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VOLUME 2
of the
LOWER ST. JOHNS RIVER BASIN
RECONNAISSANCE

SURFACE WATER HYDROLOGY

by

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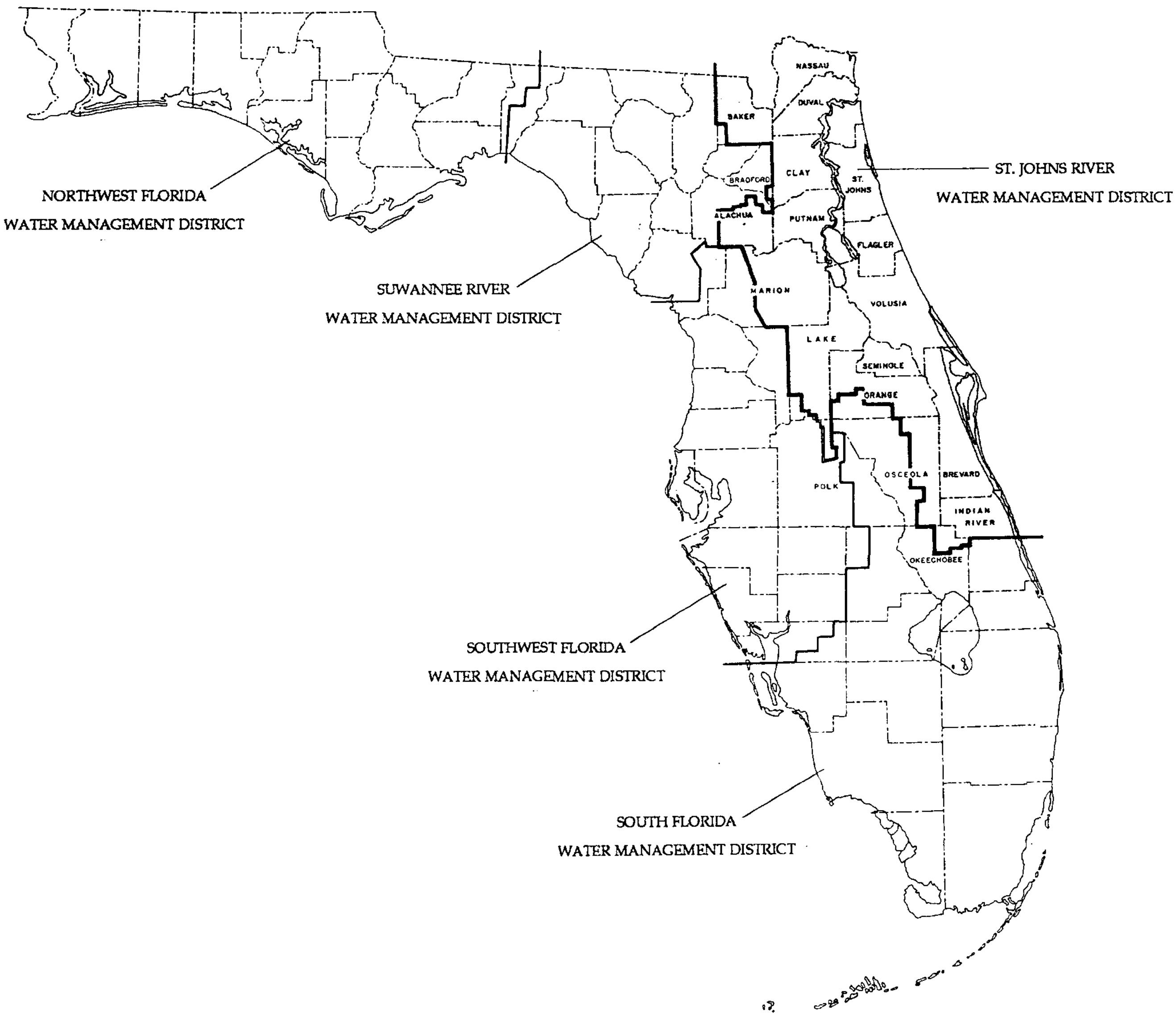

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

The St. Johns River Water Management District (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or parts of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management. Technical reports are published to disseminate information collected by SJRWMD in pursuit of its mission.

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ABSTRACT

This report is Volume 2 in a series of reconnaissance reports about the lower St. Johns River surface water drainage basin. The lower St. Johns River is the northern part of the St. Johns River from the mouth of the Oklawaha River in Putnam County to the inlet at the Atlantic Ocean in Duval County. The drainage basin includes parts of nine counties in northeast Florida. The reconnaissance reports compile information and recommendations that should help resource managers identify priority needs for research into and management of the lower St. Johns River basin. They are part of research funded under the Surface Water Improvement and Management Act of 1987 (Florida Statutes 373.451-373.4595).

This volume gives an overview of the surface water system and the existing rainfall and streamflow monitoring networks in the lower St. Johns River basin.

There are 17 permanent NOAA stations in or near the basin. Four of these stations collect or have collected in the past hourly rainfall data—Marineland (outside the basin), Jacksonville Airport (Broward River tributary basin), Jacksonville (St. Johns River tributary basin), and Raiford State Prison (outside the basin). An additional 11 temporary stations were installed in Duval County during the period 1989-90 to assist in the data collection for the calibration of water quantity and water quality models, which are being developed within the framework of the Master Stormwater Management Plan for the City of Jacksonville. Outside Duval County, McCullough Creek and Deep Creek tributary basins need at least one rainfall station each, and Sixmile Creek tributary basin needs three rainfall stations.

There are 18 long-term USGS stage recorders in the basin. An additional 14 temporary stage/discharge recorders were installed in Duval County in 1989-90 to assist in the data collection for the calibration of water quantity and water quality models, which are being developed within the

framework of the Master Stormwater Management Plan for the City of Jacksonville.

No evaporation data are being collected in the basin. The nearest pan evaporation station is located in Gainesville. Additional pan evaporation stations are needed in the basin for long-term observations.

INTRODUCTION

This report is Volume 2 in a series of reconnaissance reports about the lower St. Johns River basin. This compilation of information and recommendations should provide resource managers with a basis for identifying priority needs for future research and actions regarding the lower St. Johns River basin. The reconnaissance reports are part of the research funded under the Surface Water Improvement and Management (SWIM) Act of 1987 (*Florida Statutes* 373.451-373.4595).

The SWIM Act declares that many natural surface water systems in Florida have been or are in danger of becoming degraded from point and nonpoint sources of pollution and from the destruction of natural systems. The state's five water management districts, in cooperation with state agencies and local governments, were directed to set priorities for waterbodies of regional or statewide significance and to design plans for surface water improvement and management. Six waterbodies were named for immediate action, including the lower St. Johns River basin (LSJRB).

The LSJRB is one of ten surface water hydrologic planning units (Figure 1) of the St. Johns River Water Management District (SJRWMD). The basin is located in northeast Florida, representing about 22 percent of the area within the boundaries of the SJRWMD. The LSJRB extends from the City of De Land, in the south, to the inlet of the St. Johns River at the Atlantic Ocean. The primary counties within the basin are Clay, Duval, Flagler, Putnam, St. Johns, and Volusia (Figure 2). A minute portion of the LSJRB lies in Alachua, Baker, and Bradford counties.

The LSJRB is located in a transition area between the subtropical climate of southern Florida and the humid continental climate of the southeastern United States. The climate of the basin is classified as humid subtropical, with an average summer maximum daily temperature of 32.2°C (90°F). In the winter, the LSJRB experiences below freezing temperatures an average of 10-15

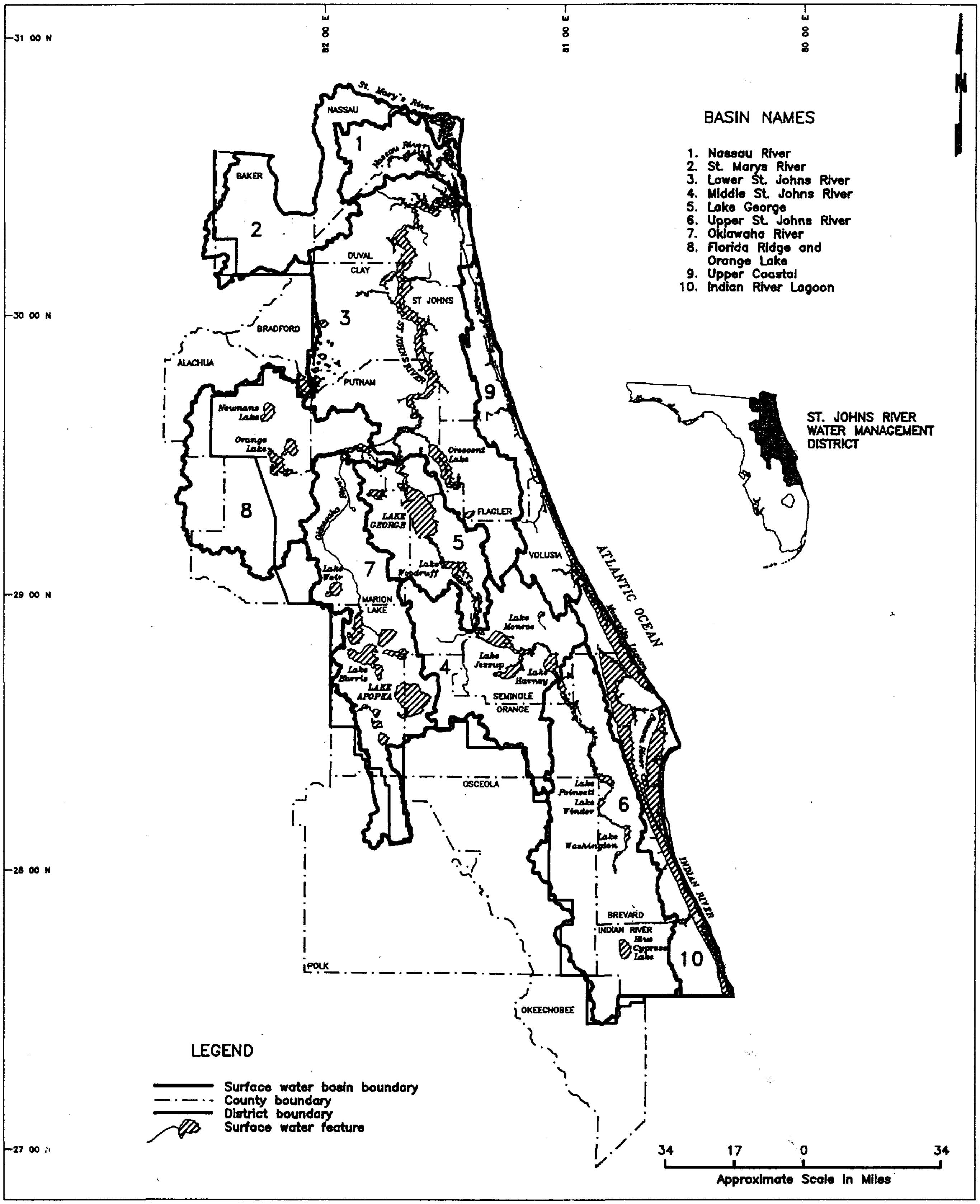


FIGURE 1

Major surface water basins within the St. Johns River Water Management District

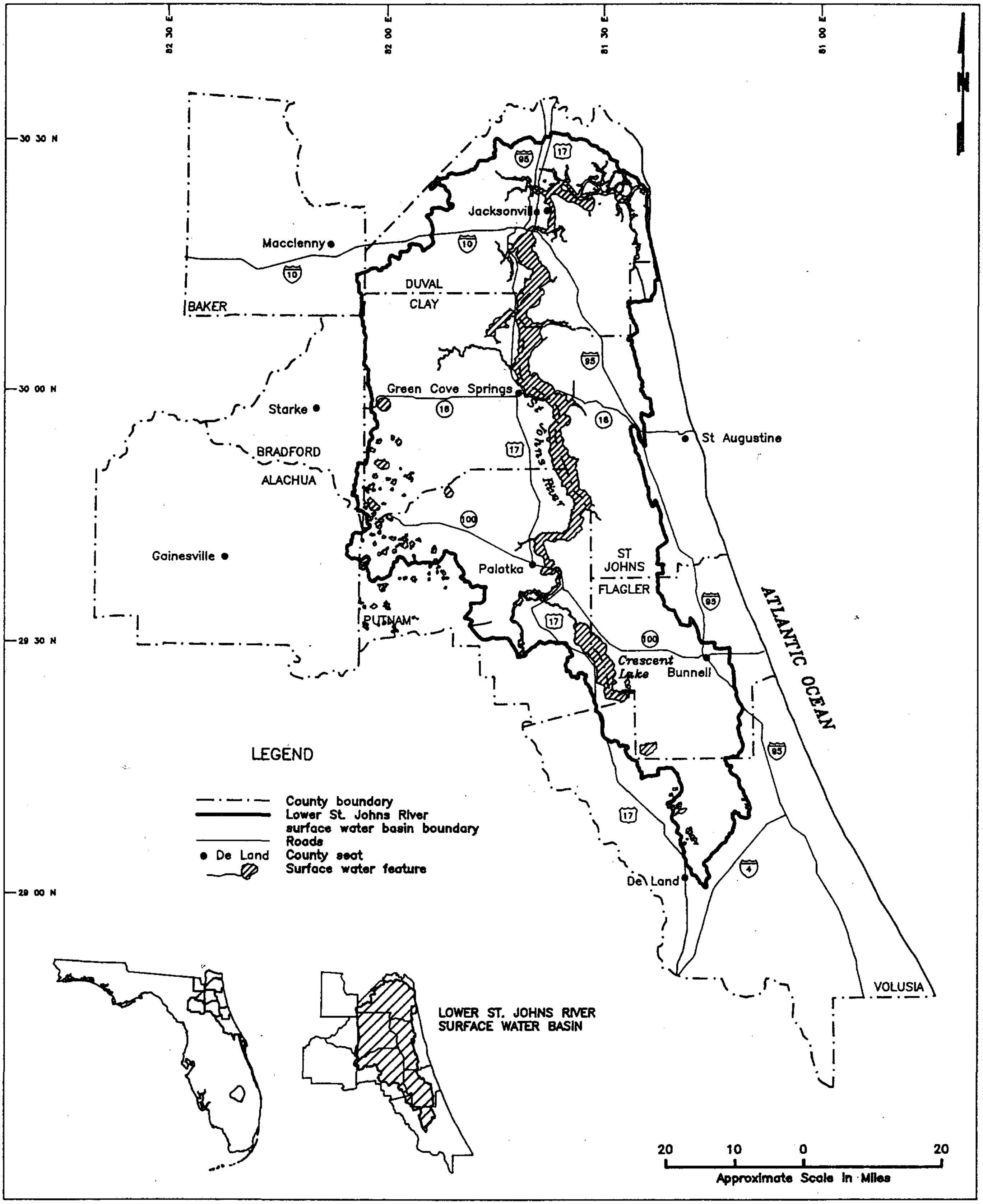


FIGURE 2

Lower St. Johns River surface water basin times per year. Average annual rainfall in the basin is approximately 132 cm (52 in). A large portion of the annual precipitation falls between June and September when convective activity generates showers and thunderstorms.

