass captured per unit of effort. Although the use of this type of index is common in most states with striped bass stocks, the methodology used to determine the JAI is unique to each state. The JAI for North Carolina pre-dates those of other states who designed their indices after that of North Carolina.

The JAI for the Roanoke-Albemarle stock is conducted in the Albemarle Sound at approximately two-week intervals from July through October of each year and was initiated in 1955 by Dr. W.W. Hassler; estimation methods for the JAI have remained essentially unchanged since that time. Hassler's studies provide an uninterrupted data base through 1987 (Table 28).

The sampling area is in western Albemarle Sound extending eastward approximately 12 miles. Seven permanent sampling stations were established in 1955 and are currently used: Station 1, Black Walnut Point; Station 2, east of Edenton Bay; Station 3, north shore side between the (now demolished) Norfolk and Southern Railway bridge and the NC 32 highway bridge; Station 4, northeast side of NC 32 bridge; Station 5, southeast side of NC 32 bridge; Station 6, south shore between the bridges; and Station 7, Albemarle Beach. Samples were collected early in the sampling season by trawl with 6.35-mm stretched mesh cod end. Samples later in the season were taken by trawl with a cod end of 12.7-mm stretched mesh. Samples are taken every two weeks starting in July and ending in October for a maximum of 56 samples for the season. Each trawl is for a period of 15 minutes at a speed of approximately 2.75 miles per hour. Trawling depth ranges between six and 10 feet. Young striped bass are counted and measured (total length) and are returned to the water as quickly as possible. Numbers (JAI) are expressed as the average number of juvenile striped bass caught per unit of effort (15-minute tow).

In 1982, the North Carolina Division of Marine Fisheries (DMF) initiated a JAI survey using the same methods and stations as the Hassler (NCSU) studies. The only change to the study involved mesh size. The DMF study, which has replaced Hassler's efforts, used the 12.7-mm stretched mesh cod end exclusively from 1984 through 1987, a 6.35-mm cod end in 1983, and a combination of 6.35-, 12.7-, and 25.4-mm stretched mesh cod ends in 1982.

The DMF JAI for 1988 was 4.09 fish per trawl (Table 30), the best value obtained since the summer and fall of 1976 (Table 28). The relatively high value for 1988 substantiated the feelings of many Committee members that the Roanoke-Albemarle stock of striped bass was not depressed beyond recovery. The monthly JAI values for 1988 were: July, 5.86; August, 3.21; September, 1.71; and October, 5.43. A JAI of 10.86 was recorded on 7 October, by far the highest daily value obtained since the early 1970s.

The JAI for 1989 was 4.27 (Table 31), the highest value since 1976 (Table 28). The indices for 1988 and 1989 represent the first time that two consecutive JAIs were greater than 1.00 since 1976-77. The monthly JAIs for 1989 were: July, 0.14; August, 2.95; September, 7.36; and October, 5.14. The trends in catch per unit effort between the two years are different. In 1988, juvenile striped bass were recruited (captured) by the gear much earlier in the season than in 1989 (Table 32). The delay in 1989 may have been the result of displacement of the young fish to more easterly sections of the Sound by the high, stable flows from the Roanoke River, and/or the late peak spawning activity (late May to mid-June) resulting in delay in recruitment to the nursery grounds.

Table 30. Number of young-of-year striped bass captured by semi-balloon trawl in Western Albemarle Sound, NC, by station, July - October, 1988. The Juvenile Abundance Index of 4.09 is calculated by the total samples (56) divided into the total number of striped bass captured (229).

	Station Number							
Date	1	2	3	4	5	6	7	Total
14 Jul 88	2	0	2	17	9	5	1	36
27 Jul 88	16	0	0	29	1	0	0	46
9 Aug 88	0	0	1	9	0	1	8	19
23 Aug 88	2	0	0	4	21	1	0	28
6 Sep 88	4	1	0	4	8	1	5	23
19 Sep 88	0	1	0	0	0	0	0	1
7 Oct 88	1	20	2	0	0	53	0	76
18 Oct 88	0	0	0	0	0	0	0	0
Total	**25**	**22**	**5**	**63**	**39**	**61**	**14**	**229**

Table 31. Number of young-of-year striped bass captured by semi-balloon trawl in western Albemarle Sound, NC, by station, July-October, 1989. The Juvenile Abunday Index of 4.27 is calculated by the total samples (56) divided into the total number of striped bass captured (239).

	Station Number							
Date	1	2	3	4	5	6	7	Total
21 Jul 89	0	0	0	0	0	0	1	1
8 Aug 89	0	0	6	1	0	0	0	7
16 Aug 89	0	0	10	27	0	0	0	37
29 Aug 89	0	1	3	0	14	0	0	18
12 Sep 89	0	1	15	4	11	13	10	54
28 Sep 89 (3 Oct 89)	1	0	5	6	3	15	20	50
10 Oct 89	1	4	13	14	22	7	0	61
27 Oct 89	1	0	9	0	1	0	0	11
Total	**3**	**6**	**61**	**52**	**51**	**35**	**31**	**239**

Table 32. JAI catch matrix for seven stations in western Albemarle Sound, NC, 1988 and 1989.

1988				1989			
Date	Stations	Fish	JAI	Date	Stations	Fish	JAI
07/14	7	36	5.14	07/21	7	1	0.14
07/27	7	46	6.57				
Monthly	14	82	5.86	Monthly	7	1	0.14
08/09	7	19	2.71	08/08	7	7	1.00
08/23	7	28	4.00	08/16	7	37	5.29
				08/29	7	18	2.57
Monthly	14	47	3.21	Monthly	21	62	2.95
09/06	7	23	3.29	09/12	7	54	7.71
09/19	7	1	0.14	09/28	7	50	7.00
Monthly	14	24	1.71	Monthly	14	104	7.36
10/07	7	76	10.86	10/10	7	61	8.71
10/18	7	0	0.00	10/27	7	11	1.57
Monthly	14	76	5.43	Monthly	14	72	5.14
Total	**56**	**229**	**4.09**	**Total**	**56**	**239**	**4.27**

Update of Striped Bass Conservation Regulations, 1989-1990

Lynn T. Henry

Several regulations enacted by the NCDMF during 1989 and 1990 resulted in significant harvest reductions and/or conservation of the recently expanding Roanoke-Albemarle striped bass stock, particularly the 1988 year class.

In September 1989, the N.C. Marine Fisheries Commission (MFC) granted the DMF Director the additional authority to proclaim regulations in order to: 1) better manage existing fisheries, 2) comply with state and federal plans, and 3) enhance restoration efforts for North Carolina striped bass. Major NCDMF regulatory actions instituted during 1989 and early 1990 by proclamation are presented in Table 33.

Table 33. Regulations resulting in conservation and/or reduction in striped bass harvest in the Roanoke River-Albemarle Sound area, North Carolina, 1979-1990. DMF = North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries; WRC = North Carolina Wildlife Resources Commission.

Prior to 1979	Minimum size limit 12 inches (TL) for inland (WRC), internal coastal (DMF) and Joint Waters (WRC and DMF).
	No trawling in Albemarle and Croatan Sounds between 1 December and 31 March.
	Roanoke River drift gill nets attended at all times (DMF)
1979	Changed gill net mesh size from 3 1/4 to 3 1/2 inch in western Albemarle Sound and Chowan River, summer and fall. (DMF/July)
	Defined small mesh "Mullet Nets" to be used only in the eastern Albemarle Sound (DMF/July)
1980	Creel limit reduced to 8 fish per day in inland waters. (WRC)
	Field possession limit reduced to one day's creel limit in inland waters. (WRC)
	Eliminated set gill nets in Roanoke River for April - May and restricted mesh size of drift nets, resulting in sharply curtailed landings. (Hassler 1984) (DMF/Oct.)
1981	Roanoke River bow netting eliminated on spawning striped bass. (WRC)
	Possession of large dip nets prohibited in the inland waters of Roanoke River. (WRC)
	Extended drift gill net regulations to mouth of Roanoke, Middle, Eastmost, and Cashie Rivers proper. (DMF/Oct.)
1982	Minimum size limit of striped bass increased to 16 inches (TL) in inland waters. (WRC)
1983	Eliminated use of small mesh gill nets in Currituck Sound, increased minimum mesh to 3 1/2 inches (June - December). (DMF/Jan.)
	Roanoke River, reinstituted use of set gill nets in April - May of 3.0 inch and less. No more than one drift gill net may be used per boat. (DMF/Jan. and Oct.)
	Eliminated use of 3 1/4 inch gill net (June - December) in all of Albemarle Sound and tributaries, increased minimum mesh to 3 1/2 inches. (DMF/Oct.)
	Prohibited possession of striped bass on a vessel using a trawl in internal coastal waters (DMF/Jan.)
1984	First limited commercial season for striped bass October - May (DMF/Aug.)
	Minimum mesh 3 1/2 inch October - December. (DMF/Aug.)

Table 33 *continued*

	Eliminated use of gill nets in Albemarle Sound and tributaries during June - September, except defined "Mullet Nets" (2 1/2 - 3.0 inch, floating, and within 300 yards of shore). (DMF/Aug.)
	First reduction in hook and line creel limit (8 fish/day) and increase in striped bass minimum size limit to 16 inches (TL) for internal joint and coastal waters (June - September). (DMF/Aug.)
	Unlawful to sell or offer for sale any striped bass from June - September. (DMF/Aug.)
	First striped bass size limit for Atlantic Ocean (24 inches TL). (DMF/Aug.)
	Closure of Atlantic Ocean to the harvest of striped bass by proclamation. (DMF/Aug.)
1985	Year-round reduction in creel limit for inland waters to 3 fish/day. (WRC)
	Sale of striped bass taken from inland waters of Roanoke River prohibited. (N.C. General Assembly)
	Roanoke River, eliminated all gill nets June - September. (DMF/Feb.)
	Reduction in striped bass commercial season (November - March). Unlawful to sell or possess striped bass taken from commercial gear except during the open season. (DMF/Aug.)
	Revisions for summer gill net use (June - September), which allowed 5.0 inch and greater "Flounder Nets" and attendance at all times provisions for "Mullet Nets" in Albemarle Sound and tributaries. (DMF/Aug.)
	Hook and line creel reduced to 3 fish/day in internal coastal and joint waters year-round. Hook-and-line-caught striped bass may not be sold. (DMF/Aug.)
	Minimum size limit increased to 16 inches (TL) for joint waters. (DMF/Aug.)
	Minimum size limit increased to 14 inches (TL) for internal coastal waters. (DMF/Oct.)
1986	Minimum size limit increased to 16 inches (TL) for internal coastal waters. (DMF/Oct.)
	Repealed 16 inch (TL) size limit and reverted back to the 14 inch (TL) minimum size limit for internal coastal waters. (DMF/Nov.)
	Revisions on depth of water and net size for the fall gill net regulations (October - December) to allow for increased striped bass conservation without severely impacting the harvest of white perch and catfish. (DMF/Nov.)
	Established proclamation authority to open or close a portion of the striped bass season (October and April). (DMF/Nov.)
	Aligned Currituck Sound net regulations with the Albemarle Sound regulations relative to striped bass conservation measures. (DMF/Nov.)
	Eliminated the harvest and sale of striped bass from the spring Albemarle Sound gill net fishery and Roanoke River delta pound net fishery. (DMF) (Effected by Aug. 1985 regulation)

Table 33 *continued*

1987 Eliminated all trawling in Albemarle Sound and tributaries year round. (DMF/Dec.)

Closed a portion of western Albemarle Sound to gill netting (Batchelor Bay area) and restricted the spring pound net fishery in the Roanoke River delta by proclamation. (DMF/April)

1988 Striped bass size limit in Atlantic Ocean will correspond to the recommendation of the ASMFC interstate striped bass plan. (DMF/Sept.)

Proclamation authority established regarding use and attendance of "striped mullet gill nets" in Albemarle Sound and tributaries (June - December). (DMF/Sept.)

Allow use of "mullet gill nets" in Currituck Sound between 2 1/2 - 3 1/4 inch, maximum of 400 yards, attended at all times (June - December). (DMF/Sept.)

Closed a portion of western Albemarle Sound to gill netting (Batchelor Bay area) and eliminated harvest of striped bass from the Roanoke River delta pound net fishery by proclamation. (DMF/April)

1989 Established proclamation authority to specify season or seasons: (a) for hook-and-line and (b) for commercial fishing equipment between October 1 and April 30. Proclamations may specify areas, quantity, size and means/methods employed in harvest and require submission of statistical and biological data. (DMF/Sept.)

By proclamation closed a portion of western Albemarle Sound and Roanoke River delta to anchor gill netting (Batchelor Bay area) and restricted the harvest of striped bass taken in pound nets to fish not less than 18 or greater than 24 inches (TL). Striped bass season in internal coastal waters for commercial fishing closed 20 April. (DMF/April)

By proclamation restricted the use of small mesh "mullet gill nets" in the Albemarle Sound and tributaries. (DMF/June) (DMF/Sept.)

By proclamation delayed the use of commercial gill nets of mesh sizes between 3.0 - 5.0 inches (Albemarle Sound and tributaries) from 1 October until 15 November, when the commercial striped bass season opened statewide. By proclamation required that "mullet gill nets" be attended at all times. (DMF/Oct.)

By proclamation striped bass season for commercial fishing equipment in internal coastal waters was closed statewide 22 November and gill net mesh sizes were restricted in Albemarle Sound (DMF/Nov.)

By proclamation striped bass season for hook-and-line fishing in internal coastal waters was closed statewide 26 November (DMF/Nov.)

1990 By proclamation striped bass season opened for hook-and-line fishing in internal coastal waters 1 January (DMF/Jan.)

By proclamation striped bass season opened for commercial fishing equipment with restrictions in internal coastal waters 1 January, with a 98,000 pound quota for 1990 to be managed on a monthly basis. (DMF/Jan.)

By proclamation striped bass season closed for commercial fishing equipment in internal coastal waters 11 January with restrictions on gill net mesh sizes in Albemarle Sound (DMF/Jan.)

Table 33 *continued*

By proclamation striped bass season in the N.C. Atlantic Ocean was opened 12 February and 19-23 February with ASMFC approval. (DMF/Feb.)

By proclamation striped bass season opened for commercial fishing equipment in internal coastal waters 21 February (DMF/Feb.)

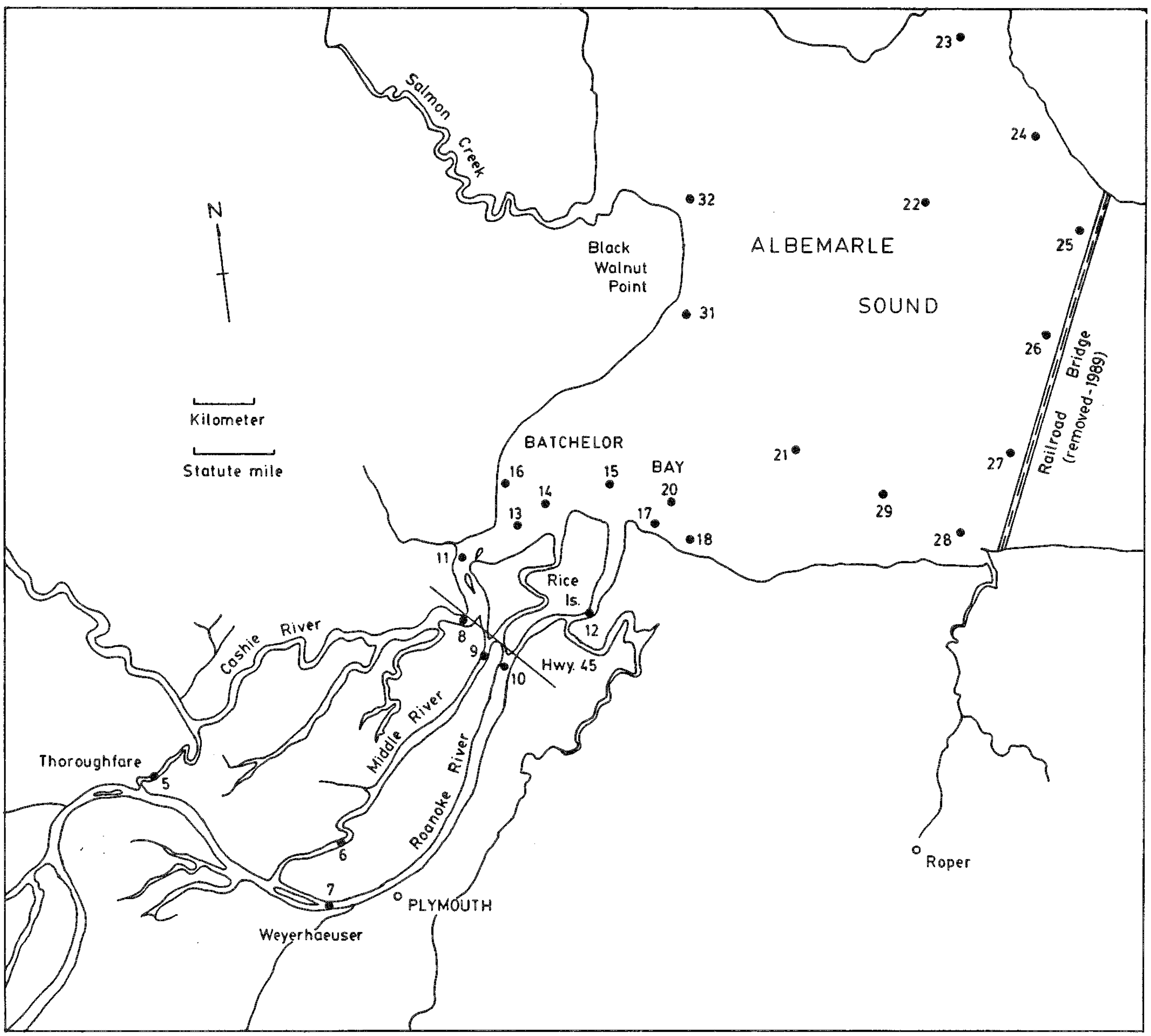


Figure 30. Fixed station array for sampling phytoplankton, zooplankton, and striped bass larvae for 1984-1989.

PHYTOPLANKTON SPECIES COMPOSITION AND BIOMASS: 1984-1989 SUMMARY AND COMPARISON WITH OTHER SYSTEMS

Donald W. Stanley, East Carolina University

Methodology

Sampling for phytoplankton and chlorophyll *a* zooplankton in the lower Roanoke River, delta, and western Albemarle Sound has been conducted since 1984 to gather information on the food chain available to support growth and development of zooplankton prey for larval fish species using the area as nursery habitat. Collection methods were similar in all years and were described in detail in Rulifson et al. 1986a, 1988a, 1988b). Selected stations of a fixed station array (Figure 30) was used each year; some stations were not sampled during certain years.

Surface phytoplankton samples (whole water) were collected at each station by submerging a 250-ml plastic bottle just below the surface of the water and allowing it to fill. Each sample was preserved with Lugol's acetic acid-iodine solution (Wetzel and Likens 1979). Additional samples of one liter were collected and chilled for laboratory measurements of chlorophyll *a*.

Phytoplankton cell densities were determined using the membrane filtration method (A.P.H.A. 1975). The preserved algae were concentrated by filtering the sample through a 0.45-um pore size membrane filter. Concentrated algae were counted using an inverted microscope and reported as number of individuals per liter. These counts were converted to volume (cubic microns) by estimating the volume of an average individual of each species with geometric formulae. The total volume of algae per liter was converted to weight by assuming a specific gravity of unity.

Chlorophyll *a* analyses were performed by the standard acetone extraction method (Strickland and Parsons 1972) and reported as micrograms per liter of water.

Results

Chlorophyll *a* levels in the lower Roanoke River appear to be about what would be expected for a river-dominated, low salinity estuary in this region during the spring. Between 1986 and 1989 chlorophyll *a* concentrations in the lower Roanoke-western Albemarle Sound have ranged generally between 1 and 10 µg/L, with occasional higher values, in the 15-30 µg/L range. While these values are low in comparison to those measured during the summertime in higher salinity estuaries in the area (e.g., the Pamlico and Neuse River estuaries), they are comparable with data from the upper Pamlico River estuary, and the lower Tar River (Stanley 1988). The Roanoke sampling usually ends in late spring, but, based on extrapolation from year-round sampling results for the Tar-Pamlico, the Chowan (Stanley and Hobbie 1981), and other estuaries, chlorophyll *a* levels in the lower Roanoke and western Albemarle Sound probably are highest in the summer and early fall. Boynton et al. (1982) compiled chlorophyll *a* data from a number of river dominated estuaries (Figure 31). In most cases, the minimum values were in the winter and the maxima occurred during the summer or fall months. Also, note that the lower Roanoke spring values fall well within the range of chlorophyll *a* given in this figure .

There is some phytoplankton species composition and biomass data from other estuaries that can be compared with the lower Roanoke results, although one should be cautioned that in some cases differences in methodology probably account for substantial differences in the results (see Stanley 1988). In every year since the Roanoke phytoplankton sampling began, species of diatoms and green algae have been the dominant taxa, together usually making up 80-

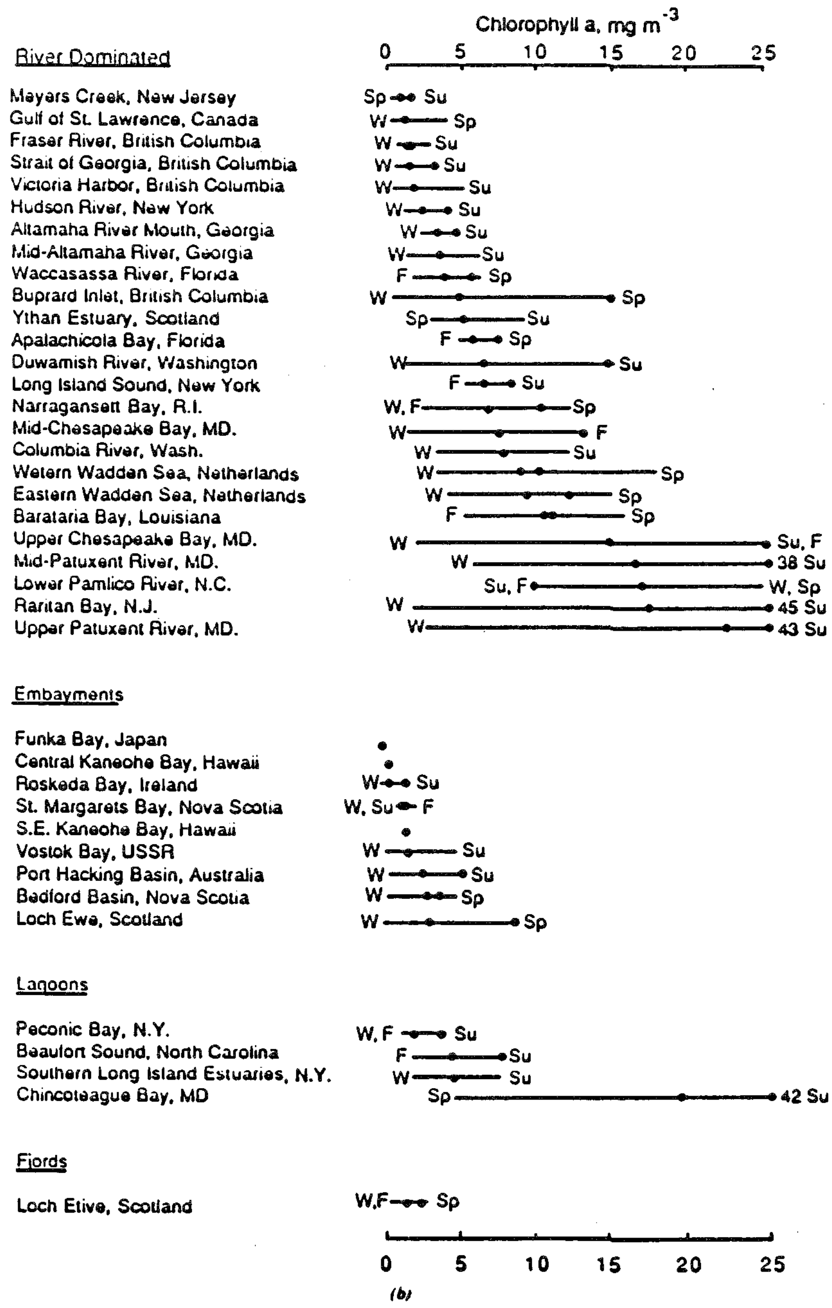


Figure 31. Summary of chlorophyll *a* concentrations in 39 estuarine systems. Annual ranges and seasons in which maximum and minimum concentrations occurred are indicated (W = winter; Sp = spring; Su = summer; F = fall). Solid dots indicate chlorophyll *a* concentrations at time of maximum production (Boynton et al. 1982).

90 percent of the total wet weight biomass. The wet weight biomass has generally ranged between 0.5 and 2.0 mg/L. Comparison of these numbers with those from other estuaries (Table 34), indicates that the Roanoke is not very different from these other, mostly low salinity, estuaries. As is the case in the Roanoke, many of these other systems have a phytoplankton community dominated by diatoms and green algae, both in terms of numbers of taxa, and percentage of total wet weight biomass.

Relationships between Roanoke River flow and either the chlorophyll *a* concentrations, algal biomass, or algal density are not immediately obvious from an examination of the data. However, we have noticed that most of the higher chlorophyll *a* concentrations at Station 1 seem to follow precipitation events by 3-5 days. This could be interpreted as an indication that algae-rich waters in floodplain swamps are being swept into the river during precipitation events. On the other hand, the 1984 data did suggest that unusually high river flow caused a washout of the phytoplankton that spring. Perhaps statistical tests, such as time-lagged regression analyses, can be made in the future which might elucidate some of the subtleties of the river flow-algae relationship.

Table 34. Summary of phytoplankton data from several east coast estuaries. BAC = Bacillariophyceae (diatoms), CHL = Chlorophyceae, CYA = Cyanophyceae, CHR = Chrysophyceae, and DIN = Dinophyceae. S = total number of species found; D = average cell density (cells l^{-1}); and B = average biomass (mg wet mass l^{-1}).

		% of Total in Algal Class						Salinity (ppt)
		BAC	CHL	CYA	CHR	DIN	Other	
South Creek (Stanley & Daniel 1985)	S: 146	47	17	2	7	10	21	0-10
	D: 3.9×10^6	14	11	6	61	6	2	
	B: 1.60	14	14	<1	16	51	4	
South Creek (Hobbie 1971)	D: 52.7×10^6							<15
	B: 9.11							
Pamlico River (Stanley & Daniel 1985)	S: 173	50	18	3	6	8	15	0-20
	D: 4.2×10^6	3	14	<1	59	20	3	
	B: 3.37	3	7	<1	8	80	1	
Cape Fear River, N.C. (Carpenter 1971)	S: 203	66	12	4	1	7	10	11-15
	D: 1.4×10^6							
Chowan River, N.C. (Stanley & Hobbie 1981)	B: 5.61	20	11	22	1	29	17	0
Neuse River, N.C. (Stanley, unpublished)	S: 297	23	37	14	9	4	13	0-10
	D: 12.5×10^6	12	16	63	3	<1	5	
	B: 3.48	15	34	2	6	17	26	
Chesapeake Bay, (Van Valkenburg et al. 1978)	S:149	49	13	2	6	17	13	5-20
	D: 10×10^6	21	21	10	18	10	20	
	B: 3.97	28	<1	<1	6	56	8	
Chesapeake Bay, Old Plantation Ck (Marshall 1980)	S: 219	59	1	4	4	19	13	>20
James River Estuary (Marshall 1967)	S: 74	70	9	1	0	11	9	>15
	D: 1.3×10^6							

19

ZOOPLANKTON ABUNDANCE IN THE LOWER ROANOKE RIVER, DELTA, AND WESTERN ALBEMARLE SOUND, 1986-89.

Roger A. Rulifson, Scott Wood, and Marsha E. Shepherd

Methodology

Sampling for zooplankton in the lower Roanoke River, delta, and western Albemarle Sound has been conducted since 1984 to gather information on the food chain available to support growth and development of larval fish species using the area as nursery habitat. Collection methods were similar in all years and were described in detail in Rulifson et al. 1986a, 1988a, 1988b). A fixed station array (Figure 30) was used each year; some stations were not sampled during certain years.

Zooplankton samples were collected using nets constructed of 250-um nitex mesh material, with a 0.5-m diameter mouth opening and a 1:6 mouth-to-tail ratio. A flowmeter with slow speed propeller (General Oceanics model 2030) was mounted in the net frame to estimate the volume of water filtered. Samples of two-minute duration were taken against the current at river stations, and against the wind or current in the Sound, whichever was strongest. Zooplankton were preserved in 10 percent buffered formalin containing Rose Bengal.

Zooplankton samples were processed using a standard subsample method. Each sample was diluted to 500 ml. A 5-ml subsample was removed from the sample, and all organisms were identified to the lowest practical taxon and enumerated. This procedure was repeated two more times. The average number of each taxonomic group was reported as number per cubic meter of water filtered.

1986

Sampling in 1986 was initiated on 1 May and ended on 10 June. A total of 15 stations was sampled in the Roanoke River, delta, and Batchelor Bay, and 10 stations were sampled in western Albemarle Sound.

Within the lower watershed and Batchelor Bay, zooplankton were most abundant at the initiation of the study on 1 May (823.8/m^3) and on 8 June (1120.6/m^3) (Table 35). Average densities were highest in the Cashie River at Station 8 (1028.9/m^3) and Station 11 (815.3/m^3). Few zooplankton were present in the lower Roanoke River from Williamston to Plymouth. The zooplankton assemblage resembled a freshwater community primarily dominated by cladocerans representing about 48.8 percent of all zooplankton, and copepods representing approximately 46 percent of the total.

In western Albemarle Sound, zooplankton were most abundant at the completion of the study on 10 June (Table 36). The average density at that time was 846.6/m^3, but abundance was quite patchy in time and space. In general, densities were lowest in the northeast part of the Sound (Stations 22, 23, and 27) and highest near the delta and south shore of the Sound (Stations 20, 21, 28, and 29). However, at no time did zooplankton densities in the western Sound approach the concentrations observed in the Cashie River and Batchelor Bay (Table 35). The western Sound zooplankton community was dominated by calanoid copepods representing 88 percent of the assemblage.

Table 35. Densities of zooplankton (number/m3), by date and station, collected in the lower Roanoke River, delta, and Batchelor Bay, North Carolina, in 1986. Period (.) indicates no sample collected.

		STATION															
Date	Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
05/01/86	N	30.2	.	65.8	127.3	222.0	601.1	313.8	2794.9	2663.7	41.0	1263.1	488.2	578.4	1603.7	733.6	823.8
05/03/86	N	86.7	83.8	108.4	144.0	147.9	216.4	202.6	964.5	209.0	335.9	43.8	31.1	1635.0	41.9	932.9	343.6
05/05/86	N	108.5	63.4	97.2	92.3	83.3	100.7	132.4	908.7	563.6	157.9	1472.4	632.5	545.0	176.6	266.0	360.0
05/07/86	N	78.7	92.8	56.4	151.1	140.0	58.6	8.4	750.2	689.2	261.1	790.2	251.5	1184.6	831.6	756.0	410.7
05/09/86	N	62.1	57.3	143.9	235.8	363.8	278.5	560.5	1267.1	394.3	238.7	1065.4	557.5	.	.	.	435.4
05/11/86	N	71.9	54.7	201.3	263.9	619.0	612.9	91.5	1487.8	1060.6	796.8	1076.9	869.2	202.7	100.7	87.5	506.5
05/13/86	N	50.7	35.2	33.1	65.4	244.8	453.2	295.2	1428.9	522.9	301.2	743.5	593.1	.	.	.	397.3
05/15/86	N	21.1	37.8	103.7	206.8	160.5	59.3	116.6	845.8	504.0	83.2	1150.0	330.1	323.1	122.8	269.9	289.0
05/17/86	N	6.3	10.6	42.0	47.2	70.9	152.1	137.4	484.5	214.7	109.0	361.1	158.3	533.7	331.3	93.6	183.5
05/19/86	N	4.1	12.5	74.3	90.4	73.1	49.6	22.9	166.5	120.3	58.3	535.1	134.4	229.8	1015.4	287.8	191.6
05/21/86	N	9.5	12.6	11.0	44.3	36.0	63.0	56.4	411.0	71.2	46.5	234.5	67.2	128.6	470.8	414.7	138.5
05/23/86	N	.	.	.	.	90.2	64.8	60.5	174.4	58.8	75.7	194.3	159.4	194.3	345.1	473.3	171.9
05/25/86	N	.	.	.	.	61.5	81.0	108.8	138.1	94.6	46.0	413.7	108.2	101.9	315.6	125.6	145.0
05/27/86	N	.	.	.	.	83.7	61.7	23.9	468.4	51.2	72.8	531.0	219.4	117.9	200.7	131.4	178.4
05/29/86	D	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
05/29/86	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
05/31/86	N	.	.	.	.	230.6	381.4	78.6	2206.6	354.6	60.3	1133.9	147.4	563.3	256.4	155.7	506.3
06/04/86	N	.	.	.	.	95.8	61.4	26.7	367.7	89.0	268.3	819.9	529.8	418.4	586.2	1172.9	403.3
06/06/86	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
06/08/86	N	.	.	.	.	245.9	485.5	696.9	2626.5	914.3	204.0	2301.0	2759.8	916.8	769.5	677.2	1120.6
06/10/86	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ave density (/m3)		48.2	46.1	85.2	133.5	174.7	222.4	172.5	1028.9	504.5	185.7	815.3	472.8	511.6	481.8	443.0	355.1
Number of efforts		11	10	11	11	17	17	17	17	17	17	17	17	15	15	15	224

Table 36. Densities of zooplankton (number/m3), by date and station, collected in western Albemarle Sound, North Carolina, in 1986. Period (.) indicates no sample collected.

		STATION										
Date	Period	20	21	22	23	24	25	26	27	28	29	Average
05/01/86	N	.	.	.	.	.	.	.	.	.	.	.
05/03/86	N	.	.	.	.	.	.	.	.	.	.	.
05/05/86	N	.	.	.	.	.	.	.	.	.	.	.
05/07/86	N	.	.	.	.	.	.	.	.	.	.	.
05/09/86	N	.	.	.	.	.	.	.	.	.	.	.
05/11/86	N	.	.	.	.	.	.	.	.	.	.	.
05/13/86	N	.	.	.	.	.	.	.	.	.	.	.
05/15/86	N	.	.	.	.	.	.	.	.	.	.	.
05/17/86	N	.	.	.	.	.	.	.	.	.	.	.
05/19/86	N	.	.	.	.	.	.	.	.	.	.	.
05/21/86	N	.	.	.	.	.	.	.	.	.	.	.
05/23/86	N	.	.	.	.	.	.	.	.	.	.	.
05/25/86	N	.	.	.	.	.	.	.	.	.	.	.
05/27/86	N	.	.	.	.	.	.	.	.	.	.	.
05/29/86	D	12.8	1.3	28.3	22.0	18.7	13.5	12.2	18.0	26.8	46.0	19.9
05/29/86	N	55.9	157.2	557.9	324.0	343.0	1105.7	354.6	110.2	179.6	108.9	329.7
05/31/86	N	.	.	.	.	.	.	.	.	.	.	.
06/04/86	N	.	.	.	.	.	.	.	.	.	.	.
06/06/86	N	248.6	284.1	452.9	.	519.5	600.8	1005.5	315.6	1168.9	1525.9	680.2
06/08/86	N	.	.	.	.	.	.	.	.	.	.	.
06/10/86	N	1843.7	1256.7	272.4	594.7	1065.9	290.1	654.2	284.9	1076.5	1126.8	846.6
Ave density (/m3)		540.3	424.8	327.9	313.6	486.8	502.5	506.6	182.2	613.0	701.9	459.9
Number of efforts		4	4	4	3	4	4	4	4	4	4	39

1987

Sampling in 1987 was initiated on 16 April and was terminated on 19 June. Fourteen stations were sampled in the Roanoke River, delta, and Batchelor Bay. A total of 12 stations was sampled in western Albemarle Sound.

Within the lower watershed and Batchelor Bay, two peaks in abundance were observed: in late April and again in mid-May (Table 37). These periods corresponded with a change from a mode of peak power generation at Roanoke Rapids Dam, to a mode of flood evacuation of the reservoir system at discharge rates the highest recorded (35,000 cfs) in the post-impoundment period (Figure 31). Average densities were highest at Stations 1 and 2 above Plymouth, indicating a possible input of zooplankton from the adjacent flooded streams and floodplain. Overall, the grand average mean zooplankton concentration was higher in 1987 than in 1986, but densities were actually lower in 1987 later in the season (Tables 35, 37). *Bosmina*, *Daphnia*, and other cladocerans made up over 84 percent of all zooplankton in the lower watershed; copepods comprised only 8.5 percent of the total.

In western Albemarle Sound, peak zooplankton abundance was observed with the first full set of samples on 9 June (Table 38). Abundance prior to 9 June was not determined. The area of greatest zooplankton abundance late in the season was along the north shore (Stations 22, 23, and 24) of western Albemarle Sound, primarily Edenton Bay (Table 38, Figure 30). These results suggest that high flows of the Roanoke River in the spring of 1987 flushed zooplankton from the river and Batchelor Bay across the western Sound to the north shore. Zooplankton concentrations along the north shore were higher than river and delta concentrations in late May and early June (Tables 37, 38). In contrast to the lower watershed, the western Sound zooplankton were dominated by copepods, representing approximately 65 percent of the community. Cladocerans made up only 22 percent of the Sound zooplankton community.

1988

Sampling in 1988 began on 14 April and ended on 15 June. The sampling schedule was similar to that in 1987: 14 stations in the lower watershed and Batchelor Bay, and 10 stations in western Albemarle Sound. The location of Station 1 was shifted upstream to Hamilton; the other stations remained in their respective locations.

Overall, zooplankton abundance in the lower Roanoke watershed was much lower in 1988 compared to the previous two years (Table 39). A peak in abundance was observed on 22 May, primarily from relatively large zooplankton concentrations in the Cashie River (Stations 8, 11, and 13). Over the season, zooplankton were in greatest numbers in the Cashie River (Stations 8 and 11) and at Station 1 just below Hamilton (Figure 30). Copepods represented about 51 percent of the watershed zooplankton community, and cladocerans were nearly 41 percent of the total. Moderate flows prevailed in 1988, but reservoir discharge during early spring (March through mid-April) was at minimal levels (Figure 6). Results of the zooplankton studies suggest that higher river flows are required in March and early April to flood the adjacent streams and floodplain to provide an initial input of zooplankton.

Zooplankton abundance in western Albemarle Sound also was lower in 1988 than in the two previous years. In general, Station 22 toward Edenton Bay had highest average zooplankton concentrations, but abundance was sporadic and shifted by date. The highest value obtained was at Station 18 on the South shore near Makeys on 15 June (Table 40). The zooplankton community was dominated by copepods (81.6 percent); cladocerans were second in abundance but represented only 6.3 percent of the total.

Table 37. Densities of zooplankton (number/m3), by date and station, collected in lower Roanoke River, delta, and Batchelor Bay, North Carolina, in 1987. Period (.) indicates no sample collected.

	STATION														
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	15	Ave.
04/16/87	1514.4	.	.	1015.1	.	.	.	1627.6	.	.	.	.	.	1609.2	1441.6
04/23/87	.	.	.	.	.	.	.	1889.8	.	.	.	.	.	1372.6	1631.2
04/29/87	1171.6	.	.	697.2	.	.	.	837.9	.	.	.	927.0	.	.	908.4
05/06/87	510.2	.	.	315.5	.	316.6	318.1	346.3	268.4	206.0	367.4	278.7	233.9	145.1	300.6
05/08/87	.	.	.	.	.	247.5	353.0	211.3	229.5	273.4	230.7	299.0	.	.	263.5
05/10/87	.	.	.	.	.	.	.	.	.	.	.	.	.	166.7	166.7
05/12/87	.	.	.	.	.	357.4	186.2	220.9	251.4	224.0	204.9	267.3	397.3	252.4	262.5
05/14/87	942.4	462.9	441.3	438.9	417.0	348.8	399.3	551.8	275.6	317.7	268.6	211.8	.	108.1	398.8
05/16/87	1198.2	767.0	608.0	561.1	725.3	.	.	.	.	.	.	.	.	.	771.9
05/18/87	1420.9	1152.5	611.7	756.3	470.8	375.7	508.5	1102.6	107.4	525.2	728.8	464.8	517.3	203.8	639.0
05/20/87	2108.7	1442.5	701.1	1002.9	1221.4	965.5	900.3	708.8	639.0	603.7	736.5	482.8	337.0	249.3	873.2
05/22/87	2136.2	2451.5	687.0	1269.7	1453.2	1592.7	935.8	1139.0	1018.0	860.2	1062.6	864.3	650.7	256.6	1174.1
05/24/87	1464.9	2019.7	626.2	623.4	1042.8	978.2	897.3	638.3	707.3	1063.8	1137.9	616.3	433.6	279.6	899.6
05/26/87	1198.6	1644.1	468.5	490.2	993.0	645.9	537.6	535.4	429.0	459.9	763.7	381.6	283.3	274.4	650.4
05/28/87	813.2	1347.4	452.0	370.0	410.5	486.9	715.7	238.4	332.6	450.1	394.7	332.4	133.4	147.8	435.0
05/30/87	330.7	691.0	120.5	211.7	221.9	266.7	·223.0	247.2	169.1	249.5	212.7	241.1	99.8	72.8	244.1
06/01/87	721.2	496.7	133.0	160.2	193.3	189.7	.	270.0	139.5	215.8	408.2	136.3	151.9	334.2	277.0
06/03/87	393.2	270.5	196.1	.	.	.	.	.	.	.	.	.	.	.	286.6
06/05/87	.	.	.	.	104.2	137.2	127.4	207.2	132.5	100.0	272.6	153.0	141.4	91.2	146.7
06/07/87	.	.	.	.	169.7	100.1	247.4	76.5	128.4	186.8	362.0	162.7	190.1	141.9	176.6
06/09/87	.	.	.	.	.	.	.	.	.	.	.	.	.	89.0	89.0
06/11/87	.	.	.	.	.	.	.	.	.	.	.	.	.	31.1	31.1
06/13/87	.	.	.	.	.	.	.	.	.	.	.	.	.	121.0	121.0
06/15/87	.	.	.	.	.	.	.	.	.	.	.	.	.	9.2	9.2
06/17/87	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
06/19/87	.	.	.	.	.	.	.	.	.	.	.	96.9	130.6	70.4	99.3
Ave.	1146.0	1158.7	458.7	608.6	618.6	500.6	488.4	641.7	349.1	410.1	515.1	376.1	233.9	237.0	560.9

Table 38. Densities of zooplankton (number/m3), by date and station, collected in western Albemarle Sound, North Carolina, in 1987. Period (.) indicates no sample collected.

	STATION												
DATE	16	17	18	20	21	22	23	24	26	28	31	32	Ave.
04/16/87	.	.	.	.	.	.	.	.	371.2	.	411.0	.	391.1
04/23/87	.	.	.	.	.	.	.	.	375.2	.	307.7	.	341.4
04/29/87	.	.	.	.	.	.	.	.	.	.	.	.	.
05/06/87	20.9	.	.	.	.	.	.	.	.	.	.	.	20.9
05/08/87	.	.	.	.	.	.	.	.	.	.	.	.	.
05/10/87	.	139.0	96.9	289.6	73.8	70.9	95.5	65.9	61.0	87.0	7.4	54.3	94.7
05/12/87	187.8	.	.	.	.	.	.	.	.	.	.	.	187.8
05/14/87	.	.	.	.	.	.	.	.	.	.	.	.	.
05/16/87	.	.	.	.	.	.	.	.	.	.	.	.	.
05/18/87	336.8	.	.	.	.	.	.	.	.	.	.	.	336.8
05/20/87	311.9	.	.	.	.	.	.	.	.	.	.	.	311.9
05/22/87	211.9	.	.	.	.	.	.	.	.	.	.	.	211.9
05/24/87	615.0	.	.	.	.	.	.	.	.	.	.	.	615.0
05/26/87	119.4	.	.	.	.	.	.	.	.	.	.	.	119.4
05/28/87	266.9	.	.	.	.	.	.	.	.	.	.	.	266.9
05/30/87	144.3	.	.	.	.	.	.	.	.	.	.	.	144.3
06/01/87	151.7	.	.	.	.	.	.	.	.	.	.	.	151.7
06/03/87	.	.	.	.	.	.	.	.	.	.	.	.	.
06/05/87	154.4	.	.	.	.	.	.	.	.	.	.	.	154.4
06/07/87	142.9	.	.	.	.	.	.	.	.	.	.	.	142.9
06/09/87	.	213.5	194.9	90.6	114.3	1957.6	3641.2	2087.1	791.7	569.1	25.2	296.6	907.4
06/11/87	.	48.6	112.4	75.9	96.5	749.4	1407.7	144.9	351.8	1499.7	79.5	1725.6	572.0
06/13/87	.	350.4	274.3	112.7	97.9	.	.	.	.	759.4	12.0	338.1	277.8
06/15/87	.	11.0	148.5	9.0	172.4	189.1	960.9	980.1	165.3	482.9	144.5	272.1	321.4
06/17/87	.	.	.	.	.	.	.	.	.	.	32.6	134.5	83.5
06/19/87	104.6	237.4	1152.6	597.2	692.7	.	.	.	902.6	491.8	132.0	71.7	487.0
Ave.	213.0	166.7	329.9	195.8	207.9	741.7	1526.3	819.5	431.2	648.3	128.0	413.3	485.1

Table 39. Densities of zooplankton (number/m3), by date and station, collected in lower Roanoke River, delta, and Batchelor Bay, North Carolina, in 1988. Period (.) indicates no sample collected.

	STATION														
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	15	Ave.
04/14/88	759.7	78.1	.	396.2	.	730.9	720.9	341.2	.	247.3	.	.	.	.	467.8
04/21/88	185.9	72.4	.	266.8	.	309.4	153.5	453.4	.	296.7	.	.	.	.	248.3
04/28/88	65.0	209.7	.	219.2	.	149.0	80.0	274.2	.	127.3	.	.	.	90.2	151.8
05/05/88	135.6	58.3	.	64.2	.	73.1	87.0	152.9	.	110.5	.	.	.	.	97.4
05/08/88	282.9	210.7	174.2	223.3	149.6	154.3	111.8	600.4	106.7	28.8	440.0	152.9	83.3	128.8	203.4
05/11/88	65.7	70.5	88.8	101.4	162.5	154.4	138.8	.	119.5	10.9	.	48.4	.	87.4	95.3
05/12/88	442.4	139.0	55.9	46.4	68.3	57.7	25.9	134.4	58.7	70.5	129.4	149.2	112.5	51.0	110.1
05/14/88	135.8	437.0	478.1	341.6	174.0	262.5	208.4	91.9	161.0	68.8	216.0	94.8	84.4	134.4	206.3
05/16/88	407.7	188.8	494.3	.	.	310.5	130.8	.	.	319.5	.	.	.	.	308.6
05/18/88	1002.9	450.0	415.0	339.4	214.5	268.8	315.7	311.6	169.2	18.6	543.2	94.1	164.8	264.7	326.6
05/20/88	401.8	479.3	524.9	354.3	247.5	140.0	124.1	36.0	216.9	125.7	12.1	253.7	159.8	154.8	230.8
05/22/88	954.1	450.6	425.5	547.6	309.9	792.8	382.7	2359.5	495.6	164.3	2722.1	198.2	1146.1	289.9	802.8
05/24/88	440.2	.	.	.	.	.	.	.	.	83.7	.	383.4	.	.	302.4
05/26/88	567.3	370.8	512.2	297.4	228.0	330.0	150.4	1448.4	200.4	142.7	1394.2	177.9	316.3	.	472.0
05/28/88	244.2	327.1	448.2	289.8	398.4	43.5	14.9	1073.0	224.2	135.5	1380.5	174.5	269.2	143.9	369.1
05/30/88	322.9	183.7	255.4	150.8	163.6	212.3	66.9	1085.4	143.2	129.7	1488.6	83.5	219.1	85.5	327.9
06/01/88	.	.	.	.	.	.	.	233.8	249.0	86.6	530.3	.	411.2	289.1	300.0
06/03/88	.	.	.	.	97.6	155.1	52.7	365.7	94.7	64.7	284.5	95.1	.	.	151.3
06/05/88	.	.	.	.	.	.	.	203.7	87.9	145.9	179.7	.	119.4	44.2	130.1
06/06/88	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
06/07/88	.	.	.	.	.	.	.	.	.	.	.	.	.	49.0	49.0
06/11/88	.	.	.	.	.	.	.	.	.	.	.	.	.	168.4	168.4
06/13/88	.	.	.	.	.	.	.	.	.	.	.	.	.	71.9	71.9
06/15/88	.	.	.	.	.	.	.	.	.	.	.	.	.	138.8	138.8
Ave.	400.9	248.4	352.1	259.9	201.3	259.0	172.8	572.8	179.0	125.1	776.7	158.8	280.6	137.0	294.6

Table 40. Densities of zooplankton (number/m3), by date and station, collected in western Albemarle Sound, North Carolina, in 1988. Period (.) indicates no sample collected.

	STATION												
DATE	16	17	18	20	21	22	23	24	26	28	31	32	Ave.
04/14/88	.	.	.	.	.	.	.	.	.	.	.	.	.
04/21/88	.	.	.	.	.	.	.	.	.	.	.	.	.
04/28/88	.	.	.	.	.	.	.	.	.	.	.	.	.
05/05/88	.	.	.	.	.	.	.	.	.	.	.	.	.
05/08/88	64.8	.	.	.	.	.	.	.	.	.	.	.	64.8
05/11/88	.	.	.	.	.	.	.	.	.	.	.	.	.
05/12/88	127.1	.	.	.	.	.	.	.	.	.	.	.	127.1
05/14/88	139.9	.	.	.	.	.	.	.	.	.	.	.	139.9
05/16/88	.	.	.	.	.	.	.	.	.	.	.	.	.
05/18/88	291.9	.	.	.	.	.	.	.	.	.	.	.	291.9
05/20/88	177.2	.	.	.	.	.	.	.	.	.	.	.	177.2
05/22/88	410.1	.	.	.	.	.	.	.	.	.	.	.	410.1
05/24/88	.	.	.	.	.	.	.	.	.	.	.	.	.
05/26/88	455.7	.	.	.	.	.	.	.	.	.	.	.	455.7
05/28/88	331.8	.	.	.	.	.	.	.	.	.	.	.	331.8
05/30/88	394.4	.	.	.	.	.	.	.	.	.	.	.	394.4
06/01/88	228.6	.	51.1	.	79.0	.	.	.	.	.	694.3	403.3	291.3
06/03/88	.	.	.	.	.	.	.	.	.	.	.	.	.
06/05/88	22.5	.	67.5	.	94.6	.	.	.	.	.	348.7	.	133.3
06/06/88	.	.	.	.	.	.	.	.	.	.	.	17.7	17.7
06/07/88	107.0	.	33.9	.	428.9	592.4	455.5	563.5	292.9	70.9	68.3	323.9	293.7
06/11/88	50.3	.	157.1	.	124.6	594.8	44.1	622.6	276.8	927.4	181.7	591.5	357.1
06/13/88	55.4	.	104.8	.	178.6	539.6	15.5	57.6	26.9	234.8	171.7	102.8	148.8
06/15/88	.	.	1520.7	.	65.4	582.8	.	.	349.4	85.5	26.7	426.8	436.8
Ave.	204.0	.	322.5	.	161.9	577.4	171.7	414.6	236.5	329.7	248.6	311.0	297.8

1989

Sampling in 1989 was initiated on 21 April and was terminated on 18 June. Fourteen stations were sampled in the Roanoke River, delta, and Batchelor Bay. An additional 11 stations were sampled in western Albemarle Sound. Location of the stations and the sampling protocol were the same as for 1988.

Within the lower river, delta, and Batchelor Bay the spatial distribution of the zooplankton community was more similar to that observed in 1987 than that observed in 1986 or 1988 (Table 41). Overall, zooplankton abundance was greatest upstream at Stations 1 and 2, and the Cashie River stations 8 and 11 (Table 41). A peak in zooplankton abundance observed on 9 May was due to relatively high concentrations of zooplankton at Station 4 and Station 5 above the delta; this also corresponds to the dramatic change in water release at the Roanoke Rapids Dam from several thousand cfs to 20,000 cfs (Figure 21). We believe that this increase in zooplankton resulted from the flushing action of floodwaters in the small tributaries and standing floodplain waters. A second peak observed on 6 June was due to concentrations of zooplankton upstream at Station 1 and Station 2, and also Station 8 in the Cashie River. Cladocerans were the most abundant zooplankters (59 percent) in the lower watershed, followed by copepods (21.5 percent) and rotifers (9.9 percent).

Zooplankton abundance in western Albemarle Sound late in the spawning season was greater than that observed for the river stations (Table 42). Greatest concentrations of zooplankton were observed in the central portion of Albemarle Sound at Stations 24, 26, and 28 (Figure 30). Also, Stations 18 and 20 just east of the discharge area of the Roanoke River mainstem had relatively high zooplankton concentrations. The bulk of the western Sound zooplankton was comprised of copepods (57.7 percent) and cladocerans (37.2 percent).

Table 41. Densities of zooplankton (number/m3), by date and station, collected in lower Roanoke River, delta, and Batchelor Bay, North Carolina, in 1989. Period (.) indicates no sample collected.

		STATION														
DATE	P	1	2	3	4	5	6	7	8	9	10	11	12	13	15	Ave.
04/21/89	N	364.1	.	.	308.1	.	.	.	.	.	.	.	.	.	.	336.1
04/28/89	N	551.9	.	.	799.0	.	372.5	368.6	638.6	.	1109.5	.	.	.	.	640.0
05/03/89	N	105.5	155.9	393.2	316.1	106.7	589.8	496.6	393.8	542.7	318.3	291.9	394.1	383.7	276.4	340.3
05/05/89	N	301.2	170.3	429.5	337.2	631.5	606.6	339.8	270.7	473.8	195.0	.	.	.	.	375.6
05/07/89	N	169.0	840.4	605.7	504.8	510.8	645.1	423.3	541.3	649.7	478.6	407.5	435.7	391.0	273.2	491.1
05/09/89	N	220.7	565.8	783.4	1029.9	1032.7	729.5	641.8	399.6	657.9	502.1	672.4	437.2	437.0	407.9	608.4
05/15/89	N	122.9	180.8	258.3	362.6	287.6	.	.	.	.	.	.	.	.	.	242.5
05/16/89	N	.	.	.	.	.	166.4	307.5	302.6	275.2	201.4	242.9	298.8	145.7	288.0	247.6
05/18/89	N	156.9	170.8	178.9	202.9	221.8	195.4	223.0	226.9	263.9	239.9	169.7	260.1	132.7	144.4	199.1
05/21/89	N	148.2	185.6	165.7	125.9	168.1	148.0	174.4	78.0	134.1	135.6	154.2	144.8	184.2	71.9	144.2
05/23/89	N	158.7	165.4	135.8	.	.	.	.	.	.	.	.	.	.	.	153.3
05/24/89	N	.	.	.	.	.	175.5	165.3	139.6	133.8	198.0	186.1	172.2	105.4	140.0	157.3
05/25/89	N	273.2	302.1	222.8	205.2	206.9	187.0	159.4	195.4	152.5	165.2	442.1	150.4	186.9	91.4	210.0
05/27/89	N	365.1	208.0	439.9	252.8	186.5	202.6	266.7	172.7	164.1	224.9	286.2	177.8	261.0	150.0	239.9
05/29/89	N	134.6	260.3	296.5	314.2	415.9	262.7	263.6	306.6	200.6	272.8	292.8	261.7	203.2	146.8	259.5
05/31/89	D	.	.	.	.	.	.	.	210.0	190.6	330.8	159.5	.	.	61.4	190.5
05/31/89	N	2780.9	351.7	154.0	365.9	286.6	232.1	223.9	368.0	159.5	161.2	578.8	172.8	248.7	180.1	447.4
06/02/89	N	1264.0	1234.7	504.0	833.7	377.2	259.9	269.3	651.7	273.3	358.2	990.5	307.1	346.7	252.5	565.9
06/04/89	N	1749.5	575.2	252.2	368.2	288.8	289.8	285.7	408.7	242.2	220.8	384.3	274.8	306.2	236.6	420.2
06/06/89	N	2537.1	1214.8	342.0	485.8	281.9	182.5	192.9	1857.1	128.9	188.6	469.8	255.7	365.4	173.1	619.7
06/08/89	N	.	.	.	.	418.4	302.0	311.8	996.1	318.5	209.5	1085.7	204.6	473.1	166.6	448.6
06/10/89	D	.	.	.	.	.	.	.	.	.	.	.	.	.	148.7	148.7
06/10/89	N	.	.	.	.	.	.	.	.	.	.	.	.	.	126.7	126.7
06/12/89	N	.	.	.	.	141.1	270.6	165.6	971.5	225.3	105.5	.	.	.	.	313.3
06/14/89	N	.	.	.	.	.	.	.	.	.	.	.	.	.	121.3	121.3
06/16/89	N	.	.	.	.	.	.	.	.	.	.	.	.	.	175.8	175.8
06/18/89	N	.	.	.	.	.	.	.	.	.	.	.	.	.	138.6	138.6
AVE.	D	.	.	.	.	.	.	.	210.0	190.6	330.8	159.5	.	.	105.0	199.2
AVE.	N	670.8	438.8	344.1	425.8	347.7	323.2	293.3	495.5	293.9	293.6	443.7	263.2	278.1	187.4	364.2

Table 42. Densities of zooplankton (number/m3), by date and station, collected in western Albemarle Sound, North Carolina, in 1989. Period (.) indicates no sample collected.

		STATION											
DATE	P	16	18	20	21	22	23	24	26	28	31	32	Ave.
05/03/89	N	404.0	.	.	.	.	.	.	.	.	.	.	404.0
05/07/89	N	148.2	.	.	.	.	.	.	.	.	.	.	148.2
05/09/89	N	387.2	.	.	.	.	.	.	.	.	.	.	387.2
05/16/89	N	165.7	.	.	.	.	.	.	.	.	.	.	165.7
05/18/89	N	219.1	.	.	.	.	.	.	.	.	.	.	219.1
05/21/89	N	101.2	.	.	.	.	.	.	.	.	.	.	101.2
05/24/89	N	111.5	.	.	.	.	.	.	.	.	.	.	111.5
05/25/89	N	165.0	.	.	.	.	.	.	.	.	.	.	165.0
05/29/89	N	219.8	.	.	.	.	.	.	.	.	.	.	219.8
05/31/89	N	207.9	.	.	.	.	.	.	.	.	.	.	207.9
06/02/89	N	271.0	.	.	.	.	.	.	.	.	.	.	271.0
06/04/89	N	320.6	.	.	.	.	.	.	.	.	.	.	320.6
06/06/89	N	198.3	.	.	.	.	.	.	.	.	.	.	198.3
06/08/89	N	276.2	.	.	.	.	.	.	.	.	.	.	276.2
06/10/89	D	.	.	.	.	.	39.7	.	103.3	36.3	38.1	.	54.3
06/10/89	N	.	815.7	1559.0	245.9	154.9	220.8	930.9	601.6	683.5	139.0	188.1	553.9
06/14/89	N	.	563.6	160.5	183.7	340.0	543.0	1171.3	764.9	548.1	211.9	304.3	479.1
06/16/89	N	.	.	.	.	.	.	.	.	.	355.0	.	355.0
06/18/89	N	.	543.4	217.1	1081.2	572.8	932.4	1124.4	446.5	1354.1	450.3	658.4	738.1
AVE.	D	.	.	.	.	.	39.7	.	103.3	36.3	38.1	.	54.3
AVE.	N	228.3	640.9	645.6	503.6	355.9	565.4	1075.5	604.3	861.9	289.0	383.6	559.5

WILDLIFE RESOURCES

Impacts on Wild Turkey

Michael H. Seamster, WRC

Periodic extended flooding of the Roanoke River basin has been suspected of causing displacement of wild turkeys and a reduction in reproductive success and poultry survival rates. Dramatic annual fluctuations in fall turkey populations have been associated with the severity of floods during the previous nesting and brood rearing seasons. A recently completed three-year research project, conducted jointly by the North Carolina Wildlife Resources Commission and North Carolina State University, on the effects of flooding on wild turkey populations, verifies that there is a significant adverse effect of such flooding on wild turkey populations.

The Roanoke River floodplain was inundated by flood waters during most of the spring and summer months of 1989. Since the previously mentioned research project has been completed, the total impact of the 1989 river conditions cannot be specifically documented. However, data gathered during the previous three years allow several conclusions to be drawn on the impacts of flooding in 1989.

The most immediate effect of the 1989 floods was on wild turkey hunting. One of the two scheduled permit hunts on the Roanoke River Wetlands had to be postponed twice. This eliminated many hunters from participating. Since most of the lowground was flooded during much of the spring season, hunting on private lands was also affected.

The combined effect of the 1987 floods and the 1989 floods on both hunting and turkey populations has caused the harvest to decline. Over the last two years, the reported harvest in the Roanoke River basin has declined by 13 percent. This becomes even more significant when one realizes that, during this time frame, the statewide reported harvest increased by 87 percent.

Undoubtedly, the 1989 floods adversely impacted wild turkey populations in the Roanoke River basin. Obviously, during flooded conditions, wild turkeys were displaced out of lowground habitats in which they would normally be found. Beyond displacement, reproduction was certainly affected. During 1986, when no floods occurred, 85 percent of the documented nesting took place in habitats that would be inundated during floods. Approximately 65 percent of the habitats utilized as brood range would have been inundated during flooding. These lowground habitats, where most of the wild turkey nesting and brood rearing takes place, were inundated during the spring and summer of 1989 and wild turkey reproduction was adversely affected.

The extent of this adverse impact on reproduction cannot be fully documented. However, conclusions can be drawn from the effects similar floods have had in the past. In 1986, when no flooding occurred, an average of 3.03 poults per hen was recorded. In 1987, when flood conditions occurred throughout most of the spring and early summer, an average of only 0.14 poults per hen was recorded. One would surmise that, due to the flooded conditions of 1989, the wild turkey reproductive index would be similar to the index for 1987.

The most significant effect of the flood in 1989 may be the fact that it so closely follows the 1987 flood, making two of the last three years in which flooding has occurred. Population modeling techniques developed using the data gathered over the last three years indicates that it takes four to five years for a wild turkey population to fully recover from the adverse effects on reproduction caused by flooding. The fact that the 1989 flood conditions occurred only two years after the 1987 flood greatly compounds the problem. The population had not fully recovered from the effects of the 1987 flood conditions. Therefore, the 1989 conditions are even more damaging to wild turkey than if the year was preceded by several years of minimal flooding.

Impacts on Deer

J. Scott Osborne, WRC

Reports from Wildlife Resources Commission personnel who frequently work in the area of the Roanoke River indicate that water levels in the floodplain were unusually high throughout the spring, summer, and fall of 1989. As documented in previous reports, flooding of short duration is not harmful to deer or their habitat. However, water level management that accounts for extended flooding during the spring and fall seasons can adversely affect the number, condition, and survival of deer along the river. It also can result in declines in harvest and hunter success when these conditions exist.

The majority of the fawns in this area are born during the period of May to the middle of June. Water levels during this period in 1989 were high, and this undoubtedly resulted in the displacement of pregnant does from normal home ranges as well as the decline in overall habitat available for rearing of fawns. The effect of survival and the associated impact on future deer numbers will not be evident until harvest records are available for the 1989 hunting season.

Flood situations also existed during the fall period and resulted in the loss of hunting opportunity for sportsmen on private lands as well as on our Roanoke River Wetlands. Several hunts had to be canceled due to high water levels. Again, the impact on total harvest and hunter success rates will be determined following the hunting season.

Perhaps the most significant impact of the fall flooding on deer is the reduction of foraging areas containing oak mast. Most of the riverbottom oaks had good quantities of mast during 1989. However, flood waters displaced deer from many of the areas where they could obtain this very important high energy diet component. We know that there is a direct relationship between mast and deer condition and productivity. Most certainly there were fewer oak flats available for deer to forage in during the fall of 1989.

For the year as a whole, conditions during 1989 were deleterious to deer populations along the Roanoke River. Displacement of deer, lower condition levels, concentration of parasite and disease organisms, high fawn mortality, and increased crop depredation have all been shown to occur in riverbottom habitats where prolonged flood waters exist. Flow conditions along the Roanoke during 1989 were such that any or all of the above factors could have been enhanced because of the duration and intensity of flooding during the year.

Impacts on Waterfowl

Dennis Luszcz, WRC

River flow needs for waterfowl in the lower Roanoke River have not been studied in detail. Therefore, the following information is of a general nature involving whether the river is flooding or within its banks.

Both wintering waterfowl, and resident breeding ducks, mainly wood ducks, need to be considered in the Roanoke basin. In a broad sense, flooding of bottomlands between mid-December and April would probably not adversely impact waterfowl and would benefit them by providing access to food resources and seclusion from human disturbance for resting and roosting. There is a possibility that extremely high flows during the period may not be desirable because of excessive depth in feeding areas and scouring of food sources by strong currents. Winter flooding extending into late March or April would benefit wood ducks by perhaps hampering nest predation and by recharging permanent and semi-permanent swamp basins and beaver ponds for the summer.

The reduction and rise of floodwaters should be gradual and not sudden. A slow flooding of ground litter and moist soil herbaceous plants makes for the most efficient use of these food resources by ducks. Wood ducks in particular are known to make heavy use of newly flooded litter.

Flooding of the bottomlands during the summer and fall (April through mid-December), as occurred in 1989, should be avoided. Prolonged flooding during the growing season causes serious stress on many tree species, even those generally thought to be flood tolerant. Highly desirable oaks could be reduced in number and in mast production. It may be that flooding every other year or every third year is preferable to annual flooding.

Another consideration may be that late summer-fall flooding may have an adverse impact on seed production from important moist soil herbaceous plants such as millet and smartweed. The plants themselves may be killed by the overflooding, or seed produced by the plants could be affected and made unavailable to ducks.

21 FORESTRY AND AGRICULTURE

Tom Ellis

Damages to agriculture from high water in the Roanoke River were the result of slowed natural drainage of swamps into the flood plain. Water accumulating in the woodland resulted in saturated conditions with overflowing waters damaging field and roads. Both of these delayed crop planting, resulting in a less than optimum growing season.

In 1988, Halifax County experienced over 1,200 acres of delayed planting of cotton and soybeans due to river related inconveniences.

The spring of 1989 was significantly different with the extended period of high water. Drainage was blocked and water accumulated in the crop areas. Locally high rainfall resulted in increased problems due to ponding of rainwater. In Bertie County, 1,000 acres of wheat were affected with an average loss of 20 bushels per acre. Approximately 3,000 acres of corn was affected - half was delayed in planting and the rest not planted at all. Field damages to 2,500 acres of peanuts caused by flooding resulted in both planting and harvesting problems. Yield loss was significant.

Forestry damages were primarily related to lost opportunities for harvest, moving of timbering operations, and road damage. Specific damages are available only for Martin County, which were estimated at $16,000 for 1988 and $122,000 for 1989. The latter included the cost ($20,000) of reforestation of 200 acres needed due to the flood waters.

Bertie and Halifax Counties also experienced flooding of large amounts of timberland with significant road damage occurring.

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APPENDIX 1

Hourly Flow Data, 1986-1989.

Hourly Flow Data (cfs) of the Roanoke River below Roanoke Rapids Reservoir, NC, for the period March-June 1986, 1987, 1988, and 1989 as recorded by U.S.G.S. water gage no. 02080500.

Column	Variable
1	Date (MM/DD/YY)
2-25	Flow in cfs starting at 0100 hours (column 2) and ending at 2400 hours (column 25)
26	Average river flow (in cfs) for the date
27	Standard deviation of river flow for the date