Landscape features within the lower basin are relatively low and flat. Three ridge systems border the drainage area. Surface elevations range from sea level at the inlet to greater than 61 m (200 ft) in the western part of the basin.

The St. Johns River is an elongated, shallow estuary with an extensive floodplain. The elevation of its headwaters near Blue Cypress Lake is less than 7.62 m (25 ft) above sea level, and the average gradient of the main river channel is only .022 m per km (0.1 ft per mile). Average annual tidal amplitude is 1.5 m (4.9 ft) at the ocean inlet and varies unequally upstream because of channel morphology. However, due to the low gradient of the river, tides affect the entire LSJRB along with the lower reaches of its tributaries. The mixing of salt water and fresh water has an influence on water quality as well as the quantity and characteristics of sediments deposited in the basin. Water quality conditions for the LSJRB range from good in the sparsely populated southern end of the basin to poor in the urban reaches of Jacksonville.

The basin is drained by 12 major tributaries. The drainage basins of the tributaries are called tributary basins (Figure 3) and bear the name of the major tributary flowing through them. A thirteenth tributary basin (the St. Johns River tributary basin) represents the minor tributaries draining directly into the St. Johns River.

For reasons of organization, planning, and management, the SJRWMD has divided the lower St. Johns River basin into three SWIM planning regions: North, East, and West (Figure 4, Campbell et al. 1989a, Campbell et al. 1989b).

Planning Region	Tributary Basins
North	Ortega River, Trout River, Broward River, Dunn Creek, Arlington River, Julington Creek, and northern portion of St. Johns River tributary basin
East	Crescent Lake, Deep Creek, McCullough Creek, Sixmile Creek, and southeastern portion of St. Johns River tributary basin
West	Etonia Creek, Black Creek, and western portion of St. Johns River tributary basin

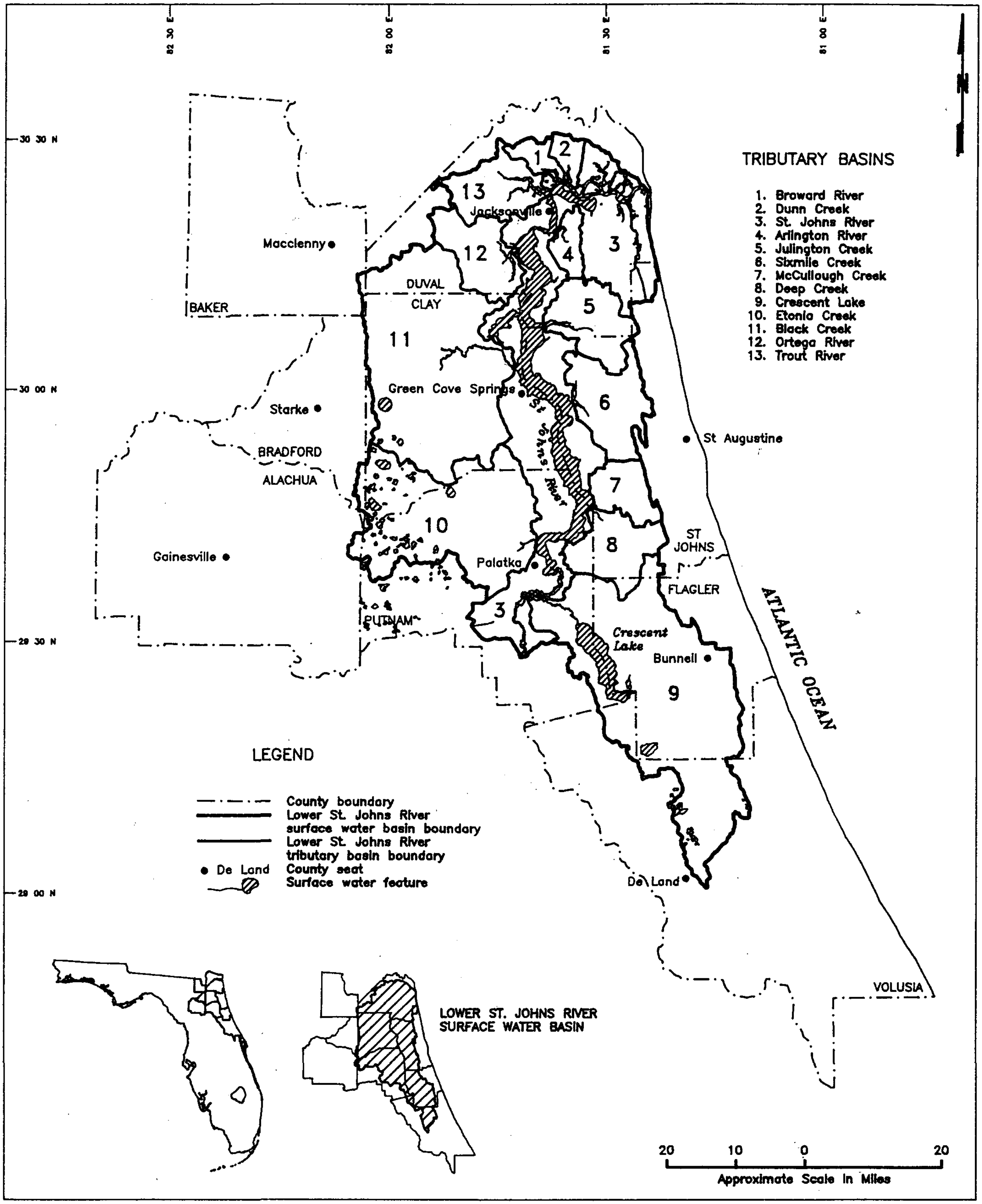


FIGURE 3

Lower St. Johns River surface water tributary basins

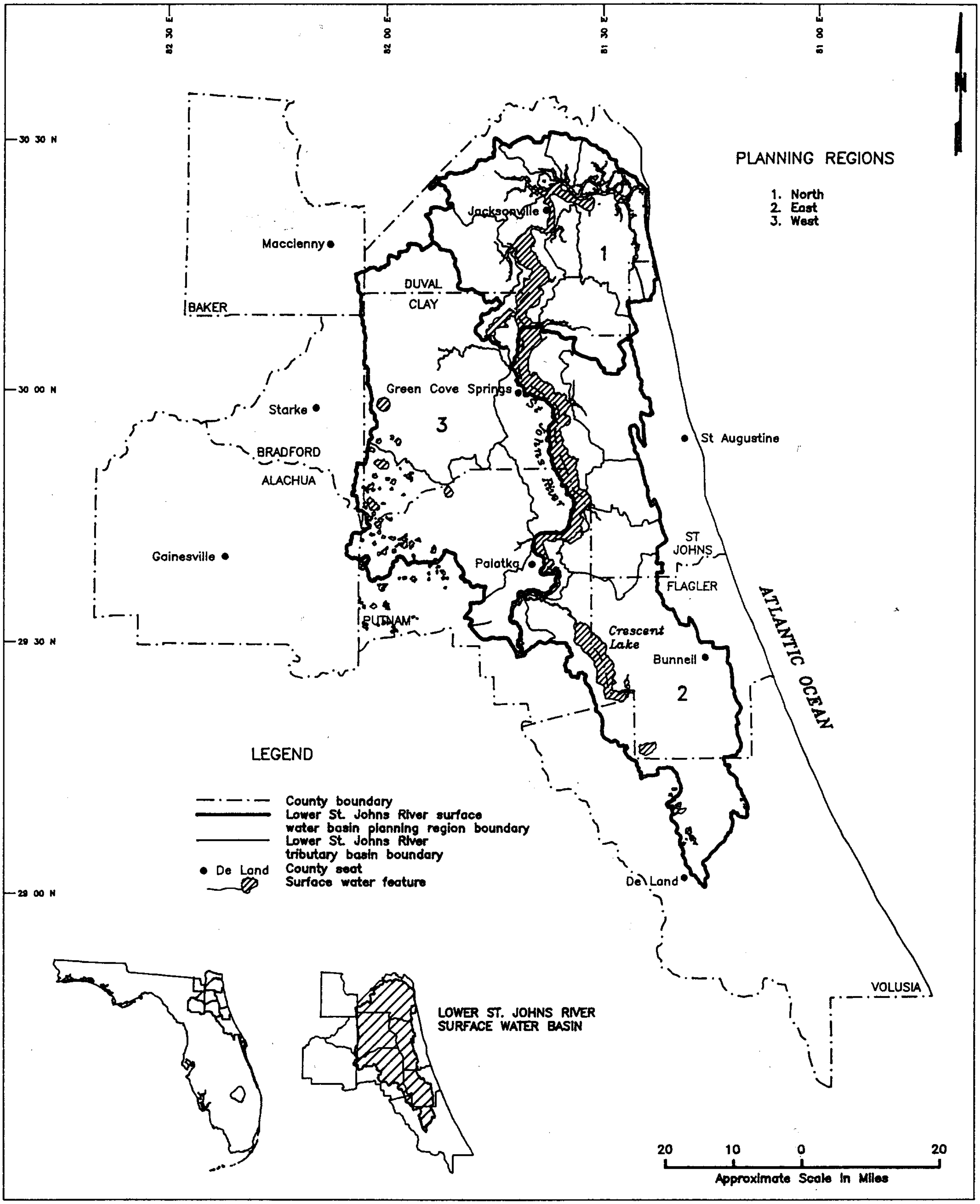


FIGURE 4

Lower St. Johns River surface water basin planning regions

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

The *Lower St. Johns River Basin Reconnaissance Report* provides a synthesis of what is known about the condition of the lower St. Johns River and its tributaries from three perspectives: hydrologic, environmental, and socioeconomic. Volume 1, *Basin Hydrogeology,* presents information on the ground water system in the basin and its connection to surface waterbodies. Volume 2, *Surface Water Hydrology,* discusses the surface water system, including hydrologic and hydraulic data collection networks. Volume 3, *Hydrodynamics of Surface Water,* describes relationships between river water levels, velocity, flow, storage, and salinity and reviews previous hydrodynamic modeling studies. Volume 4, *Surface Water Quality,* and Volume 5, *River Sediment Characteristics and Quality,* present details on the levels and trends of chemical contaminants present in the water column and in the bottom sediments. Volume 6, *Biological Resources,* describes plant communities and fish, shellfish, and marine animal communities. Volume 7, *Population, Land Use, and Water Use,* ties population estimates and projections to land use and residential, commercial, industrial, and agricultural water use. Volume 8, *Economic Values,* discusses the commercial, recreational, and aesthetic values of the river. Finally, Volume 9, *Intergovernmental Management,* discusses jurisdictional boundaries, regulatory authorities, and management efforts of governmental agencies, offices, and commissions involved in restoration or protection of water quality and habitat.

This volume, *Surface Water Hydrology,* assesses the availability and quality of existing surface water quantity data in the lower St. Johns River basin, identifies hydrologic problems in the various tributary systems, and lays the foundation for developing hydrologic models that are needed for formulating possible solutions.

The following sets of data are assessed:

- Physiographic data. Topography, soils, and basin drainage areas.
- Hydrologic data. These include streamflow, rainfall, and evaporation.
- Hydraulic data. Locations and dimensions of hydraulic structures and information on flooding.

Under the SWIM Act, the District, in cooperation with the City of Jacksonville, has initiated a Master Stormwater Management Plan (MSMP) to improve the water quantity and water quality conditions in the lower St. Johns River basin. There are several phases to the MSMP:

- In phase 1, reconnaissance studies will assess the extent and severity of water quality and water quantity problems in the basin and determine the availability and quality of hydrologic, environmental, and biological data. This report is part of phase 1.