03/01/86	1,339	1,156	1,075	1,025	1,045	1,045	1,035	1,045	1,055	1,065	1,045	1,035	1,016	1,016	1,035	1,035	1,035	1,045	1,055	1,065	1,065	1,055	1,055	1,055	1,062	13
03/02/86	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,035	1,035	1,035	1,035	1,025	1,025	1,016	1,016	1,045	1,045	1,045	1,055	1,035	1,016	1,016	1,025	1,035	1,036	2
03/03/86	1,035	1,035	1,025	1,035	1,025	1,025	10,744	16,408	13,911	13,075	12,851	12,777	12,703	12,703	12,703	12,703	12,703	9,928	4,676	3,044	2,498	2,297	2,232	2,199	7,347	1,163
03/04/86	2,183	2,167	2,152	2,152	2,105	2,076	2,076	2,105	8,386	11,761	12,482	12,629	12,740	5,934	3,671	3,259	2,447	2,447	6,830	8,080	8,355	8,416	8,416	8,447	5,888	804
03/05/86	8,447	4,419	2,837	2,280	2,090	2,047	3,928	7,632	11,339	12,409	12,629	12,629	12,629	12,629	12,666	12,666	12,629	12,629	12,629	12,629	12,629	12,666	12,666	12,629	9,766	869
03/06/86	12,629	5,543	3,180	2,379	2,105	2,018	1,989	6,774	11,304	12,300	12,446	12,556	12,592	12,592	12,592	14,496	17,310	14,300	13,452	13,262	13,225	13,150	13,150	12,556	10,329	971
03/07/86	5,262	3,102	2,379	2,152	2,032	2,003	2,018	8,854	11,975	12,703	12,814	12,814	15,335	16,534	13,834	6,527	2,930	1,753	10,332	15,908	16,915	16,872	17,132	17,044	9,551	1,242
03/08/86	16,915	16,915	16,957	16,957	16,957	16,957	16,915	16,915	16,872	16,915	16,957	16,915	16,872	9,829	3,994	2,120	1,499	1,262	1,167	3,608	10,918	12,336	5,934	2,709	11,475	1,355
03/09/86	1,647	1,262	1,125	1,055	1,035	1,055	1,055	1,065	1,251	7,083	3,928	2,090	1,475	1,241	1,125	1,065	1,384	1,230	1,136	1,177	6,609	2,968	1,753	1,328	1,923	339
03/10/86	1,188	1,105	1,075	1,045	1,035	1,016	1,016	1,016	1,016	1,464	1,946	1,876	1,834	1,821	2,430	2,061	2,003	2,032	2,032	1,608	5,364	7,485	7,990	8,111	2,482	462
03/11/86	4,081	2,152	1,487	1,262	1,156	1,105	1,085	1,065	1,055	1,045	1,035	1,045	1,045	1,045	4,059	12,011	15,867	16,534	14,066	16,408	16,872	16,915	16,915	16,618	6,914	1,459
03/12/86	16,534	16,534	16,576	16,576	16,576	16,576	16,576	16,576	16,534	16,534	16,534	16,492	16,830	17,265	17,000	16,492	11,975	9,467	9,995	15,053	16,115	16,282	16,324	16,324	15,739	429
03/13/86	16,282	16,282	16,282	15,376	9,467	8,854	8,697	14,575	16,324	16,534	16,872	17,221	13,452	5,088	2,498	1,608	1,960	3,380	2,656	6,281	8,020	3,972	2,090	1,441	9,384	1,248
03/14/86	1,241	1,167	1,136	1,125	1,115	1,125	5,088	14,066	16,492	17,044	17,177	17,399	14,143	5,908	2,911	1,780	12,519	13,262	9,729	3,994	2,136	1,499	1,262	1,167	6,853	1,322
03/15/86	1,115	1,065	1,085	6,093	3,972	2,120	11,409	15,539	6,040	2,837	13,604	15,539	7,139	3,141	1,821	1,395	1,241	1,136	1,105	1,085	1,055	1,035	1,035	1,055	4,277	989
03/16/86	1,065	1,065	1,065	1,065	1,065	1,065	1,065	1,075	3,044	2,800	3,972	2,280	1,475	1,209	1,105	1,065	1,045	1,035	1,025	4,465	3,400	1,862	1,339	1,156	1,700	213
03/17/86	1,065	1,025	1,016	1,055	1,075	1,085	1,095	13,075	15,826	8,263	3,524	8,355	3,587	9,631	7,139	5,492	4,892	4,373	2,215	3,503	2,447	1,511	1,177	1,045	4,311	842
03/18/86	1,475	13,719	16,074	16,450	13,300	11,059	15,457	16,576	11,549	9,434	5,338	2,585	1,739	3,735	2,447	1,974	1,522	1,219	1,251	1,284	1,115	1,045	1,006	977	6,347	1,249
03/19/86	968	1,016	1,016	1,006	996	996	996	1,025	1,045	1,095	1,115	1,075	1,045	1,035	1,025	1,025	1,025	1,025	1,016	1,251	1,904	1,395	1,188	1,095	1,099	40
03/20/86	1,035	1,016	1,025	1,025	1,006	996	996	996	1,006	1,006	996	996	996	1,115	1,188	9,271	15,133	16,282	16,492	8,447	3,566	1,974	10,129	6,363	4,294	1,090
03/21/86	2,930	1,766	1,350	1,198	1,136	1,115	1,105	12,300	12,851	12,925	12,963	12,963	12,963	12,963	11,444	6,691	3,025	11,726	15,498	16,282	10,196	8,447	15,133	16,324	8,971	1,159
03/22/86	16,534	5,908	2,745	1,686	1,306	1,156	1,095	1,025	996	996	996	977	996	1,016	1,115	1,384	1,177	1,085	12,703	15,991	16,830	13,376	10,028	4,305	4,809	1,188
03/23/86	2,183	1,475	1,219	1,105	1,055	1,035	1,025	1,006	1,006	1,006	996	987	987	987	1,016	1,105	6,609	14,773	13,642	9,078	7,283	3,608	2,018	1,429	3,193	830
03/24/86	1,177	1,095	1,045	1,025	1,025	1,016	1,006	996	987	1,035	1,075	1,209	1,167	1,105	1,065	1,035	1,035	1,025	1,125	2,855	1,780	1,295	1,146	1,105	1,185	80
03/25/86	1,075	1,035	1,016	1,006	1,006	1,006	1,016	11,655	5,212	2,498	1,570	1,251	1,115	1,045	1,035	1,035	1,035	1,660	3,545	12,851	15,053	12,629	9,500	3,928	3,907	944
03/26/86	2,061	1,441	1,219	1,125	1,095	1,075	1,035	977	10,848	15,661	16,576	16,745	17,088	17,177	17,221	15,295	8,293	3,482	1,946	11,200	15,376	8,478	3,587	1,960	7,957	1,389
03/27/86	1,372	1,156	1,065	1,025	1,006	996	996	8,141	15,335	16,702	16,915	17,000	17,044	9,962	4,015	2,120	1,464	1,241	1,146	1,821	1,608	1,317	1,167	12,011	5,693	1,315
03/28/86	5,415	2,567	1,596	1,262	1,125	1,974	14,182	16,408	16,830	16,915	16,915	16,915	16,915	12,083	4,605	2,280	1,487	1,230	1,136	1,085	1,065	1,045	1,045	1,035	6,546	1,410
03/29/86	1,025	1,035	1,085	1,085	1,055	1,035	1,025	1,055	1,065	1,699	1,429	1,177	3,994	2,464	1,546	1,230	1,105	1,055	1,025	1,025	1,016	1,016	1,035	1,065	1,306	134
03/30/86	1,065	1,055	1,055	1,075	1,085	1,085	1,095	1,085	1,065	1,075	1,075	1,075	1,095	1,105	1,115	1,105	1,065	1,035	1,025	1,035	1,035	1,035	1,025	1,025	1,066	6
03/31/86	1,016	1,025	1,085	1,095	1,065	1,025	1,025	1,045	1,065	1,075	1,085	1,085	1,085	1,075	1,075	1,075	1,075	1,075	1,065	1,085	1,095	1,065	1,045	1,035	1,064	5
04/01/86	1,125	1,284	1,558	2,498	2,498	2,481	2,481	2,481	2,481	2,481	2,481	2,727	2,800	2,800	3,441	3,063	2,533	2,567	2,199	2,090	3,121	5,778	5,856	3,994	2,784	228
04/02/86	2,782	2,550	2,498	2,464	2,464	2,464	2,464	2,464	2,430	2,379	2,363	2,481	2,498	2,430	2,379	2,464	2,363	2,498	4,396	7,691	8,823	9,078	8,447	5,492	3,682	475
04/03/86	3,339	2,638	2,447	2,413	2,346	2,313	2,330	2,346	2,330	2,264	2,215	2,248	2,464	2,481	2,673	2,515	2,297	2,379	3,545	6,719	9,664	14,694	16,450	15,376	4,604	927
04/04/86	9,895	5,908	3,545	2,745	2,447	2,313	2,248	2,232	2,199	2,215	2,248	2,264	2,430	3,421	3,950	4,081	4,125	4,148	4,170	4,215	4,237	4,192	3,400	2,515	3,548	343
04/05/86	2,248	2,248	2,248	2,248	2,248	2,264	2,280	2,280	2,280	2,313	2,280	2,264	2,248	2,248	2,232	2,232	2,232	2,232	2,248	2,248	2,248	2,248	2,248	2,248	2,254	4
04/06/86	2,248	2,248	2,248	2,248	2,248	2,232	2,248	2,232	2,232	2,232	2,232	2,232	2,232	2,232	2,232	2,430	4,260	7,369	8,293	8,509	8,572	10,230	14,378	15,991	4,733	849
04/07/86	16,240	13,338	8,416	4,535	3,160	2,745	2,602	2,764	5,063	9,533	11,940	12,373	12,629	12,703	12,703	12,703	12,703	12,703	12,666	12,666	12,703	12,666	12,629	11,797	10,166	856
04/08/86	7,930	4,373	2,930	2,515	2,363	2,313	2,280	2,346	3,219	5,262	10,332	12,083	12,519	12,592	12,629	12,629	12,629	12,666	12,666	12,666	12,373	9,533	8,202	5,674	8,114	901
04/09/86	3,650	2,727	2,447	2,363	2,330	2,313	2,313	2,396	3,735	8,111	11,904	12,629	12,703	12,740	12,703	11,024	6,719	5,440	7,340	9,598	12,119	12,300	9,829	6,227	7,319	862
04/10/86	3,950	2,800	2,430	2,346	2,313	2,313	2,620	3,714	6,093	10,028	12,119	12,556	12,629	12,629	10,332	11,726	12,482	12,666	12,703	12,703	12,740	11,761	8,982	5,778	8,350	905
04/11/86	3,380	2,602	2,330	2,313	2,264	2,232	2,215	2,264	3,219	5,908	7,751	8,293	8,416	8,447	9,014	10,503	12,446	12,814	12,629	9,304	4,989	3,299	2,818	2,656	5,921	775
04/12/86	2,602	2,567	2,567	2,550	2,550	2,550	2,550	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,515	2,515	2,515	2,515	2,498	2,515	2,498	2,498	2,498	2,532	5
04/13/86	2,498	2,498	2,481	2,481	2,481	2,481	2,481	2,481	2,481	2,481	2,481	2,481	2,464	2,464	2,481	2,464	2,464	2,464	2,481	2,481	2,481	2,498	2,481	2,481	2,480	2
04/14/86	2,481	2,481	2,481	2,481	2,481	2,481	2,481	2,673	4,868	10,196	10,988	9,631	7,139	3,972	2,930	2,709	2,673	2,620	2,585	2,567	2,550	2,533	2,533	2,515	3,877	549
04/15/86	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	3,482	4,125	4,282	3,279	2,782	2,620	2,567	2,550	2,533	2,533	2,533	2,533	2,533	2,751	104
04/16/86	2,533	2,515	2,533	2,533	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,413	2,105	2,363	2,447	2,481	2,709	5,830	12,300	16,157	13,300	4,057	799
04/17/86	6,970	4,037	3,006	2,691	2,567	2,533	2,515	3,044	5,569	10,332	14,973	15,867	16,074	16,115	16,157	16,157	16,450	16,618	16,660	16,618	16,660	16,660	13,338	8,509	10,838	1,241
04/18/86	4,771	3,239	2,782	2,620	2,567	2,550	2,533	2,533	2,533	2,533	2,515	2,515	2,515	2,515	2,533	2,515	2,498	2,498	2,515	2,585	2,602	2,620	2,620	2,620	2,680	96
04/19/86	2,620	2,638	2,656	2,602	2,550	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,549	8
04/20/86	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,550	2,533	2,550	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,534	1
04/21/86	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,550	2,550	2,550	2,550	2,533	2,533	2,533	2,533	2,515	2,515	2,533	2,533	2,533	2,533	2,533	2,533	2,534	2
04/22/86	2,533	2,515	2,533	2,533	2,533	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,498	2,498	2,498	2,498	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2
04/23/86	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,498	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,515	2,533	2,533	2,533	2,517	1
04/24/86	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,533	2,515	2,515	1,932	2,818	3,102	2,968	2,464	2,498	2,602	2,602	2,727	2,691	2,673	2,656	2,638	2,591	43

04/25/86	2,620	2,620	2,620	2,620	2,620	2,620	2,602	2,602	2,602	2,602	2,638	2,818	2,764	3,063	3,180	3,006	2,602	2,602	2,673	2,691	2,691	2,691	2,691	2,709	2,706	32
04/26/86	2,709	2,709	2,709	2,691	2,691	2,691	2,691	2,691	2,691	2,691	2,691	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,703	2
04/27/86	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,709	2,691	2,691	2,691	2,691	2,691	2,691	2,709	2,709	2,709	2,709	2,705	2
04/28/86	2,709	2,709	2,709	2,691	2,691	2,691	2,691	2,691	4,512	6,227	6,636	6,554	6,254	6,147	6,040	5,934	5,882	5,934	5,987	6,013	6,040	6,040	6,040	6,040	4,911	335
04/29/86	6,013	6,013	6,013	6,040	6,013	6,040	6,040	6,040	6,013	6,040	6,013	6,013	6,013	5,908	5,961	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,934	6,000	7
04/30/86	5,987	5,961	5,961	5,934	5,934	5,934	5,934	5,934	5,934	5,934	5,908	5,908	5,908	5,908	5,908	5,908	5,908	5,882	5,908	5,934	5,961	5,961	5,961	5,987	5,933	6
05/01/86	5,987	5,987	5,987	5,961	5,961	5,961	5,961	5,987	5,987	5,987	5,987	5,961	5,961	5,961	5,961	5,961	5,961	5,961	5,934	5,934	5,961	5,934	5,934	5,908	5,962	4
05/02/86	5,934	5,961	5,934	5,934	5,934	5,934	5,987	6,013	6,040	6,093	6,040	6,200	6,120	6,040	6,040	6,040	6,013	5,987	6,013	5,987	6,040	6,040	6,013	5,961	6,012	13
05/03/86	5,961	5,961	5,987	5,987	5,961	5,961	5,961	5,961	5,987	5,987	5,987	5,856	5,961	6,013	5,987	6,013	6,013	6,040	6,013	6,013	6,040	6,066	6,040	6,040	5,991	9
05/04/86	6,013	6,013	6,013	6,013	6,013	6,013	6,040	6,040	6,040	6,013	5,961	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,961	5,961	5,987	6,013	6,013	6,013	6,001	5
05/05/86	6,013	6,013	6,013	6,013	6,013	5,961	5,987	6,013	6,013	6,013	5,987	5,987	6,013	6,040	6,066	5,569	5,961	5,987	5,987	5,987	5,987	6,013	5,961	6,040	5,985	19
05/06/86	6,040	6,093	6,093	6,066	6,040	6,040	5,987	5,961	5,961	5,961	5,934	5,961	5,961	5,934	5,882	5,908	5,908	5,882	5,961	6,066	6,040	5,961	5,882	5,882	5,975	14
05/07/86	5,961	6,040	6,040	6,040	6,040	6,040	6,040	6,040	6,013	5,987	5,961	5,934	5,987	6,013	6,040	5,987	5,934	5,934	6,013	6,013	5,987	5,934	5,908	5,934	5,992	9
05/08/86	5,961	5,961	6,013	6,040	6,066	6,120	6,013	5,908	5,830	5,830	5,908	5,856	5,882	5,934	5,961	5,987	5,961	5,934	5,908	5,987	6,040	5,987	5,908	5,882	5,953	15
05/09/86	5,908	5,934	5,934	5,908	5,961	5,961	5,908	5,908	5,908	5,908	5,908	5,934	5,934	6,013	6,066	6,013	5,908	5,882	5,882	5,882	6,040	6,173	6,120	6,093	5,962	17
05/10/86	6,040	6,040	6,040	6,040	6,040	6,040	6,040	6,040	6,066	6,066	6,093	6,093	6,066	6,013	6,066	6,066	6,066	6,066	6,040	6,040	6,040	5,987	5,934	5,908	6,039	9
05/11/86	5,908	5,908	5,908	5,882	5,882	5,908	5,908	5,934	5,908	5,856	5,778	5,830	5,882	5,934	5,934	5,934	5,934	5,934	5,934	5,934	5,987	5,987	5,934	5,882	5,909	9
05/12/86	5,856	5,856	5,856	5,830	5,882	5,908	5,908	5,882	5,882	5,882	5,882	6,147	6,582	6,013	5,961	5,908	5,934	5,961	5,961	5,961	5,961	5,987	5,987	5,987	5,957	31
05/13/86	5,961	5,961	5,961	5,961	5,961	5,961	5,961	5,961	6,013	6,013	5,961	5,961	5,961	5,987	6,013	5,934	5,908	5,908	5,961	5,987	5,987	5,987	5,987	5,987	5,968	6
05/14/86	5,987	6,013	6,040	6,066	6,040	6,013	6,013	6,040	6,066	6,066	6,093	6,066	6,093	6,308	6,254	6,500	6,472	5,961	5,856	5,882	5,934	5,934	5,961	5,987	6,069	33
05/15/86	6,147	6,120	6,066	6,066	6,040	6,066	6,066	6,093	6,120	6,040	6,040	6,093	6,093	6,120	6,120	6,093	6,093	6,093	6,093	6,066	6,040	6,040	6,013	6,013	6,076	7
05/16/86	6,013	5,804	5,908	5,987	6,013	6,013	6,066	6,066	6,066	6,093	6,040	6,013	6,013	5,987	6,200	6,173	6,147	6,120	6,120	6,120	6,120	6,120	6,147	6,120	6,061	18
05/17/86	6,173	6,013	5,961	5,934	5,961	5,987	5,934	5,934	6,013	6,013	5,961	5,934	5,987	6,093	6,120	6,066	6,040	6,040	6,040	6,013	5,987	5,987	5,987	5,987	6,007	12
05/18/86	6,093	5,934	5,961	5,987	5,987	5,961	5,961	5,961	5,961	5,987	5,961	6,040	6,147	6,013	5,987	5,961	6,040	6,066	6,013	5,987	5,987	6,013	5,987	5,882	5,995	11
05/19/86	6,227	6,147	6,040	6,040	6,066	6,093	6,093	6,093	6,120	6,120	6,147	6,120	6,093	6,093	6,120	6,093	6,093	6,093	6,147	6,120	6,120	6,147	6,147	6,093	6,111	8
05/20/86	6,093	5,934	5,830	5,934	6,013	6,040	5,987	5,987	6,013	6,013	6,013	5,987	5,961	5,987	6,013	6,040	6,040	6,040	6,040	6,013	6,040	6,066	5,987	6,227	6,012	14
05/21/86	6,336	6,147	6,093	6,013	5,961	5,987	6,858	9,928	10,332	7,603	6,527	6,227	6,120	6,066	6,093	6,066	6,040	6,013	5,987	5,987	6,066	6,093	6,066	6,040	6,527	238
05/22/86	5,752	5,804	6,093	5,961	5,804	5,882	5,987	5,987	5,961	5,934	6,173	6,093	6,227	6,227	6,254	6,147	6,093	6,066	6,254	6,308	6,093	6,013	5,961	5,908	6,041	32
05/23/86	5,934	5,882	5,934	5,961	5,961	5,961	6,013	6,013	6,013	6,013	6,040	5,961	5,961	6,013	6,093	6,093	6,120	6,147	6,147	6,120	6,147	6,120	6,093	6,040	6,032	16
05/24/86	6,066	6,093	6,093	6,093	6,093	6,066	6,040	6,013	6,013	6,040	6,040	6,013	6,013	6,013	5,987	5,987	5,987	6,013	6,013	6,013	6,040	6,013	6,013	5,987	6,031	7
05/25/86	6,040	6,173	6,066	5,987	6,013	6,040	6,013	6,013	6,040	6,093	6,066	6,040	6,040	6,040	6,040	6,013	6,040	6,066	6,066	6,066	6,040	6,066	6,040	6,040	6,048	7
05/26/86	6,147	6,013	6,040	6,040	6,040	6,013	5,987	5,961	4,373	3,160	2,818	2,691	2,656	2,638	2,638	2,620	2,620	2,620	2,620	2,602	2,602	2,515	2,481	2,464	3,848	331
05/27/86	2,413	2,379	2,379	2,396	2,447	2,413	2,330	2,297	2,313	2,264	2,215	2,199	2,215	2,215	2,199	2,183	2,183	2,199	2,183	2,152	2,076	2,105	2,183	2,232	2,257	21
05/28/86	2,330	2,183	2,105	2,120	2,105	2,090	2,090	2,090	2,105	2,105	2,105	2,105	2,105	2,120	2,120	2,105	2,346	3,587	5,804	4,465	2,987	4,465	6,500	3,629	2,824	259
05/29/86	2,673	2,346	2,248	2,199	2,199	2,183	2,167	2,152	2,152	2,167	2,183	2,199	2,183	3,714	9,336	15,214	16,787	16,702	8,697	4,305	2,911	2,447	2,264	2,183	4,734	988
05/30/86	2,152	2,152	2,152	2,152	2,136	2,120	2,167	2,215	2,248	2,782	2,396	2,264	2,232	2,215	2,183	2,136	2,152	2,183	2,199	2,199	2,215	2,215	2,183	2,120	2,215	27
05/31/86	2,152	2,183	2,199	2,183	2,167	2,167	2,167	2,167	2,183	2,199	2,199	2,199	2,215	2,199	2,199	4,940	8,293	13,757	13,642	8,202	4,037	2,745	13,262	6,308	4,499	809
06/01/86	3,671	2,800	2,363	2,199	2,199	2,199	2,183	2,167	2,167	2,167	2,167	2,167	2,167	2,167	2,167	2,167	2,152	2,152	2,152	2,136	2,136	2,136	2,136	2,136	2,261	67
06/02/86	2,120	2,120	2,120	2,120	2,136	2,136	2,136	2,136	2,136	2,248	2,199	2,550	2,264	2,136	2,567	3,082	2,498	2,313	3,907	5,778	3,339	2,550	2,264	2,167	2,543	168
06/03/86	2,152	2,090	2,105	2,120	2,120	2,105	2,120	2,136	2,120	2,120	2,105	2,105	2,090	2,090	2,120	2,152	2,167	2,167	2,167	2,152	2,136	8,447	4,373	2,930	2,516	276
06/04/86	2,447	2,297	2,248	2,232	2,232	2,232	2,215	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,183	2,032	1,974	2,199	2,280	2,313	2,330	2,346	2,363	2,230	20
06/05/86	2,363	2,363	2,363	2,363	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,330	2,363	2,396	2,413	2,413	2,430	2,430	2,447	2,430	2,413	2,396	2,396	2,379	2,389	6
06/06/86	2,363	2,346	2,313	2,313	2,346	2,363	2,379	2,379	2,379	2,379	2,363	2,363	2,346	2,363	2,346	2,346	2,346	2,363	2,363	2,363	2,363	2,363	2,363	2,363	2,357	4
06/07/86	2,363	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	9,239	12,264	12,888	12,963	6,147	3,650	2,837	2,567	2,481	2,464	2,464	2,464	2,447	2,447	2,447	4,215	740
06/08/86	2,430	2,430	2,430	2,430	2,413	2,430	2,413	2,447	2,498	2,533	2,379	2,264	2,215	2,183	2,183	2,167	2,183	2,183	2,183	2,183	2,183	2,183	2,183	2,199	2,305	27
06/09/86	2,199	2,199	2,199	2,199	2,183	2,167	2,167	2,183	2,183	2,183	2,183	2,183	2,183	2,893	3,928	4,305	5,237	3,566	2,673	2,363	2,248	2,215	2,199	2,199	2,593	168
06/10/86	2,199	2,183	2,183	2,183	2,183	2,183	2,183	2,183	2,183	2,183	2,183	2,183	2,183	2,199	2,183	2,183	2,183	2,183	2,167	2,167	2,167	2,167	2,167	2,167	2,181	2
06/11/86	2,167	2,167	2,167	2,167	2,167	2,167	2,167	2,215	2,264	2,297	1,766	1,406	1,273	1,219	1,429	2,152	2,430	2,550	2,533	2,533	2,533	2,533	2,533	2,533	2,140	85
06/12/86	7,573	4,305	3,160	2,782	2,673	2,620	2,585	2,567	2,567	2,638	2,656	2,691	3,972	4,373	4,489	4,535	4,558	4,535	4,535	4,535	4,535	4,535	3,219	2,567	3,717	246
06/13/86	2,363	2,297	2,297	2,297	2,297	2,297	2,297	2,280	2,280	2,264	2,264	2,280	2,280	2,297	2,297	2,413	2,396	2,363	2,363	2,346	2,346	2,346	2,346	2,346	2,319	9
06/14/86	2,346	2,346	2,330	2,413	2,515	2,550	2,567	2,585	2,585	2,567	2,550	2,567	2,567	2,567	2,567	2,585	2,567	2,567	2,567	2,567	2,567	2,567	2,567	2,567	2,531	17
06/15/86	2,567	2,567	2,567	2,567	2,550	2,550	2,550	2,550	2,567	2,585	2,602	2,602	2,602	2,602	2,602	2,602	2,602	2,620	2,620	2,602	2,602	2,602	2,602	2,602	2,587	5
06/16/86	2,602	2,585	2,550	2,498	2,481	2,464	2,464	2,464	2,481	2,481	2,481	2,481	2,464	11,726	13,490	12,888	15,991	16,576	13,338	6,363	3,778	2,949	2,673	2,567	5,618	1,038
06/17/86	2,481	2,430	2,413	2,413	2,396	2,396	2,396	2,396	2,396	2,396	2,396	2,379	2,379	2,379	2,396	2,396	2,430	2,533	3,025	3,239	3,400	3,524	3,566	3,587	2,656	91
06/18/86	4,015	3,907	3,503	2,949	2,709	2,585	2,533	2,430	2,379	2,379	2,379	2,379	2,430	2,498	2,464	2,464	2,464	2,464	2,447	2,430	2,430	2,464	2,464	2,430	2,650	96

06/19/86	2,379	2,379	2,413	2,413	2,413	2,413	2,413	2,413	2,430	2,430	2,447	2,447	2,447	2,430	2,430	2,430	2,447	2,430	2,396	2,363	2,330	2,396	2,396	2,396	2,412	6
06/20/86	2,379	2,363	2,379	2,379	2,363	2,363	2,363	2,379	2,379	2,396	2,396	2,396	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,363	2,363	2,379	2,379	2,379	2,377	2
06/21/86	2,363	2,346	2,346	2,346	2,363	2,363	2,363	2,379	2,396	2,413	2,413	2,396	2,464	2,515	2,464	2,481	2,515	2,533	2,515	2,481	2,464	2,464	2,481	2,447	2,430	13
06/22/86	2,413	2,430	2,447	2,447	2,430	2,413	2,413	2,447	2,498	2,498	2,481	2,430	2,447	2,430	2,396	2,379	2,379	2,363	2,330	2,313	2,313	2,346	2,363	2,346	2,406	11
06/23/86	2,330	2,330	2,379	2,379	2,346	2,313	2,313	2,330	2,346	2,330	2,330	2,313	2,297	2,280	2,280	2,264	2,264	2,264	2,280	2,297	2,280	2,280	2,280	2,264	2,307	7
06/24/86	2,232	2,232	2,248	2,248	2,248	2,215	2,215	2,248	2,280	2,297	2,297	2,280	2,264	5,440	7,662	4,125	2,911	2,498	2,346	2,297	2,280	2,280	2,280	2,280	2,738	262
06/25/86	2,264	2,264	2,264	2,264	2,264	2,280	2,280	2,673	3,482	2,727	3,800	6,147	5,112	4,282	3,141	2,745	2,656	2,602	2,550	2,515	2,464	2,447	2,430	2,430	2,920	203
06/26/86	2,396	2,396	2,396	2,396	2,396	2,413	2,396	2,346	2,481	2,968	3,025	9,110	6,200	4,015	10,298	9,862	9,078	9,962	11,514	6,774	4,192	2,930	2,481	2,330	4,848	666
06/27/86	2,280	2,248	2,232	2,199	2,136	2,136	2,199	2,199	2,248	2,313	10,230	12,409	12,925	8,020	7,168	8,416	10,537	10,779	7,083	5,162	3,141	2,464	2,232	2,152	5,204	786
06/28/86	2,090	2,061	2,090	2,199	2,215	2,215	2,183	2,183	2,215	2,215	2,215	3,082	10,640	12,519	6,120	3,524	2,620	2,297	2,199	2,167	2,120	2,120	2,136	2,152	3,233	555
06/29/86	2,167	2,167	2,136	2,136	2,152	2,167	2,136	2,136	2,152	2,167	2,167	2,167	2,167	2,152	2,167	2,167	2,183	2,199	2,199	2,183	2,183	2,167	2,167	2,167	2,165	4
06/30/86	2,167	2,167	2,167	2,183	2,167	2,167	2,167	2,183	2,167	2,167	2,167	2,183	2,183	2,313	2,280	2,313	2,313	2,183	2,105	2,152	2,280	2,167	2,136	2,152	2,193	12
03/01/87	19,182	19,135	19,135	19,182	19,182	19,182	19,229	19,276	19,512	19,559	19,559	19,559	19,512	19,276	19,229	19,229	19,229	19,229	19,276	19,276	19,276	19,276	19,229	19,229	19,290	28
03/02/87	19,276	19,276	19,323	19,323	19,182	19,088	19,135	19,182	19,135	19,229	19,370	19,417	19,844	20,036	20,083	20,131	20,083	20,035	20,131	20,228	20,324	20,372	20,324	20,372	19,704	100
03/03/87	20,324	20,324	20,324	20,324	20,324	20,276	20,276	20,228	20,180	20,131	20,180	20,180	20,228	20,324	20,324	20,324	20,324	20,324	20,421	20,372	20,421	20,421	20,324	20,372	20,302	16
03/04/87	20,324	20,324	20,276	20,276	20,228	20,131	20,131	20,180	20,131	20,180	20,180	20,228	20,180	20,131	20,131	19,987	19,940	20,469	20,518	20,372	20,324	20,276	20,180	20,276	20,224	27
03/05/87	20,228	20,228	20,276	20,276	20,276	20,324	20,324	20,324	20,324	20,276	20,372	20,372	20,372	20,421	20,372	20,372	20,372	20,372	20,421	20,469	20,469	20,469	20,469	20,518	20,362	16
03/06/87	20,518	20,518	20,566	20,566	20,615	20,566	20,566	20,421	20,276	20,180	20,908	21,650	23,020	23,487	23,539	24,222	24,488	24,541	24,594	24,808	24,915	25,023	25,131	25,185	22,513	412
03/07/87	25,347	25,347	25,401	25,401	25,401	25,347	25,293	25,185	25,185	25,131	25,077	25,023	25,077	25,131	25,131	25,077	25,077	25,077	25,077	25,077	25,131	25,077	25,131	25,131	25,181	26
03/08/87	25,077	25,077	25,023	25,077	25,023	24,915	24,862	24,862	24,862	24,915	24,862	24,862	24,862	24,915	24,969	25,023	25,077	25,023	25,077	25,077	25,077	25,023	25,023	25,131	24,987	19
03/09/87	25,185	25,185	25,131	25,077	25,023	24,969	24,915	24,969	25,023	25,023	25,077	25,131	25,131	25,131	25,185	25,185	25,077	24,969	25,239	25,401	25,619	25,673	25,673	25,564	25,190	47
03/10/87	25,564	25,564	25,564	25,510	25,510	25,510	25,510	25,510	25,510	25,564	25,619	25,619	25,673	25,673	25,728	25,673	25,673	25,619	25,564	25,673	25,673	25,619	25,510	25,564	25,592	14
03/11/87	25,619	25,619	25,564	25,510	25,456	25,401	25,293	25,293	25,239	25,185	25,185	25,131	25,131	25,077	25,077	25,077	25,077	25,077	25,023	25,077	25,131	25,131	25,131	25,185	25,237	38
03/12/87	25,131	25,077	25,077	25,023	25,077	25,023	24,969	24,969	25,023	25,023	25,023	25,077	25,077	25,077	25,077	25,077	25,077	25,077	25,077	25,185	25,239	25,293	25,347	25,347	25,102	22
03/13/87	25,347	25,293	25,293	25,293	25,239	25,239	25,185	25,239	25,239	25,239	25,239	25,239	25,293	25,293	25,347	25,347	25,401	25,401	25,401	25,456	25,510	25,619	25,673	25,619	25,352	28
03/14/87	25,673	25,673	25,673	25,673	25,673	25,728	25,728	25,673	25,673	25,619	25,619	25,510	25,401	25,347	25,239	25,131	25,131	25,131	25,185	25,185	25,239	25,293	25,239	25,293	25,447	47
03/15/87	25,293	25,239	25,239	25,239	25,293	25,347	25,347	25,347	25,293	25,239	25,185	25,077	25,023	25,023	25,077	25,131	25,185	25,239	25,239	25,293	25,293	25,347	25,347	25,401	25,239	22
03/16/87	25,347	25,239	25,185	25,185	25,185	25,185	25,239	25,239	25,347	25,401	25,510	25,510	25,564	25,564	25,510	25,510	25,510	25,510	25,510	25,564	25,564	25,619	25,619	25,564	25,424	32
03/17/87	25,510	25,510	25,456	25,456	25,510	25,510	25,564	25,619	25,673	25,673	25,728	25,728	25,837	25,892	25,892	25,892	25,728	25,619	25,564	25,510	25,456	25,456	25,456	25,510	25,615	31
03/18/87	25,456	25,401	25,401	25,401	25,456	25,401	25,401	25,456	25,401	25,401	25,401	25,401	25,401	25,456	25,456	25,401	25,456	25,510	25,456	25,456	25,456	25,401	25,456	25,401	25,428	7
03/19/87	25,347	25,293	25,239	25,185	25,185	25,185	25,185	25,293	25,293	25,347	25,347	25,401	25,510	25,564	25,564	25,401	24,594	24,275	23,227	22,763	22,712	22,610	22,406	22,304	24,593	240
03/20/87	21,900	21,800	21,700	21,105	20,566	20,421	20,421	20,421	20,276	20,228	20,228	20,228	20,228	20,228	20,131	19,987	19,940	19,940	19,892	19,892	19,892	19,940	19,940	19,940	20,385	125
03/21/87	19,987	19,987	20,035	19,987	19,987	19,987	19,987	19,987	19,987	19,987	19,987	19,940	19,940	19,940	19,892	19,892	19,844	19,844	19,844	19,892	19,844	19,892	19,844	19,892	19,934	13
03/22/87	19,892	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,892	19,892	19,844	19,892	19,892	19,892	19,892	19,892	19,844	19,844	19,844	19,844	19,844	19,844	19,844	19,844	19,888	8
03/23/87	19,892	20,083	20,180	20,180	20,228	20,228	20,180	20,083	20,035	20,035	20,035	20,035	20,083	20,083	20,083	20,083	20,083	20,035	20,035	20,035	20,035	20,035	19,987	19,987	20,073	16
03/24/87	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,892	19,892	19,892	19,892	19,892	19,892	19,928	4
03/25/87	19,892	19,892	19,892	19,892	19,892	19,892	19,892	19,892	19,892	19,892	19,892	19,987	20,035	19,940	19,940	18,165	15,539	15,174	15,093	15,093	15,053	15,093	15,093	15,053	18,253	464
03/26/87	15,053	15,053	15,053	15,053	15,013	15,013	15,013	15,053	15,053	15,053	15,053	15,053	15,013	15,013	15,013	15,093	19,042	19,749	19,844	19,892	19,892	19,940	19,892	19,892	16,616	466
03/27/87	19,892	19,940	19,987	19,940	19,844	19,892	19,844	19,940	20,035	20,083	20,083	20,035	20,035	19,987	19,987	19,987	7,026	2,855	2,585	15,417	18,578	18,948	19,088	19,042	17,627	1,090
03/28/87	18,995	15,991	9,369	6,040	2,874	3,821	5,137	9,110	15,661	16,240	18,348	18,809	18,809	18,762	18,716	18,762	18,809	18,809	18,809	18,809	18,855	18,855	15,661	9,078	14,714	1,157
03/29/87	6,609	5,961	4,015	2,047	1,406	1,306	3,219	5,569	13,075	17,622	18,439	18,578	18,485	18,531	18,531	18,439	18,716	18,948	18,995	18,995	18,995	18,995	18,029	16,366	13,328	1,451
03/30/87	5,987	12,629	18,165	19,135	6,802	3,044	10,196	17,577	18,348	18,029	18,302	18,348	17,399	18,074	17,488	17,265	17,177	18,256	18,716	18,809	18,809	18,762	18,762	18,716	16,033	949
03/31/87	18,762	18,762	18,762	18,995	19,042	19,042	19,088	19,088	19,042	19,042	19,042	18,995	18,995	18,948	18,762	17,667	17,938	18,485	18,995	19,042	19,042	19,088	19,088	19,088	18,867	74
04/01/87	19,088	19,042	19,042	19,042	19,088	19,042	19,042	18,855	18,762	18,762	18,809	18,855	18,948	18,948	19,276	19,559	19,892	19,892	19,892	19,844	19,892	19,844	19,844	19,749	19,292	90
04/02/87	19,940	19,987	19,940	19,987	19,987	19,987	19,987	20,035	19,987	20,035	20,035	20,083	20,083	20,083	20,083	20,083	19,987	19,987	19,940	19,987	19,987	20,035	19,987	19,987	20,009	10
04/03/87	19,940	19,892	19,892	19,892	19,844	19,796	19,796	19,892	19,940	19,987	20,180	20,228	20,131	20,083	19,987	19,987	20,035	19,892	19,701	19,417	19,276	19,182	19,135	19,135	19,802	67
04/04/87	19,088	19,182	19,276	19,229	19,276	19,229	19,182	19,182	19,229	19,229	19,229	19,276	19,276	13,604	18,165	19,135	19,323	19,323	19,323	19,323	19,370	19,370	19,370	19,370	18,982	239
04/05/87	19,370	19,370	19,370	19,370	19,323	19,323	19,276	19,276	19,276	19,276	19,323	19,323	19,323	19,323	19,323	19,323	19,323	19,323	19,323	19,370	19,370	19,370	19,370	19,370	19,333	7
04/06/87	19,370	19,370	19,323	19,323	19,276	19,276	19,276	19,088	18,948	19,182	19,276	19,276	19,276	19,276	19,276	19,276	19,276	19,276	19,323	19,323	19,276	19,276	19,323	19,276	19,268	18
04/07/87	19,276	19,276	19,229	19,229	19,182	19,182	19,182	19,229	19,229	19,229	19,229	13,719	10,918	10,298	10,163	8,854	4,305	2,481	1,876	1,904	2,032	2,018	1,904	1,918	11,828	1,564
04/08/87	1,932	1,946	1,946	1,974	2,550	5,440	12,482	17,310	15,702	10,062	5,162	3,299	2,447	2,105	2,061	3,400	7,810	14,813	17,667	18,439	17,712	11,514	6,747	3,608	7,839	1,263
04/09/87	2,533	2,199	2,090	2,047	2,396	4,676	9,336	16,745	18,578	19,088	19,182	19,182	19,135	18,995	18,948	18,948	18,902	18,855	14,893	9,174	4,700	2,818	2,264	2,076	11,157	1,579
04/10/87	2,018	2,003	1,989	1,989	2,248	4,535	9,795	16,032	18,762	19,276	19,323	19,276	19,323	19,276	19,276	19,229	19,276	19,276	19,276	17,667	11,904	7,283	3,994	2,585	12,317	1,565
04/11/87	2,120	2,032	2,032	2,032	2,120	3,482	4,305	3,006	2,533	2,363	2,313	2,297	2,297	2,280	2,280	2,280	2,297	3,524	6,830	5,212	3,239	2,430	2,152	2,047	2,813	239
04/12/87	2,003	1,960	1,932	1,932	1,960	2,167	3,319	3,025	2,550	2,379	2,313	2,297	2,297	2,297	2,297	2,297	2,911	5,987	7,900	5,674	3,629	2,745	2,447	2,330	2,944	304

04/13/87	2,297	2,297	2,297	2,297	2,430	3,566	7,369	15,053	18,074	18,809	18,995	18,348	12,373	7,751	4,125	2,709	2,248	2,413	5,187	8,886	7,632	4,843	2,968	2,379	7,306	1,254
04/14/87	2,167	2,120	2,076	2,076	2,076	2,076	2,047	2,032	1,918	1,876	1,848	1,834	1,890	1,989	2,032	2,090	2,620	5,908	11,269	17,310	16,157	11,129	9,795	8,232	4,774	984
04/15/87	5,038	3,102	2,447	2,248	2,167	2,136	2,120	2,120	2,120	2,120	2,136	2,183	2,183	2,800	4,582	5,162	8,634	15,991	18,256	18,762	18,762	18,762	15,580	13,037	7,185	1,370
04/16/87	17,221	18,531	18,716	18,716	18,762	19,135	19,182	19,276	19,464	19,512	19,749	19,940	19,844	19,749	19,654	19,606	20,035	20,324	20,324	20,372	20,372	20,372	20,372	20,372	19,567	159
04/17/87	20,372	20,372	20,372	20,372	20,469	20,566	20,664	20,566	20,469	20,372	20,372	20,372	20,372	20,372	20,372	20,372	20,324	20,276	20,276	20,276	20,276	20,324	20,324	20,276	20,382	20
04/18/87	20,276	20,276	20,228	20,228	20,180	20,131	20,131	20,131	20,131	20,131	20,131	20,131	21,055	22,610	23,020	23,072	23,227	23,331	23,383	23,591	23,696	23,696	23,958	24,434	21,716	342
04/19/87	24,862	24,915	24,808	25,077	25,347	25,293	25,293	25,347	25,401	25,456	25,456	25,401	25,293	25,347	25,401	25,401	25,456	25,510	25,456	25,401	25,401	25,456	25,510	25,564	25,327	42
04/20/87	25,673	25,728	25,673	25,564	25,456	25,347	25,239	25,185	25,239	25,293	25,347	25,347	25,401	25,401	25,456	25,456	25,892	26,888	27,158	27,793	27,953	27,634	27,740	27,900	26,073	209
04/21/87	27,953	28,007	28,060	28,060	28,114	28,167	28,167	28,652	29,578	29,798	30,686	31,247	32,500	33,078	33,310	33,543	33,719	33,836	34,130	34,366	34,603	34,603	34,662	34,722	31,398	560
04/22/87	34,781	34,781	34,781	34,841	34,841	34,841	34,900	34,841	34,781	34,722	34,722	34,722	35,019	34,900	34,900	34,960	34,960	34,960	35,079	35,019	35,079	35,139	35,079	35,139	34,908	27
04/23/87	35,079	35,019	34,960	34,841	34,841	34,900	34,960	35,019	35,139	35,139	35,139	35,079	35,079	35,019	35,019	35,019	35,019	35,019	35,079	35,079	35,079	35,079	35,079	35,079	35,032	17
04/24/87	35,079	35,139	35,139	35,139	35,139	35,199	35,199	35,258	35,318	35,318	35,498	35,498	35,558	35,558	35,679	35,679	35,558	35,618	36,041	36,222	36,404	36,526	36,526	36,587	35,620	101
04/25/87	36,587	36,587	36,587	36,465	36,404	36,344	36,283	36,222	36,162	36,222	35,378	34,900	34,722	34,603	34,603	34,544	34,544	34,484	34,425	34,484	34,544	34,484	34,544	34,544	35,361	186
04/26/87	34,544	34,544	34,484	34,544	34,425	34,366	34,307	34,248	34,130	34,071	34,012	34,012	34,012	34,012	34,012	34,012	33,954	34,012	33,954	33,954	34,012	34,012	34,012	34,012	34,152	44
04/27/87	34,012	34,012	33,954	33,954	34,012	34,012	34,012	34,012	34,012	34,012	34,012	34,307	34,425	34,484	34,544	34,662	34,781	34,841	34,841	34,841	34,900	34,841	34,841	34,900	34,384	79
04/28/87	34,900	34,900	34,781	34,722	34,722	34,722	34,722	34,722	34,722	34,722	34,781	34,960	35,139	35,199	35,199	35,258	35,199	35,258	35,258	35,318	35,258	35,258	35,258	35,258	35,010	50
04/29/87	35,258	35,318	35,318	35,318	35,318	35,318	35,438	35,438	35,378	35,438	35,438	35,438	35,318	35,199	35,199	35,079	35,019	34,960	34,900	34,900	34,960	34,960	34,960	34,900	35,199	41
04/30/87	34,900	34,900	34,900	34,900	34,900	34,900	34,900	34,960	34,960	34,960	34,900	34,960	34,900	34,960	34,900	34,900	34,960	34,960	34,960	34,900	34,960	35,019	35,079	35,139	34,945	13
05/01/87	35,258	35,258	35,318	35,318	35,318	35,318	35,378	35,378	35,318	35,258	35,199	35,139	35,079	34,960	34,841	34,781	34,662	34,603	34,544	34,544	34,662	34,603	34,603	34,603	34,998	66
05/02/87	34,722	34,781	34,841	34,900	34,960	34,960	35,079	35,139	35,199	35,438	35,618	35,498	35,438	35,498	35,618	35,498	35,318	35,199	35,079	35,019	34,900	34,900	35,019	35,139	35,157	56
05/03/87	35,139	35,199	35,258	35,438	35,438	35,558	35,618	35,438	35,318	35,258	35,199	35,139	35,079	35,079	35,079	35,139	35,139	35,139	35,199	35,199	35,199	35,199	35,199	35,199	35,244	30
05/04/87	35,199	35,199	35,199	35,318	35,258	35,258	35,258	35,318	35,318	35,318	35,318	35,318	35,318	35,378	35,378	35,378	35,318	35,318	35,378	35,318	35,318	35,258	35,258	35,199	35,296	12
05/05/87	35,199	35,258	35,258	35,258	35,258	35,258	35,258	35,258	35,318	35,258	35,438	35,438	35,378	35,378	35,378	35,378	35,318	35,258	35,199	35,079	34,960	34,960	34,841	34,841	35,226	35
05/06/87	34,900	34,900	34,960	35,019	35,079	35,079	35,079	35,079	35,079	35,139	35,139	35,199	35,199	35,199	35,199	35,199	35,258	35,258	35,318	35,318	35,318	35,378	35,378	35,378	35,169	29
05/07/87	35,318	35,199	35,199	35,139	35,139	35,139	35,139	35,139	35,199	33,895	31,587	31,643	33,895	34,722	34,960	35,019	35,079	35,199	35,258	35,258	35,318	35,318	35,318	35,378	34,769	213
05/08/87	35,438	35,498	35,498	35,498	35,498	35,498	35,498	35,438	35,079	35,019	35,019	34,960	35,019	34,960	34,960	34,841	34,841	34,781	34,662	34,662	34,544	34,544	34,544	34,484	35,033	75
05/09/87	34,484	34,366	34,366	34,366	34,307	34,366	34,366	34,425	34,662	34,722	34,781	34,781	34,841	34,781	34,841	34,781	34,841	34,841	34,900	34,900	34,900	34,960	34,960	34,960	34,687	48
05/10/87	35,019	35,079	35,079	35,079	35,079	35,079	35,079	35,079	35,139	35,139	35,139	35,139	35,139	35,139	35,139	35,199	35,199	35,079	35,079	35,079	35,079	35,079	35,079	35,019	35,102	9
05/11/87	35,019	34,960	34,960	34,900	34,841	34,781	34,722	34,722	34,722	34,722	34,781	34,722	34,781	34,781	34,841	34,781	34,781	34,781	34,781	34,841	34,841	34,841	34,841	34,900	34,818	17
05/12/87	34,900	34,900	34,900	34,900	34,841	34,841	34,900	34,900	34,900	34,900	34,900	34,900	34,900	34,960	34,960	34,960	34,960	34,960	34,960	34,960	34,960	34,960	34,960	34,960	34,923	8
05/13/87	34,960	34,900	34,900	34,841	34,781	34,722	34,662	34,603	34,662	34,781	34,841	34,425	34,189	34,130	34,189	34,248	34,248	34,366	34,722	34,841	34,900	34,960	34,841	34,781	34,646	56
05/14/87	34,662	34,722	34,722	34,603	34,484	34,425	34,307	34,307	34,307	34,248	34,425	34,544	34,662	34,781	34,900	35,019	35,079	35,199	35,258	35,378	35,558	35,558	35,498	35,378	34,834	89
05/15/87	35,139	35,079	35,019	34,960	34,841	34,781	34,722	34,662	34,662	34,722	34,130	33,777	31,757	30,019	29,414	29,359	29,468	29,468	29,468	29,578	29,688	29,743	29,798	29,798	32,252	523
05/16/87	29,743	29,743	29,743	29,743	29,743	29,688	29,688	29,688	29,688	29,633	29,688	29,798	29,853	29,908	29,908	29,908	29,853	29,853	29,798	29,743	29,688	29,688	29,688	29,688	29,757	17
05/17/87	29,688	29,688	29,688	29,633	29,633	29,688	29,633	29,633	29,633	29,633	29,743	29,798	29,798	29,853	29,853	29,908	29,964	29,964	29,964	30,019	30,019	30,019	30,019	30,019	29,812	32
05/18/87	29,908	29,798	29,688	29,523	29,359	29,086	28,977	28,814	28,706	25,564	23,958	25,293	25,510	25,510	25,510	25,510	25,456	24,808	24,541	25,185	24,648	24,488	24,754	24,862	26,644	442
05/19/87	24,862	24,862	24,915	24,862	24,808	24,754	24,701	24,701	24,754	22,763	20,664	23,279	24,594	24,808	24,862	24,808	24,808	25,023	25,239	25,185	25,185	25,131	25,131	25,077	24,574	205
05/20/87	25,023	25,023	25,023	24,969	24,915	24,808	24,754	24,808	24,808	24,862	24,915	24,969	24,969	24,969	24,969	24,862	24,862	24,862	24,862	24,862	24,808	24,808	24,808	24,862	24,891	16
05/21/87	24,862	24,915	24,862	24,862	24,862	24,862	24,862	24,862	24,808	24,754	24,648	24,648	24,648	24,701	24,754	24,862	24,862	24,915	24,915	24,969	24,969	24,969	25,023	25,023	24,851	23
05/22/87	25,023	25,023	25,023	24,969	24,915	24,808	24,594	24,541	24,541	24,541	24,594	24,648	24,701	24,701	24,701	24,754	24,754	24,808	24,808	24,808	24,808	24,754	24,808	24,808	24,768	30
05/23/87	24,808	24,754	24,648	24,594	24,754	24,862	24,862	24,862	24,862	24,862	24,862	24,915	24,915	24,969	24,969	24,915	24,862	24,701	22,969	21,203	20,664	20,566	20,518	20,421	23,888	354
05/24/87	20,324	20,180	19,987	19,892	19,844	19,796	19,749	19,701	20,228	20,566	20,615	20,566	20,566	20,566	20,566	20,566	20,372	20,228	20,324	20,228	20,180	20,228	20,228	20,180	20,237	59
05/25/87	20,180	20,131	20,083	20,083	20,035	20,035	19,987	19,987	19,940	19,940	19,940	19,940	19,987	20,035	20,131	20,131	20,083	20,131	20,180	20,180	20,180	20,228	20,228	20,180	20,081	20
05/26/87	20,180	20,131	20,131	20,083	20,035	20,083	20,083	20,131	20,131	20,131	20,180	20,180	20,228	20,228	20,276	20,276	20,276	20,276	20,276	20,276	20,276	20,276	20,276	20,324	20,198	17
05/27/87	20,324	20,276	20,276	20,228	20,228	20,180	20,131	20,131	20,131	20,131	19,606	19,987	20,083	20,083	20,131	20,131	20,180	20,083	20,083	20,131	20,180	20,228	20,228	20,228	20,142	28
05/28/87	20,180	20,131	20,083	20,035	19,987	19,987	19,987	19,987	19,987	19,987	20,083	20,083	20,131	20,131	20,180	20,180	20,228	20,228	20,228	20,228	20,228	20,276	20,276	20,276	20,129	22
05/29/87	20,276	20,276	20,276	20,228	20,228	20,180	20,131	20,131	20,083	20,083	20,083	20,035	20,035	19,940	19,749	19,654	19,606	19,606	19,606	19,606	19,654	19,701	19,749	19,749	19,944	52
05/30/87	19,749	19,749	19,701	19,701	19,654	19,606	19,559	19,559	19,606	19,559	19,559	19,512	19,512	19,464	19,464	19,464	19,512	19,464	19,512	19,512	19,559	19,606	17,177	10,814	19,107	375
05/31/87	8,080	7,369	7,168	6,970	6,942	6,858	6,830	6,802	7,691	12,592	17,622	18,948	19,182	19,229	19,229	19,182	19,229	19,182	19,182	19,135	19,135	19,182	16,408	10,814	13,873	1,160
06/01/87	7,780	6,970	6,774	6,691	6,691	7,603	10,298	13,300	17,354	18,439	18,762	18,855	18,855	18,855	18,855	18,902	18,948	19,042	18,995	19,042	19,042	19,042	19,182	19,135	15,309	1,075
06/02/87	19,088	19,042	16,450	10,196	7,603	6,914	8,080	9,174	9,729	9,928	9,995	9,995	9,729	9,631	9,598	9,598	14,733	18,029	18,531	18,531	18,670	18,762	18,716	18,578	13,304	950
06/03/87	18,485	18,624	18,624	18,624	18,624	18,624	18,624	18,578	18,624	18,531	18,211	18,531	18,624	18,624	18,624	18,624	18,670	18,716	18,670	18,948	18,995	18,995	18,902	18,809	18,663	35
06/04/87	18,809	17,443	11,374	7,751	6,609	6,281	7,168	8,854	9,271	9,369	9,369	9,369	9,598	12,629	16,702	16,915	12,083	7,810	6,664	6,336	6,227	6,173	6,147	6,147	9,796	816
06/05/87	6,120	6,147	6,120	6,120	6,147	6,147	6,200	8,355	9,078	9,014	9,110	9,631	9,762	9,862	9,696	9,565	9,795	9,928	9,962	9,962	9,962	9,962	9,962	8,728	8,555	334
06/06/87	6,858	6,254	6,093	6,040	6,040	7,870	14,733	18,119	18,762	18,902	18,902	19,276	19,276	19,229	17,983	12,482	8,202	6,970	6,636	6,527	6,500	6,445	6,418	6,418	11,289	1,183

06/07/87	6,336	6,336	6,363	6,363	6,363	6,336	6,336	6,363	6,390	6,390	6,390	6,390	6,390	7,197	8,950	9,467	9,598	9,631	9,631	10,230	13,680	13,795	15,013	15,376	8,555	622
06/08/87	17,399	17,757	17,847	17,847	17,802	17,757	17,757	17,757	17,712	17,893	18,485	18,578	18,578	18,439	18,439	18,348	18,348	18,762	19,042	19,135	19,182	19,182	19,182	19,182	18,350	120
06/09/87	19,229	18,809	13,680	8,886	7,168	6,691	6,554	6,527	6,527	6,527	6,527	6,942	12,409	17,622	18,624	18,948	19,088	19,088	19,088	19,088	19,135	19,182	19,135	19,135	13,942	1,186
06/10/87	19,135	19,135	19,088	16,157	9,895	7,573	6,942	6,747	6,691	6,554	6,472	6,445	6,445	6,472	6,445	6,472	6,445	6,445	6,445	6,445	6,472	6,500	6,500	6,472	8,683	922
06/11/87	6,472	6,472	6,500	6,500	6,747	16,032	18,348	15,826	10,571	7,632	6,830	6,636	6,582	7,691	12,155	13,680	13,988	13,988	12,519	8,293	6,970	6,636	6,582	6,527	9,591	789
06/12/87	6,500	6,527	6,527	6,527	6,527	6,500	7,311	9,110	10,434	14,933	17,667	18,348	18,670	18,902	18,995	19,042	15,743	9,729	7,398	6,774	6,609	6,472	6,418	6,390	10,752	1,074
06/13/87	6,390	6,390	6,363	6,336	6,281	6,281	6,281	6,281	6,308	7,840	9,598	10,028	10,129	10,129	10,129	10,163	10,163	10,163	10,129	8,791	7,139	6,664	6,527	6,390	7,954	361
06/14/87	6,281	6,254	6,254	6,227	6,227	6,227	6,200	6,227	7,111	9,207	9,795	9,895	9,928	9,928	9,928	9,928	9,928	9,928	9,962	9,962	8,386	6,942	6,500	6,336	8,065	356
06/15/87	6,281	6,281	6,281	6,281	6,281	6,281	6,308	7,721	9,631	12,446	13,680	13,338	12,963	13,642	13,950	13,988	14,027	14,066	14,066	14,066	14,105	14,105	8,509	5,088	10,558	743
06/16/87	4,125	3,821	10,298	6,527	3,994	6,093	11,904	13,757	13,757	13,338	12,228	8,355	4,396	3,141	2,709	2,567	2,515	2,498	2,481	2,481	2,464	2,481	2,481	2,481	5,871	868
06/17/87	2,363	2,105	1,960	2,003	2,076	2,018	2,003	2,003	1,989	2,215	11,304	13,338	13,757	13,834	13,757	13,757	13,834	13,757	13,757	13,642	13,642	13,680	13,642	13,604	8,752	1,181
06/18/87	8,050	4,037	2,727	2,264	2,105	2,061	2,047	2,047	2,061	2,090	8,823	12,814	13,604	13,680	13,642	13,528	13,528	13,414	13,376	13,376	13,452	13,604	13,719	13,680	8,905	1,095
06/19/87	12,446	5,518	3,441	2,745	2,498	2,396	2,346	2,330	2,313	2,313	2,313	2,313	2,297	2,297	2,346	3,299	5,569	9,239	8,202	6,774	6,363	6,254	3,735	2,837	4,258	558
06/20/87	2,533	2,430	2,346	2,313	2,313	2,313	2,280	2,232	2,215	2,968	4,237	8,509	12,666	13,490	13,604	13,490	13,414	13,300	13,300	13,300	13,338	13,300	13,262	13,262	8,184	1,099
06/21/87	8,634	4,237	2,800	2,313	2,120	2,061	2,032	2,032	2,152	2,183	2,199	2,199	2,199	5,726	4,558	3,380	6,802	7,780	8,050	6,802	4,629	12,083	13,604	13,911	5,187	773
06/22/87	10,366	4,676	2,911	2,297	2,061	2,003	3,400	7,398	8,263	8,509	8,509	8,386	8,634	9,895	12,666	13,225	13,338	13,338	13,338	9,500	7,662	7,139	6,970	6,445	7,955	754
06/23/87	3,587	2,602	2,264	2,167	2,105	2,090	2,090	2,076	2,076	2,090	2,090	2,090	2,855	8,232	9,467	9,795	11,269	13,490	13,795	13,795	13,834	13,872	13,834	13,757	6,889	1,078
06/24/87	13,757	13,757	13,757	13,719	13,719	13,719	13,680	13,757	13,795	13,834	13,872	12,519	5,987	3,757	3,006	2,893	2,638	1,834	1,647	1,793	4,081	13,075	7,780	4,148	9,022	1,073
06/25/87	3,044	2,691	2,550	2,498	2,464	2,447	2,447	2,447	2,447	2,396	3,735	2,911	2,911	2,602	2,498	2,464	2,447	2,447	2,430	2,430	2,727	7,840	5,364	3,441	2,987	249
06/26/87	2,800	2,567	2,498	2,464	2,464	2,464	2,264	2,152	2,248	2,330	2,363	2,346	2,330	2,313	2,313	2,313	2,313	2,297	2,346	2,481	2,550	2,464	2,363	2,363	2,392	27
06/27/87	2,346	2,363	2,363	2,346	2,346	2,330	2,330	2,330	2,346	2,346	2,363	2,346	2,346	2,346	2,346	2,346	2,346	2,363	2,363	2,346	2,330	2,346	2,346	2,346	2,347	2
06/28/87	2,330	2,330	2,313	2,313	2,313	2,313	2,313	2,330	2,330	2,264	2,248	2,215	2,215	2,215	2,215	2,199	2,183	2,183	2,105	2,076	2,061	2,090	2,120	2,120	2,225	19
06/29/87	2,105	2,120	2,120	2,120	2,136	2,136	2,136	2,167	2,183	2,183	2,167	2,167	2,152	2,136	2,136	2,136	2,120	2,120	2,105	2,090	2,090	2,105	2,105	2,105	2,131	6
06/30/87	2,076	2,090	2,167	2,183	2,183	2,167	2,152	2,105	2,120	2,152	2,167	2,183	2,379	2,533	2,533	2,498	2,498	2,602	7,427	8,950	9,046	8,263	4,373	3,102	3,415	480
03/01/88	1,105	1,025	996	987	977	977	968	968	968	958	958	958	958	949	949	958	987	1,045	2,567	3,885	10,640	11,690	4,582	2,363	2,226	597
03/02/88	1,608	1,339	1,230	1,188	1,167	1,156	1,146	1,136	1,146	1,136	1,125	1,125	1,115	1,115	1,125	1,125	1,125	1,125	1,125	1,125	1,136	1,136	1,146	1,146	1,169	21
03/03/88	1,146	1,146	1,125	1,115	1,115	1,105	1,115	1,125	1,125	1,115	1,125	1,115	1,105	1,085	1,075	1,065	1,045	1,035	1,035	1,075	1,105	1,105	1,105	1,105	1,101	6
03/04/88	1,105	1,105	1,105	1,115	1,125	1,136	1,136	1,136	1,136	1,146	1,156	1,167	1,167	1,167	1,167	1,167	1,156	1,156	1,156	1,156	1,156	1,167	1,167	1,167	1,146	4
03/05/88	1,167	1,156	1,156	1,146	1,146	1,136	1,136	1,136	1,136	1,146	1,146	1,146	1,146	1,146	1,146	1,146	1,146	1,146	1,146	1,156	1,156	1,156	1,167	1,167	1,149	2
03/06/88	1,156	1,156	1,156	1,146	1,146	1,146	1,146	1,136	1,136	1,136	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,136	1,136	1,136	1,146	1,156	1,156	1,156	1,140	2
03/07/88	1,156	1,156	1,146	1,146	1,146	1,146	1,146	1,156	1,156	1,156	1,156	1,156	1,156	1,085	1,095	1,105	1,105	1,105	1,105	1,115	1,125	1,136	1,136	1,125	1,134	5
03/08/88	1,125	1,115	1,125	1,136	1,125	1,125	1,115	1,115	1,125	1,125	1,125	1,105	1,075	1,065	1,075	1,075	1,035	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,096	6
03/09/88	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,065	1,075	1,065	1,065	1,075	1,085	1,085	1,418	3,735	6,254	12,925	14,300	9,995	6,664	5,700	3,257	816
03/10/88	5,440	5,364	5,338	5,313	5,313	9,110	13,680	14,773	14,893	14,893	14,933	14,853	14,853	14,893	14,813	14,733	14,733	14,733	14,733	14,773	14,733	14,654	14,614	14,614	12,533	804
03/11/88	6,173	2,745	1,608	1,219	8,509	13,795	14,773	15,013	15,053	15,013	14,973	6,691	3,006	1,807	1,384	1,230	1,167	1,136	1,105	1,105	1,105	1,105	1,105	1,105	5,497	1,187
03/12/88	1,105	1,105	1,105	1,095	1,105	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,105	1,105	1,095	1,105	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,098	1
03/13/88	1,095	1,095	1,095	1,095	1,105	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,085	1,085	1,085	1,085	1,085	1,085	1,085	1,085	1,085	1,085	1,091	1
03/14/88	1,085	1,085	1,085	1,075	1,075	1,075	1,065	1,075	1,075	1,085	1,726	3,629	2,018	1,475	1,284	1,339	3,907	4,868	5,137	9,336	13,719	14,575	14,654	14,694	4,297	1,023
03/15/88	14,733	14,733	14,813	14,654	14,614	14,614	14,654	13,642	5,063	2,430	1,558	1,262	1,136	1,085	1,065	1,452	3,545	1,946	2,280	10,744	12,228	14,300	11,690	4,558	8,033	1,232
03/16/88	2,330	1,583	1,328	1,219	1,177	1,209	9,402	12,228	10,883	5,987	2,745	1,699	1,328	1,188	1,115	1,095	1,075	1,075	4,653	10,640	14,221	15,133	15,295	5,987	5,191	1,054
03/17/88	2,782	1,739	1,339	1,177	1,095	1,065	1,045	1,035	1,035	1,025	1,025	1,025	1,025	1,025	1,016	1,025	1,016	1,025	1,016	1,006	996	996	996	987	1,147	78
03/18/88	977	968	977	977	977	977	968	968	1,025	1,055	1,035	977	930	939	996	977	958	949	949	977	1,006	1,025	1,025	1,035	985	7
03/19/88	1,035	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,035	1,045	1,045	1,035	1,035	1,035	1,025	3,339	12,925	14,813	15,214	15,214	15,254	15,254	15,214	15,174	5,745	1,354
03/20/88	13,225	11,235	9,336	6,609	5,804	5,569	5,518	5,492	10,814	14,105	14,339	8,171	4,748	2,248	1,441	1,167	1,045	1,016	1,035	1,035	1,035	2,481	1,834	1,350	5,444	934
03/21/88	1,177	1,125	1,105	1,095	1,045	987	977	6,664	4,237	2,120	1,452	1,209	1,085	1,045	1,025	1,016	1,016	1,025	1,016	1,016	996	996	996	1,035	1,477	265
03/22/88	1,055	1,085	1,105	1,105	1,065	1,035	1,016	1,025	1,045	1,045	1,045	1,045	1,045	1,006	977	977	996	1,035	1,055	1,065	1,065	1,055	1,045	1,035	1,043	7
03/23/88	1,016	1,006	1,045	1,045	1,045	1,055	1,075	1,075	1,075	1,085	1,085	1,085	1,085	1,085	1,085	1,085	1,075	1,075	1,065	1,065	1,055	1,045	1,045	1,045	1,062	5
03/24/88	1,035	1,025	1,016	996	987	977	996	1,025	1,035	1,035	1,016	996	996	1,025	1,016	1,006	1,006	1,006	996	996	996	996	996	996	1,007	3
03/25/88	987	977	1,045	1,095	1,105	1,115	1,065	1,045	1,035	1,025	1,025	1,025	1,025	1,016	1,016	1,016	1,006	1,045	1,045	1,035	1,035	1,570	1,384	1,188	1,080	27
03/26/88	1,095	1,065	1,055	1,055	1,065	1,006	996	1,016	1,045	1,045	1,045	1,035	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,035	1,035	1,035	1,055	1,065	1,039	4
03/27/88	1,065	1,065	1,045	1,045	1,055	1,055	1,055	1,045	1,045	1,045	1,035	1,035	1,035	1,035	1,035	1,025	1,035	1,035	1,035	1,035	1,035	1,035	1,016	1,006	1,040	3
03/28/88	996	987	996	987	1,025	1,055	1,055	1,065	1,075	1,075	1,075	1,065	1,075	1,075	1,065	1,065	1,065	1,065	1,065	1,065	1,065	1,055	1,065	1,055	1,051	6
03/29/88	1,055	1,065	1,065	1,065	1,065	1,045	1,045	2,550	1,634	1,328	1,209	1,177	1,146	1,136	1,136	1,105	1,105	1,105	1,105	1,105	1,105	1,105	1,105	1,095	1,194	64
03/30/88	1,095	1,095	1,105	1,095	1,085	1,085	1,085	1,075	1,085	1,095	1,085	1,075	1,075	1,075	1,075	1,105	1,105	1,105	1,105	1,105	1,115	1,125	1,125	1,136	1,096	4
03/31/88	1,125	1,105	1,105	1,105	1,105	1,105	1,095	1,095	1,085	1,085	1,075	1,065	1,065	1,136	1,125	1,075	1,065	1,055	1,055	1,055	1,055	1,045	1,045	1,035	1,082	6

147

04/01/88	1,035	1,156	1,317	1,441	1,511	1,534	1,475	1,441	1,441	1,441	1,441	1,441	1,429	1,418	1,452	1,464	1,464	1,464	1,464	1,464	1,464	1,452	1,452	1,441	1,421	22
04/02/88	1,441	1,441	1,464	1,464	1,464	1,464	1,464	1,464	1,452	1,464	1,464	1,464	1,464	1,464	1,452	1,441	1,452	1,464	1,464	1,464	1,464	1,464	1,464	1,464	1,459	2
04/03/88	1,452	1,452	1,452	1,475	1,475	1,487	1,464	1,429	1,418	1,418	1,441	1,487	1,522	1,522	1,534	1,534	1,522	1,452	1,418	1,441	1,487	1,499	1,499	1,475	1,473	8
04/04/88	1,487	1,487	1,487	1,487	1,487	1,487	1,499	1,499	1,511	1,522	1,522	1,511	1,499	1,487	1,499	1,487	1,487	1,511	1,499	1,511	1,522	1,522	1,511	1,499	1,501	3
04/05/88	1,499	1,499	1,499	1,511	1,499	1,511	1,511	1,522	1,522	1,522	1,522	1,511	1,499	1,487	1,487	1,487	1,487	1,475	1,475	1,475	1,487	1,487	1,487	1,487	1,498	3
04/06/88	1,487	1,487	1,487	1,499	1,499	1,499	1,511	1,511	1,511	1,534	1,511	1,511	1,511	1,499	1,499	1,499	1,487	1,487	1,487	1,487	1,499	1,499	1,522	1,499	1,501	3
04/07/88	1,499	1,499	1,511	1,511	1,499	1,511	1,511	1,511	1,522	1,522	1,522	1,511	1,499	1,499	1,499	1,499	1,499	1,499	1,487	1,487	1,608	1,699	1,570	1,499	1,520	9
04/08/88	1,487	1,487	1,487	1,475	1,475	1,487	1,487	1,499	1,608	2,248	4,868	9,895	9,829	9,434	6,691	3,800	2,297	1,834	1,673	1,686	1,848	1,904	1,904	1,974	3,141	577
04/09/88	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,076	3,160	4,700	5,112	5,014	3,650	2,620	2,330	2,232	2,199	2,183	2,183	2,167	2,136	2,120	2,076	2,587	202
04/10/88	2,061	2,061	2,061	2,061	2,061	2,061	2,047	2,047	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,047	2,047	2,032	2,032	2,042	3
04/11/88	2,018	2,032	2,047	2,047	2,032	2,032	2,047	2,061	2,061	2,061	2,047	2,047	2,047	2,047	2,047	2,047	2,032	2,047	2,032	2,032	2,047	2,047	2,032	2,032	2,042	2
04/12/88	2,032	2,032	2,032	2,047	2,047	2,061	2,183	3,063	6,636	9,078	9,762	9,895	10,503	7,691	6,527	6,173	7,026	9,239	9,928	10,779	13,795	13,795	9,664	7,083	6,878	793
04/13/88	6,254	6,013	5,934	5,934	5,934	5,934	6,308	9,207	13,872	14,933	15,093	15,133	15,133	12,556	10,675	10,332	10,230	10,230	10,264	10,264	10,230	10,196	10,129	8,293	9,962	657
04/14/88	6,802	6,418	6,308	6,308	6,281	6,254	8,355	13,452	14,933	15,013	11,269	7,870	6,719	6,390	6,227	6,200	6,200	6,147	6,147	6,147	6,173	6,147	6,120	6,120	7,667	585
04/15/88	6,120	6,040	6,013	5,987	5,987	6,013	6,281	8,823	9,533	7,632	6,747	6,390	6,281	6,227	6,200	6,200	6,200	6,173	6,173	6,173	6,173	6,173	6,173	6,173	6,495	183
04/16/88	6,147	6,173	6,173	6,173	6,147	6,147	6,147	7,930	9,369	9,565	7,870	6,664	6,336	6,254	6,227	6,227	6,227	6,227	6,227	6,227	6,227	6,173	6,120	6,066	6,627	204
04/17/88	6,040	6,040	6,040	6,040	6,040	6,040	6,013	6,013	6,040	6,040	6,040	6,066	6,066	6,066	6,040	6,013	6,013	6,013	6,013	6,013	6,040	6,040	6,040	6,040	6,035	3
04/18/88	6,040	6,040	6,013	6,013	6,013	6,040	6,040	6,040	6,040	6,040	6,066	6,066	6,040	6,066	6,066	6,040	6,040	6,013	5,987	6,013	6,120	6,093	6,066	6,066	6,044	6
04/19/88	6,040	6,066	6,040	6,040	6,093	6,066	6,093	6,093	6,120	6,120	6,147	6,147	6,147	6,173	6,147	6,120	6,093	6,093	8,202	12,925	15,053	15,417	15,539	12,011	7,874	695
04/20/88	7,960	6,858	6,609	6,527	6,390	6,336	6,336	6,308	6,281	6,281	6,254	6,227	6,173	6,173	6,173	6,200	6,582	8,665	7,369	6,582	6,774	8,665	7,960	6,774	6,769	158
04/21/88	6,445	6,363	6,363	6,281	6,254	6,227	6,227	6,227	6,200	6,200	6,200	6,173	6,173	6,173	6,227	7,283	11,374	14,143	14,614	14,773	12,264	8,760	6,802	6,254	7,917	614
04/22/88	6,093	6,066	6,040	6,013	6,013	6,040	6,013	6,013	6,013	6,013	5,987	5,987	5,987	5,961	5,961	5,961	5,961	7,632	9,500	9,962	13,187	12,925	8,791	6,858	7,124	443
04/23/88	6,363	6,227	6,173	6,173	6,173	6,200	6,173	6,173	6,200	6,147	6,093	6,093	6,066	6,040	6,040	6,040	7,456	9,631	10,264	10,366	9,533	7,456	6,636	6,445	6,923	294
04/24/88	6,363	6,363	6,227	6,173	6,173	6,120	6,120	6,093	6,147	6,147	6,120	6,040	6,013	6,013	6,040	6,040	6,066	6,040	6,040	6,040	6,066	6,066	6,066	6,040	6,109	20
04/25/88	6,040	6,093	6,120	6,093	6,066	6,093	6,093	6,093	6,308	6,418	6,390	6,363	6,363	6,390	6,363	6,363	6,336	6,254	6,200	6,120	6,173	6,173	6,147	6,200	6,219	26
04/26/88	6,227	6,254	6,281	6,173	6,040	6,013	6,066	6,093	6,093	6,093	6,093	6,093	6,120	6,120	6,120	6,120	6,093	6,093	6,093	6,066	6,120	6,120	6,120	6,066	6,115	13
04/27/88	6,013	6,040	6,066	6,040	6,066	6,066	6,066	6,093	6,147	6,120	6,173	6,173	6,147	6,147	6,147	6,147	6,120	6,120	6,093	6,066	6,066	6,120	6,227	6,227	6,112	12
04/28/88	6,173	6,227	6,227	6,227	6,227	6,254	6,254	6,281	6,281	6,013	5,543	5,569	5,804	5,830	5,830	5,830	5,856	5,856	5,856	5,856	5,856	5,856	5,882	5,882	5,978	46
04/29/88	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,934	5,961	5,961	5,908	5,856	5,830	5,830	5,830	5,856	5,830	5,830	5,878	7
04/30/88	5,830	5,856	5,856	5,856	5,830	5,830	5,830	5,830	5,830	5,830	5,830	5,830	5,830	5,856	5,856	5,882	5,882	5,882	5,882	5,882	5,908	5,908	5,908	5,908	5,859	6
05/01/88	5,934	5,934	5,908	5,908	5,908	5,908	5,908	5,908	5,908	5,908	5,908	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,908	5,908	5,882	5,898	3
05/02/88	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,856	5,882	5,882	5,882	5,882	5,882	5,908	5,908	5,934	5,885	3
05/03/88	5,934	5,934	5,934	5,934	5,934	5,934	5,934	5,934	5,961	5,961	5,961	5,934	5,934	5,934	5,934	5,934	5,934	5,934	5,908	5,934	5,934	5,934	5,934	5,934	5,936	2
05/04/88	5,908	5,908	5,934	6,013	5,987	5,934	5,908	5,934	7,900	9,829	10,298	10,366	10,400	10,400	10,400	10,400	10,400	10,366	10,366	10,434	7,573	6,445	6,120	5,987	8,134	434
05/05/88	5,961	5,934	5,934	5,961	5,934	6,281	9,402	10,537	10,744	10,779	10,814	10,779	10,332	9,928	10,264	10,332	10,366	10,332	8,386	6,664	6,173	5,987	5,908	5,830	8,315	447
05/06/88	5,882	5,934	5,934	5,934	5,934	5,934	8,111	9,369	9,631	9,729	9,829	9,895	9,928	10,129	8,854	6,942	6,363	6,227	6,173	6,173	6,120	6,093	6,093	6,093	7,388	352
05/07/88	6,040	5,987	5,961	5,908	5,882	5,934	5,961	5,987	6,013	5,987	5,961	5,961	5,961	5,934	5,934	5,882	5,856	5,856	5,856	5,882	5,882	5,882	5,882	5,882	5,928	11
05/08/88	5,856	5,856	5,856	5,882	5,934	5,908	5,934	5,934	5,961	5,987	5,934	5,908	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,856	5,896	7
05/09/88	5,856	5,856	5,856	5,856	5,856	5,882	5,908	5,908	5,908	5,908	5,934	5,908	5,908	5,961	9,046	9,565	9,696	9,729	9,729	9,696	9,631	8,854	6,858	6,200	7,146	351
05/10/88	5,961	5,934	5,908	5,934	5,934	5,934	5,934	5,934	5,882	5,882	5,882	5,908	5,882	6,093	8,886	10,264	10,400	10,129	9,928	9,895	9,962	8,080	6,500	6,013	7,211	378
05/11/88	5,882	5,934	5,961	5,961	5,961	5,987	5,961	5,961	5,961	5,961	5,961	5,961	5,961	5,961	8,509	10,264	10,468	9,762	9,369	9,304	9,304	8,111	6,527	6,040	7,126	346
05/12/88	5,908	5,882	5,856	5,856	5,856	5,882	5,882	5,882	5,752	5,621	5,595	5,595	5,595	6,173	8,509	9,500	9,533	9,304	9,271	9,239	9,271	8,355	6,830	6,363	6,980	324
05/13/88	6,227	6,013	5,908	5,882	5,882	5,882	5,882	5,908	6,040	6,066	5,987	5,934	5,961	5,987	6,013	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,977	15
05/14/88	5,961	5,934	5,934	5,961	5,961	5,987	5,961	5,961	5,961	5,961	5,961	5,961	5,961	5,961	6,636	8,447	9,174	9,207	8,982	8,854	9,078	9,078	7,026	6,281	6,924	280
05/15/88	6,066	6,013	6,013	5,987	5,987	5,987	5,961	5,987	5,987	5,987	5,987	6,013	6,013	6,013	6,418	7,930	8,324	8,447	8,603	8,697	8,823	8,540	6,691	6,120	6,775	233
05/16/88	5,961	5,934	5,934	5,961	5,934	5,961	5,961	5,961	6,582	8,416	9,434	9,664	9,598	9,862	10,163	9,696	9,500	9,174	9,046	9,046	9,046	8,760	6,802	6,227	7,859	345
05/17/88	6,066	6,013	5,987	5,987	5,987	5,987	5,987	6,390	8,572	9,207	9,304	9,304	9,304	9,304	9,304	9,271	9,304	9,304	9,304	9,304	9,271	8,791	6,747	6,120	7,922	320
05/18/88	5,934	5,934	5,961	5,934	5,934	5,934	6,147	6,066	5,961	5,804	5,934	6,040	6,066	6,066	6,554	6,227	6,147	6,093	6,093	6,066	6,066	6,066	6,093	6,093	6,051	29
05/19/88	6,093	6,093	6,093	6,093	6,093	6,093	6,093	6,093	6,093	6,120	6,120	6,120	6,147	6,147	6,147	6,363	7,780	8,728	8,886	8,886	8,918	8,982	7,691	6,418	6,845	237
05/20/88	6,066	6,013	5,961	5,961	5,987	6,013	6,013	6,747	8,478	8,982	9,110	9,174	9,110	9,078	9,046	9,014	9,014	8,982	8,982	8,950	8,950	9,014	7,168	6,363	7,840	290
05/21/88	6,120	6,093	6,066	6,066	6,040	6,066	6,040	6,040	5,961	5,856	5,856	5,856	5,830	5,830	6,066	8,050	8,760	8,918	8,886	8,982	9,078	9,110	7,340	6,281	6,883	269
05/22/88	5,987	5,908	5,882	5,882	5,882	5,882	5,856	5,882	5,882	5,908	5,908	5,908	5,908	5,908	6,147	8,050	8,886	9,110	9,142	9,174	9,174	7,083	6,227	5,961	6,731	272
05/23/88	5,908	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	6,445	8,416	9,014	9,174	9,239	9,239	9,239	8,572	6,664	6,066	6,852	290
05/24/88	5,908	5,882	5,882	5,856	5,908	5,908	5,934	6,147	8,020	8,886	9,110	9,110	9,046	9,014	9,014	9,014	8,854	9,239	9,239	9,239	9,631	11,094	8,416	6,472	7,951	335
05/25/88	5,804	5,700	5,856	5,934	5,882	5,804	5,804	5,856	5,882	5,961	6,013	5,961	5,882	5,856	6,120	8,050	8,603	8,293	8,634	8,886	8,886	8,886	7,054	6,173	6,741	257