- In phase 2, computer simulation models will be developed and used to assess, evaluate, and quantify problems related to water quantity and water quality; regional stormwater management alternatives will be evaluated and recommended.

- In phase 3, stormwater management improvements will be designed and implemented in order to restore and maintain surface waterbodies.

This reconnaissance report on surface water hydrology is part of the Phase I MSMP project. This volume of the reconnaissance report has five sections:

1. An introduction to the physiographic and surface drainage features of the lower St. Johns River basin

2. A discussion of the hydrologic and hydraulic data that have been collected in the study area

3. A discussion of the rainfall-runoff process and an evaluation of various computer models to simulate this process in LSJRB

4. An example of statistical data analysis for one of the streamflow records in the study area.

5. A summary and a list of recommendations

GENERAL BASIN DESCRIPTION

PHYSIOGRAPHY

An extensive description of the physiographic features of the State of Florida is given by Brooks (1981). Two major physiographic sections are associated with the LSJRB: the Atlantic Coastal Plain Section in the northeast and the Florida Section in the remaining part of the basin (Brooks 1981). A subdivision of the Atlantic Coastal Plain Section is the Sea Island District (Figure 2.1). It includes almost all of Duval County, all of Clay County except for the southwestern part (Keystone Heights area), and the northern part of St. Johns County. The remainder of the LSJRB lies within two subdivisions of the Florida Section, namely the Eastern Flatwoods District and the Central Lake District (Brooks 1981).

Sea Island District

Brooks (1981) differentiates between the following physiographic subdistricts: the Okefenokee Upland, the Duval Upland, and the Northern Coastal Strip.

The Okefenokee Upland. This subdistrict includes the Trail Ridge, which is a depositional ridge with very gentle westward slope and a more pronounced eastward slope (Brooks 1981). Elevations are up to 240 ft. Streams originating on the Trail Ridge include the North and South forks of Black Creek and Etonia Creek.

The Duval Upland. This subdistrict is subdivided into the St. Marys Upland, the Black Creek Basin, and the Penney Farms Upland. St. Marys Upland consists mainly of flatwoods. Typical elevations range from 70 to 100 ft above mean sea level. The Black Creek Basin is an erosional river valley partially backfilled with late Pleistocene estuarine deposits (Brooks 1981).

Flatwoods and swamps are other features of its physiography. Elevations range from 20 to 25 ft. The Penney Farms Upland is part of the drainage basins of Black Creek and Etonia Creek. Elevations are slightly over 100 ft.

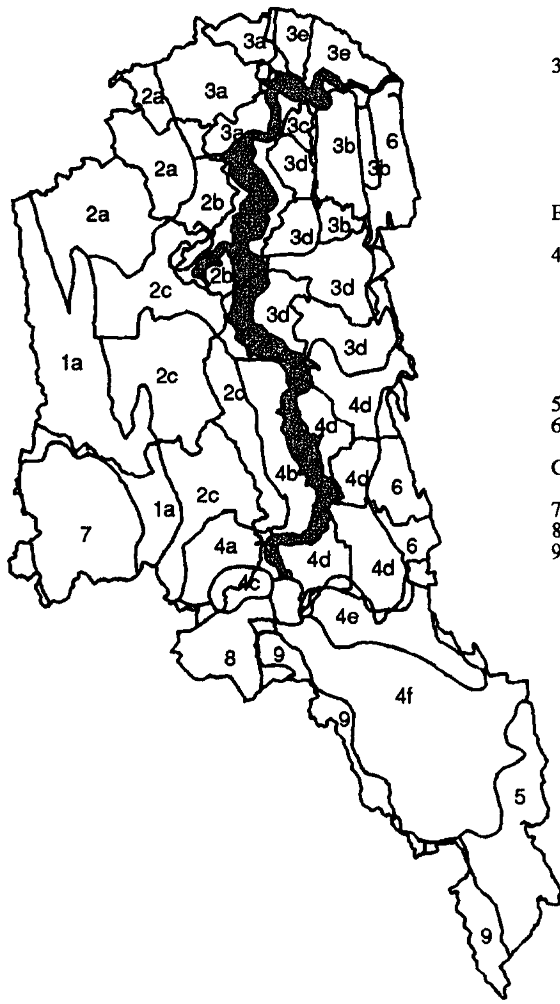
The Northern Coastal Strip. This subdistrict includes the eastern and central parts of Duval County and the northern tip of St. Johns County. In general, elevations range from sea level to approximately 30 ft, although there are a few exceptions. For instance, in the Dinsmore Plain, located north of Jacksonville, elevations may be as high as 95 ft at some spots. In the Fort Caroline Ridge Set, located west of the Intracoastal Waterway between Jacksonville and Jacksonville Beach, elevations are up to 72 ft. In the Arlington Plain, a moderately drained plain north of Arlington in Duval County, elevations range from 40 to 50 ft. The Mandarin Plain is located east of the St. Johns River and is part of the drainage basins of Arlington River and Julington Creek. Elevations range from 20 to 30 ft, and the area is covered with flatwoods and river swamps. The Sea Islands, which is another subdivision of the Northern Coastal Strip, is located north of the St. Johns River in the northeastern part of Duval County. Elevations are at or about present mean high tide (Brooks 1981).

The Eastern Flatwoods District

This physiographic district, belonging to the Florida Section, covers the eastern part of the LSJRB. According to Brooks (1981), elevations in the Eastern Flatwoods are less than 90 ft. It originated as a sequence of barrier islands and lagoons during Plio-Pleistocene and Recent time.

The Palatka Anomalies. This subdistrict covers approximately the area between the cities of Palatka, Green Cove Springs, Bunnell, and Lake Disston. Named subdivisions are: Rice Creek Swamp, the Bostwick Terrace, the Palatka Relic Hills, the Hastings Plain, the Roy Divide, and the Crescent Lake drainage basin (Brooks 1981).

The Volusia Ridge Sets. Brooks (1981) describes this subdistrict as "accreted coastal deposits consisting of four distinct parts, a flatwoods plain of subdued beach ridge sets, typically about 40 ft in elevation (the Talbot Terrace), an eastern boundary sand ridge with a crest typically at 46 ft elevation, an eastern set of beach ridges forming a flatwoods plain 25 to 30 ft



PHYSIOGRAPHIC FEATURES

Sea Island District

1 Okefenokee Upland
  a Trail ridge
2 Duval Upland
  a St. Marys Upland
  b Black Creek Basin
  c Penney Farms Upland
3 Northern Coastal Strip
  a Dinsmore Plain
  b Ft. Caroline Ridge Set
  c Arlington Plain
  d Mandarin Plain
  e Sea Islands

Eastern Flatwoods District

4 Palatka Anomalies
  a Rice Creek Swamp
  b Bostwick Terrace
  c Palatka Relic Hills
  d Hastings Plain
  e Roy Divide
  f Crescent Lake Basin
5 Volusia Ridge Sets
6 St. Augustine Ridge Sets

Central Lake District

7 Interlachen Sand Hills
8 St. Johns Offset
9 Crescent City-De Land Ridge

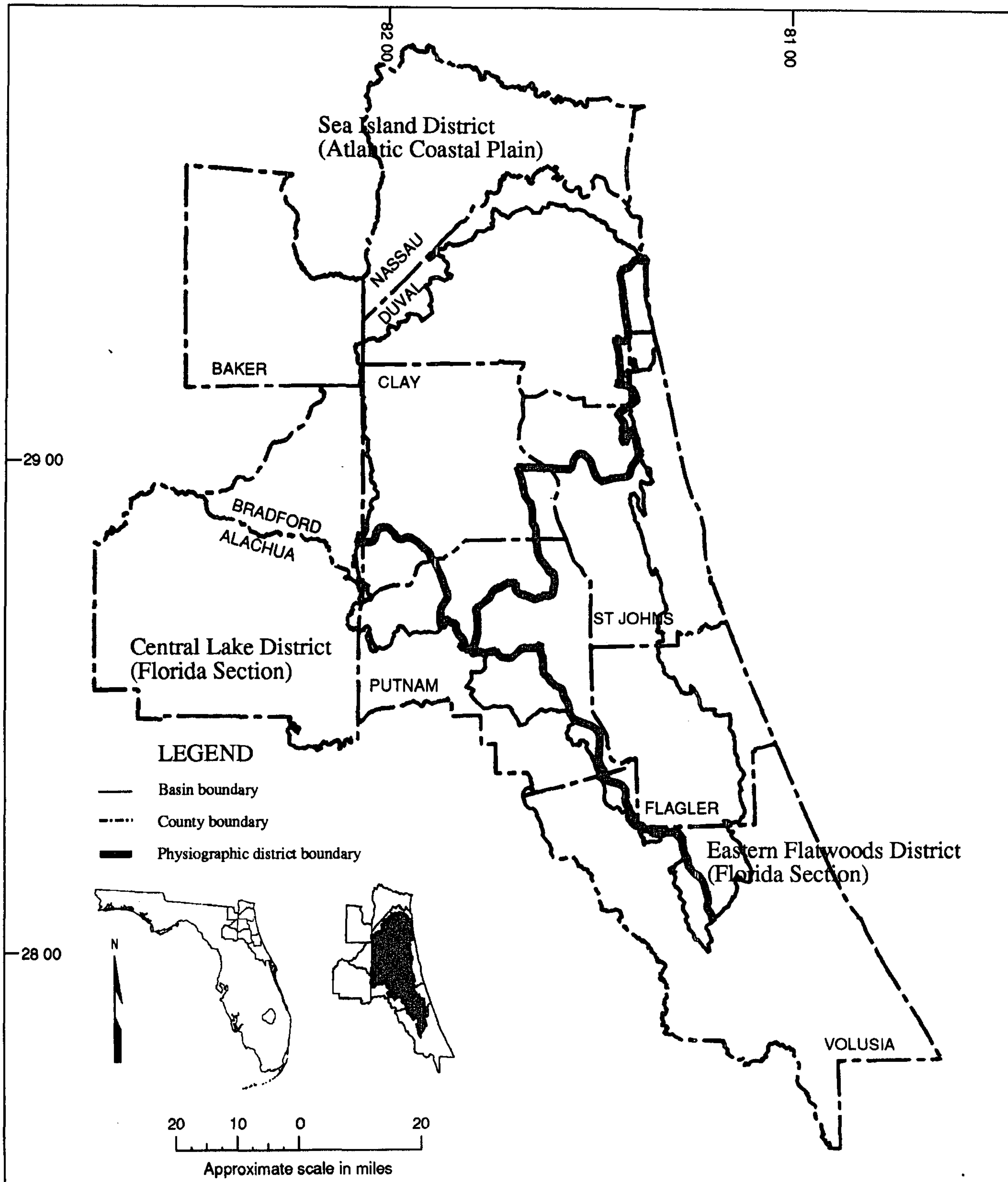


FIGURE 2.1

Physiographic features of the lower St. Johns River basin
Source: Brooks 1981

in elevation (the Pamlico Terrace) and the high coastal ridge (the Atlantic Coastal Ridge) that is up to 55 ft in elevation."

The St. Augustine Ridge Sets. Only the western portion of this subdistrict is located in the LSJRB. It is the remaining part of a barrier island. Elevations range from 30 to 50 ft. The swales contain cypress stands and the low ridges are covered by flatwoods (Brooks 1981).

The Central Lake District

The portion of the Central Lake District associated with the LSJRB, extends from Keystone Heights via Interlachen to De Land. It is an area with karstic features and sinkhole development. It is also a recharge area of the Floridan aquifer. Subdistricts are: the Interlachen Sand Hills, the St. Johns Offset, and the Crescent City-De Land Ridge.

The Interlachen Sand Hills. The Interlachen Sand Hills extend from the city of Interlachen to Keystone Heights. Many lakes are located in this area, with Lake Geneva as one of the bigger ones. There exists a direct hydraulic connection with the Floridan aquifer through thick sand and gravel deposits. Elevations are up to 220 ft (Brooks 1981).

The St. Johns Offset. This subdistrict is an ancient portion of the St. Johns River valley. "It is partially filled with Pleistocene estuarine deposits. The Eocene limestone is very near the surface and solution has contributed to the development of the broad valley" (Brooks 1981). Several large springs are active near Salt Springs. Flatwoods and swamp forests are predominant.

The Crescent City-De Land Ridge. This subdistrict is a sand deposit with summits generally between 80 and 100 ft in elevation. It rests directly upon the Floridan aquifer (Brooks 1981).

SOILS

Detailed soil surveys were developed by the Soil Conservation Service of the U.S. Department of Agriculture (SCS) for Duval, St. Johns, Volusia, and

Putnam counties. Soil mappings in Clay and Flagler counties have been completed and are awaiting publication.

The soils in the LSJRB range from well-drained sandy soils on the ridges to very poorly drained, acidic, peat and muck soils in marshes and swamps (U.S. Army Corps of Engineers 1986). Based on drainage characteristics, the soils in the LSJRB can be differentiated into the following broad groupings (Fernald and Patton 1984):

- Soils of the Central Ridge

These soils are dominated by nearly level to sloping, excessively drained thick sands, occurring in Clay and Putnam counties, and in the western part of Volusia County. They are primarily used for field crops, tobacco, watermelons, and forest products.

- Soils of the Flatwoods

These soils consist for the most part of somewhat poorly to poorly drained soils with dark, sandy subsoil layers. They occur in parts of Duval and Clay counties, and the eastern portion of the LSJRB. They are mostly used for pastures, vegetables, flowers, and forestry.

- Soils of Organic Origin

These are mostly level, very poorly drained organic soils, underlain by marl and/or limestone. They are primarily used for pastures and vegetables and are very poor for homesites and urban developments. Their locations are scattered throughout Florida, but in the LSJRB they can be found in St. Johns and Putnam counties.

CLIMATE

Precipitation

Most precipitation in the LSJRB falls during the summer from June through September. During this period, rainfall occurs mostly in association with convectional activity and averages about 26 in., which accounts for about half of the average annual basin rainfall. During the winter, rainfall is generally associated with frontal activity as the result of large scale weather developments. As a consequence, winter rainfalls may persist for days and usually affect larger areas than the summer showers. Average rainfall in the basin for the period December through March is about 12.5 in. Some occurrences of snow in the LSJRB have been recorded. The total annual rainfall in the LSJRB shows a trend of increasing in an inland direction (Jenab et al. 1986).

Tropical storms affect the LSJRB usually during the late summer and early fall at irregular intervals. These storms may have rain areas as large as 300 miles across and move relatively slowly.

Periods of prolonged drought are of particular importance. Analysis of rainfall records over the period 1951-1980 for six different locations in Florida shows that droughts occur mostly in the off-summer months (Fernald and Patton 1984). In mid-summer, periods of fifteen or more dry days (no more than 0.1 in. on any day) are very rare.

Winds

Winds in the lower St. Johns River basin are generally from the northeast during September through January, and from the southeast or southwest during February through August. Average monthly wind speeds range from 6-10 miles per hour (mph), but winds of greater than 50 mph have been recorded during thunderstorm activity and tropical storms. Wind speeds greater than 74 mph are associated with hurricanes.

TRIBUTARY BASINS

In the following sections, a description is given of the thirteen tributary basins listed in Table 2.1. The description focuses on the major topographic and drainage features of each basin and details physiographic characteristics. See also CDM (1989). The hydrologic soil groups A, B, C, and D refer to the soil classification developed by the Soil Conservation Service (SCS 1972) (Table 2.2).

Table 2.1. Tributary basins in the lower St. Johns River basin

SURFACE DRAINAGE BASIN	AREA (SQ MI)	TRIBUTARY	LENGTH (MI)
Arlington River	32.4	Arlington River	1.9
		Pottsburg Creek	7.5
		Little Pottsburg Creek	3.2
		Strawberry Creek	3.3
		Silversmith Creek	2.1
		Red Bay Branch	1.9
Black Creek	496.5	Black Creek	13.3
		Bradley Creek	5.3
		Peters Creek	6.7
		Little Black Creek	10.1
		Double Branch	2.3
		North Prong	2.3
		South Prong	2.8
		North Fork Black Creek	28.2
		Big Branch	5.0
		Long Branch	4.2
		Yellow Water Creek	11.0
		South Fork Black Creek	22.3
		Bull Creek	8.5
		Greens Creek	10.7
		Ates Creek	10.5
Broward River	26.8	Broward River	4.0
		Cedar Creek	5.5
		Little Cedar Creek	4.2
Crescent Lake	605.0	Dunns Creek	8.5
		Haw Creek	4.8
		Middle Haw Creek	9.9
		Little Haw Creek	7.2
		Black Branch	3.8
Deep Creek	76.0	Deep Creek	10.4
		Sixteenmile Creek	7.0
Dunn Creek	23.3	Dunn Creek	2.0
		Terrapin Creek	0.8
		Rushing Creek	1.7
		Caney Branch	2.3
Etonia Creek	355.0	Rice Creek (Main)	6.4
		Etonia Creek	17.5
		Simms Creek	14.8
		Rice Creek	16.1
Julington Creek	104.3	Julington Creek	8.5
		Flora Branch	1.0
		Big Davis Creek	3.8
		Durbin Creek	4.0
		Sampson Creek	1.1
		Oldfield Creek	2.2
		Sweetwater Creek	2.2
McCullough Creek	61.8	McCullough Creek	3.2

Table 2.1. Continued

SURFACE DRAINAGE BASIN	AREA (SQ MI)	TRIBUTARY	LENGTH (MI)
Ortega River	99.2	Ortega River	16.0
		Fishing Creek	3.4
		McGirts Creek	7.4
		Cedar River	8.0
		Butcher Pen Creek	1.7
		Wills Branch	4.5
Sixmile Creek	121.8	Sixmile Creek	4.9
		Mill Creek	2.3
		Trout Creek	3.6
		Turnbull Creek	15.0
St. Johns River	210.0	Newcastle Creek	1.2
		Jones Creek	2.4
		Ginhouse Creek	2.9
		Mt. Pleasant Creek	5.0
		Tiger Pond Creek	1.6
		Greenfield Creek	5.0
		McCoy Creek	3.4
		Hogan Creek	2.4
		Long Branch	1.8
		Deer Creek	0.9
		Big Fishweir Creek	1.8
		Little Fishweir Creek	1.6
		Deep Bottom Creek	1.1
		Goodbys Creek	1.7
		Christopher Creek	1.4
		Craig Creek	1.7
		Miller Creek	1.0
		Governors Creek	8.4
		Clarkes Creek	7.6
		Cedar Creek	3.5
		Camp Branch	9.1
		Tocoi Creek	3.6
		Dog Branch	1.8
		Mill Branch	2.0
Trout River	94.0	Trout River	19.2
		Moncrief Creek	5.5
		Blockhouse Creek	2.7
		Half Creek	2.7
		Gulley Branch	1.8
		Little Trout River	1.8
		Ribault River	7.6
		Sixmile Creek	6.5
		West Branch	1.9

Source: SJRWMD 1977

Table 2.2 Major soil units in the lower St. Johns River basin, with categories of permeability

Soil Name	Category*
Alpine	B
Blanton	A
Chobee	D
Felda	B/D
Kershaw	A
Kureb	A
Leon	A/D
Mandarin	C
Mascotte	D
Meggett	D
Myakka	A/D
Olustee	B/D
Ortega	B
Pelham	B/D
Placid	A/D
Ridgeland	D
Sapelo	D
Surrency	B/D
Tavares	A
Tisonia	D
Wabassa	B/D
Wauchula	B/D
Wesconnett	D

* A = Very well drained
B = Moderately well drained
C = Somewhat poorly drained
D = Very poorly drained

Sources: SCS 1978, SCS 1972

Soils range from those in group A—well-drained soils (high infiltration rates)—to soils in group D—poorly drained soils (low infiltration rates).

Arlington River Basin (Figure 2.2)

The Arlington River tributary basin is located east of the St. Johns River near the City of Jacksonville. It covers an area of approximately 32 square miles with elevations ranging from 70 ft National Geodetic Vertical Datum (NGVD) to sea level (CDM 1989). Physiographically, it belongs to the Northern Coastal Strip. The Arlington River discharges into the St. Johns River at river mile 21.5. The Arlington River is in fact an estuary. The tributary system consists of Pottsburg Creek, which is the upstream continuation of the Arlington River, Little Pottsburg Creek, Strawberry Creek, and Red Bay Branch. The tides affecting Pottsburg Creek extend as far as Beach Boulevard (U.S. 90) in Jacksonville. One basin interconnection exists with the Julington Creek basin: the headwaters of Pottsburg Creek are hydraulically connected with the headwaters of Julington Creek via the Pottsburg Creek Swamp.

According to the SCS soil classification, soils within the basin belong to the Kershaw-Ortega, Leon-Ortega, and Leon-Ridgeland-Wesconnett groups (SCS 1972). Natural drainage of these soils ranges from excessively to moderately drained for the first group to poorly and very poorly drained for the third group (Table 2.2). Hydrologic soil group percentages are: 70 percent A soils, 2 percent B soils, and 28 percent D soils (CDM 1989).

Currently, about 50 percent of the basin's land consists of residential development. Predictions are that by the year 2010 it will be fully developed.

Recent FEMA (Federal Emergency Management Agency) studies along Strawberry Creek and Red Bay Branch indicate serious water quantity problems. Water quality problems are encountered along Strawberry Creek and Pottsburg Creek due to pollution loads from wastewater treatment plants and stormwater runoff (CDM 1989).

Black Creek Basin (Figure 2.3)

The Black Creek tributary basin is located west of the St. Johns River and discharges between Green Cove Springs and Doctors Lake. It lies almost