05/26/88	5,908	5,856	5,856	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882	5,856	5,752	5,856	6,120	8,324	8,886	8,982	8,982	8,950	8,982	8,540	6,691	6,147	6,781	275
05/27/88	5,987	5,961	6,013	5,961	5,934	5,934	5,934	5,934	5,961	5,882	5,830	5,882	5,934	5,961	6,472	8,080	8,886	8,886	8,918	8,950	8,982	8,324	6,609	6,040	6,802	261
05/28/88	5,882	5,830	5,830	5,830	5,882	5,908	5,856	5,804	5,752	5,648	5,621	5,621	5,621	5,595	5,595	5,595	5,595	5,621	5,595	5,621	5,621	5,621	5,648	5,674	5,703	23
05/29/88	5,778	5,882	5,908	5,908	5,934	5,961	5,934	5,804	5,674	5,648	5,621	5,621	5,621	5,595	5,595	5,595	5,595	5,595	5,595	5,595	5,595	5,595	5,595	5,595	5,702	29
05/30/88	5,595	5,595	5,595	5,595	5,569	5,569	5,569	5,595	5,595	5,621	5,621	5,621	5,621	5,621	5,595	5,595	5,621	5,648	5,648	5,648	5,648	5,648	5,648	5,648	5,614	6
05/31/88	5,648	5,648	5,648	5,648	5,621	5,621	5,621	5,621	7,900	8,823	9,110	11,940	13,225	13,376	13,452	13,528	13,911	13,950	14,733	14,027	13,911	13,872	13,795	12,409	10,293	770
06/01/88	10,298	9,762	9,631	9,598	9,598	9,598	9,598	9,598	9,565	9,598	9,598	9,598	9,598	9,565	9,598	9,598	9,696	9,729	9,664	9,664	9,664	9,239	6,942	6,254	9,385	180
06/02/88	6,040	5,856	5,830	5,830	5,804	5,778	5,778	5,518	5,569	5,466	5,569	5,648	5,648	5,674	5,856	5,752	5,726	5,726	5,726	5,752	5,726	5,726	5,726	5,726	5,727	25
06/03/88	3,714	2,498	2,061	1,904	2,061	2,167	2,152	2,105	2,061	2,076	2,061	2,076	2,076	2,076	2,047	2,061	2,413	2,199	2,061	4,192	12,703	16,282	11,620	5,137	3,825	795
06/04/88	3,160	2,498	2,248	2,167	2,120	2,120	2,105	2,090	9,962	13,452	14,182	14,300	14,339	14,339	6,719	3,757	2,745	2,413	2,280	2,199	2,167	2,152	2,152	2,136	5,325	1,008
06/05/88	2,136	2,136	2,136	2,136	2,152	2,136	2,136	2,120	2,120	2,120	2,120	2,120	7,111	4,442	2,930	2,396	3,082	2,413	2,105	2,105	2,120	2,105	2,090	2,090	2,523	226
06/06/88	2,090	2,090	2,090	2,061	2,047	2,032	1,974	1,946	2,105	2,199	2,183	2,136	2,136	2,602	7,930	9,696	10,298	10,400	10,366	10,366	11,235	14,260	14,813	14,773	5,993	1,002
06/07/88	8,478	13,528	14,733	15,093	15,295	15,335	15,295	10,196	4,892	10,434	10,709	5,088	6,554	12,409	13,566	14,378	14,654	14,733	14,694	14,853	14,973	14,973	14,933	14,575	12,682	686
06/08/88	5,908	3,545	2,764	2,464	2,379	2,330	2,363	9,174	5,364	3,380	2,709	2,481	4,373	4,419	2,930	2,430	2,248	2,199	2,152	2,136	2,120	6,998	3,821	2,727	3,475	365
06/09/88	2,363	2,248	2,199	2,167	2,167	2,152	2,152	2,152	2,152	2,152	2,136	2,136	2,152	2,152	2,136	2,152	2,152	2,167	3,735	3,503	2,515	2,215	2,105	2,061	2,301	85
06/10/88	2,136	2,199	2,199	2,183	2,167	2,136	2,105	3,671	2,855	2,379	2,248	2,136	2,076	2,032	2,018	2,018	2,930	2,330	2,105	2,061	2,047	2,047	2,018	1,974	2,253	79
06/11/88	1,974	2,003	2,105	2,152	2,136	2,105	2,076	2,003	2,018	7,139	3,843	2,673	2,280	2,136	2,076	2,047	2,047	2,047	2,032	2,018	2,018	2,047	2,047	2,032	2,377	221
06/12/88	2,032	2,032	2,047	2,032	2,032	2,032	2,018	2,018	2,018	2,032	2,047	2,047	2,047	2,047	2,032	2,032	2,047	5,038	8,263	5,492	3,200	2,413	2,152	2,090	2,635	309
06/13/88	2,047	2,018	2,018	2,018	2,003	2,018	2,032	2,061	2,047	2,018	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,030	2
06/14/88	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,090	2,105	2,105	2,120	2,120	2,105	2,105	2,105	6,609	8,111	8,478	5,338	4,373	4,081	3,994	3,950	3,252	408
06/15/88	3,928	5,882	8,603	6,582	5,882	5,700	5,648	5,621	3,239	2,330	2,032	1,932	1,904	1,904	1,946	2,018	5,212	4,237	2,800	2,330	6,719	7,603	3,907	3,545	4,229	419
06/16/88	4,305	4,489	4,676	4,892	4,940	4,965	3,082	2,346	2,105	2,032	2,003	1,989	1,989	2,018	2,018	2,018	2,018	2,003	2,003	2,003	2,003	2,003	2,032	2,018	2,748	242
06/17/88	2,018	2,018	2,018	2,018	2,018	2,018	2,003	2,003	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,032	2,018	2,017	1
06/18/88	2,047	2,120	2,152	2,183	2,183	2,183	2,167	2,167	2,183	2,199	2,199	2,199	2,447	4,059	3,972	2,782	2,379	2,264	2,199	2,183	5,313	7,254	3,907	2,782	2,814	257
06/19/88	2,396	2,264	2,199	2,199	2,183	2,167	2,167	2,264	2,232	2,199	2,152	2,120	2,105	2,105	2,105	2,152	2,183	2,313	2,330	2,330	2,330	3,380	2,987	2,481	2,306	60
06/20/88	2,313	2,264	2,232	2,215	2,199	2,199	2,199	2,199	2,199	2,199	2,215	2,232	2,232	7,603	4,582	8,080	9,142	16,199	19,512	12,814	7,780	7,398	3,950	2,782	5,364	996
06/21/88	2,379	2,232	2,183	2,152	2,167	2,167	2,152	2,152	2,152	2,136	5,726	9,014	9,795	11,549	15,498	19,229	20,083	19,796	19,654	19,654	19,701	19,701	19,654	19,606	10,439	1,649
06/22/88	19,559	19,606	19,559	20,035	20,469	20,615	8,020	4,170	2,874	2,968	8,603	9,962	15,214	19,654	20,469	20,615	20,664	20,615	20,469	20,421	20,469	8,111	4,237	2,968	14,598	1,483
06/23/88	2,515	2,363	2,313	2,313	2,297	2,280	2,280	2,280	3,141	9,598	16,957	18,995	19,370	19,323	8,854	4,396	2,968	2,498	2,313	2,232	2,215	2,199	2,183	2,183	5,753	1,270
06/24/88	2,183	2,232	2,232	2,215	2,199	2,199	2,199	2,183	2,313	2,464	2,515	2,533	2,533	2,533	2,413	1,848	1,848	2,090	2,199	2,232	2,215	2,183	2,167	2,199	2,247	37
06/25/88	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,232	2,232	2,248	2,232	2,232	2,232	2,215	2,215	2,215	2,215	2,215	2,199	2,199	2,199	2,199	2,199	2,217	3
06/26/88	2,199	2,183	2,183	2,199	2,199	2,199	2,199	2,215	2,215	2,232	2,215	2,215	2,215	2,199	2,199	2,183	2,167	2,152	2,152	2,183	2,183	2,152	2,090	2,076	2,184	8
06/27/88	2,061	2,047	2,047	2,047	2,032	2,032	2,047	2,061	2,076	2,076	2,090	2,076	2,061	2,076	2,076	2,076	2,076	2,076	2,076	2,076	2,076	2,090	2,090	2,076	2,067	4
06/28/88	2,076	2,076	2,076	2,090	2,090	2,105	2,090	2,090	2,076	2,076	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,061	2,076	2,105	2,120	2,088	2
06/29/88	2,120	2,105	2,120	2,105	2,105	2,120	2,136	2,136	2,120	2,136	2,120	2,120	2,120	2,120	2,105	2,120	2,136	3,441	7,026	3,821	2,727	2,379	2,264	2,199	2,496	216
06/30/88	2,183	2,183	2,183	2,199	2,183	2,167	2,167	2,167	2,183	2,183	2,167	2,167	2,167	2,167	2,167	2,183	2,183	2,183	2,183	2,167	2,167	6,093	3,545	2,585	2,414	170
03/01/89	20,469	20,469	20,421	20,372	20,372	20,324	20,324	20,372	20,372	20,372	20,372	19,987	19,796	19,749	19,701	19,987	20,131	20,131	20,131	20,131	20,083	20,180	20,131	20,180	20,190	46
03/02/89	20,131	20,083	20,083	20,131	20,083	20,035	20,035	20,035	20,035	20,035	19,940	19,844	19,701	19,749	19,276	19,182	19,229	19,276	19,276	19,606	19,749	19,701	19,701	19,654	19,774	65
03/03/89	19,606	19,606	19,606	19,606	19,701	19,749	19,749	19,892	19,940	19,940	19,940	19,987	19,987	13,376	13,037	18,348	17,488	19,987	20,469	20,518	20,566	20,566	20,615	19,512	19,241	404
03/04/89	19,042	12,373	6,691	3,821	3,121	4,350	3,180	14,221	19,088	19,987	20,180	20,180	20,180	20,180	11,832	18,578	19,987	20,228	20,276	20,276	18,948	12,373	13,988	9,046	14,672	1,311
03/05/89	6,093	3,778	3,421	2,968	2,691	2,968	3,566	10,744	15,214	14,339	12,446	11,620	12,155	8,634	10,298	4,868	2,363	1,522	2,280	9,533	8,478	5,700	2,673	1,634	6,666	900
03/06/89	1,306	1,177	1,136	1,115	1,095	1,075	1,075	8,324	18,119	20,035	20,372	20,469	20,421	20,469	20,469	20,469	20,518	20,518	20,518	20,566	20,615	20,664	20,712	20,761	14,250	1,826
03/07/89	20,761	20,712	20,712	20,615	20,518	20,421	20,421	20,421	20,421	20,469	20,469	20,469	20,518	20,518	20,518	20,518	20,518	20,518	20,566	20,566	20,615	20,615	20,615	20,615	20,546	20
03/08/89	20,615	20,615	20,615	20,566	20,518	20,469	20,421	20,469	20,469	20,421	20,421	20,469	20,469	20,469	20,469	20,421	20,421	20,421	20,421	20,469	20,469	20,518	20,469	20,469	20,481	13
03/09/89	20,469	20,469	20,421	20,421	20,372	20,324	20,324	20,324	20,324	20,276	20,324	20,228	20,180	20,083	20,083	18,394	13,225	9,533	9,271	9,467	9,500	9,110	7,485	5,804	16,517	1,111
03/10/89	7,083	8,171	8,050	8,447	15,254	18,394	18,902	18,995	19,042	18,995	19,042	18,995	18,995	18,948	18,995	19,276	20,035	20,324	20,372	20,421	20,421	20,372	20,421	20,421	17,432	914
03/11/89	18,902	16,702	18,948	19,464	19,559	13,262	14,027	18,256	19,042	19,182	19,182	19,182	19,182	19,135	19,182	19,182	19,229	19,182	18,809	19,276	19,417	19,417	14,813	11,761	18,096	457
03/12/89	16,157	14,496	11,940	16,915	18,119	18,995	17,893	16,366	12,482	4,676	13,834	15,457	15,580	7,054	3,044	1,753	1,306	1,146	1,075	1,055	1,045	1,035	1,025	1,016	8,894	1,475
03/13/89	1,006	1,006	1,016	1,016	1,016	1,016	2,691	14,260	18,394	16,074	18,074	14,773	17,938	18,531	16,324	15,702	19,701	20,421	20,761	20,908	21,006	21,006	20,957	18,029	13,401	1,674
03/14/89	7,544	6,527	8,854	9,434	12,740	12,336	17,000	18,995	19,323	19,512	19,512	19,512	19,512	19,749	19,796	19,844	19,796	19,796	19,796	19,796	19,844	19,796	13,490	10,163	16,361	968
03/15/89	12,373	18,624	19,987	20,180	20,228	20,180	20,180	20,180	20,180	20,228	20,228	20,276	20,276	20,228	20,276	9,369	3,800	2,047	4,629	7,427	3,319	1,960	1,534	1,361	13,711	1,646
03/16/89	1,328	1,350	1,295	1,241	1,219	1,198	6,970	18,165	19,135	17,938	20,324	20,712	20,810	20,712	20,518	20,518	20,518	20,518	20,469	20,469	20,372	20,372	20,372	20,372	14,871	1,732
03/17/89	20,324	13,187	12,083	13,187	15,743	15,133	16,115	17,088	12,888	11,269	10,163	7,603	7,283	7,456	7,139	8,823	8,854	11,549	14,182	17,577	15,620	13,911	15,620	13,795	12,775	742
03/18/89	9,962	8,950	7,960	7,721	7,632	7,603	10,163	13,795	12,777	12,592	12,556	15,908	17,354	16,830	15,335	17,354	16,534	16,408	16,408	16,366	16,366	16,157	16,324	12,336	13,391	723
03/19/89	7,485	7,197	7,721	7,810	8,697	16,830	15,826	10,366	9,336	8,823	8,572	7,990	12,851	8,950	5,882	5,088	5,882	5,674	8,050	15,867	18,948	17,938	17,088	17,533	10,683	930

03/20/89	10,848	8,791	8,293	3,907	3,441	6,664	6,830	8,540	8,665	7,254	6,093	5,752	7,515	5,830	5,212	5,882	10,814	16,282	14,654	12,963	12,592	13,112	12,446	11,761	8,922	716
03/21/89	17,177	15,335	6,147	2,855	1,766	2,413	11,409	11,690	10,230	8,355	12,191	11,479	13,075	14,575	10,640	7,197	5,752	5,187	16,282	18,394	18,578	18,855	15,785	17,000	11,349	1,099
03/22/89	13,000	17,667	19,135	18,902	18,716	19,088	19,042	18,670	17,000	13,112	13,414	12,336	13,112	12,409	11,200	6,609	5,569	8,355	15,826	17,533	18,165	18,624	17,088	17,488	15,086	840
03/23/89	17,354	18,165	18,485	19,042	19,606	19,370	19,323	19,182	18,809	18,211	19,182	18,394	19,370	19,276	19,749	19,940	19,229	19,417	19,940	19,749	19,749	14,893	18,256	18,302	18,875	220
03/24/89	18,439	20,712	21,105	21,105	21,055	21,006	20,957	20,957	21,006	21,006	21,006	20,908	20,908	20,908	20,908	20,957	20,957	20,908	20,957	21,006	21,006	21,006	21,055	21,105	20,873	107
03/25/89	21,055	20,957	20,957	20,908	20,957	20,908	20,859	20,810	20,712	20,761	20,761	20,761	20,712	20,761	20,712	20,761	20,761	20,810	20,810	20,810	20,859	20,859	20,908	20,859	20,835	19
03/26/89	20,761	20,761	20,761	20,761	20,712	20,664	20,664	20,615	20,615	20,566	20,615	20,615	20,664	20,664	20,664	20,664	20,664	20,664	20,712	20,712	20,712	20,712	20,712	20,712	20,682	11
03/27/89	20,712	20,712	20,712	20,664	20,615	20,615	20,615	20,615	20,664	20,664	20,664	20,664	20,712	20,712	20,761	20,761	20,761	20,712	20,712	20,761	20,810	20,810	20,761	20,761	20,706	12
03/28/89	20,810	20,761	20,761	20,761	20,712	20,664	20,664	20,664	20,664	20,712	20,712	20,712	20,712	20,712	20,615	20,566	20,664	20,664	20,664	20,664	20,712	20,712	20,712	20,712	20,696	10
03/29/89	18,995	10,196	8,020	7,456	7,515	14,339	14,694	17,938	19,135	19,464	19,464	19,323	16,282	18,074	19,229	19,135	19,042	19,654	19,892	20,324	19,654	18,670	15,013	13,037	16,439	863
03/30/89	8,355	3,587	2,018	1,475	1,273	1,209	4,081	17,177	18,948	13,911	14,182	14,027	13,642	15,908	16,872	18,531	18,995	18,439	18,762	19,229	18,716	17,757	17,983	17,622	13,029	1,392
03/31/89	18,485	18,394	18,302	17,983	18,348	19,749	19,088	15,174	5,440	2,656	8,728	17,622	18,119	19,276	13,911	5,313	2,567	4,843	8,603	8,886	9,239	9,271	4,676	2,280	11,956	1,315
04/01/89	1,499	1,406	1,395	1,384	1,429	1,475	1,487	1,487	1,753	4,489	5,187	5,674	5,961	6,147	6,363	6,527	6,582	6,664	6,554	6,527	6,527	6,554	6,609	7,083	4,448	491
04/02/89	6,998	6,719	6,942	6,858	6,942	7,139	6,886	7,026	6,914	6,802	6,886	6,774	6,664	6,554	6,636	6,719	6,691	6,609	6,582	6,636	6,664	6,664	6,858	6,886	6,794	32
04/03/89	7,054	6,914	6,886	7,340	7,311	7,632	7,603	7,197	7,340	7,427	7,225	7,168	7,283	7,083	7,054	6,942	6,886	6,802	6,719	7,083	6,886	6,747	6,802	6,747	7,089	54
04/04/89	6,774	6,774	6,747	6,802	7,311	7,197	7,197	7,083	6,914	6,858	6,858	6,802	6,747	6,719	6,719	6,802	6,830	6,774	6,774	7,254	7,054	7,083	6,830	6,691	6,900	39
04/05/89	6,914	6,886	6,970	7,026	7,054	7,054	7,111	6,998	6,970	7,197	6,914	7,197	7,083	7,168	6,858	7,026	7,283	7,369	7,254	7,369	6,942	7,398	7,168	7,026	7,093	32
04/06/89	7,111	7,225	7,054	6,998	7,283	7,603	7,721	7,691	7,573	7,662	7,662	7,225	7,721	7,721	8,854	8,324	8,171	8,232	8,416	8,447	8,478	8,386	8,447	8,447	7,852	111
04/07/89	8,416	8,416	8,386	8,416	8,416	8,416	8,416	8,665	8,760	8,918	8,728	8,634	8,202	8,141	8,447	8,355	8,728	9,664	9,895	9,895	9,598	9,795	9,304	9,174	8,824	116
04/08/89	9,014	9,046	9,271	9,631	9,598	9,565	9,533	9,631	9,729	9,533	9,271	9,565	9,631	9,271	10,434	10,814	10,883	10,918	10,953	11,514	11,620	11,200	11,409	11,059	10,129	177
04/09/89	11,409	11,479	11,339	11,374	11,797	11,514	12,228	12,592	12,666	12,629	12,629	11,690	11,868	11,868	11,690	12,191	12,777	12,556	12,519	12,740	12,703	12,446	12,373	12,409	12,145	103
04/10/89	12,191	12,482	12,703	12,592	12,963	12,777	12,925	12,851	12,703	12,629	15,174	17,533	18,670	18,855	19,229	19,796	20,228	20,372	20,083	20,180	20,131	19,749	19,796	19,749	16,515	710
04/11/89	19,135	20,035	20,324	20,421	20,372	19,987	20,421	20,664	20,859	20,761	20,908	20,957	20,908	20,908	20,908	20,035	19,892	19,512	20,324	20,615	20,664	20,810	19,987	19,323	20,364	108
04/12/89	19,749	19,749	20,083	20,035	19,606	19,654	19,940	20,615	20,664	20,810	20,859	20,810	20,908	20,957	20,908	20,908	20,859	20,761	20,761	20,761	20,761	20,664	20,518	20,421	20,490	94
04/13/89	20,372	20,421	20,469	20,712	20,810	20,324	20,664	20,810	20,908	20,908	20,957	20,957	20,908	20,810	20,761	20,761	20,712	20,761	20,518	20,518	20,566	19,892	19,559	19,606	20,570	80
04/14/89	19,749	19,654	19,749	19,654	19,512	19,559	19,940	20,712	20,908	20,957	20,957	20,908	20,859	20,957	20,957	21,006	20,957	21,006	20,957	20,957	21,006	19,182	15,620	11,975	19,904	420
04/15/89	9,696	7,900	8,141	8,447	8,540	9,142	9,369	9,631	9,402	9,369	9,304	9,304	9,304	9,174	9,142	9,142	9,110	9,110	9,336	9,434	9,467	9,467	10,095	10,264	9,220	109
04/16/89	9,862	9,598	9,664	10,129	10,434	10,400	9,696	9,500	9,862	9,467	9,336	9,304	9,304	9,304	9,304	9,304	9,304	9,336	10,163	9,664	9,696	10,095	10,028	9,995	9,698	75
04/17/89	9,995	10,028	10,028	10,028	10,028	10,129	10,366	10,640	10,434	10,366	10,434	10,298	10,230	10,129	9,304	9,239	9,271	9,304	9,304	9,336	9,336	9,336	9,271	9,271	9,838	100
04/18/89	9,271	9,271	9,271	9,271	9,271	9,271	9,271	9,271	9,207	9,664	9,962	10,298	10,366	10,366	10,400	10,400	10,400	10,400	10,366	10,366	10,366	10,366	10,332	10,332	9,907	109
04/19/89	10,366	10,400	10,366	10,537	10,571	10,503	10,468	10,503	10,503	10,503	10,537	10,537	10,571	10,571	10,606	10,606	10,606	10,571	10,571	10,571	10,571	10,571	10,571	10,571	10,531	14
04/20/89	10,571	10,537	10,537	10,537	10,503	10,537	10,503	10,503	10,503	10,468	10,503	10,503	10,503	10,537	10,537	10,537	10,537	10,537	10,537	10,537	10,537	10,537	10,537	10,537	10,526	4
04/21/89	10,537	10,571	10,571	10,537	10,537	10,537	10,537	10,537	10,468	10,468	10,744	10,779	10,744	10,848	10,953	10,918	10,953	10,814	10,779	10,744	10,953	10,848	10,675	10,571	10,693	34
04/22/89	10,468	10,468	10,571	10,434	10,606	10,675	10,537	10,468	10,468	10,571	10,744	10,537	10,640	10,606	10,537	10,537	10,779	10,675	10,640	10,640	10,709	10,537	10,503	10,298	10,569	22
04/23/89	10,606	9,995	8,791	8,886	9,174	9,014	9,014	9,631	9,142	9,207	8,950	8,697	8,950	8,982	8,950	9,046	9,110	9,565	9,434	9,336	9,664	9,533	9,467	9,336	9,270	87
04/24/89	9,239	8,918	8,886	9,500	9,142	9,207	10,779	11,235	11,165	11,024	10,640	10,848	10,779	10,606	10,709	10,366	10,814	10,779	10,744	10,606	11,690	11,235	10,883	10,332	10,422	165
04/25/89	9,962	10,028	10,028	9,928	9,895	9,928	9,995	10,095	10,129	8,950	8,603	8,509	8,603	8,603	8,355	8,386	8,447	8,665	8,728	8,728	8,760	8,791	7,691	6,173	8,999	195
04/26/89	5,569	5,648	5,778	5,856	5,856	5,987	6,120	6,147	6,147	6,147	6,227	6,173	6,147	6,445	6,582	6,636	7,456	9,467	10,779	11,444	11,235	10,571	10,779	10,883	7,503	444
04/27/89	10,883	10,883	10,918	10,918	10,918	11,059	11,094	11,165	11,200	11,200	11,235	11,269	10,640	9,110	8,202	7,632	6,281	5,364	5,830	6,013	5,908	5,856	5,752	5,752	8,962	497
04/28/89	5,778	5,778	5,804	5,908	6,040	6,066	6,093	6,066	6,040	6,040	6,013	6,013	6,013	5,987	5,987	5,961	5,961	5,961	5,961	5,908	5,648	5,674	5,752	5,804	5,927	26
04/29/89	5,830	5,830	5,830	5,830	5,830	5,830	5,830	5,830	5,830	5,856	5,856	5,856	5,856	5,856	5,856	5,856	5,856	6,200	6,500	6,527	6,472	6,418	6,308	6,093	5,993	52
04/30/89	6,013	5,908	5,856	5,830	5,804	5,778	5,778	5,752	5,752	5,752	5,752	5,726	5,726	5,726	5,752	5,752	5,778	5,778	5,778	5,778	5,726	5,621	5,621	5,674	5,767	17
05/01/89	5,440	5,112	5,014	4,940	4,892	4,868	4,819	4,819	4,795	4,771	5,415	6,445	8,886	10,332	9,895	9,631	9,696	9,500	9,402	9,729	9,500	9,862	9,239	9,565	7,357	476
05/02/89	9,829	10,264	10,468	10,468	10,503	10,503	10,503	10,129	9,829	9,829	10,709	11,797	12,888	14,182	15,661	17,399	18,348	19,229	20,518	20,908	21,006	20,810	19,892	19,940	14,400	925
05/03/89	20,035	20,180	20,228	20,324	20,083	19,987	19,987	19,987	19,940	20,035	20,131	20,083	20,131	20,131	20,083	20,083	20,035	20,035	20,035	20,035	20,083	20,035	20,035	20,035	20,073	17
05/04/89	20,083	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	15,174	19,229	19,987	20,180	20,083	20,035	19,987	19,987	19,987	19,987	19,940	19,940	19,987	19,987	19,987	19,785	203
05/05/89	19,940	19,940	19,940	19,940	19,892	19,940	19,940	19,940	19,987	19,987	20,035	20,035	19,987	19,987	20,035	20,131	20,180	20,324	20,324	20,324	20,372	20,372	20,324	19,892	20,074	35
05/06/89	19,701	19,940	20,180	20,276	20,131	20,083	20,035	20,035	20,083	20,035	20,083	20,083	20,035	20,035	20,035	20,035	20,083	20,083	20,083	20,035	20,035	20,035	20,035	20,035	20,051	20
05/07/89	19,987	19,987	19,987	19,987	19,987	20,035	19,987	19,987	19,987	19,987	19,987	19,987	20,035	20,035	20,035	20,035	19,987	20,035	20,035	19,987	20,035	20,035	20,083	20,035	20,011	6
05/08/89	20,035	20,083	20,083	20,083	20,083	20,035	20,083	20,083	20,083	20,083	20,083	20,083	20,035	20,083	20,083	20,035	20,083	20,083	20,083	20,035	20,083	20,083	20,180	20,228	20,083	9
05/09/89	20,131	20,131	20,180	20,131	20,131	20,131	20,228	20,228	20,228	20,180	20,180	20,180	20,228	20,228	20,228	20,180	20,228	20,180	20,180	20,180	20,180	20,180	20,180	20,180	20,184	7
05/10/89	20,228	20,180	20,228	20,180	20,180	20,180	20,180	20,180	20,180	20,180	20,180	20,228	20,228	20,228	20,228	20,180	20,180	20,228	20,180	20,180	20,228	20,228	20,180	20,180	20,198	5
05/11/89	20,228	20,228	20,180	20,228	20,228	20,228	20,180	20,566	19,987	19,654	20,131	20,957	20,615	19,892	19,559	20,035	20,518	22,969	24,434	23,435	22,355	21,650	21,302	20,859	20,851	256
05/12/89	20,615	20,518	20,324	20,180	20,131	20,131	20,035	19,796	19,749	19,987	20,083	20,083	20,083	20,083	20,131	20,083	20,083	20,083	20,083	20,083	20,083	20,131	20,035	20,035	20,110	37
05/13/89	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,035	20,083	20,035	20,035	20,035	19,987	19,987	20,035	20,083	20,131	20,131	20,131	20,131	20,131	20,131	20,131	20,083	20,079	9

05/14/89	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,131	20,083	20,083	20,085	2
05/15/89	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,131	19,987	19,987	19,987	19,987	19,987	19,987	19,940	19,940	19,940	19,940	19,940	19,940	19,940	19,987	19,987	19,940	20,005	13
05/16/89	19,940	19,940	20,035	20,035	20,083	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	19,987	19,987	19,987	19,987	20,035	20,035	19,987	20,019	7
05/17/89	19,987	20,035	19,987	19,987	19,940	19,892	19,844	19,892	19,940	19,940	19,940	19,940	19,940	19,987	20,035	19,987	20,035	19,987	19,987	19,987	19,987	20,035	19,987	19,987	19,969	10
05/18/89	19,987	19,987	19,987	19,940	19,940	19,940	19,940	19,940	19,940	19,987	19,987	19,940	19,940	19,987	19,987	19,987	20,035	20,035	20,035	19,987	20,035	20,083	20,035	20,035	19,987	9
05/19/89	20,035	20,035	20,083	20,083	20,083	20,083	20,083	20,083	20,083	20,131	20,035	19,987	19,987	19,987	19,987	19,987	19,987	19,987	19,987	19,987	19,940	19,987	19,987	19,987	20,025	10
05/20/89	19,940	19,940	19,987	19,940	19,940	19,940	19,940	19,940	19,987	19,987	19,987	19,987	19,987	19,987	19,940	19,940	19,940	19,987	19,940	19,940	19,940	19,940	19,940	19,940	19,956	5
05/21/89	19,940	19,940	19,892	19,940	19,940	19,987	19,987	19,987	20,035	20,083	20,035	20,035	19,987	19,987	19,940	19,940	19,940	19,892	19,892	19,892	19,940	19,987	19,987	19,987	19,966	10
05/22/89	19,940	19,987	19,987	19,987	19,987	19,940	19,940	19,987	19,987	20,035	20,035	20,035	19,987	19,987	19,987	19,987	19,987	19,987	20,035	20,035	20,035	20,083	20,083	20,083	20,005	9
05/23/89	20,035	20,083	20,083	20,083	20,131	20,131	20,131	20,131	20,131	20,131	20,131	20,180	20,131	20,131	20,131	20,131	20,180	20,180	20,131	20,083	20,083	20,083	20,131	20,131	20,121	7
05/24/89	20,083	20,131	20,083	20,083	20,035	20,035	19,987	20,035	20,035	20,035	20,035	20,035	20,035	20,083	20,083	20,131	20,131	20,131	20,035	20,035	20,083	20,131	20,083	20,131	20,071	9
05/25/89	20,180	20,180	20,131	20,131	20,180	20,180	20,180	20,228	20,228	20,228	20,180	20,131	20,083	20,228	20,276	20,228	20,228	20,228	20,228	20,228	20,180	20,180	20,228	20,180	20,194	9
05/26/89	20,180	20,131	20,131	20,083	20,035	19,987	19,987	20,035	20,131	20,083	20,083	20,035	20,035	20,035	20,035	20,083	20,083	20,083	20,035	20,035	20,035	20,035	20,083	20,083	20,065	10
05/27/89	20,035	20,083	20,083	20,083	20,083	20,083	20,083	20,035	20,035	20,035	20,035	19,987	19,987	19,987	19,987	19,940	19,940	19,940	19,940	20,276	20,421	20,372	19,987	19,892	20,055	27
05/28/89	19,892	19,844	19,892	19,940	19,940	19,940	19,987	19,987	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,083	20,083	20,083	20,005	13
05/29/89	20,131	20,131	20,131	20,180	20,180	20,180	20,180	20,180	20,228	20,228	20,180	20,180	20,131	20,131	20,131	20,131	20,131	20,131	20,131	20,131	20,131	20,180	19,796	17,712	20,041	103
05/30/89	15,950	14,535	13,300	11,690	10,814	10,503	9,795	9,402	9,207	9,142	9,014	8,950	8,886	8,728	8,665	8,697	8,697	8,634	8,603	8,603	8,634	8,665	8,509	8,447	9,836	417
05/31/89	8,509	8,540	8,540	8,540	8,540	8,540	8,509	8,540	8,540	8,540	8,540	8,572	8,603	8,634	8,603	8,540	8,509	8,509	8,509	8,509	8,478	8,540	8,540	8,540	8,540	7
06/01/89	8,540	8,540	8,540	8,509	8,478	8,478	8,509	8,509	8,509	8,509	8,509	8,509	8,478	8,478	8,478	8,478	10,468	14,654	15,620	15,908	16,157	16,240	16,240	16,282	10,734	695
06/02/89	16,240	16,282	16,240	16,240	16,240	16,240	16,240	16,199	16,157	16,199	16,199	16,199	16,199	16,240	16,240	16,282	16,282	16,282	16,282	16,240	16,324	16,324	16,324	16,324	16,251	9
06/03/89	15,174	13,795	12,703	10,779	9,533	9,598	9,631	9,696	9,729	9,729	9,664	9,631	9,631	9,631	8,886	7,515	6,093	4,916	4,629	4,465	4,350	4,305	4,305	4,260	8,444	645
06/04/89	4,215	4,170	4,170	4,170	4,170	4,170	4,148	4,148	4,148	4,125	4,125	4,125	4,103	4,103	4,103	4,103	4,103	4,192	4,148	4,170	4,170	4,148	4,148	4,148	4,147	6
06/05/89	4,192	4,192	4,170	4,170	4,148	4,148	4,148	4,148	4,125	3,994	3,972	4,059	4,148	4,081	3,950	3,907	3,885	3,885	3,994	4,037	4,037	4,037	4,037	4,037	4,063	20
06/06/89	4,037	4,037	4,015	4,015	4,015	3,994	3,994	3,994	3,994	3,994	3,994	3,994	3,994	3,972	3,972	3,972	3,972	3,972	4,037	4,015	4,015	4,015	4,015	4,015	4,002	4
06/07/89	3,994	3,994	3,972	3,972	3,972	3,972	3,972	3,972	3,972	3,950	3,972	3,950	4,059	4,059	4,037	4,965	6,858	8,293	10,028	10,163	9,631	9,369	9,304	9,271	5,737	514
06/08/89	9,271	9,239	9,336	9,369	9,369	9,402	9,467	9,598	9,631	9,565	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,565	9,565	9,565	9,565	9,493	21
06/09/89	9,565	9,565	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,533	9,500	9,500	9,500	9,500	9,533	9,533	9,533	9,565	9,531	4
06/10/89	9,533	9,533	9,500	9,500	9,500	9,500	9,467	9,467	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,467	9,467	9,500	9,500	9,500	9,500	9,497	3
06/11/89	9,467	9,467	9,500	9,533	9,500	9,500	9,500	9,500	9,500	9,533	9,565	9,533	9,533	9,500	9,467	9,467	9,467	9,467	9,467	9,467	9,467	9,500	9,500	9,500	9,496	6
06/12/89	9,500	9,500	9,500	9,467	9,467	9,467	9,434	9,434	9,533	9,631	9,631	9,598	9,598	9,598	9,598	9,565	10,468	11,797	13,604	14,853	15,214	15,013	14,933	14,973	10,974	470
06/13/89	14,973	15,013	15,013	14,973	14,973	14,933	15,133	15,417	15,498	15,498	15,376	15,376	15,254	12,814	14,733	14,973	14,893	14,933	14,933	14,893	14,933	14,893	14,893	14,893	14,967	104
06/14/89	14,853	14,853	14,853	14,853	14,813	14,813	14,813	14,853	14,893	14,893	14,893	14,853	14,853	14,853	14,853	14,813	14,813	14,853	14,813	14,813	14,853	14,853	14,853	14,813	14,845	5
06/15/89	14,773	14,773	14,813	14,813	14,773	14,813	14,813	14,813	14,853	14,813	14,813	14,813	14,813	14,813	14,813	14,813	14,893	14,893	14,893	14,893	14,893	14,893	14,973	14,733	14,833	11
06/16/89	14,773	14,813	14,813	14,853	14,813	14,813	14,893	14,933	14,973	14,973	14,973	14,973	15,013	14,973	14,973	14,973	14,973	15,053	15,053	15,013	15,013	15,053	15,053	15,013	14,948	18
06/17/89	14,973	14,973	15,013	15,013	14,973	14,973	14,933	14,973	15,013	15,053	15,013	15,013	15,013	15,013	15,013	15,093	15,093	15,093	15,093	15,093	15,053	15,053	15,093	15,093	15,030	10
06/18/89	15,093	15,053	15,013	14,973	14,973	14,973	14,893	14,933	14,933	14,893	14,893	14,893	14,853	14,853	14,853	15,053	15,093	15,053	15,053	15,053	15,053	15,053	15,093	15,093	14,986	18
06/19/89	15,093	14,973	14,933	15,053	15,093	14,973	14,933	14,933	14,933	14,933	14,933	14,893	14,893	14,853	14,893	14,933	14,973	14,973	14,973	14,973	14,973	14,973	14,973	15,013	14,961	12
06/20/89	15,013	15,254	15,335	15,376	15,457	15,498	15,539	15,376	15,702	15,867	18,029	18,670	18,809	18,995	19,182	16,957	9,598	24,915	25,837	20,957	19,796	19,654	19,796	19,844	17,727	699
06/21/89	19,844	19,796	19,749	19,749	19,749	19,701	19,654	19,654	19,654	19,701	19,701	19,464	18,029	17,712	17,622	17,533	17,443	17,221	17,265	17,221	17,088	17,044	17,044	17,000	18,527	249
06/22/89	16,957	16,915	16,915	16,872	16,915	16,872	16,872	16,872	16,787	16,450	16,366	16,366	16,366	16,366	16,366	16,366	16,366	16,408	16,366	16,408	16,408	16,408	16,408	16,408	16,575	51
06/23/89	16,366	16,366	16,366	16,366	16,324	16,324	16,282	16,324	16,324	16,324	16,324	16,324	16,324	16,366	16,366	16,366	16,366	16,366	16,366	16,366	16,366	16,366	16,366	16,366	16,349	5
06/24/89	7,632	4,260	3,141	2,727	2,620	2,567	2,498	2,413	2,396	2,363	2,413	2,346	2,313	2,297	2,313	2,280	2,330	2,363	2,379	2,396	2,430	2,413	2,413	2,396	2,737	229
06/25/89	2,379	2,363	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,363	2,363	2,330	2,330	2,346	2,346	2,346	2,346	2,368	4
06/26/89	2,346	2,346	2,346	2,346	2,346	2,330	2,346	2,330	2,346	2,930	13,376	15,908	16,366	16,450	16,408	16,366	16,408	16,199	15,785	15,295	15,133	15,093	15,093	15,093	10,124	1,368
06/27/89	15,093	15,093	15,093	15,053	15,053	15,053	15,093	15,053	15,013	15,013	15,013	15,013	15,013	15,013	15,013	15,013	15,013	14,973	14,973	14,973	14,973	14,973	14,933	14,933	15,018	10
06/28/89	14,933	14,933	14,893	14,893	14,893	14,853	14,853	14,893	14,973	15,013	15,093	15,093	15,093	15,013	14,973	15,013	15,013	15,013	15,013	15,013	15,013	15,053	15,053	15,053	14,985	15
06/29/89	15,053	15,053	15,093	15,093	15,093	15,053	15,053	15,053	15,053	15,053	15,013	15,013	15,013	15,013	15,053	15,053	15,093	15,093	15,133	15,133	15,133	15,133	15,133	15,133	15,075	9
06/30/89	15,133	15,133	15,133	15,093	15,093	15,053	15,214	15,013	15,013	15,013	15,053	15,013	15,053	15,053	15,053	15,093	15,093	15,093	15,093	15,093	15,133	15,174	15,174	15,214	15,095	12

APPENDIX 2.