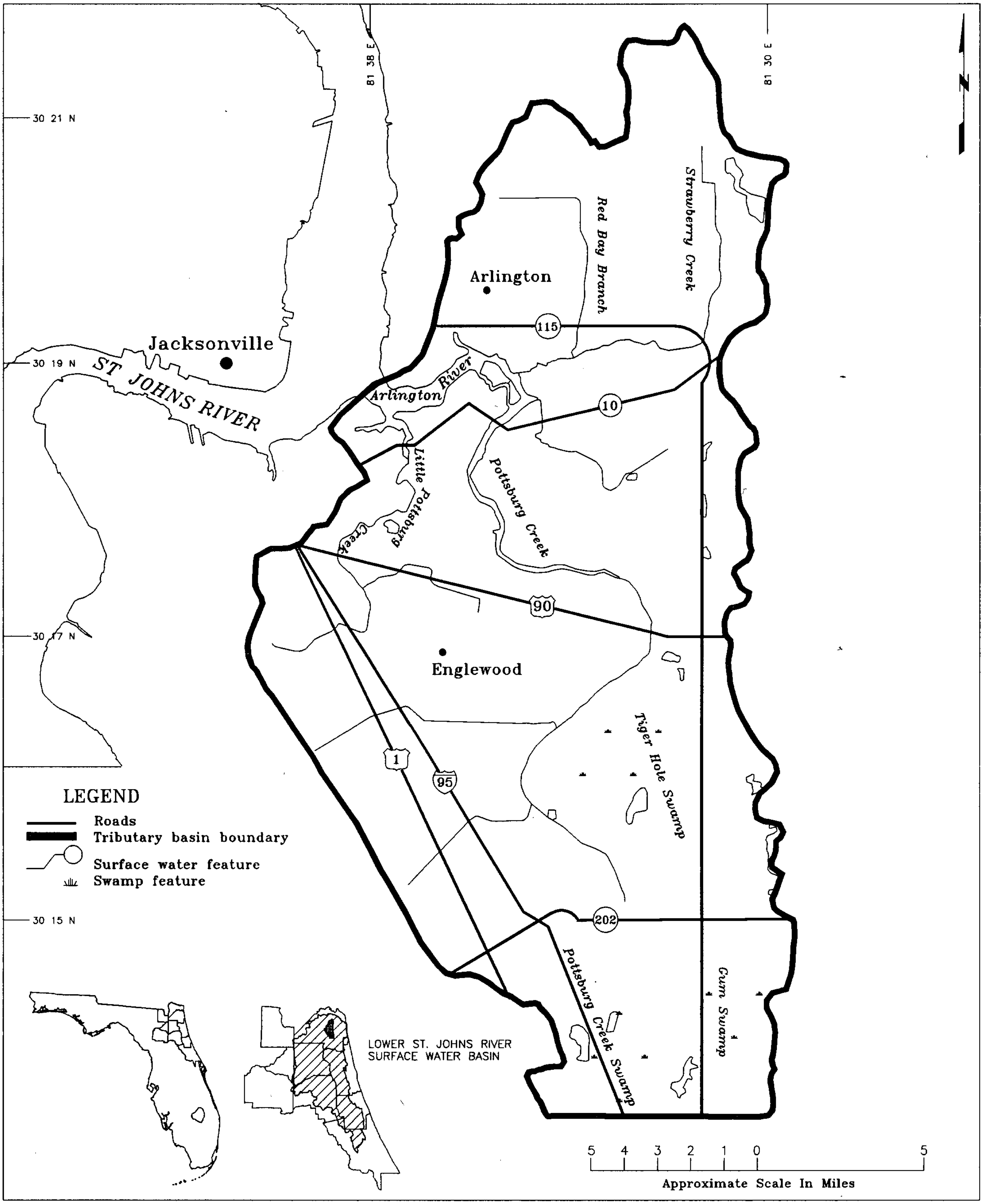


FIGURE 2.2

Arlington River tributary basin of the lower St. Johns River basin

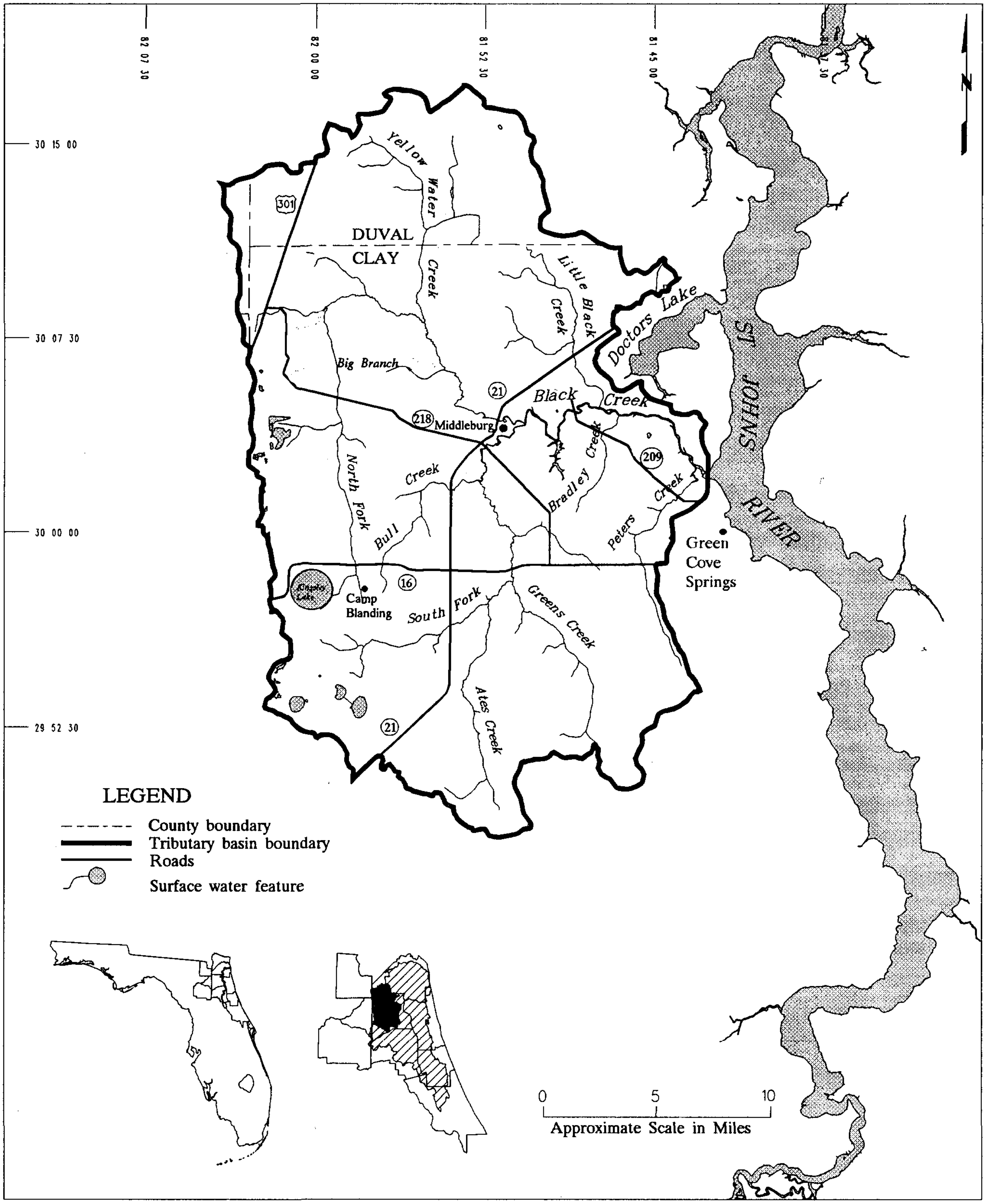


FIGURE 2.3

The Black Creek tributary basin of the lower St. Johns River basin entirely in Clay County. The total area approximates 496 square miles, with elevations ranging from sea level to 250 ft south of Kingsley Lake. Physiographically, it belongs to the Duval Upland. The headwaters of Black Creek originate on the Trail Ridge. Major tributaries are the North and South forks of Black Creek and Little Black Creek. The contributing areas of both forks are almost equal in magnitude: 195 square miles. The confluence of the North and South forks is located near Middleburg. From this point, the Black Creek runs an additional 13 miles before its mouth at the St. Johns River. Tidal effects are evident over the lower eight miles of the North Fork and South Fork.

Soils in the watershed, according to the SCS classification method, belong for a large part to the Mascotte-Leon-Surrency and the Alpon-Blanton series, although other types are also present. CDM (1989) reports 24 percent A soils, 24 percent B soils, and 52 percent D soils in the basin (Table 2.2).

CDM (1989) reports that the Black Creek basin is largely undeveloped. Predominant land uses are silviculture and natural vegetative cover.

Water quantity problems exist in the area of Middleburg, near the confluence of the South and North Forks. Some flooding occurred along the South Fork of Black Creek during the September 7, 1988 storm (U.S. Army Corps of Engineers 1988). Flooding was limited to the east bank of the stream.

<u>Broward River Basin (Figure 2.4)</u>

The Broward River tributary basin is located in the northern part of Duval County, extending in a southeastern direction from Jacksonville International Airport to its mouth at the St. Johns River between Drummond Point and Broward Point (CDM 1989). The drainage area approximates 27 square miles. Physiographically, it belongs to the Dinsmore Plain, which is a subdivision of the Northern Coastal Strip. The topography of the basin is rather flat, although at some locations elevations of 80 ft NGVD occur. Major tributaries are Cedar Creek and Little Cedar Creek. Cedar Creek is, in fact, the upstream extension of Broward River, while Little Cedar Creek joins Cedar Creek between Interstate 95 and U.S. Highway 17.

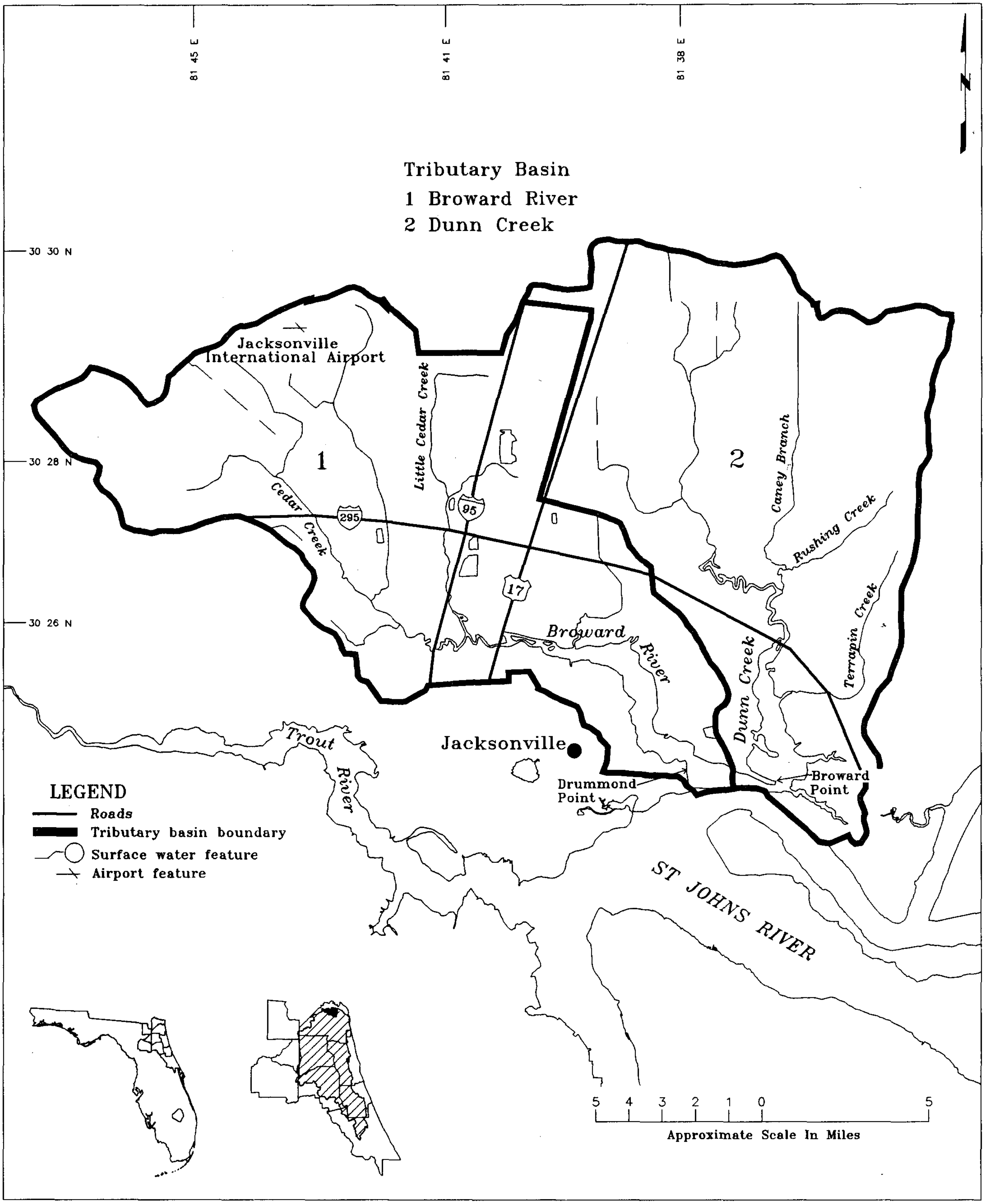


FIGURE 2.4

Broward River and Dunn Creek tributary basins of the lower St. Johns River basin

Soil types in the basin, according to the SCS classification, belong to the Kershaw-Ortega or the Pelham-Mascotte-Sapelo series. The first group can be found in the lower part of the basin, while the latter group is dominant in the upper part of the basin. According to CDM (1989) the hydrologic soil group classification in the basin is as follows: 38 percent A soils, 12 percent B soils, and 50 percent D soils (Table 2.2).

Jacksonville International Airport is one of the dominant land use features in the watershed, representing almost 15 percent of the basin. The remaining area is rather evenly distributed between residential, agricultural, industrial, and vacant land.

Flooding problems exist on both Cedar Creek and Little Cedar Creek, as indicated by recent FEMA studies. Water quality problems in the basin are rather serious due to numerous bacteriological water quality violations (CDM 1989). A major regional wastewater treatment plant (Cedar Bay) is located in the southern part of the basin.

Crescent Lake Basin (Figure 2.5)

The Crescent Lake basin is located east of the St. Johns River. Its discharge point into the St. Johns River is south of San Mateo, just downstream of Murphy Island. The watershed area is approximately 605 square miles and extends over parts of Putnam County, Flagler County, and Volusia County. It includes upland habitats (9.9%), inundated habitats (60.8%), and disturbed habitats (29.4%) (Frydenborg et al. 1990). Physiographically, the basin belongs to the Eastern Flatwoods District and the Central Lake District. Major subdistricts are the Palatka Anomalies, the Volusia Ridge Sets, and the Crescent City-De Land Ridge. The topography of the basin is relatively flat, with elevations ranging from near sea level at the mouth to approximately 45 ft above NGVD in the south.

The major components of the streamflow system are Dunns Creek, Crescent Lake, and Haw Creek. Important tributaries include Middle Haw Creek, Little Haw Creek, and Black Branch. The general direction of the flow is from southeast to the northwest, and the basin discharges ultimately through Dunns Creek in the St. Johns River at river mile 86.4. Little Haw Creek extends as far south as the City of De Land. On its way north, it crosses various swamps, so that the streambed is not always well defined.

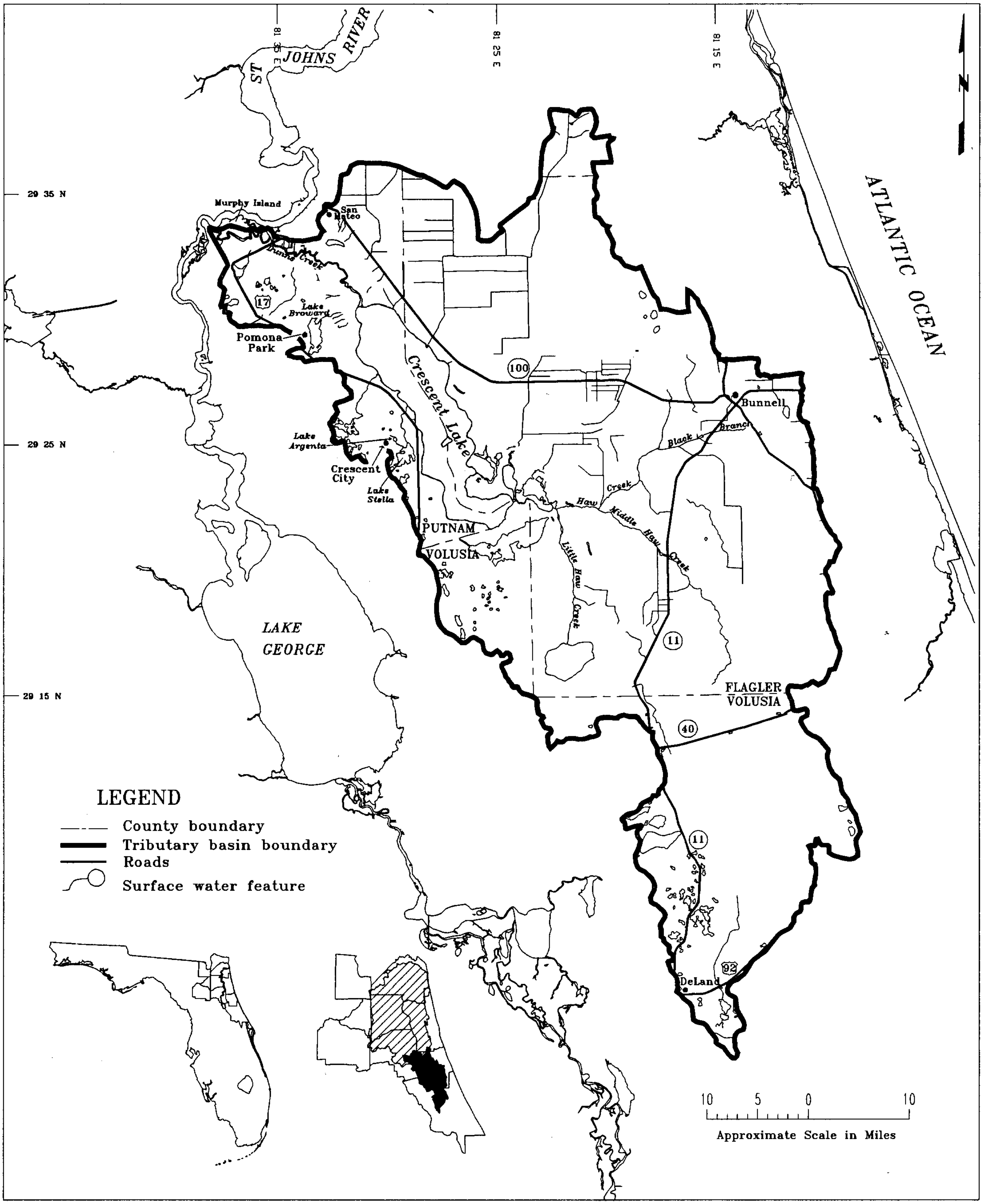


FIGURE 2.5
The Crescent Lake tributary
basin of the lower St. Johns River basin

Most soils in the basin are moderately to poorly drained, but not subject to flooding. The Wabassa-Myakka-Felda and Meggett-Felda associations dominate (SCS 1972) (Table 2.2). Bordering Crescent Lake and along Haw Creek, soils are poorly to very poorly drained and are subject to flooding.

Land use in the basin is primarily agricultural, consisting of silviculture (57%), row crops (15%), and cattle operations (8%). This pattern of land use is not different from that of the rest of the state.

Three flood insurance studies (FEMA 1981a, 1981b, 1981c) were performed in the watershed, all located in the area between the St. Johns River and Crescent Lake in unincorporated areas of Putnam County, Crescent City, and the Town of Pomona Park. The studies focused on flood events caused by Crescent Lake, Lake Stella, Lake Argenta, Lake Broward, Dunns Creek, the St. Johns River, and other small lakes and streams. The lakes are located in the northwestern portion of the watershed and form a potential flood hazard when an unfortunate combination of high lake levels, high ground water levels, and high rainfall occurs. The study of Dunns Creek (FEMA 1981a) extends from the mouth of Dunns Creek at the St. Johns River to the downstream side of Crescent Lake. Ten cross-sections were used for this reach. Flood profiles for 10-, 50-, 100-, and 500-year frequencies were computed.

Deep Creek Basin (Figure 2.6)

This tributary basin covers an area of approximately 76 square miles, and is located almost entirely in St. Johns County. Physiographically it belongs to the Hastings Plain, which is a subdivision of the Palatka Anomalies in the Eastern Flatwoods District (Brooks 1981). Elevations range from approximately 30 ft above NGVD in the eastern part of the basin to near sea level at the mouth.

The general flow direction of Deep Creek is from south to north. The mouth at the St. Johns River is located about 4 miles northwest of the City of Hastings, and 68 miles from the mouth of the St. Johns River. A major tributary is Sixteenmile Creek.

Soils are, in general, poorly drained. Typical units belong to the Olustee-Placid-Myakka and the Meggett-Wauchula-Chobee series (Table 2.2).

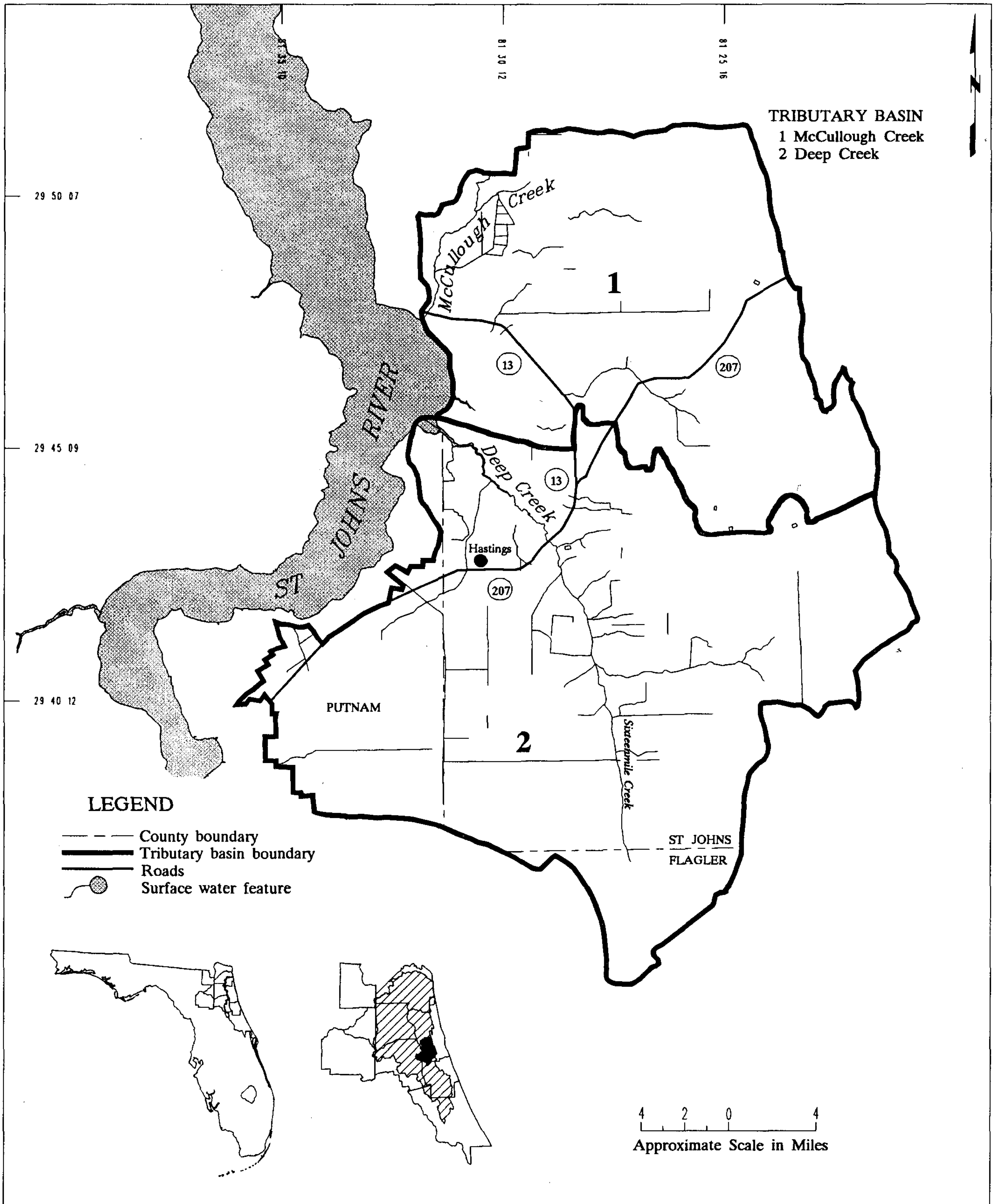


FIGURE 2.6
The Deep Creek and the McCullough Creek tributary basins of the lower St. Johns River basin

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

Along Sixteenmile Creek and near the mouth of Deep Creek, soils occur which are very poorly drained and are subjected to prolonged flooding.

Land use in the basin is, in general, related to agricultural production. The Florida Department of Environmental Regulation (FDER) reports the use of pesticides, fertilizers, and herbicides in extensive row crop farming operations (Hand et al. 1988).

A flood insurance study was performed for the City of Hastings in 1987. This study addresses the flooding of Hastings by Deep Creek (FEMA 1987). It was mentioned that the worst flooding occurred in September 1951, when a four-day rainstorm, which totaled 20 in., caused Deep Creek to flood much of the City of Hastings.

Dunn Creek Basin (Figure 2.4)

The Dunn Creek tributary basin is located in the northern part of Duval County, north of the St. Johns River and east of the Broward River drainage basin. The area is approximately 23 square miles, and elevations range from near sea level to approximately 30 ft NGVD. There is little topographic relief. Physiographically, the Dunn Creek tributary basin belongs to the Dinsmore Plain of the Northern Coastal Strip. The general flow direction is north to south. Delineation of the basin is rather difficult in areas where headwaters originate, due to the flatness of the topography and the possible interconnection with the Nassau River basin (CDM 1989). Tributaries to Dunn Creek are Terrapin Creek and Rushing Creek. Caney Branch is a tributary to Rushing Creek. Tidal effects in the drainage basin extend to New Berlin Road, which is about 2 miles north of the confluence of Rushing Creek and Caney Branch (CDM 1989).

Soils in the lower portion of the basin belong to the Kershaw-Ortega series, and in the upper portion of the basin to the Pelham-Mascotte-Sapelo series. CDM (1989) reports that the hydrologic soil group classification for the basin is 40 percent A soils, 12 percent B soils, and 48 percent D soils (Table 2.2).

Land use is approximately 80 percent forest, residential, urban, and agricultural, with the remainder composed of wetlands, waterbodies, and commercial/industrial land (CDM 1989).

Both water quality and water quantity problems are reported for the Dunns Creek basin (CDM 1989). FEMA indicates problems with several structures, based on overtopping, excessive head loss, or excessive velocities (CDM 1989).

Etonia Creek Basin (Figure 2.7)

The Etonia Creek tributary basin covers approximately 355 square miles, and is located on the west bank of the St. Johns River. The major portion of the watershed is contained in Putnam County. Physiographically, the upstream portion belongs to the Trail Ridge, which is a subdivision of the Sea Island District. The downstream portion belongs to the Rice Creek Swamp, which is a subdivision of the Eastern Flatwoods District (Brooks 1981). Elevations range from about 140 ft above NGVD in the west to near sea level at the confluence with the St. Johns River.

The main stream in the basin is Rice Creek, which discharges into the St. Johns River near Palatka. Major tributaries are Etonia Creek, Simms Creek, and Rice Creek (with the same name as the mainstem). The headwaters of this tributary system originate on the eastern slopes of the Trail Ridge. The general flow direction is east.

A large part of the basin consists of moderately to poorly drained soils, not subject to flooding. These are of the Myakka-Wauchula-Placid association (Table 2.2). Along Rice Creek and near its confluence with the St. Johns River some swampy areas occur. These areas are subject to flooding. In the upper part of the basin, some patches of sandy soils can be found.

Land use in the basin is predominantly agricultural. Some industrial activity can be found near Palatka, where Georgia-Pacific operates a paper mill.

A flood insurance study was carried out for the City of Palatka (FEMA 1979). Flooding of Palatka, caused by the St. Johns River, was studied in detail. In the upper portion of Etonia Creek basin, serious flooding occurred in 1946, 1964, 1965, and 1973, in the areas of Keystone Heights and Putnam Hall (U.S. Army Corps of Engineers 1975). The September 1964 flood was caused by a combination of above normal rainfall during June, July, and August and the arrival of Hurricane Dora in September. State Road 26 was closed and extensive damage of property and residencies was reported. Putnam Hall was again flooded in 1965. The flood of 1973 was centered in the

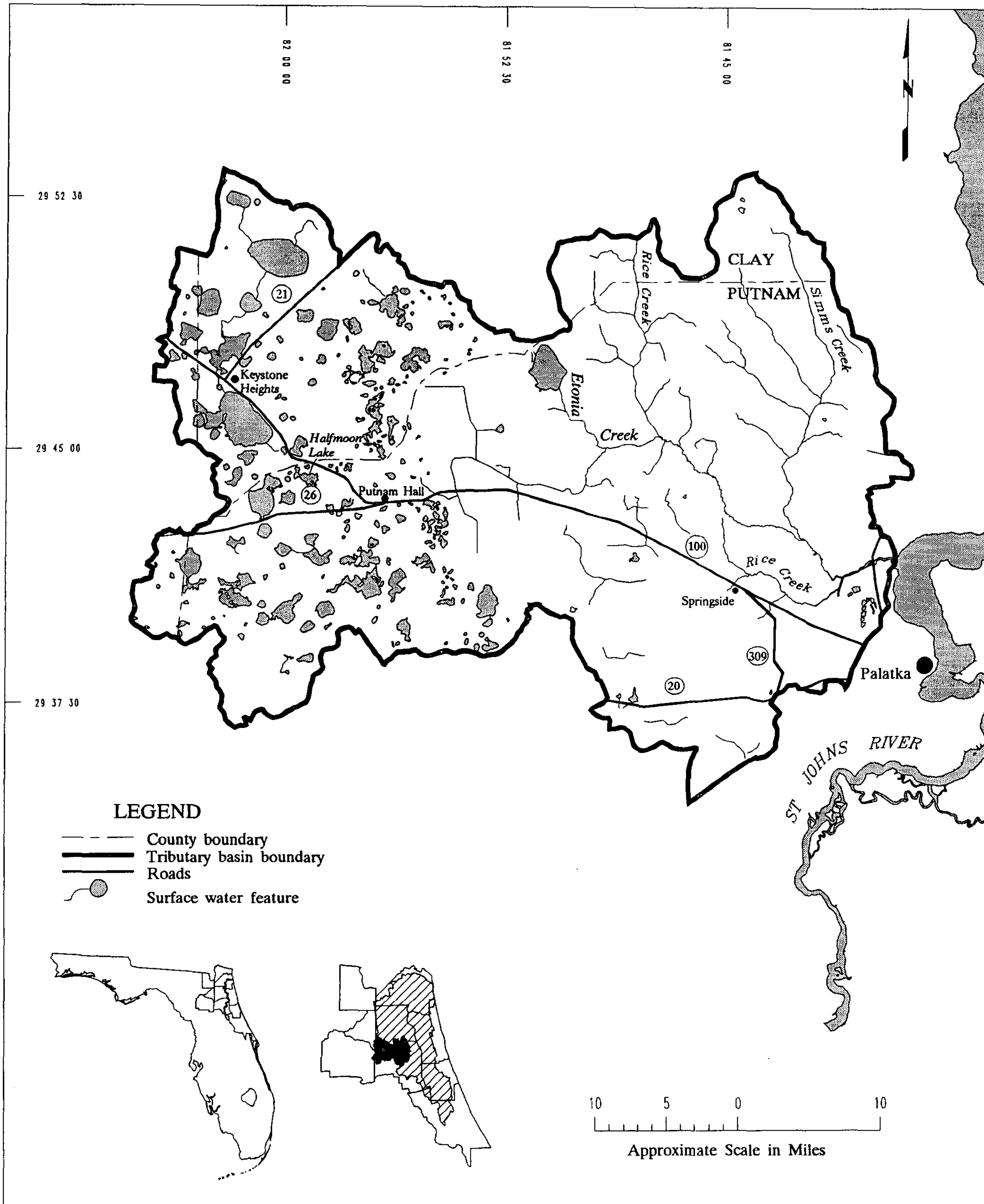


FIGURE 2.7
The Etonia Creek tributary basin of the lower St. Johns River basin

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area near Halfmoon Lake. Many residences, commercial establishments, septic tanks, and roads were damaged.