John H. Kerr Reservoir Inflow Computations, January-June, 1989.

RESERVOIR INFLOW COMPUTATIONS (1)
ROANOKE RIVER BASIN, VA.-N.C.

JOHN H. KERR RESERVOIR JANUARY 1989

DATE	(2) HOUR	ELEVATION, FT, MSL RULE CURVE	RESERVOIR LEVEL	TOTAL CONTENTS AF	CHANGE IN CONTENTS ACRE-FEET	DAY-SEC-FEET STORED	DRAWDOWN	FLOW, CFS (3) OUTFLOW	INFLOW
		295.50	295.46	1276140.					
1		295.50	295.68	1285820.	9680.	4880.		148.	5028
2		295.50	295.85	1293300.	7480.	3771.		750.	4521
3		295.50	296.10	1304420.	11120.	5606.		2639.	8245
4		295.50	296.03	1301256.	-3164.		-1595.	2657.	1062
5		295.50	296.05	1302160.	904.	456.		2811.	3267
6		295.50	296.20	1308940.	6780.	3418.		905.	4323
7		295.50	296.14	1306228.	-2712.		-1367.	4240.	2873
8		295.50	296.33	1314816.	8588.	4330.		136.	4466
9		295.50	296.25	1311200.	-3616.		-1823.	5709.	3886
10		295.50	296.20	1308940.	-2260.		-1139.	4478.	3339
11		295.50	296.35	1315720.	6780.	3418.		473.	3891
12		295.50	296.56	1325212.	9492.	4786.		145.	4931
13		295.50	296.33	1314816.	-10396.		-5241.	10156.	4915
14		295.50	296.37	1316624.	1808.	912.		4758.	5670
15		295.50	296.60	1327020.	10396.	5241.		150.	5391
16		295.50	296.48	1321596.	-5424.		-2735.	7264.	4529
17		295.50	296.50	1322500.	904.	456.		4380.	4836
18		295.50	296.38	1317076.	-5424.		-2735.	6855.	4120
19		295.50	296.35	1315720.	-1356.		-684.	5928.	5244
20		295.50	296.43	1319336.	3616.	1823.		1051.	2874
21		295.50	296.57	1325664.	6328.	3190.		159.	3349
22		295.50	296.72	1332444.	6780.	3418.		161.	3579
23		295.50	296.65	1329280.	-3164.		-1595.	4881.	3286
24		295.50	296.51	1322952.	-6328.		-3190.	5437.	2247
25		295.50	296.46	1320692.	-2260.		-1139.	4968.	3829
26		295.50	296.32	1314364.	-6328.		-3190.	5902.	2712
27		295.50	296.33	1314816.	452.	228.		3352.	3580
28		295.50	296.46	1320692.	5876.	2963.		142.	3105
29		295.50	296.58	1326116.	5424.	2735.		138.	2873
30		295.50	296.55	1324760.	-1356.		-684.	3834.	3150
31		295.50	296.06	1302612.	-22148.		-11166.	12375.	1209
TOTAL FOR MONTH.................					26472.	51631.	-36283.	106982.	120330.
NET CHANGE IN DAY-SECOND-FEET..					13346.	13348.			13348.
AVERAGE FLOW IN C.F.S..........						431.		3451.	3882.

CHANGE IN CONTENTS FOR MO.(4).. 26472.

(1) COMPUTATIONS BASED ON THE OCTOBER 1980 CAPACITY TABLE.

(2) BY 24-HOUR CLOCK, TIME IS 2400(MIDN.) OF DAY INDICATED UNLESS OTHERWISE NOTED. AVERAGE FLOW OR CHANGE IN RESERVOIR CONTENTS ARE FOR PERIOD ENDING AT TIME INDICATED.

(3) BASED ON PROJECT RECORDS. DOES NOT INCLUDE EVAPORATION LOSSES.

(4) BASED ON TOTAL CONTENTS AT BEGINNING AND END OF MONTH.

RESERVOIR INFLOW COMPUTATIONS (1)
ROANOKE RIVER BASIN, VA.-N.C.

JOHN H. KERR RESERVOIR FEBRUARY 1989

DATE	(2) HOUR	ELEVATION, FT, MSL RULE CURVE	RESERVOIR LEVEL	TOTAL CONTENTS AF	CHANGE IN CONTENTS ACRE - FEET	DAY-SEC-FEET STORED	DRAWDOWN	FLOW, CFS (3) OUTFLOW	INFLOW
		295.50	296.06	1302612.					
1		295.50	296.09	1303968.	1356.	684.		2062.	2746
2		295.50	296.17	1307584.	3616.	1823.		1668.	3491
3		295.50	296.13	1305776.	-1808.		-912.	3043.	2131
4		295.50	296.13	1305776.	0.	0.		3190.	3190
5		295.50	296.29	1313008.	7232.	3646.		1550.	5196
6		295.50	296.31	1313912.	904.	456.		2803.	3259
7		295.50	296.52	1323404.	9492.	4786.		164.	4950
8		295.50	296.52	1323404.	0.	0.		4999.	4999
9		295.50	296.16	1307132.	-16272.		-8204.	11930.	3726
10		295.50	296.05	1302160.	-4972.		-2507.	5232.	2725
11		295.50	296.20	1308940.	6780.	3418.		533.	3951
12		295.50	296.32	1314364.	5424.	2735.		196.	2931
13		295.50	296.47	1321144.	6780.	3418.		202.	3620
14		295.50	296.61	1327472.	6328.	3190.		185.	3375
15		295.50	296.73	1332896.	5424.	2735.		163.	2898
16		295.50	296.70	1331540.	-1356.		-684.	4089.	3405
17		295.50	296.05	1302160.	-29380.		-14813.	17860.	3047
18		295.50	296.18	1308036.	5876.	2963.		3341.	6304
19		295.50	296.39	1317528.	9492.	4786.		205.	4991
20		295.50	296.37	1316624.	-904.		-456.	4682.	4226
21		295.50	297.57	1371662.	55038.	27749.		193.	27942
22		295.50	298.82	1430896.	59234.	29864.		5454.	35318
23		295.50	299.36	1457176.	26280.	13250.		16876.	30126
24		295.50	299.90	1483690.	26514.	13368.		12907.	26275
25		295.50	300.45	1511325.	27635.	13933.		868.	14801
26		295.50	300.91	1534555.	23230.	11712.		195.	11907
27		295.50	301.07	1542712.	8157.	4113.		8133.	12246
28		295.50	301.50	1564900.	22188.	11187.		14176.	25363

TOTAL FOR MONTH.................	262288.	159816.	-27576.	126899.	259139.
NET CHANGE IN DAY-SECOND-FEET..	132238.	132240.			132240.
AVERAGE FLOW IN C.F.S..........		4723.		4532.	9255.

CHANGE IN CONTENTS FOR MO.(4).. 262288.

(1) COMPUTATIONS BASED ON THE OCTOBER 1980 CAPACITY TABLE.

(2) BY 24-HOUR CLOCK, TIME IS 2400(MIDN.) OF DAY INDICATED UNLESS OTHERWISE NOTED. AVERAGE FLOW OR CHANGE IN RESERVOIR CONTENTS ARE FOR PERIOD ENDING AT TIME INDICATED.

(3) BASED ON PROJECT RECORDS. DOES NOT INCLUDE EVAPORATION LOSSES.

(4) BASED ON TOTAL CONTENTS AT BEGINNING AND END OF MONTH.

RESERVOIR INFLOW COMPUTATIONS (1)

ROANOKE RIVER BASIN, VA.-N.C.

JOHN H. KERR RESERVOIR — MARCH 1989

DATE	(2) HOUR	ELEVATION, FT, MSL: RULE CURVE	ELEVATION, FT, MSL: RESERVOIR LEVEL	TOTAL CONTENTS AF	CHANGE IN CONTENTS: ACRE - FEET	CHANGE IN CONTENTS: DAY-SEC-FEET STORED	CHANGE IN CONTENTS: DAY-SEC-FEET DRAWDOWN	FLOW, CFS: (3) OUTFLOW	FLOW, CFS: INFLOW
		295.50	301.50	1564900.					
1		295.68	301.53	1566448.	1548.	780.		19514.	20294
2		295.86	301.57	1568512.	2064.	1041.		19859.	20900
3		296.04	301.50	1564900.	-3612.		-1821.	16051.	14230
4		296.22	301.46	1562836.	-2064.		-1041.	12292.	11251
5		296.40	301.87	1583992.	21156.	10666.		157.	10823
6		296.58	301.88	1584508.	516.	260.		17731.	17991
7		296.76	301.88	1584508.	0.	0.		24717.	24717
8		296.94	302.33	1608124.	23616.	11906.		22284.	34190
9		297.12	302.51	1617628.	9504.	4792.		14180.	18972
10		297.30	302.53	1618684.	1056.	532.		10210.	10742
11		297.48	302.24	1603372.	-15312.		-7720.	15874.	8154
12		297.66	302.55	1619740.	16368.	8252.		150.	8402
13		297.84	302.18	1600204.	-19536.		-9849.	17547.	7698
14		298.02	301.82	1581412.	-18792.		-9474.	17185.	7711
15		298.20	301.88	1584508.	3096.	1561.		10460.	12021
16		298.37	301.76	1578316.	-6192.		-3122.	14524.	11402
17		298.55	301.61	1570576.	-7740.		-3902.	12017.	8115
18		298.72	301.47	1563352.	-7224.		-3642.	12282.	8640
19		298.90	301.58	1569028.	5676.	2862.		5634.	8496
20		299.07	301.36	1557676.	-11352.		-5723.	10958.	5235
21		299.25	301.18	1548388.	-9288.		-4683.	12893.	8210
22		299.42	300.92	1535060.	-13328.		-6720.	14835.	8115
23		299.60	300.67	1522435.	-12625.		-6365.	19167.	12802
24		299.77	301.59	1569544.	47109.	23751.		12955.	36706
25		299.95	302.33	1608124.	38580.	19451.		18924.	38375
26		300.12	302.99	1642972.	34848.	17569.		16625.	34194
27		300.30	302.81	1633468.	-9504.		-4792.	22404.	17612
28		300.47	302.40	1611820.	-21648.		-10914.	22612.	11698
29		300.65	302.06	1593868.	-17952.		-9051.	16170.	7119
30		300.62	302.12	1597036.	3168.	1597.		10676.	12273
31		301.00	301.95	1586120.	-8916.		-4495.	13903.	9408

	ACRE - FEET	STORED	DRAWDOWN	OUTFLOW	INFLOW
TOTAL FOR MONTH..................	23220.	105020.	-93314.	454790.	466496.
NET CHANGE IN DAY-SECOND-FEET..	11707.	11706.			11706.
AVERAGE FLOW IN C.F.S..........		378.		14671.	15048.

CHANGE IN CONTENTS FOR MO. (4).. 23220.

(1) COMPUTATIONS BASED ON THE OCTOBER 1980 CAPACITY TABLE.

(2) BY 24-HOUR CLOCK, TIME IS 2400(MIDN.) OF DAY INDICATED UNLESS OTHERWISE NOTED. AVERAGE FLOW OR CHANGE IN RESERVOIR CONTENTS ARE FOR PERIOD ENDING AT TIME INDICATED.

(3) BASED ON PROJECT RECORDS. DOES NOT INCLUDE EVAPORATION LOSSES.

(4) BASED ON TOTAL CONTENTS AT BEGINNING AND END OF MONTH.

RESERVOIR INFLOW COMPUTATIONS (1)
ROANOKE RIVER BASIN, VA.-N.C.
JOHN H. KERR RESERVOIR APRIL 1989

DATE	(2) HOUR	ELEVATION, FT, MSL RULE CURVE	RESERVOIR LEVEL	TOTAL CONTENTS AF	CHANGE IN CONTENTS ACRE - FEET	DAY-SEC-FEET STORED	DRAWDOWN	FLOW, CFS (3) OUTFLOW	INFLOW
		301.00	301.95	1588120.					
1		301.07	302.24	1603372.	15252.	7690.		102.	7792
2		301.13	302.42	1612876.	9504.	5000. (5)		1881.	6881
3		301.20	302.45	1614460.	1584.	799.		5431.	6230
4		301.27	302.46	1614988.	528.	266.		7437.	7703
5		301.33	302.50	1617100.	2112.	1065.		5960.	7025
6		301.40	302.50	1617100.	0.	0.		11759.	11759
7		301.47	302.81	1633468.	16368.	8252.		11335.	19587
8		301.53	303.48	1669372.	35904.	18102.		4526.	22628
9		301.60	303.98	1696322.	26950.	13587.		5566.	19153
10		301.67	304.07	1701250.	4928.	2485.		13263.	15748
11		301.73	303.88	1690932.	-10318.		-5202.	17260.	12058
12		301.80	303.54	1672606.	-18326.		-9239.	17055.	7816
13		301.87	303.03	1645117.	-27489.		-13859.	20392.	6533
14		301.93	302.06	1593868.	-51249.		-25838.	31039.	5201
15		302.00	302.24	1603372.	9504.	4792.		5508.	10300
16		302.00	302.28	1605484.	2112.	1065.		8034.	9099
17		302.00	302.38	1610764.	5280.	2662.		5506.	8168
18		302.00	302.49	1616572.	5808.	2928.		3774.	6702
19		302.00	302.40	1611820.	-4752.		-2396.	8649.	6253
20		302.00	302.24	1603372.	-8448.		-4259.	10356.	6097
21		302.00	301.73	1576768.	-26604.		-13413.	16858.	3445
22		302.00	301.70	1575220.	-1548.		-780.	5781.	5001
23		302.00	301.88	1584508.	9288.	4683.		86.	4769
24		302.00	301.48	1563868.	-20640.		-10406.	15255.	4849
25		302.00	301.36	1557676.	-6192.		-3122.	10048.	6926
26		302.00	301.60	1570060.	12384.	6244.		8194.	14438
27		302.00	301.92	1586572.	16512.	8325.		6314.	14639
28		302.00	302.42	1612876.	26304.	13262.		81.	13343
29		302.00	302.87	1636636.	23760.	11979.		82.	12061
30		302.00	303.35	1662365.	25729.	12972.		81.	13053
TOTAL FOR MONTH..................					74245.	126158.	-88514.	257613.	295257.
NET CHANGE IN DAY-SECOND-FEET..					37644.	37644.			37644.
AVERAGE FLOW IN C.F.S...........						1255.		8587.	9842.

CHANGE IN CONTENTS FOR MO. (4).. 74245.

(1) COMPUTATIONS BASED ON THE OCTOBER 1980 CAPACITY TABLE.

(2) BY 24-HOUR CLOCK, TIME IS 2400(MIDN.) OF DAY INDICATED UNLESS OTHERWISE NOTED. AVERAGE FLOW OR CHANGE IN RESERVOIR CONTENTS ARE FOR PERIOD ENDING AT TIME INDICATED.

(3) BASED ON PROJECT RECORDS. DOES NOT INCLUDE EVAPORATION LOSSES.

(4) BASED ON TOTAL CONTENTS AT BEGINNING AND END OF MONTH.

(5) ADJUSTED FOR 23-HOUR DAY (CONVERTING FROM EST TO EDT).

RESERVOIR INFLOW COMPUTATIONS (1)
ROANOKE RIVER BASIN, VA.-N.C.

JOHN H. KERR RESERVOIR — MAY 1989

DATE	(2) HOUR	ELEVATION, FT, MSL RULE CURVE	ELEVATION, FT, MSL RESERVOIR LEVEL	TOTAL CONTENTS AF	CHANGE IN CONTENTS ACRE - FEET	CHANGE IN CONTENTS DAY-SEC-FEET STORED	CHANGE IN CONTENTS DAY-SEC-FEET DRAWDOWN	FLOW, CFS (3) OUTFLOW	FLOW, CFS INFLOW
		302.00	303.35	1662365.					
1		302.00	303.38	1663982.	1617.	815.		9429.	10244
2		302.00	304.53	1726550.	62568.	31545.		14198.	45743
3		302.00	305.58	1784996.	58446.	29467.		20139.	49606
4		302.00	306.35	1828655.	43659.	22012.		15584.	37596
5		302.00	306.48	1836104.	7449.	3756.		19877.	23633
6		302.00	307.23	1879355.	43251.	21806.		14634.	36440
7		302.00	308.30	1942280.	62925.	31725.		15896.	47621
8		302.00	309.42	2009494.	67214.	33887.		19502.	53389
9		302.00	309.82	2033774.	24280.	12241.		20473.	32714
10		302.00	309.89	2038023.	4249.	2142.		23452.	25594
11		302.00	309.90	2038630.	607.	306.		20087.	20393
12		302.00	309.66	2024062.	-14568.		-7345.	19326.	11981
13		302.00	309.38	2007066.	-16996.		-8569.	18970.	10401
14		302.00	309.08	1988856.	-18210.		-9181.	16893.	7712
15		302.00	308.56	1958968.	-29888.		-15069.	22936.	7867
16		302.00	308.31	1942876.	-16092.		-8113.	19093.	10980
17		302.00	308.13	1932148.	-10728.		-5409.	14680.	9271
18		302.00	307.62	1902170.	-29978.		-15114.	22815.	7701
19		302.00	307.25	1880525.	-21645.		-10913.	15628.	4715
20		302.00	306.80	1854440.	-26085.		-13151.	19117.	5966
21		302.00	306.33	1827509.	-26931.		-13578.	18132.	4554
22		302.00	305.76	1795112.	-32397.		-16334.	20117.	3783
23		302.00	304.91	1747450.	-47662.		-24030.	28581.	4551
24		302.00	304.63	1732050.	-15400.		-7764.	15494.	7730
25		302.00	304.12	1704000.	-28050.		-14142.	20152.	6010
26		302.00	303.57	1674223.	-29777.		-15013.	18464.	3451
27		302.00	303.12	1649968.	-24255.		-12229.	15900.	3671
28		302.00	302.44	1613932.	-36036.		-18168.	20668.	2500
29		302.00	301.78	1579348.	-34584.		-17436.	20414.	2978
30		302.00	301.41	1560256.	-19092.		-9626.	12615.	2989
31		302.00	300.91	1534555.	-25701.		-12958.	15556.	2598
TOTAL FOR MONTH................					-127810.	189702.	-254142.	568822.	504382.
NET CHANGE IN DAY-SECOND-FEET..					-64438.		-64440.	64440.	
AVERAGE FLOW IN C.F.S..........							-2079.	18349.	16270.

CHANGE IN CONTENTS FOR MO.(4)..-127810.

(1) COMPUTATIONS BASED ON THE OCTOBER 1980 CAPACITY TABLE.

(2) BY 24-HOUR CLOCK, TIME IS 2400(MIDN.) OF DAY INDICATED UNLESS OTHERWISE NOTED. AVERAGE FLOW OR CHANGE IN RESERVOIR CONTENTS ARE FOR PERIOD ENDING AT TIME INDICATED.

(3) BASED ON PROJECT RECORDS. DOES NOT INCLUDE EVAPORATION LOSSES.

(4) BASED ON TOTAL CONTENTS AT BEGINNING AND END OF MONTH.

RESERVOIR INFLOW COMPUTATIONS (1)
ROANOKE RIVER BASIN, VA.-N.C.

JOHN H. KERR RESERVOIR JUNE 1989

DATE	(2) HOUR	ELEVATION, FT, MSL RULE CURVE	ELEVATION, FT, MSL RESERVOIR LEVEL	TOTAL CONTENTS AF	CHANGE IN CONTENTS ACRE-FEET	CHANGE IN CONTENTS DAY-SEC-FEET STORED	CHANGE IN CONTENTS DAY-SEC-FEET DRAWDOWN	FLOW, CFS (3) OUTFLOW	FLOW, CFS INFLOW
		302.00	300.91	1534555.					
1		301.83	300.49	1513345.	-21210.		-10693.	13733.	3040
2		301.67	300.18	1497690.	-15655.		-7893.	10527.	2634
3		301.50	300.02	1489610.	-8080.		-4074.	6403.	2329
4		301.33	300.22	1499710.	10100.	5092.		79.	5171
5		301.17	300.40	1508800.	9090.	4583.		4937.	9520
6		301.00	300.94	1536070.	27270.	13749.		128.	13877
7		300.83	301.19	1548904.	12834.	6470.		2974.	9444
8		300.67	301.64	1572124.	23220.	11707.		8969.	20676
9		300.50	302.50	1617100.	44976.	22675.		5800.	28475
10		300.33	303.30	1659670.	42570.	21462.		8716.	30178
11		300.17	303.97	1695783.	36113.	18207.		5070.	23277
12		300.00	303.90	1692010.	-3773.		-1902.	11864.	9962
13		299.83	303.71	1681769.	-10241.		-5163.	16405.	11242
14		299.67	303.74	1683386.	1617.	815.		13230.	14045
15		299.50	303.74	1683386.	0.	0.		14173.	14173
16		299.50	303.85	1689315.	5929.	2989.		15030.	18019
17		299.50	304.21	1708950.	19635.	9899.		12443.	22342
18		299.50	304.55	1727650.	18700.	9428.		9228.	18656
19		299.50	304.30	1713900.	-13750.		-6932.	15230.	8298
20		299.50	303.86	1689854.	-24046.		-12123.	19685.	7562
21		299.50	303.63	1677457.	-12397.		-6250.	15946.	9696
22		299.50	303.28	1658592.	-18865.		-9511.	19818.	10307
23		299.50	303.10	1648890.	-9702.		-4891.	15529.	10638
24		299.50	303.48	1669372.	20482.	10326.		202.	10528
25		299.50	303.87	1690393.	21021.	10598.		81.	10679
26		299.50	303.66	1679074.	-11319.		-5707.	13990.	8283
27		299.50	303.20	1654280.	-24794.		-12500.	16084.	3584
28		299.50	302.98	1642444.	-11836.		-5967.	9697.	3730
29		299.50	302.71	1628188.	-14256.		-7187.	11759.	4572
30		299.50	302.34	1608652.	-19536.		-9849.	12934.	3085
TOTAL FOR MONTH..................					74097.	148000.	-110642.	310664.	348022.
NET CHANGE IN DAY-SECOND-FEET..					37357.	37358.			37358.
AVERAGE FLOW IN C.F.S..........						1245.		10355.	11601.

CHANGE IN CONTENTS FOR MO. (4).. 74097.

(1) COMPUTATIONS BASED ON THE OCTOBER 1980 CAPACITY TABLE.

(2) BY 24-HOUR CLOCK, TIME IS 2400(MIDN.) OF DAY INDICATED UNLESS OTHERWISE NOTED. AVERAGE FLOW OR CHANGE IN RESERVOIR CONTENTS ARE FOR PERIOD ENDING AT TIME INDICATED.

(3) BASED ON PROJECT RECORDS. DOES NOT INCLUDE EVAPORATION LOSSES.

(4) BASED ON TOTAL CONTENTS AT BEGINNING AND END OF MONTH.

APPENDIX 3.

Water Use by Existing and Proposed Electrical Generation Facilities in the Virginia Roanoke Basin.

Source: Virginia State Water Control Board. 1988. Roanoke Basin Water Supply Plan. Planning Bulletin 339. Richmond, VA.

TABLE I-1
POWER PLANTS OF THE ROANOKE RIVER BASIN IN VIRGINIA

Plant Name	Location	Owner	Installed Capacity (kw)	Type	Notes
Smith Mountain	Roanoke River Pittsylvania & Bedford Counties	APCO	547,594	Pumped Storage	
Leesville	Roanoke River Campbell County	APCO	40,000	Hydro	650 cfs MIF (average weekly)
John H. Kerr (Buggs Island)	Roanoke River Mecklenburg Co.	Corps of Engineers	206,000	Hydro	
Philpott	Smith River Henry County	Corps of Engineers	14,000	Hydro	
Schoolfield	Dan River Danville	Dan River Mills, Inc.	3,500	Hydro	
Martinsville	Smith River Martinsville	City of Martinsville	1,300	Hydro	
Pinnacles	Dan River Patrick County	City of Danville	10,125	Hydro	Up for relicensing
Niagara	Roanoke River	APCO	2,400	Hydro	Up for relicensing
		TOTAL	824,919		
Schoolfield	Danville	Dan River Mills, Inc.	9,600	Steam Electric	
Altavista	Roanoke River	Lane Company	2,700	Steam Electric	
		TOTAL	12,300		
North Carolina (Halifax and Northampton Counties)					
Gaston	Roanoke River	VA Power	225,000 KW	Hydro	
Roanoke Rapids	Roanoke River	North Carolina Power	100,000 KW	Hydro	

CONSUMPTIVE WATER DEMAND (MGD)

IN

ROANOKE RIVER BASIN, VIRGINIA

from ROANOKE BASIN WATER SUPPLY PLAN

Sub-Basin	1980 Annual Average	1980 Peak Month	2030 Annual Average	2030 Peak Month
Upper Roanoke	10.72	12.86	17.50	21.00
Smith-Dan	14.85	17.82	19.18	23.01
Lower Roanoke	5.33	6.40	9.10	10.92
Basin Total	30.90	37.08	45.78	54.94

Source: Virginia State Water Control Board. 1988. Roanoke Basin Water Supply Plan. Planning Bulletin 339. Richmond, VA.

PROPOSED CO-GENERATION AND POWER

PLANTS ON THE ROANOKE RIVER

AS OF 2/90

1. Ultrasystems Development Corporation
(Hadson Power Systems, Irvine, CA and Westmoreland Energy, Charlottesville, VA)

Location - Altavista, VA
Plant - Coal-Fired/Steam, 76 MW
Users - Lane Furniture and VA Power
Withdrawal - 1.4 MGD
Permits - Has VA SWCB permit
MIF - 48% MAF - Feb. 1 - June 6
30% MAF - June 7 - Jan. 30

2. Multitrade Group

Location - Altavista, VA
Plant - Wood/Coal, 76 MW
Users - Lane Furniture and VA Power
Withdrawal - 1.6 MGD
Permits - Has VA SWCB permit
MIF - 48% MAF - Feb. 1 - June 6
30% MAF - June 7 - Jan. 30

3. Commonwealth Co-Generation
(Duke Energy and Transco Energy Ventures)

Location - Hurt, VA
Plant - Coal/Steam, 124 MW
Users - Burlington Industries and VA Power
Withdrawal - 2.9 MGD
Permits - None yet

4. Mecklenburg Cogeneration Limited Partnership
(Duke Energy and Transco Energy Ventures)

Location - Clarkesville, VA
Plant - Coal/Steam, 120 MW
Users - Burlington Industries and VA Power
Withdrawal - 2.9 MGD 3 MGD return 0.4 MGD
Permits - None yet
Corps - to require use permit
VaSWCB - on hold until Corps NEPA review complete

5. Old Dominion Electric Cooperative and Virginia Power

   Location - Clover, VA
   Plant - Coal Fired Power Plant, 800 MW
   Withdrawal - 11.5 MGD
   Permits - has VA SWCB permit
   MIF - 44% MAF - Mar. 1 - June 6
   30% MAF - June 7 - Feb. 28

   mean annual flow

6. Virginia Power

   Location - either: 1) Kerr Reservoir, Mecklenburg County, VA
   2) Roanoke Rapids Reservoir, Greensville County, VA
   Plant - Coal Fired Power Plant, 2400 MW
   Withdrawal - 39 MGD
   Permits - No permits yet
   Corps to require EIS

7. MC Squared and First Virginia Corp. ← Max Grimes contact

   Location - Dan River near Staunton River State Park, VA
   Plant - Coal Fired Power Plant, 400-800 MW
   Withdrawal - ~~Unknown~~ 15 MGD
   Permits - No permits yet, only option to buy

8. Westmoreland Energy Co.

   Location - Dan River near Riverdale, Halifax County, VA
   Plant - Coal Fired Power Plant, 100-150 MW
   Withdrawal - Unknown
   Permits - No permits yet

9. Unspecified Owner

   Location - Dan River
   Other Information - Unknown

CONTACTS REGARDING

ROANOKE RIVER IN VIRGINIA

Ann Jennings
U.S. Fish & Wildlife Service
P.O. Box 480
White Marsh, VA 23183
(804) 693-6694

Robert Kelsey
U.S. Fish & Wildlife Service
1825 Virginia Street
Annapolis, MD 21401
(301) 269-5448

Mr. William Neal, Chief
Environmental Section
VA Department of Game & Inland Fisheries
4010 West Broad Street, P.O. Box 11104
Richmond, VA 23230
(804) 367-1000

Mr. A.L. (Bud) LaRoche, III
VA Department of Game & Inland Fisheries
209 E. Cleveland Avenue
Vinton, VA 24179
(703) 857-7704

William Tanger, President
Friends of the Rivers of Virginia
P.O. Box 1750
Roanoke, VA 24008
(703) 343-3693

Shelton Miles
Citizens for the Preservation of the River
P.O. Box 175
Long Island, VA 24569
(804) 432-9616

Roy E. St.John, Jr., Conservation Chair
Blue Ridge River Runners
Rt. 3, Box 400
Hurt, VA 24563

David Bailey
Environmental Defense Fund
1108 E. Main Street, Suite 800
Richmond, VA 23219
(804) 780-1297

25

Virginia Wildlife Federation
4602 D. West Grove Court
Virginia Beach, VA 23455

REGULATORY AGENCIES

Colonel J.J. Thomas
District Engineer
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, VA 23510-1096

Richard Burton, Executive Director
Virginia State Water Control Board
2111 Hamilton Street
P.O. Box 11143
Richmond, VA 23230

Lt. Colonel Thomas C. Suermann
District Engineer
Wilmington District
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402

APPENDIX 4.

Pertinent Correspondence.

North Carolina Wildlife Resources Commission

512 N. Salisbury Street, Raleigh, North Carolina 27611, 919-733-3391
Charles R. Fullwood, Executive Director

February 21, 1989

Colonel Paul Woodbury
U.S. Army Corps of Engineers
P. O. Box 1890
Wilmington, NC 28401

Dear Colonel Woodbury:

As you are aware the Roanoke River Water Flow Committee has been evaluating water flows in the Roanoke River and the impact of various flow regimes on the reproductive success of striped bass. Although the committee's final report has not been released, we think it is appropriate to implement the recommended flow regime during 1989. To this end we request that the 1971 Memorandum of Understanding signed by Virginia Power and Electric Co., the U.S. Army Corps of Engineers, and the Wildlife Resources Commission be amended as follows:

1. During the period April 1-15 establish a target flow of 8500 CFS with a range of 6600 - 13700 CFS.

2. During the period April 16-30 establish a target flow of 7800 CFS with a range of 5800 - 11000 CFS.

3. During the period May 1-15 establish a target flow of 6500 CFS with a range of 4700 - 9500 CFS.

4. During the period May 16-31 establish a target flow of 5900 CFS with a range of 4400 - 9500 CFS.

5. During the period June 1-15 establish a target flow of 5300 CFS with a range of 4000 - 9500 CFS.

We further recommend that this amendment become effective on April 1, 1989 and that it remain in effect until June 15, 1992 to allow a thorough evaluation of its impact upon striped bass spawning. Following this evaluation, we should negotiate a new long term agreement to provide acceptable flows in the Roanoke River during the time of striped bass spawning.

We appreciate your assistance in this matter.

Sincerely,

Charles R. Fullwood

Charles R. Fullwood
Executive Director

CRF/lr

cc: Jack Mitchell, Virginia Electric Power Co.
Lois D. Cashell, Secretary, FERC
Charles Manooch, Co-Chairman, Roanoke Water Flow Comm.
Roger Rulifson, Co-Chairman, Roanoke Water Flow Comm.
Jaman Vithalani, Corps of Engineers

Post Office Box 26666
Richmond, Virginia 23261

VIRGINIA POWER

March 6, 1989

Colonel Paul Woodbury
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, NC 28401

Dear Colonel Woodbury:

Virginia Power has reviewed the request by the North Carolina Wildlife Resources Commission for modifications to water flows in the Roanoke River, dated February 21, 1989. Although this recommendation will deny Virginia Power the full utilization of the Roanoke Rapids project and impact the operation of the Gaston project, we are prepared to participate in the modified scheduling and reregulation of water releases from the Kerr Dam project during the recommended period.

We view the modified flow regime as a guideline to be followed during normal power system conditions, and go on record as opposing them as mandatory constraints on the scheduling and operation of the Roanoke River projects. Consideration should be given to the possibility that full plant output of approximately 20,000 CFS may be required to avoid curtailment of customer electrical load during periods of severe power shortages.

During the spring of 1988, modified flows were implemented on a trial basis, and we found it necessary to utilize flood storage at Gaston between 200 feet and 201 feet in order to meet the power requirements and flow constraints. The 1989-1992 recommendations are different from those previously tested, and we may find it desirable to seek some further modifications to the reregulated flow guidelines.

As previously pointed out to the flow committee, we believe the wildlife interests in North Carolina should be in direct contact with your staff and the Virginia Power operation center to provide better control of flows during the more critical periods. Strict calendar dates for flow changes may not provide for optimum electrical operation and environmental benefits (see attachment).

1081HWA0136

We will cooperate with the Wildlife Commission's request to the fullest extent possible. If there are other concerns, please contact our operating center directly.

Sincerely,

H. W. Adams, Jr.

H. W. Adams, Jr.
Manager - Power Supply

JDM/aj

cc: Lois D. Cashell, Secretary FERC
Charles Manooch, Roanoke River Water Flow Committee
Roger Rulifson, Roanoke River Water Flow Committee
Max Grimes, Corps of Engineers
Charles R. Fullwood, N.C. Wildlife Resources Commission

1081HWA0136

LARRY W. ELLIS
Vice President
System Planning and Power Supply

One James River Plaza
Post Office Box 26666
Richmond, Virginia 23261
804-771-3757

July 18, 1988

VIRGINIA POWER

Dr. Charles S. Manooch, III
National Marine Fisheries Service
Southeast Fisheries Center
Beaufort, NC 28516-9722

Dear Dr. Manooch:

In reply to your memorandum of June 24, 1988 requesting comments on the recommendations of the flow subcommittee, there are concerns to Virginia Power which the Roanoke River Water Flow Committee should consider in formulating any binding recommendations concerning the operation of the Company's Roanoke Rapids and Gaston projects.

The proposed upper limit of flow will deny the Company full use of the Roanoke Rapids project and could impose restrictions on operation of the Gaston project as a peaking facility. Virginia Power can schedule operation to meet these guidelines to the greatest extent possible, but we will not abandon our right to operate within the full authorization of our license when power system demands cannot be satisfied within the proposed guidelines. The most likely time of difficulty in keeping within these restrictions will be late May and June.

The variation of flow rate of 1500 cfs per hour is considerably below the present license authorized rate of change which allows up to double the pervious 60 minute flow. The 1500 cfs value was selected by the flow subcommittee to prevent elevation changes in excess of one foot per hour when increasing output from minimum flow. Virginia Power will schedule generation changes to minimize drastic elevation changes during normal operation in the spawning season, however it must be recognized that these will be considered as guidelines which may be exceeded during times of unforeseen power requirements.

It is suggested that Virginia Power's System Operation Center be kept informed of significant events during the spawning season when flow variations may be harmful to the striped bass. Day to day constraints may be more practical than full season limitations.

1081JDM040

We appreciate the opportunity to work with the Committee and we share your concern for the striped bass resource as well as for the entire Roanoke River Basin Resource. Mr. Mitchell will be available for further consultation if needed.

Sincerely,

Larry W. Ellis

Larry W. Ellis

bc: Mr. J. A. Ahladas
Mr. W. R. Cartwright
Mr. J. L. Andrews, Jr.
Mr. H. W. Adams, Jr.
Mr. B. M. Marshall
Mr. G. F. Trice
Mr. J. D. Mitchell

1081JDM040

26

North Carolina Wildlife Resources Commission

512 N. Salisbury Street, Raleigh, North Carolina 27611, 919-733-3391
Charles R. Fullwood, Executive Director

March 7, 1989

Colonel Paul Woodbury
U.S. Army Corps. of Engineers
P. O. Box 1890
Wilmington, NC 28401

Dear Colonel Woodbury:

Subsequent to my letter of February 21, 1989 to you concerning water flows in Roanoke River during striped bass spawning season, our staffs have agreed to remove specific target flows from the recommended flow regimes. As a result, I request that the amendments to the 1971 Memorandum of Understanding be stated as follows:

Dates	Flow Range
April 1-15	6,600 - 13,700 cfs
April 16-30	5,800 - 11,000 cfs
May 1-15	4,700 - 9,500 cfs
May 16-31	4,400 - 9,500 cfs
June 1-15	4,000 - 9,500 cfs

As stated in my previous letter, we recommend that this amendment take effect on April 1, 1989 and that it remain in effect until June 15, 1992.

Sincerely,

Charles R. Fullwood

Charles R. Fullwood

cc: Jack Mitchell, Virginia Electric Power Co.
Lois D. Cashell, Secretary, FERC
✓Charles Manooch, Co-Chairman, Roanoke Water Flow Committee
Roger Rulifson, Co-Chairman, Roanoke Water Flow Committee
Jaman Vithalani, Corps of Engineers

CRF/ae

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

March 16, 1989

Mr. Max Grimes
U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402-1890

Dear Max,

I wish to clarify a request that I made to Frank Yelverton yesterday concerning Roanoke River water flow data. It would be very beneficial to the Flow Committee and NC Striped Bass Study Management Board to receive timely flow information for the period 1 March - 30 June. If possible we would like to obtain tabular data every two weeks. Would it be possible to receive the information in the following format:

(Example) Roanoke Rapids Dam Daily Flow Releases (cfs)

Date	Mean	Median	Lowest	Highest
1 March	18,532	17,658	13,400	20,300

Thank you for your consideration.

Sincerely,

Charles S. Manooch, III

cc: Bill Cole, USFWS
Roger Rulifson, ECU

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402-1890

IN REPLY REFER TO
Planning Division

Dear Sir or Madam:

Enclosed for your information is a copy of the Environmental Assessment (EA) and Finding of No Significant Impact for Modification to the Operation of John H. Kerr Dam and Reservoir, Virginia and North Carolina, by Amending the 1971 Memorandum of Understanding (MOU) for Reregulation of Augmentation Flows for Fish from John H. Kerr Dam and Reservoir Project. The EA has been prepared in accordance with the Council on Environmental Quality (40 CFR 1500-1508) and the Corps of Engineers' (33 CFR 230) regulations for implementing the National Environmental Policy Act of 1969, as amended.

The 1971 MOU is being amended at the request of the North Carolina Wildlife Resources Commission in order that a new flow regime can be implemented during the striped bass spawning season. The purpose of the new flow regime is to attempt to reverse the decline of the striped bass population in the Roanoke River. The new flow regime is to be implemented for a four spawning season trial period beginning April 1, 1989. At the end of the trial period, the results will be evaluated and permanent changes to the MOU may be recommended.

If you have any questions concerning this matter, please contact Mr. Frank Yelverton, Environmental Resources Branch, at (919) 251-4640.

Sincerely,

Paul W. Woodbury
Colonel, Corps of Engineers
District Engineer

Enclosure

ENVIRONMENTAL ASSESSMENT

AND

FINDING OF NO SIGNIFICANT IMPACT

FOR

MODIFICATION TO THE OPERATION OF JOHN H. KERR DAM AND RESERVOIR
VIRGINIA AND NORTH CAROLINA

BY

AMENDING THE
1971 MEMORANDUM OF UNDERSTANDING (MOU) SIGNED BY
VIRGINIA ELECTRIC AND POWER COMPANY (now Virginia Power Company),
WILMINGTON DISTRICT, CORPS OF ENGINEERS (COE) AND
N.C. WILDLIFE RESOURCES COMMISSION (WRC)
FOR
REREGULATION OF AUGMENTATION FLOWS FOR FISH FROM
JOHN H. KERR DAM AND RESERVOIR PROJECT

Since 1971, water has been released for striped bass spawning from John H. Kerr Reservoir (operated by the COE) and reregulated through Gaston and Roanoke Rapids Dams (operated by Virginia Power Company) under terms of the MOU. The minimum target stage of the Roanoke River at Weldon, N.C., established for spawning was 13 feet (between 5,500 and 6,000 cubic feet per second (c.f.s.)), normally from April 26 through June 15 (50 days). Storage space has been provided in John H. Kerr Reservoir between elevations 299.5 and 302.0 feet m.s.l. for these releases. The 50-day release schedule has not been met in some years because either adequate storage was not available in John H. Kerr Reservoir due to insufficient inflows or spawning was completed before June 15.

Since the late 1970's, the Roanoke River striped bass population has declined significantly. Because of the striped bass decline, the Roanoke River Water Flow Committee was formed in an attempt to develop a solution to reverse this decline. The committee consisted of experts from universities, the State of North Carolina, Federal agencies, and included advisors from the COE and Virginia Power Company. The committee's final report recommended a new 75-day augmentation flow regime for the striped bass spawning season. This new flow regime was based on flow conditions that existed prior to the impoundment of John H. Kerr Reservoir. By letter of February 21, 1989, (and follow-up letter of March 7, 1989), the WRC requested that beginning April 1, 1989, the 1971 MOU be amended for a four spawning season trial period to implement the flow ranges and dates (table 1) of the 75-day flow regime.

Evaluation performed by the COE indicated that this new flow regime would not have significant adverse impacts on the operation or project purposes of John H. Kerr Reservoir or on downstream resources. The storage space provided in John H. Kerr Reservoir for striped bass releases will not be altered by the recommended flow regime. However, initiation of drawdown from 302.0 to 299.5 feet m.s.l. would occur earlier than under the 1971 MOU, but the committee's recommended flow regime would generally result in an overall lower rate of drawdown.

Virginia Power Company (by letter of March 6, 1989) and the COE have agreed to implement the WRC request to the extent that hydropower needs and reservoir inflows permit. For example, the WRC request cannot be met when severe power shortages are experienced by Virginia Power Company. In addition, as with the 50-day flow regime, the COE cannot guarantee that the 75-day flow regime can be achieved every year. During flood conditions, the upper flow ranges may be exceeded in order to meet flood control obligations. Drought conditions may cause storage in John H. Kerr Reservoir to be inadequate to achieve the lower ranges and/or to provide adequate augmentation for the entire 75-day period. However, the flow will be within the upper and lower ranges during the 75-day flow period whenever possible.

During the trial period, the COE will continue coordination with all appropriate agencies, especially if flood or drought conditions are anticipated. At the end of the trial period, the results will be evaluated and permanent changes to the MOU may be recommended.

Table 2 is a list of agencies, organizations, and individuals consulted during preparation of this Environmental Assessment.

FINDING OF NO SIGNIFICANT IMPACT (FONSI)

Based on the information presented in the Environmental Assessment and related files, I have determined that modifying the operation of John H. Kerr Reservoir by amending the 1971 MOU in order to implement the 75-day flow regime for a four spawning season trial period is not a major Federal action significantly affecting the quality of the human environment. Therefore, an Environmental Impact Statement will not be prepared.

Date: 27 Mar 89

LAWRENCE W. SAUNDERS
Chief, Planning Division

Date: 28 Mar 89

PAUL W. WOODBURY
Colonel, Corps of Engineers
Commanding

Table 1. Trial flow ranges and dates amending the 1971 MOU, Regulation of Augmentation Flows for Fish from John H. Kerr Dam and Reservoir Project. Trial period, April 1, 1989 - June 15, 1992.

Date	Lower Range	Upper Range
April 1-15	6,600	13,700
April 16-30	5,800	11,000
May 1-15	4,700	9,500
May 16-31	4,400	9,500
June 1-15	4,000	9,500

Table 2. Agencies, groups, and persons consulted regarding preparation of the environmental assessment.

1. Norfolk District, Corps of Engineers
2. U.S. Department of Justice
3. N. C. Office of Attorney General
4. City of Virginia Beach
5. Virginia Power Company
6. Virginia Department of Game and Inland Fisheries
7. Roanoke River Flow Committee including:

<u>Representatives From</u>:

a. N. C. Wildlife Resources Commission
b. N. C. Division of Marine Fisheries
c. N. C. Division of Water Resources
d. U.S. Fish and Wildlife Service
e. National Marine Fisheries Service

<u>Individuals:</u>

a. Dr. Roger Rulifson, East Carolina University
b. Dr. Tom Quay, N. C. State University

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

March 29, 1989

MEMORANDUM FOR: Kathy Hill, Chief, USGS Records Department

FROM: Charles S. Manooch, III, Co-Chairman, Roanoke River Water Flow Committee, Technical Coordinator, NC Striped Bass Study Management Board

SUBJECT: Real Time Flow Data on a Continual Basis for Roanoke River, N.C.

A Management Board has been established by Mr. James Pulliam, Jr., US Fish and Wildlife Service, Region Four Director to develop and implement coordination protocol between State and Federal conservation agencies and university scientists responsive to requirements of Public Law 100-589. Under Section 5 of P.L. 100-589, Congress has requested a three-year study of the causes for the decline of the North Carolina (Roanoke River Basin-Albemarle Sound) stock of striped bass. Experts believe that one of the major causes for the decline has been controlled releases of Roanoke River water flow during the spring and early summer (please note enclosed publication: NOAA Technical Memorandum, NMFS-SEFC-216). It is very important that the Roanoke Water Flow Committee, which produced the enclosed document, and the Management Board be able to obtain real time flow data on a continual basis from the Roanoke River water gage number 02080500 located in Halifax County, NC approximately 2.8 miles downstream from the Roanoke Rapids Dam.

I would like to retrieve data on an hourly basis, daily, from approximately 1 March-15 June each year for the three-year study period.

Thank you very much for your assistance.

cc: James W. Pulliam, Jr., Reg. Dir.
USFWS, Atlanta

Roger Rulifson, Co-Chairman
Roanoke River Water Flow Committee
East Carolina University
Greenville, NC

obtained
acc[?]
3/29/89

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

April 11, 1989

Mr. Max Grimes
U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402-1890

Dear Max,

I was sorry to note that yesterday at 12:00 the Roanoke Rapids Dam gage (USGS Station Number 02080500) recorded 16,700 cfs, clearly exceeding the Roanoke River Water Flow Committee's upper flow limit for the period April 1 - April 15. I assume that high flows will continue for several days as the hourly flow data that I have received for today all exceed 13,700 cfs. It is hard to envision now what the impact of these flows will be. However, I suspect that the wild turkey population will be one of the first impacted resources. As you know, now is the time that turkeys utilize the lower Roanoke River floodplain as their breeding and nesting areas. Hopefully, these high waters will not last very long.

Sincerely,

Charles S. Manooch, III
Co-Chairman, Roanoke River
Water Flow Committee

cc: Richard Hamilton, NCWRC
Roger Rulifson, ECU

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

April 25, 1989

MEMORANDUM FOR: Roanoke River Water Flow Committee Members and Advisors

FROM: Charles S. Manooch, III, Co-Chairman

SUBJECT: Spring 1989 Update

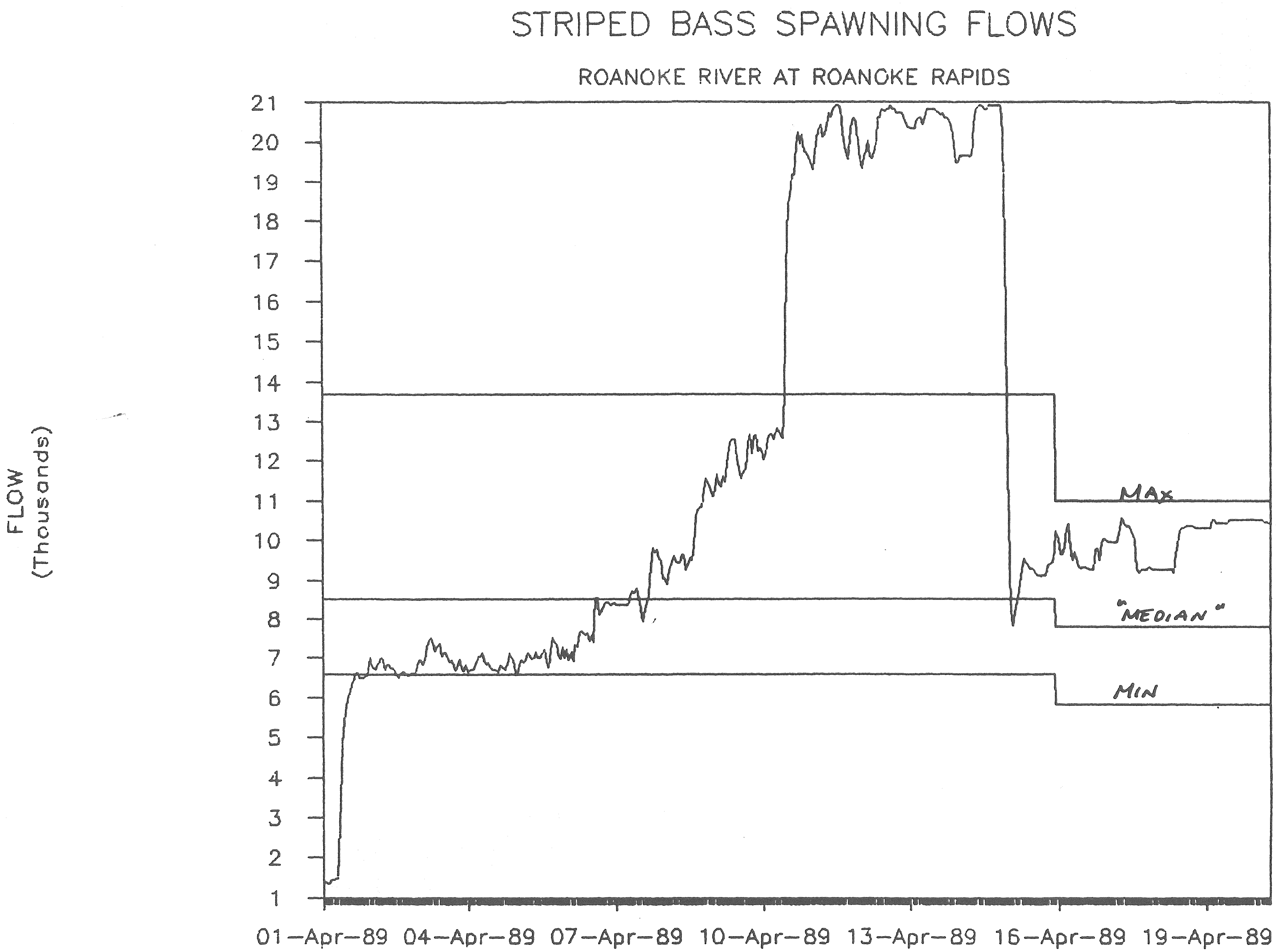
Throughout the Roanoke River Basin the "dogwoods are blooming and the fig leaf's as big as a cat's ear". And in conjunction with these biological signs, striped bass continue to migrate up the Roanoke and are arriving on the spawning grounds.

Sampling for eggs and larvae by East Carolina University and Wildlife Resources Commission personnel has begun, the recreational creel survey is underway, and the hatchery at Weldon is open.

As you know, this spring has been unusually wet, particularly during March, resulting in much higher water levels and rates of discharge compared with last spring. However, the Virginia Power Company and Wilmington District, Corps of Engineers are working with Committee members to provide recommended water flows during the spawning season. Please note the enclosed Wildlife Resources Commission news release dated April 14.

I am receiving hourly flow data from the USGS Raleigh Office. For a comparison of 1989 to date and 1988 refer to figures 1 and 2, respectively. Also, David Crawford, Division of Water Resources, has provided the enclosed computerized graph of flows (cfs) for April 1 - April 19, 1989. If you desire specific tabular data for either 1988 or 1989, March 1 - June 15, please give me a call (919-728-8716).

Enclosures
As Stated


STRIPED BASS SPAWNING FLOWS
ROANOKE RIVER AT ROANOKE RAPIDS
FLOW
(Thousands)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
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2
1
01–Apr–89
04–Apr–89
07–Apr–89
10–Apr–89
13–Apr–89
16–Apr–89
19–Apr–89
MAX
"MEDIAN"
MIN

North Carolina Wildlife Resources Commission

NEWS RELEASE • NEWS RELEASE • NEWS RELEASE • NEWS RELEASE • NEWS RELEASE • NEWS RELEASE

512 N. Salisbury Street, Raleigh, North Carolina 27611, 919-733-3391

For more information, contact: Angela Dorman Hill Telephone 733-3391 Date 4 / 14/ 89

ROANOKE RIVER WATER CONTROLLED FOR STRIPED BASS

Critical for fish survival

Flood conditions along the Roanoke River are displacing wild turkeys now, but the U.S. Army Corps of Engineers' decision to open the Kerr Lake dams may save this year's production of striped bass.

Before making the decision to release additional water into the Roanoke River earlier this week, the Corps and Virginia Power Co. had agreed to control water flows this spring for striped bass spawning. The N.C. Wildlife Resources Commission had requested the control of water flows during the striped bass spawning period which lasts from April through June.

"We are pleased that Virginia Power and the Corps of Engineers agreed to control discharges as much as possible for striped bass," said Richard B. Hamilton, assistant director of the Commission. "The recent heavy rainfall is responsible for the high flows this week. The Corps is releasing surplus water so that ideal flows for striped bass can be met during their critical spawning period. It is unfortunate that this high water has disrupted spring turkey hunting activity by flooding much of the Roanoke lowgrounds. We can only hope that rainfall is normal for the rest of April and May and that the river subsides to allow successful turkey nesting and striped bass spawning."

The dwindling striped bass population has become a major

more

environmental concern in North Carolina.

The Wildlife Commission, the Corps of Engineers and Virginia Power Co. set target water flows in the Roanoke River for four years to make conditions ideal for striped bass spawning. When water levels are too high, striped bass larvae are flushed into the Albemarle Sound and away from their food supply. When water levels are too low, the larvae remain upstream in the river, and never make it to their food supply which is located at the mouth of the Roanoke River.

By controlling water releases at the dams on Kerr, Gaston and Roanoke Rapids lakes, the Corps controls the flow of water in the Roanoke River all the way to the Albemarle Sound. When striped bass larvae ride the ideal flow of water and reach the mouth of the river when their food supply is at its peak, the chances of spawning success and a high survival rate of fish is greatly increased.

"We want to do what we can to support the striped bass," said Max Grimes, chief of hydrologic engineering for the U.S. Army Corps of Engineers. "We'll go overboard to satisfy these flow needs. But it's a gambling venture. If we hold water back now, we run the risk of having high water when the main body of fish start spawning.

"We're spending more time computing the necessary water flows. As far as the lakes are concerned, it should be an improvement in maintaining a suitable elevation for fish and recreation interests."

"We're having to closely monitor what we're doing," said Jack Mitchell, system engineer for supply for Virginia Power Co. "We're concerned about striped bass. We welcome the opportunity to work with the Wildlife Commission and the Corps of Engineers."

########

EAST CAROLINA UNIVERSITY
GREENVILLE, NORTH CAROLINA 27858-4353

INSTITUTE FOR COASTAL AND MARINE RESOURCES
(919) 757-6779

May 17, 1989

Roanoke River Water Flow Committee
c/o Institute for Coastal and Marine Resources
East Carolina University
Greenville, NC 27858

MEMORANDUM TO: All Flow Committee members and advisors

FROM: R.A. Rulifson and C.S. Manooch, III

SUBJECT: Update on the 1989 striped bass spawning season

Enclosed are a number of graphs depicting environmental conditions on the Roanoke River during spring 1989. The first set of graphs show discharge from the Roanoke Rapids dam on an hourly basis since 1 March 1989 through 9 May. Striped bass egg deposition, as monitored at Barnhill's Landing (between Tillary and Halifax), has been noted on each graph. In my (Rulifson's) opinion, major striped bass spawning activity should have occurred the first week in May, as indicated by increasing numbers of eggs. However, the critical need of evacuating Kerr Reservoir necessitated the release of 20,000 cfs, which reduced and eventually stopped egg deposition the week of 30 April - 6 May.

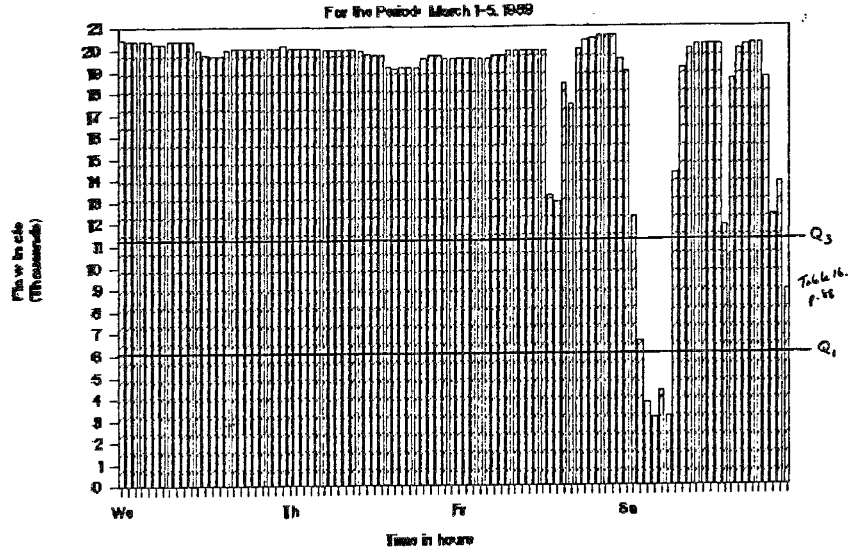
The second set of graphs shows measurements of water temperatures, relative change in river stage, surface water velocity, and surface water pH monitored at four-hour intervals at Barnhill's Landing since 15 April. Note that early egg deposition was not at the optimal spawning temperature, but rather was probably triggered by sudden reduction of water flow from the dam (see flow data). The low egg production observed at the end of April and early May was correlated with water temperatures reaching 18^{o} C. Surface water pH has been good, with the exception of a brief period near the end of April, when values were below 7.0 (neutral). Water depth at the Barnhill sampling site during early May rose approximately 12 feet within a two-day period. Water velocity appears to be a function of whether the water is contained within the channel, or has moved out from the channel to flood the "steps" or plateaus typical of the riverbed in this area.

During last weekend, water temperatures dipped to about 13^{o} C, but now are increasing and presently about 16^{o} C. Weather predictions for the week indicate spotty rainshowers but increasing temperatures. If the weather and flows hold, we may see major spawning activity by the end of the week.

On another note, we should have a Committee meeting this summer to review river flow conditions for the first half of 1989. The week of 17 July is now scheduled for the Striped Bass Management Board, which will meet in Beaufort. Please keep the week of 17 July free for a potential Committee meeting.

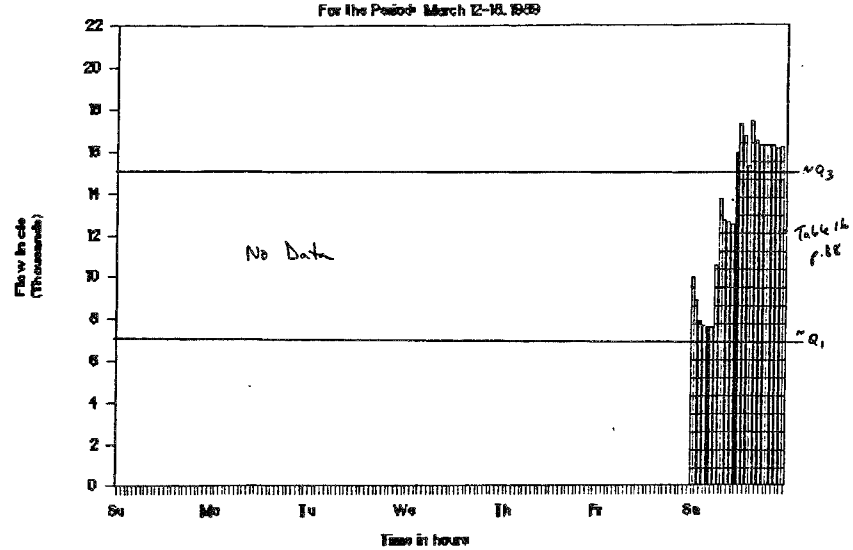
HOURLY FLOW BELOW ROANOKE RAPIDS, NC

For the Period March 1-5, 1989



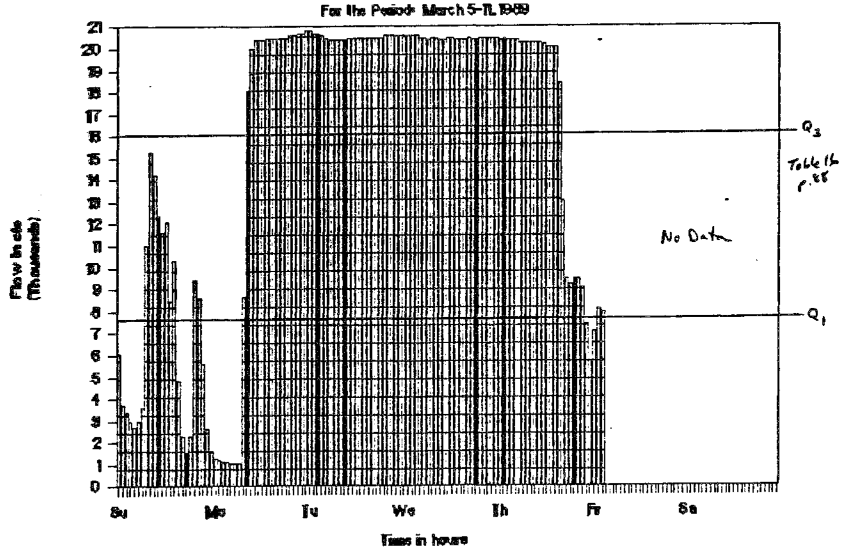
HOURLY FLOW BELOW ROANOKE RAPIDS, NC

For the Period March 12-18, 1989



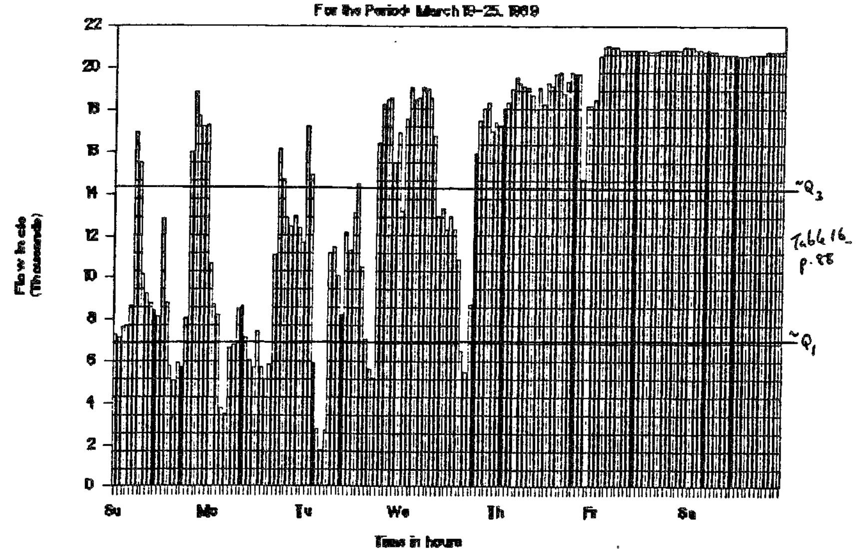
HOURLY FLOW BELOW ROANOKE RAPIDS, NC

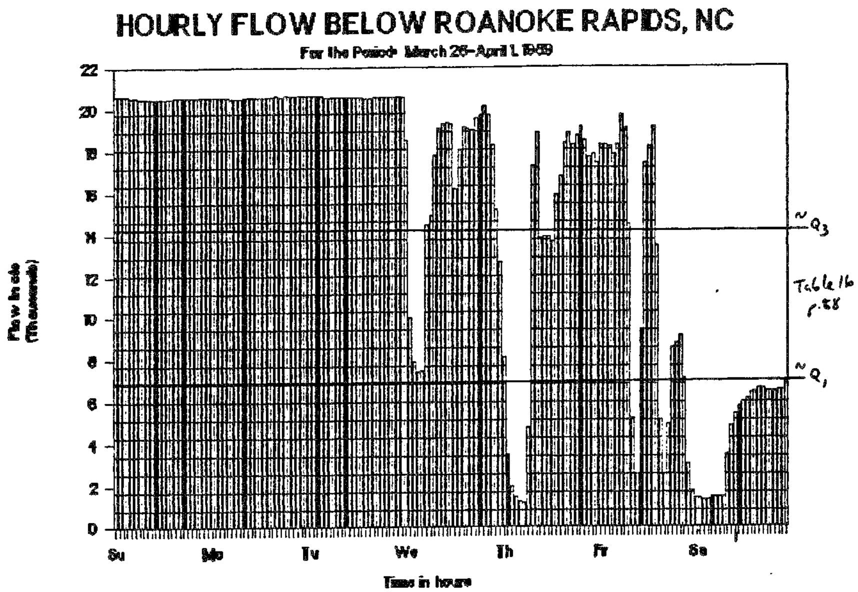
For the Period March 5-11, 1989

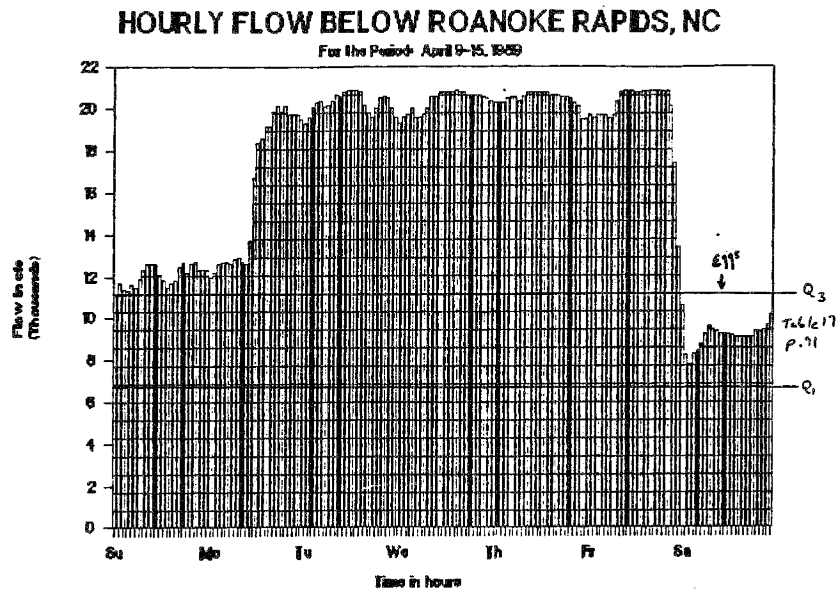


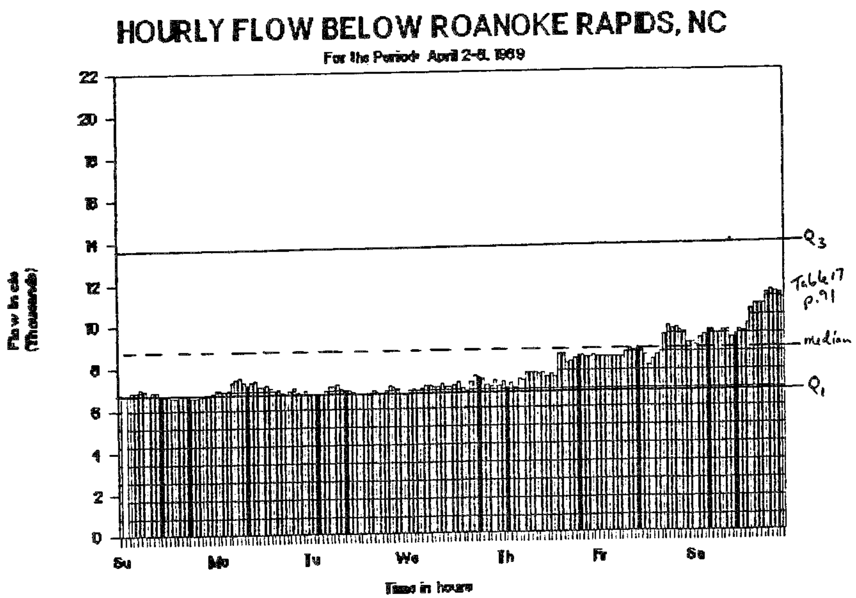
HOURLY FLOW BELOW ROANOKE RAPIDS, NC

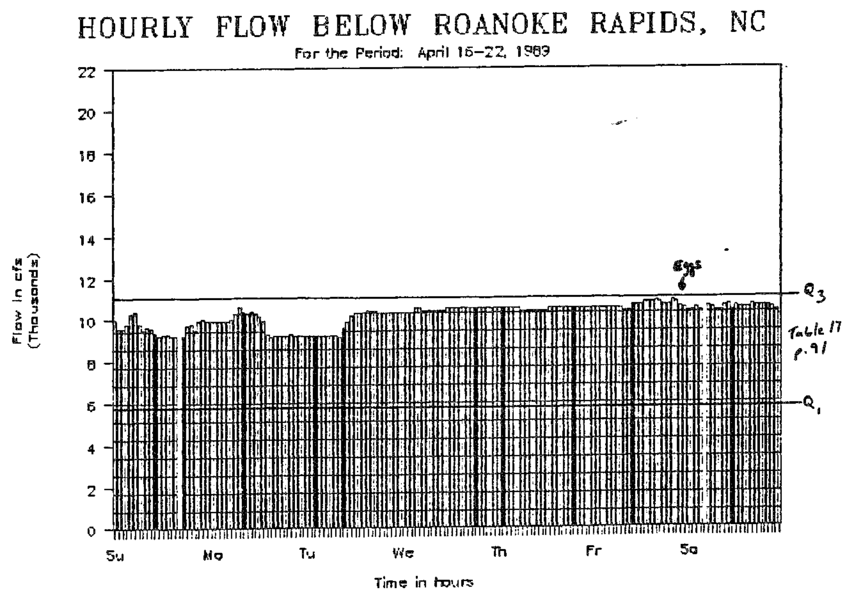
For the Period March 19-25, 1989




HOURLY FLOW BELOW ROANOKE RAPIDS, NC
For the Period: March 26–April 1, 1989
Flow in cfs (Thousands)
Time in hours
Su Mo Tu We Th Fr Sa
~Q3
Table 16 p.88
~Q1


HOURLY FLOW BELOW ROANOKE RAPIDS, NC
For the Period: April 9–15, 1989
Flow in cfs (Thousands)
Time in hours
Su Mo Tu We Th Fr Sa
Eggs
Q3
Table 17 p.91
Q1