Julington Creek Basin (Figure 2.8)

The Julington Creek drainage basin is located on the eastern bank of the St. Johns River and extends over the southern part of Duval County and the northern part of St. Johns County. The drainage area is approximately 104 square miles. In physiographic terms, it belongs to the Mandarin Plain, which is a subdivision of the Northern Coastal Strip. The Mandarin Plain is a rather flat terrace, poorly drained, covered with flatwoods and river swamps (Brooks 1981). Elevations are near sea level at the confluence with the St. Johns River and 30 ft NGVD more inland. Major tributaries include Durbin Creek, Big Davis Creek, Sampson Creek, Oldfield Creek, and Flora Branch. The headwaters of Julington Creek and Pottsburg Creek are hydraulically connected via Pottsburg Creek Swamp (Figure 2.2). In a similar way, a hydraulic connection exists between Big Davis Creek and the Pablo Creek in the St. Johns River tributary basin (Figures 2.11a and b) (CDM 1989). Interconnections also exist between Julington Creek basin and Sixmile Creek basin via Sampson Creek and Twelvemile Swamp (CDM 1989) (Figure 2.10). Tidal effects in the watershed extend to approximately one mile upstream of the confluence with Durbin Creek.

According to CDM (1989) hydrologic soil group percentages are as follows: 23 percent A soils, 11 percent B soils, 6 percent C soils, and 60 percent D soils (Table 2.2).

The basin is mostly undeveloped, with natural vegetative cover and agriculture/silviculture composing over 40 percent of the area (CDM 1989). Predictions are that urban development in the basin will increase.

Water quantity problems, such as excessive flow velocities and overtopping of bridges, exist along Julington Creek, Big Davis Creek, Oldfield Creek, and Sweetwater Creek (CDM 1989).

McCullough Creek Basin (Figure 2.6)

This tributary basin covers an area of approximately 62 square miles and is located on the east bank of the St. Johns River in St. Johns County.

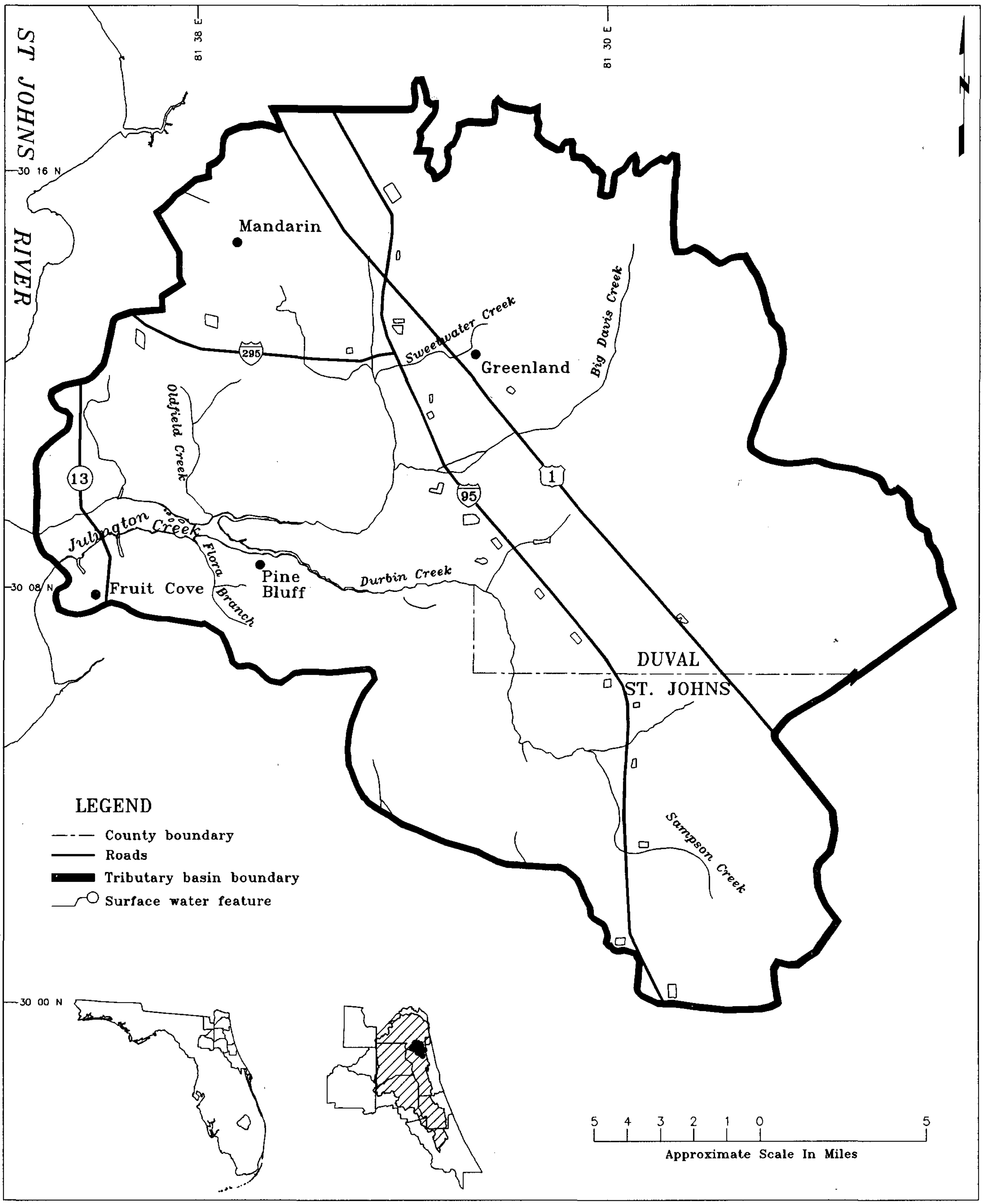

FIGURE 2.8
Julington Creek tributary basin of the lower St. Johns River basin

Physiographically, it belongs to the Hastings Plain, which is a subdivision of the Palatka Anomalies in the Eastern Flatwoods District. The junction with the St. Johns River is at river mile 66.8. The major tributary in this basin is McCullough Creek.

Soils are predominantly of the Myakka-Wauchula-Placid type, and are well to poorly drained. Land use is primarily agricultural.

Ortega River Basin (Figure 2.9)

The Ortega River basin is located in south central Duval County, west of the St. Johns River. Its area is approximately 99 square miles. Major tributaries are Fishing Creek, McGirts Creek, Cedar River, Butcher Pen Creek, and Wills Branch (CDM 1989). The headwaters of McGirts Creek originate in the St. Marys Upland, which is a physiographic subdivision of the Duval Upland. The flow direction of McGirts Creek, which eventually becomes the Ortega River, is southeast before crossing Blanding Boulevard (S.R. 21), but becomes north-northeast afterwards. The flow direction of Cedar River, the largest tributary of the Ortega River, is predominantly southeast. Tributaries of Cedar River are Wills Branch, Butcher Pen Creek, and Fishing Creek. Elevations in the basin range from near sea level near the junction with the St. Johns River to nearly 90 ft NGVD in the Duval Upland. The tidal interface for the Ortega River is at Collins Road (about 0.5 mile downstream of I-295), while the tidal interface for Cedar River is at Lane Avenue (just over 2 miles upstream of S.R. 21) (CDM 1989).

Soils in the basin belong to the following soil groups: Pelham-Mascotte-Sapelo, Leon-Ortega, and Leon-Ridgeland-Wesconnett. The hydrologic soil groups are 22 percent A soils, 8 percent B soils, and 70 percent D soils (CDM 1989) (Table 2.2).

Approximately one-third of the land use in the basin is residential, while the remaining part of the basin consists of commercial/industrial and vacant land uses (CDM 1989).

Both water quantity and water quality problems were observed in the basin (CDM 1989). Water quality problems were bacteriological, due to septic tank failures (CDM 1989).

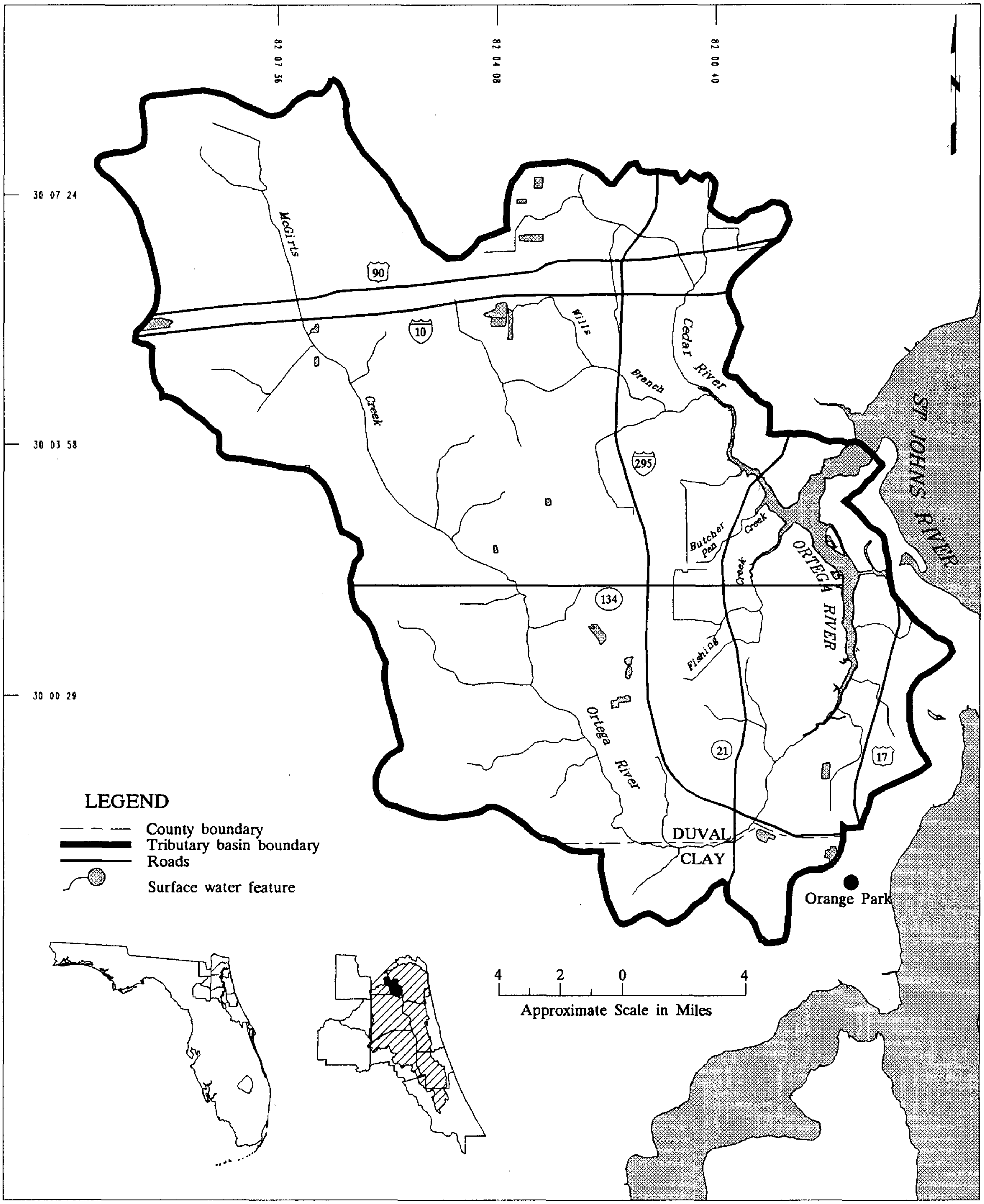

FIGURE 2.9
The Ortega River tributary basin of the lower St. Johns River basin

Sixmile Creek Basin (Figure 2.10)

The Sixmile Creek basin is located in St. Johns County and has a total area of approximately 122 square miles. Physiographically, it belongs to the Hastings Plain, which is a physiographic subdivision of the Palatka Anomalies. Drainage of the soils is poor. Elevation of the land is less than 25 ft above NGVD.

Sixmile Creek is the major tributary in the basin. Mill Creek, Trout Creek, and Turnbull Creek are other important tributaries. Trout Creek and Sixmile Creek join the St. Johns River independently, approximately 50 miles from the mouth. Mill Creek and Turnbull Creek, on the other hand, are tributaries of Sixmile Creek.