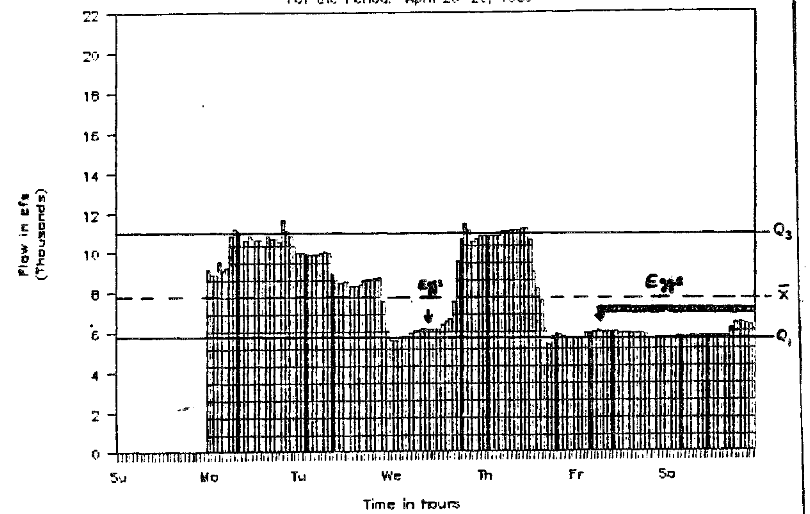

HOURLY FLOW BELOW ROANOKE RAPIDS, NC
For the Period: April 2–8, 1989
Flow in cfs (Thousands)
Time in hours
Su Mo Tu We Th Fr Sa
Q3
Table 17 p.91
median
Q1


HOURLY FLOW BELOW ROANOKE RAPIDS, NC
For the Period: April 16–22, 1989
Flow in cfs (Thousands)
Time in hours
Su Mo Tu We Th Fr Sa
Eggs
Q3
Table 17 p.91
Q1

188

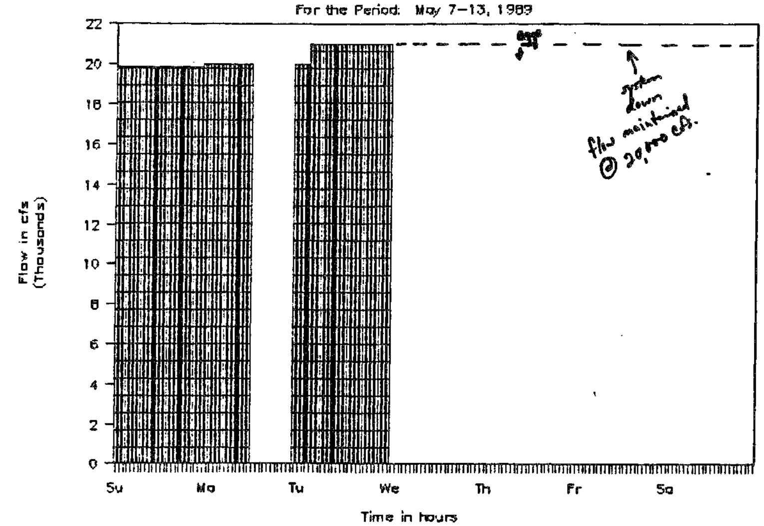
HOURLY FLOW BELOW ROANOKE RAPIDS, NC

For the Period. April 23–29, 1989



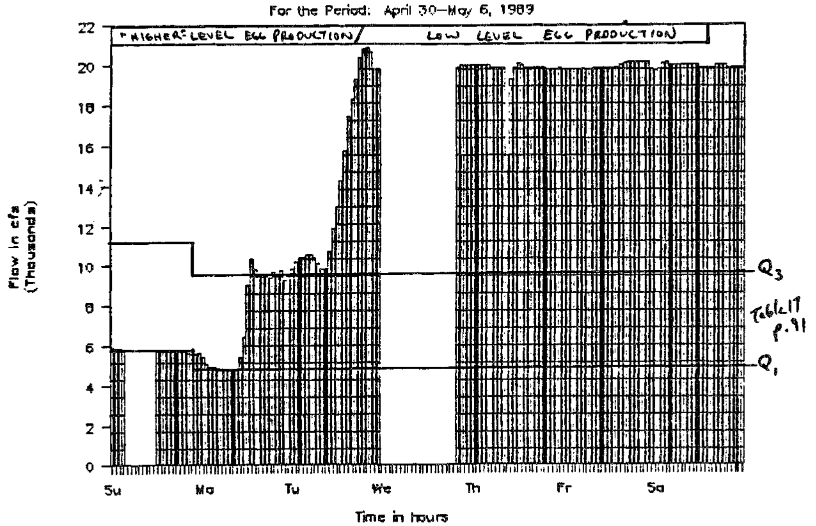
HOURLY FLOW BELOW ROANOKE RAPIDS, NC

For the Period: May 7–13, 1989



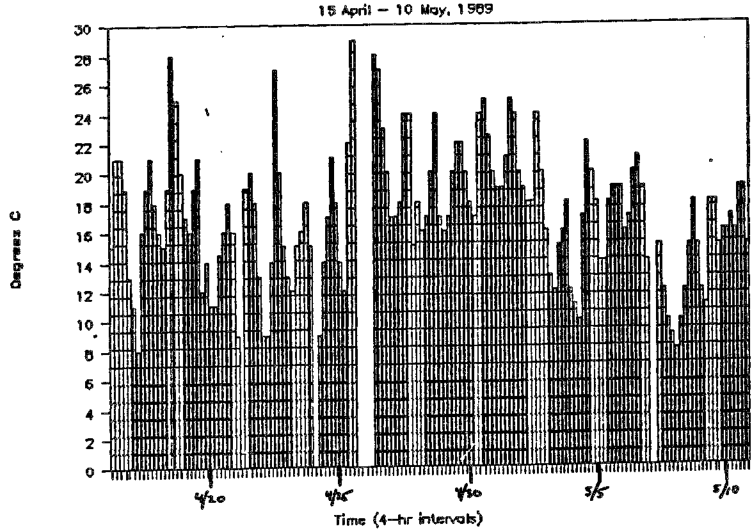
HOURLY FLOW BELOW ROANOKE RAPIDS, NC

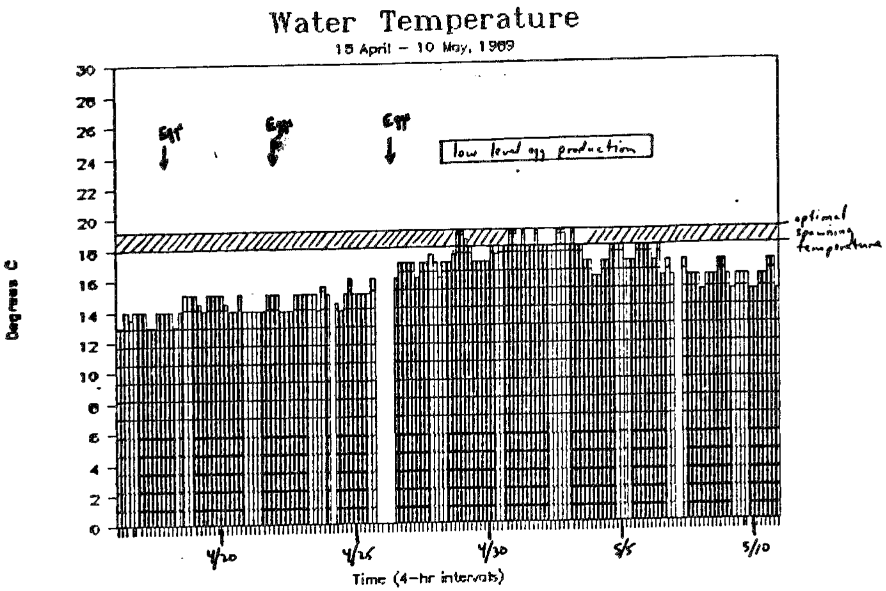
For the Period: April 30–May 6, 1989

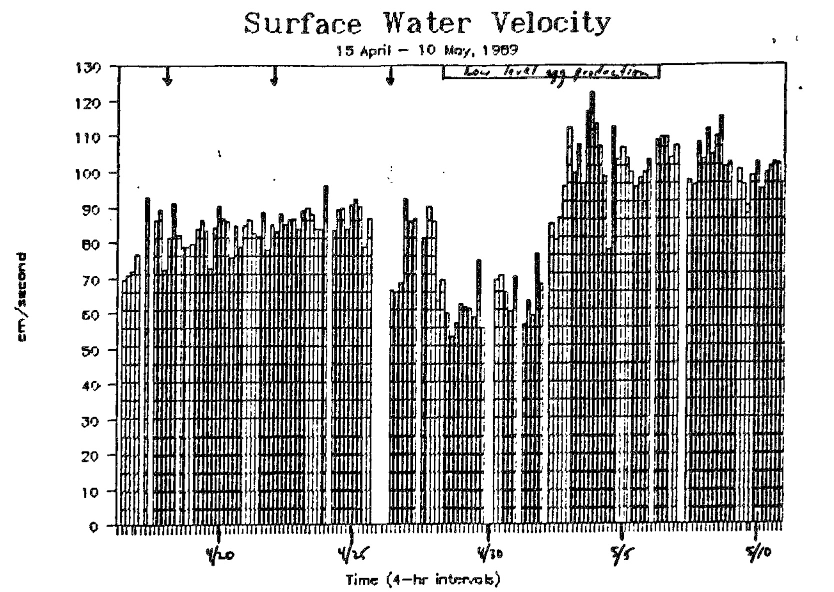


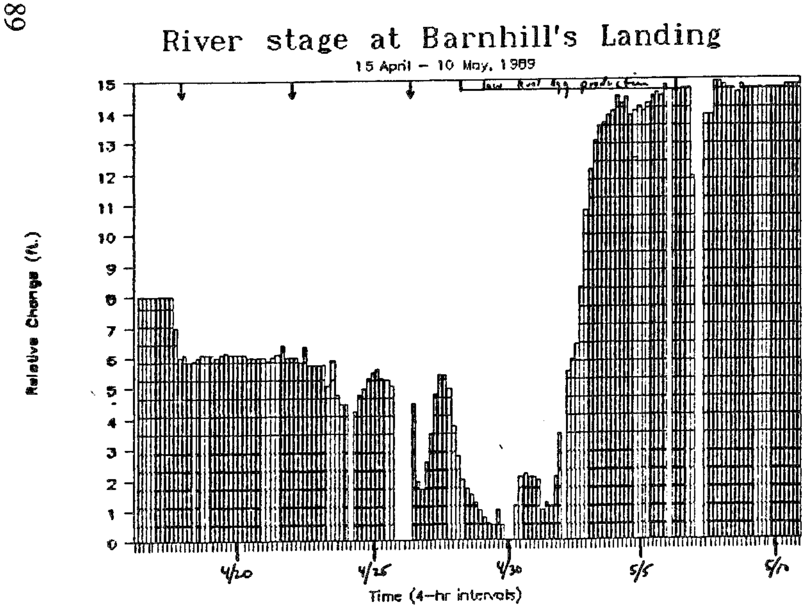
Air Temperature

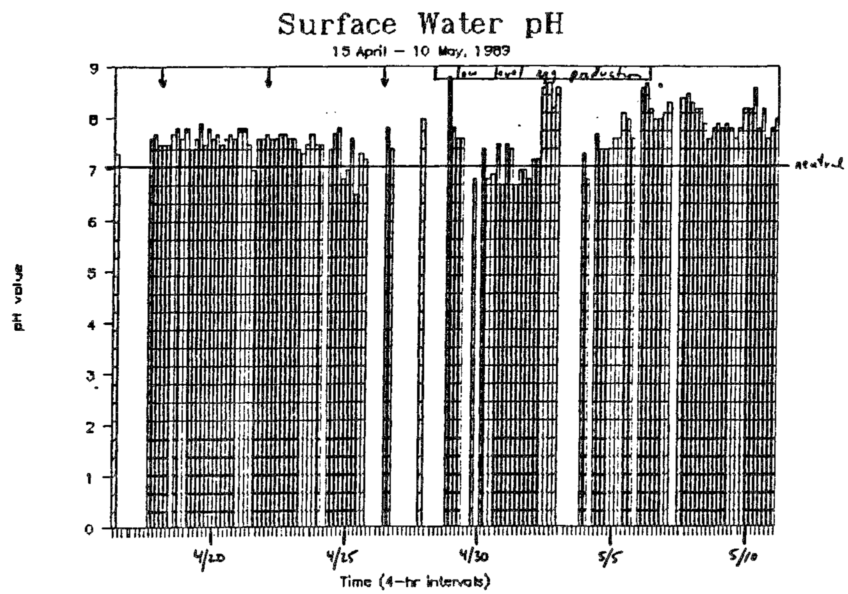
15 April – 10 May, 1989




Water Temperature
15 April – 10 May, 1989
Degrees C
Egg
Egg
Egg
low level egg production
optimal spawning temperature
4/20
4/25
4/30
5/5
5/10
Time (4-hr intervals)


Surface Water Velocity
15 April – 10 May, 1989
cm/second
low level egg production
4/20
4/25
4/30
5/5
5/10
Time (4-hr intervals)


River stage at Barnhill's Landing
15 April – 10 May, 1989
Relative Change (%)
low level egg production
4/20
4/25
4/30
5/5
5/10
Time (4-hr intervals)


Surface Water pH
15 April – 10 May, 1989
pH value
low level egg production
neutral
4/20
4/25
4/30
5/5
5/10
Time (4-hr intervals)

National Marine Fisheries Service
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, NC 28516

September 15, 1989

MEMORANDUM FOR: Roanoke River Water Flow Committee Members and Advisors

FROM: Charles S. Manooch, III and Roger A. Rulifson, Co-Chairmen

SUBJECT: October Meeting

You will recall that at our July meeting in Beaufort we decided to meet again in October after most data had been collected for the 1989 striped bass season. We have set the meeting for October 24, at 1000 at the East Carolina University Institute for Coastal and Marine Resources. The focus of the meeting will be our report for 1989, and Committee recommendations for the 1990 spring season. We hope you will plan to attend.

Please take time to review the enclosure which very briefly outlines topics that we may wish to include in the 1989 report. Note those topics for which your agency has responsibility and come prepared to discuss them. If your studies are complete for the 1989 season, we would appreciate receiving any text, tables, or figures that could be incorporated in a draft report. This would save us time. Thank you.

Enclosure as Stated

Water Flow Committee Annual Report Format

Editors: Co-chairmen of the Flow Committee. This concept was discussed and agreed upon at Committee meeting held in Beaufort, July 18, 1989 as were format, publicaion date, and funding itemized below.

Format: NOAA Technical Memorandum Series, NMFS-SEFC-.

Publication Delivery Date: By March 1 each year.

Funding: NC Striped Bass Study Management Board.

Areas Covered in Reports:	Completion Date:
Roanoke water flow	At any time
Sport creel survey	Fall
Egg production	Fall
Egg viability	Fall
Phytoplankton	Fall
Zooplankton	Fall
Larvae	Fall
Water quality	Fall
Juvenile Abundance Index	October
Commercial landings (Alb)	January
Wildlife status	Summer
Comments from industry	Summer
Comments from municipalities	Summer
Agriculture status	Summer
Forestry status	Summer

Committee needs to stress target flows and other recommendations.

Extra funds may be required from the Board to provide more timely analyses of data for items 3-8 listed above.

Next meeting of the Committee will be held in October. At that time, agency/university members and advisors will bring specific information for the report to the meeting for discussion and recommendations. The editors will proceed as materials are received. A draft copy of the report will be submitted to Committee members and advisors for review prior to printing.

reminder mailed out 12/18/89

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

October 31, 1989

MEMORANDUM FOR: Roanoke River Water Flow Committee Members and Advisors

FROM: Charles S. Manooch, III and Roger a Rulifson, Co-Chairmen

SUBJECT: Report Assignments

The Committee held a meeting at East Carolina University on October 24. One of the major topics discussed was our report for the 1989 season, which will be published as a NOAA Technical Memorandum (same as last time) in March 1990. Those in attendance were asked to refer to our memorandum of September 15 for guidance relating to editorship, format, publication costs, and topics to be included.

The group agreed that the report for 1989 should follow a different format. That is, individuals or agencies will author their own sections which will appear as chapters in the report. This will not only save the editors time, but will also give credit where it is due - to those who collected the data and conducted analyses.

Following is a list of topics (chapters) that will appear in the report with assignments. Draft materials should be mailed to Roger during the first week in January.

Topic	Responsibility
Hydrology:	
1. Hourly flow by date, March 1 - June 30 1988 and 1989	NCD Water Resources, COE, Wilmington Shepherd, ECU
2. Hourly variation in flow by date, March 1 - June 30 (Variation from 1500 cfs/hr), 1988 and 1989.	
3. Interpretation: Compare hourly variation in flow during 1988 and 1989 with previous post-impoundment years.	
4. Number of days within negotiated Q1-Q3 bounds during 1988 and 1989.	
5. Reservoir operations during 1988 and 1989, March 1 - June 30.	

Sport Creel Survey, Roanoke River, 1988 and 1989.			NCWRC (Mullis)
Egg Production	1988 and 1989		Rulifson
Egg Viability	1988 and 1989		Rulifson
Phytoplankton	1988 and 1989		Stanley
Zooplankton	1988 and 1989		Rulifson
Larvae	1988 and 1989		Rulifson
Water Quality	1988 and 1989		Rulifson
JAI	1988 and 1989		NCDMF (Henry)
Comm. Landings	1988 and 1989	by water body and gear	NCDMF (Henry)
Wildlife Status	1988 and 1989		NCWRC
Forestry Status	1988 and 1989		NCDA (Ellis)
Agriculture Status	1988 and 1989		NCDA (Ellis)
Hydrological-Biological	1988 and 1989		Zincone, Manooch, Shepherd, Rulifson

Please let us know if you foresee any problems with this list or with the deadlines - first week of January for drafts; publication in March.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

February 15, 1990

MEMORANDUM FOR: Roanoke River Water Flow Committee Members and Advisors

FROM: Charles S. Manooch, III and Roger A. Rulifson, Co-Chairmen

SUBJECT: Committee Meeting

We would like to meet on 8 March at 10:00 AM in Greenville, NC at the Institute for Coastal and Marine Resources on the East Carolina University campus. An agenda will be developed and distributed at the meeting.

The primary purpose of the meeting will be to discuss our report for the 1989 season and to make recommendations for this spring and have them published in the report. A very rough draft of the report should be mailed to you before the meeting. The Raleigh Office of the US Fish and Wildlife Service has asked for time during the meeting to present information on potential watershed developments in central-western Virginia. If you have another agenda item, please let us know before the meeting.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

March 9, 1990

Mr. Charles R. Fullwood
Executive Director
N.C. Wildlife Resources Commission
512 N. Salisbury St.
Raleigh, N.C. 27611

Dear Charles,

As you are aware the Roanoke River Water Flow Committee has been evaluating water flows in the Roanoke River and the impact of a revised spring water flow regime on striped bass and other downstream resources. A copy of the Committee's recommended guidelines and a table of suggested flows are attached.

Last year you informed Colonel Paul Woodbury, US Army Corps of Engineers, Wilmington District, of the Committee's recommendations and your support of them in your letter dated February 21. At its meeting in Greenville, NC yesterday, the Committee agreed that a similar letter this year would enhance the implementation of the Committee's guidelines. We respectfully request that you identify the spring flow regime by dates, lower and upper boundaries, expected ("target") flows, and allowable hourly variation in flows. This information is covered in the attached materials. We also ask that the Commission stress the importance of the expected flows. The Corps should attempt not only to stay within the upper and lower boundaries, but also meet the expected rates when possible.

I understand that there has been a change of command in the Corps Wilmington District. Lt. Colonel Thomas C. Suermann has replaced Colonel Woodbury. Also, members of the Flow Committee asked that Fred Harris, Mike Gantt (U.S. Fish and Wildlife Service), John Norris (N.C. Div. Water Resources), and George McCabe (Virginia Power Co.) be included on your list of names to receive copies.

The Committee appreciates the service provided by you and members of your staff as we strive together to manage the natural resources in the lower Roanoke River Basin.

Sincerely,

Charles S. Manooch, III
Co-Chairman
Roanoke River Water Flow
Committee

Enclosures
As Stated

cc: Roger A. Rulifson

COMMITTEE RECOMMENDATIONS

Recommended flows presented in Table 17 were agreed upon by members of the Recommendation Subcommittee after consultation with Mr. Max Grimes, US Army Corps of Engineers, Wilmington District and Mr. J.D. Mitchell, Virginia Power Company. Pre-impoundment USGS data for the years 1912-1950 were used to develop the recommended flows for the dates indicated.

Upper and Lower Flow Limits

At no time must flows (cfs) be greater than or less than those specified for the dates indicated. As an example, for May 1-15 the maximum, or upper flow limit is 9500 cfs, and the minimum, or lower flow limit is 4700 cfs. Flows must be within these values at all times during the indicated dates.

The Subcommittee recognizes the certainty of extremely wet (flood) and extremely dry (drought) years. Under these extreme conditions, where the US Army Corps of Engineers has very little control over watershed events, we merely expect the Corps to attempt to meet the flow regime as well as possible. However, the Subcommittee remains concerned that the flow regime does not adequately address low flow augmentation for striped bass during dry years, when the Kerr Reservoir level is below 299.5', nor any flood storage in Kerr above elevation 302' during wet, nondisastrous flood (20,000 cfs) periods. In other words, where does the priority status of the anadromous striped bass resource rank when flood control, hydropower, and above dam recreational interests are considered? Additional Committee discussion and action on this concern are needed.

It should be noted that the recommended flow regime is not consistent with the current Memorandum of Understanding between the North Carolina Wildlife Resources Commission, US Army Corps of Engineers, and Virginia Power Company. Specifically, minimum allowable flows recommended for 1 May - 15 June are lower than those in the 1971 Memorandum. However, the timeframe of 1 April - 15 June is consistent with the FERC license requirement and Memorandum of Understanding.

Variation of Flow

A maximum variation rate of 1500 cfs per hour is recommended. Flows may be increased or decreased as long as they do not fall outside the proposed upper and lower units for the dates indicated. The Subcommittee underscores the importance of moderate, sustained flows during the actual spawning period(s). Therefore, as little variation as possible in flow during this period of time is preferred.

Friendly Amendments to Negotiated, Recommended Flow Regime

1. The Ad Hoc Committee shall compile and issue a formal report of its findings and recommendations in Federal FY 1989, preferably by Spring 1989 (this document).

2. A standing committee on Roanoke River Water Flows should be formed. The committee should meet at least annually and issue a progress report. It is recommended that the standing committee compile and issue a formal report at approximately five year intervals.

   The negotiated, recommended flow regime as adopted by the Ad Hoc Committee shall be evaluated over a four-year period. During the evaluation period, the following shall be studied and shall be subject to change:

   a. Flow augmentation period (i.e. dates).
   b. Upper and lower flow limits.
   c. Hourly variation in flow.
   d. Impacts on other resources and users.

3. The Ad Hoc Committee recommends that the Memorandum of Understanding (MOU) between the U.S. Army Corps of Engineers, Virginia Power Company, and North Carolina Wildlife Resources Commission be re-examined to incorporate the recommendations of the Ad Hoc Committee. The MOU should also be re-examined at the conclusion of the trial/evaluation period discussed above. We recommend that the N.C. Division of Marine Fisheries participate in these discussions.

4. Anadromous striped bass shall receive "high" priority status, at least equal to other resources and uses/users in the Roanoke River Basin.

5. At the conclusion of the four-year trial period, if the recommended or amended flow regime has proved to be beneficial to striped bass and in consideration with other resources and users, then the Rule Curve and FERC license should be re-examined to ensure a regularly maintained, new, recommended flow regime for the Roanoke River.

Additional Comments

If meaningful flow regime changes are to be accomplished, then the Corps may have to modify the operating rules of Kerr both in the flood and in normal power operation zones. These modifications may take the form of adjustments to the Rule Curve or to operations policy on such things as rates of drawdown in early spring (to retain storage for spring flows) or in hydropower operations during critical periods of spawning runs.

Table 17. Negotiated (Q_1-Q_3) water flow regime (in cfs) for the Roanoke River below Roanoke Rapids dam for the period 1 April to 15 June each year.

Dates	Expected Average Daily Flow	Lower Limit	Upper Limit
April 1-15	8,500	6,600	13,700
April 16-30	7,800	5,800	11,000
May 1-15	6,500	4,700	9,500
May 16-31	5,900	4,400	9,500
June 1-15	5,300	4,000	9,500

North Carolina Wildlife Resources Commission

512 N. Salisbury Street, Raleigh, North Carolina 27611, 919-733-3391
Charles R. Fullwood, Executive Director

March 20, 1990

Lt. Colonel Thomas C. Suermann
U.S. Army Corps of Engineers
P. O. Box 1890
Wilmington, NC 28401

Dear Colonel Suermann:

Last year the 1971 Memorandum of Understanding for maintenance of spawning flows for striped bass in Roanoke River was amended to reflect the recommendations of the Roanoke River Flow Committee. We request that the amended flow regime established last year be continued this year with the inclusion of target flows and allowable hourly variations in flows. Our recommended flow regime for 1990 is as follows:

Dates	Flow Range	Target Flow	Max. Hourly Variation
April 1-15	6,600-13,700 cfs	8,500 cfs	1,500 cfs
April 16-30	5,800-11,000 cfs	7,800 cfs	1,500 cfs
May 1-15	4,700- 9,500 cfs	6,500 cfs	1,500 cfs
May 16-31	4,400- 9,500 cfs	5,900 cfs	1,500 cfs
June 1-15	4,000- 9,500 cfs	5,300 cfs	1,500 cfs

We strongly encourage the maintenance of flows in the river that closely approximate the target values. These flows represent our best estimates of optimum flows for striped bass spawning and subsequent survival of striped bass larvae.

We appreciate your assistance in restoring the Roanoke River/ Albemarle Sound striped bass population.

Sincerely,

Charles R Fullwood

Charles R. Fullwood

CRF/lr

cc: Mike Gantt, U.S. Fish & Wildlife Service
John Morris, Division of Water Resources
George McCabe, Virginia Power Company
Charles Manooch, Roanoke River Flow Committee
Roger Rulifson, Roanoke River Flow Committee

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Fisheries Center
Beaufort Laboratory
Beaufort, NC 28516

April 9, 1990

Mr. J.D. Mitchell
Virginia Power Company
Box 26666, Power Supply
Richmond, VA 23261

Dear Mr. Mitchell:

At our last meeting of the Roanoke River Water Flow Committee on March 8, Mr. George McCabe announced that you were planning to retire this month. The Committee members asked that I write you on their behalf, thank you for your service, dedication, and positive attitude while working with our group. We wish you well during your retirement.

As tangible evidence of our appreciation, we enclose a copy of the book: "Fishermen's Guide to the Fishes of the Southeastern United States" for your enjoyment and reading pleasure. We merely ask that you take this book to your favorite fishing locations and see just how many of the species of fish found in the book that you can catch. Please have George keep us posted on your progress.

Sincerely,

Charles S. Manooch, III
Co-Chairman, Roanoke
River Water Flow Committe

Enclosure as stated

cc Roger Rulifson, Co-Chairman, Roanoke River
Water Flow Committee

PUBLIC UTILITIES DEPARTMENT
WATER RESOURCES DIVISION
(804) 427-8035

City of Virginia Beach

RECEIVED
APR 20 1990
ICMR/ECU

MUNICIPAL CENTER
VIRGINIA BEACH, VIRGINIA 23456-9002

FAX COVER LETTER

Please deliver the following pages to:

NAME: Dr. Roger Rulifson

FROM: Rita Sweet

DATE: 4/20/90

Total number of pages 3 including FAX Cover Letter.

IF YOU DO NOT RECEIVE ALL THE PAGES, PLEASE CALL BACK AS SOON AS POSSIBLE. Our main office number is (804) 427-8035.

OPERATOR

WE ARE SENDING FROM A MURATA F-32.
OUR FAX NUMBER IS (804) 426-5778.

Dr. Rulifson -
The original of this letter will be mailed to you today.
Thank you.
Rita Sweet

RECEIVED
APR 20 1990
ICMR/ECU

City of Virginia Beach

PUBLIC UTILITIES DEPARTMENT
WATER RESOURCES DIVISION
(804) 427-8035

MUNICIPAL CENTER
VIRGINIA BEACH, VIRGINIA 23456-9002

April 20, 1990

Dr. Roger Rulifson
Associate Scientist
Institute for Coastal and Marine Resources
East Carolina University
Greenville, NC 27858

Dr. Charles Manooch
National Marine Fisheries Service
Southeast Fisheries Center
Beaufort, NC 28516

Gentlemen:

The City of Virginia Beach submits the following comments regarding the Roanoke River Water Flow Committee's Report on the 1988 and 1989 Spawning Seasons, which we understand is nearing final editing and completion. As recently suggested by Dr. Manooch, we request that these comments be included in the record for the report, and be attached as an appendix to the final version.

The City's requests for a copy of the draft version of the report, which was discussed at the March 8, 1990 meeting of the Flow Committee at East Carolina University, have been denied. The document was not produced under a January 23, 1990 Freedom of Information Act request to the National Marine Fisheries Service; the City was not permitted to copy the document during its review of NMFS files at the Beaufort Laboratory on April 11 and 12, 1990. Therefore, our comments must be limited to our knowledge of the draft report obtained through attendance of Flow Committee meetings and discussions with Committee members.

RECEIVED

APR 20 1990

ICMR/ECU

The latest draft version of the document indicates that the flows released during the spring of 1988 implemented the Committee's recommended regime, rather than the regime specified in the Memorandum of Understanding (MOU) between the Corps, Virginia Power and the North Carolina Wildlife Resources Commission. This is not correct. Augmentation flows began on April 12 in 1988, yet the Recommendation Subcommittee did not make its recommendations with respect to the regime until June 23, 1988. The augmentation flows for 1988 were made pursuant to the MOU, not according to the Flow Committee's recommendations; the Wilmington District of the Corps, which is responsible for making the augmentation releases, has indicated this in an October 5, 1988 memo to the Norfolk District, and has indicated it to the Flow Committee on numerous occasions, including the Committee's August 11, 1988 meeting and during the comment period for reviewing this draft document.

The peer review process for the Committee's reports is inadequate. Internal review only by authors of the various report sections does not allow for appropriate, unbiased scientific analysis. All interested parties, such as Virginia Beach, should be permitted to review and comment on the draft document. Scientists from other geographic areas removed from the system should be solicited for review and comment. In addition, there is at least one section of the draft report ("Interpretation of Hydrological Events on Watershed Resources") that apparently will not be subject to review by even the full Committee membership before the final report is printed. To present conclusions or recommendations in such sections as having been reviewed and accepted by the Committee would be misleading and inappropriate.

The City would like the opportunity to offer further comments of a technical nature, but we are unable to do so because we have not been permitted to study the actual document. We respectfully request that in the future, review by all interested parties and other outside scientists be encouraged by the Committee.

Sincerely,

Rita Sweet for

Thomas M. Leahy, III, P.E.
Water Resources Engineer

EAST CAROLINA UNIVERSITY

GREENVILLE, NORTH CAROLINA 27858-4353

INSTITUTE FOR COASTAL
AND MARINE RESOURCES

(919) 757-6779

21 April 1990

Ms. Rita Sweet
(for Thomas M. Leahy, III, P.E.)
City of Virginia Beach
Public Utilities Department
Water Resources Division
Municipal Center
Virginia Beach, Virginia 23456-9002

re: RRWFC Report for 1988-1989

Dear Ms. Sweet:

Thank you for submitting comments to the Roanoke River Water Flow Committee concerning our report for 1988-1989. You have requested that this document be placed in the Appendix to the report. Although I gave a directive to Committee members stating that no materials submitted after 18 April would be allowed, I have elected on behalf of the Committee to include your comments in the report (even though I received your materials by Telefax on 20 April).

I think that it is important and appropriate to address the concerns outlined in your comments of 20 April. Below, I have tried to respond to each of your points in the same order as it appeared in your letter.

1). In the first paragraph, you state that, at Dr. Manooch's suggestion, your comments should "be included in the record for the report, and be attached as an appendix to the final version". This suggestion by Dr. Manooch was intended to allow you the opportunity to comment on the final published manuscript, not a draft manuscript; your comments would then be published in next year's (1991) report. An appropriate response by your department would have been to submit comments to the Committee concerning the original report (Manooch and Rulifson 1989) for inclusion into the 1988-1989 report. However, no comments about the original report by your department were received by the Committee.

2). In the second paragraph, you state that we denied your request to provide the draft copy to you for review. You are correct in your statement, but the denial was not for the reasons alluded to in your statement. The ethics of science dictate that a scientific manuscript with original data should not be released outside of the peer review process. There are several reasons for this practice. There is always the chance that someone will obtain a draft copy of a manuscript and plagiarize or steal original data and ideas. Another reason is that a draft manuscript is not final until all authors have carefully reviewed and revised the information; consequently, numbers and text can change between a rough copy and final published text. To summarize, the practice of supplying draft manuscripts for scrutiny outside of the peer review process is not practiced by any scientific publisher or journal editor.

3). In your third paragraph, you dispute the Committee's claim that "the flows released during the spring of 1988 implemented the Committee's recommended regime, rather than the regime specified in the ...(MOU) between the Corps, Virginia Power, and the North Carolina Wildlife Resources Commission". I refer you to Page 19 of the 1988-1989 report (this document), which discusses the sequence of events in the spring of 1988. In April 1988, a Committee meeting was held in Beaufort, NC at which a discussion ensued about the early spawning activity of striped bass in the River. Committee members asked the Corps and Virginia Power if they were willing to attempt regulation of flows in accordance with the flow guidelines under discussion at the time (but which had not been formally adopted). These two parties agreed that they could attempt to comply with this request within the existing MOU. This trial flow regime was implemented on 12 April 1988. Please refer to the letter from H.W. Adams, Jr., of Virginia Power Company dated 6 March 1989, which is presented in this document. You are correct in stating that the formal adoption of the Committee's recommended (negotiated) flow regime was on 23 June 1988.

4). In paragraph four of your 20 April comments, you state that the "peer review process for the Committee's reports is inadequate". Editors of scientific journals select three, or at most five, peer researchers to examine a manuscript for potential publication. In the case of the Committee's reports, a minimum of 27 researchers review the manuscript. These reviewers are members of the Committee, a few of which are authors, and others not associated with the report. A total of 23 referees are from the Committee, representing four State agencies, three Federal agencies (including the U.S. Army Corps of Engineers), university scientists, private consultants, and representatives of industry. The NOAA Technical Memorandum Series mandates that an additional three people (not affiliated with our work) at the Southeast Fisheries Center review the document prior to publication, and at least one person in Miami must review it before it is finalized. Also, information in the report can be published by the individual authors in the primary literature, which subjects the work to additional peer review. We believe that the peer review process for our work is more rigorous than required by the scientific community.

5). At the end of paragraph four, you raise concern that a section entitled "Interpretation of Hydrological Events on Watershed Resources" will not be subjected to peer review prior to publication. Please note that there is no section of this document bearing that title, although we had hoped that we could write the section in time for distribution. However, time did not permit the writing of the text and therefore the section was never included. All sections of this report, with the exceptions of the Literature Cited and Appendices, were distributed to all members of the Committee for review.

I hope that this letter has addressed your concerns adequately. May I suggest that your department provide the Committee with any comments you might have concerning the Manooch and Rulifson (1989) report, or this document, after you have had the opportunity to review the published documents. You should have a copy of the first report, and we will provide your department with this document when it becomes available. Your comments, along with those of other agencies or organizations, could be incorporated into next year's (1991) report. Please keep in mind when submitting comments that all work done by the Committee is voluntary, and publication funds are limited, so try and keep comments to only several pages.

Sincerely,

Roger A. Rulifson

Roger A. Rulifson, Ph.D.
Co-Chair, Roanoke River Water Flow Committee

cc: Dr. C.S. Manooch, III

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Fisheries Center
Beaufort Laboratory
Beaufort, N.C. 28516-9722

April 23, 1990

Mr. Thomas M. Leahy, III
City of Virginia Beach
Public Utilities Department
Water Resources Division
Municipal Center
Virginia Beach, VA 23456-9002

Dear Mr. Leahy:

Thank you for your letter of April 20 in which you express concern over the "Roanoke River Water Flow Committee Report for 1988-1989". As you are aware, the report is in a state of preparation. Since Dr. Roger Rulifson is senior editor of the report, he has agreed to respond in detail to your letter. He should do so in a few days.

There is one issue that you raise, however, that refers directly to the National Marine Fisheries Service and I feel obligated to address it. That is, the City of Virginia Beach's Freedom of Information Act request to the National Marine Fisheries Service and subsequent visit to the Beaufort Laboratory on April 11-12, 1990. As you point out in your letter, I did not allow the City's representatives to copy the Committee's draft report. My action was predicated by my telephone conversations with U.S. Department of Commerce General Counsel. My understanding is that a draft manuscript does not constitute a government agency record, and is therefore exempt under the Freedom of Information Act. In particular, the draft that you requested to copy had not been reviewed by the Committee members, including those who had submitted written sections, and in some cases, original data and analyses. To release the draft prior to the authors' review and approval would unquestionably exceed the ethical authority of an editor. You will recall that the basis for the denial was discussed in detail with the City's attorney during his visit to Beaufort.

If you desire, I will be happy to send you a copy of the report after the authors' comments have been incorporated in the edited version. This will be prior to printing.

Sincerely,

Charles S. Manooch, III
Co-Chairman, Roanoke River
Water Flow Committee