Soils belong, in general, to the Tavares-Leon association, which are well to poorly drained soils, not subject to flooding (Table 2.2). Near the mouth of Sixmile Creek are swamps, which drain very poorly and are subject to prolonged flooding.

Land use is primarily related to agricultural production. For instance, row crop farming occurs along Sixmile Creek.

St. Johns River Basin (Figure 2.11a and b)

This basin is the collection of streams and creeks in the lower St. Johns River basin that are not included in other tributary basins and drain directly into the St. Johns River. It is estimated that the total area is 210 square miles. Because the various drainage areas are scattered along the St. Johns River, a wide range of soil types and land uses can be found.

The small streams in the St. Johns River basin, outside Duval County, discharging directly into the St. Johns River are Governors Creek, Clarkes Creek, Cedar Creek, Camp Branch, Mill Branch, Dog Branch, and Tocoi Creek.

Detailed information is available for the St. Johns River tributary basin in Duval County. This area was divided into two parts (CDM 1989). The first part is located downstream of Trout River (LSJR-D/S), while the second part is located upstream of Trout River (LSJR-U/S).

LSJR-D/S. This basin has a contributing area of approximately 83 square miles, with elevations ranging from sea level to 90 ft NGVD along

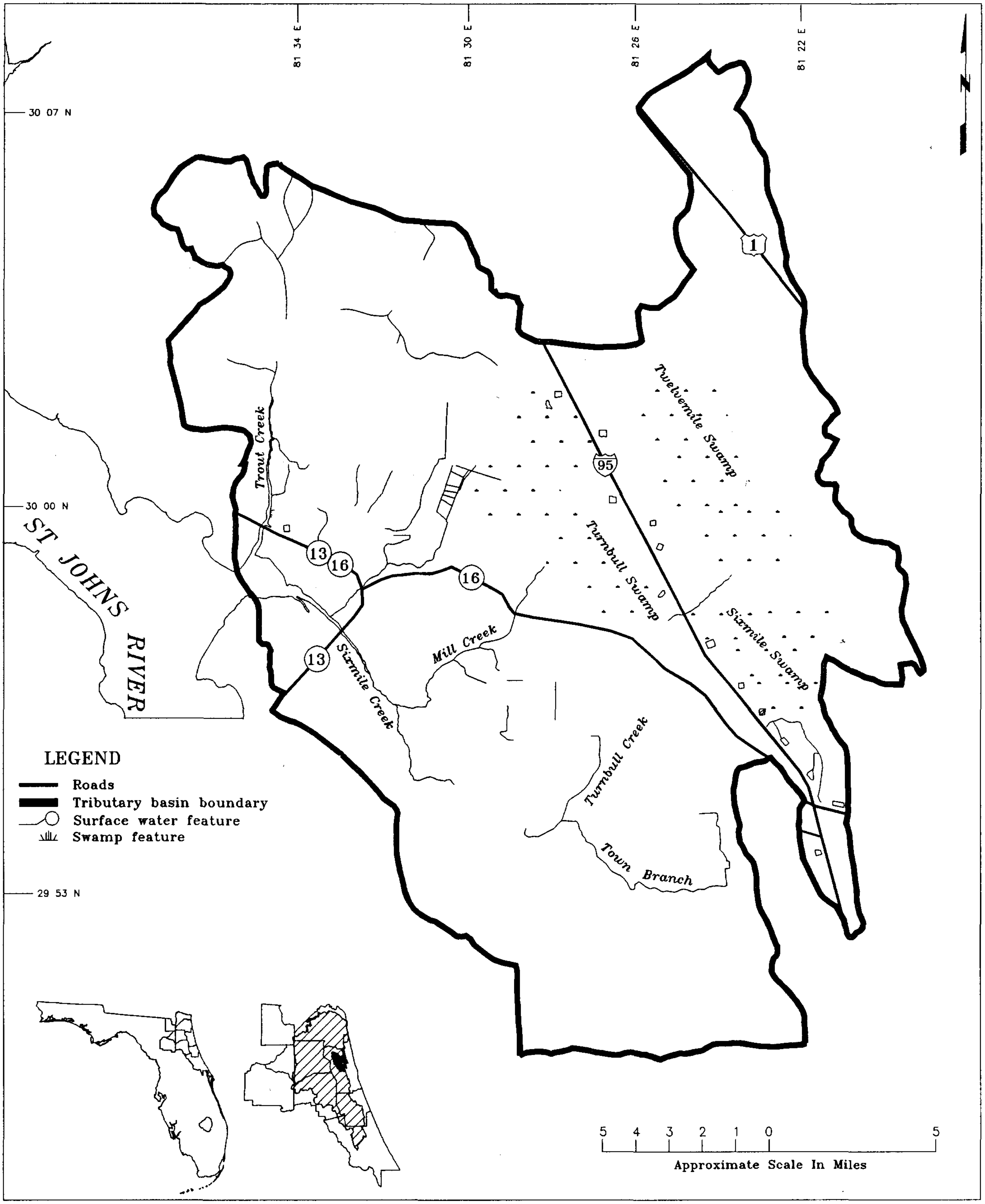

FIGURE 2.10
Sixmile Creek tributary basin of the lower St. Johns River basin

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

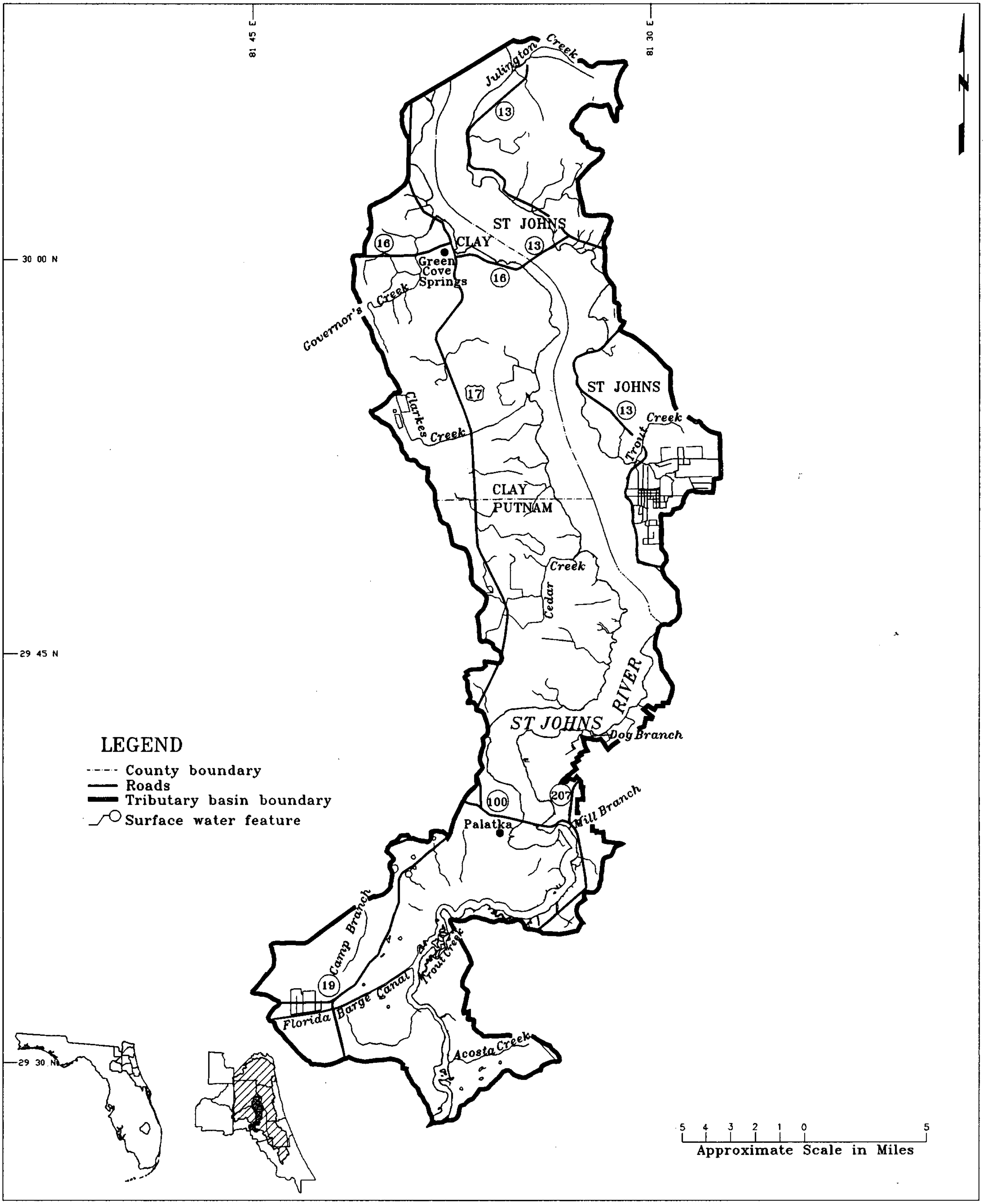

FIGURE 2.11a
The southern part of the St. Johns tributary basin of the lower St. Johns River basin

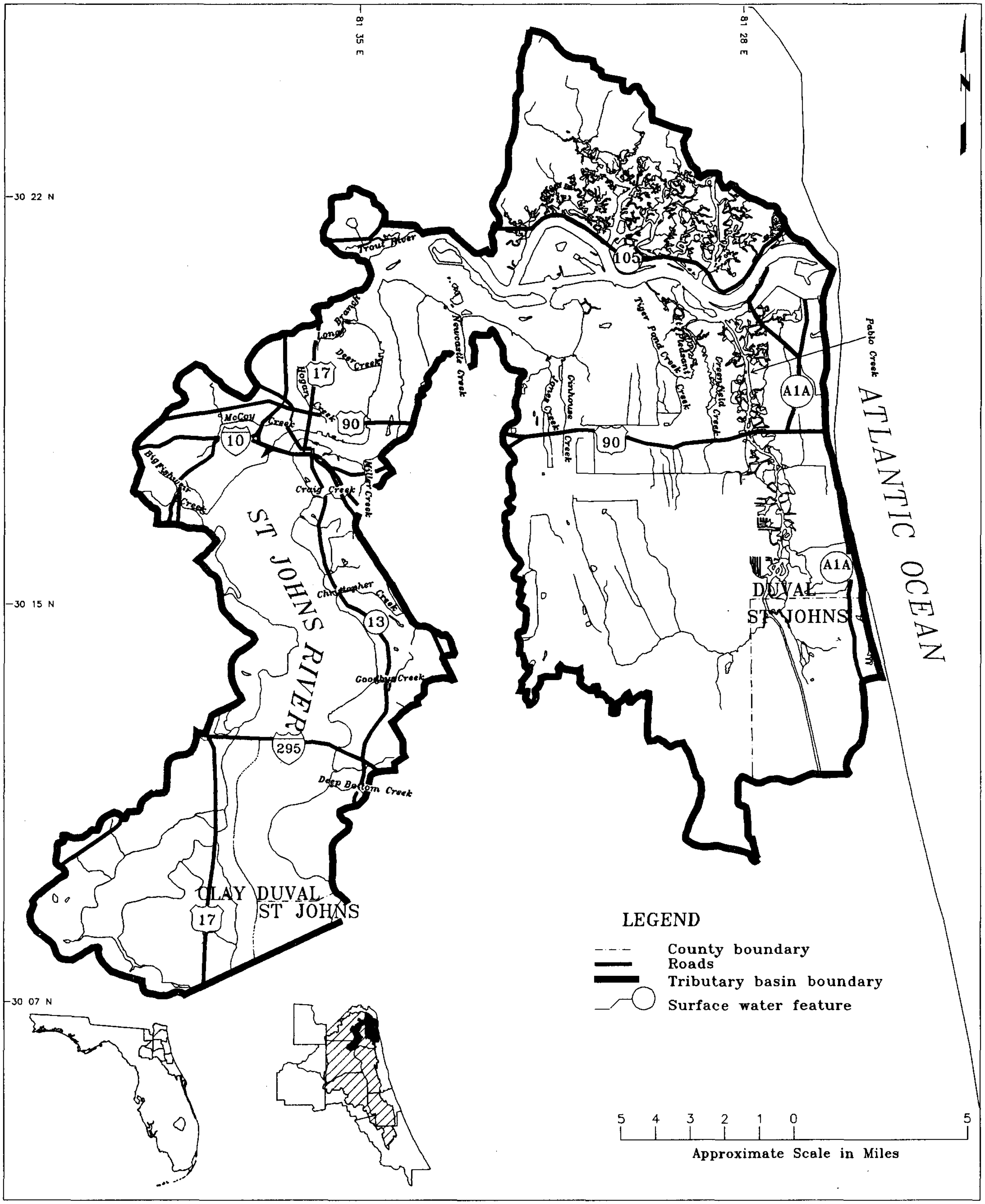

FIGURE 2.11b

The northern part of the St. Johns tributary basin of the lower St. Johns River basin

Monument Road south of Fort Caroline (near the mouth of Mt. Pleasant Creek) (CDM 1989). Physiographically, it belongs to the Northern Coastal Strip. Major tributaries within the basin are Newcastle Creek, Jones Creek, Ginhouse Creek, Tiger Pond Creek, Mt. Pleasant Creek, and Greenfield Creek.

At least four different soil types are found within the basin. These are Kershaw-Ortega, Mandarin-Kureb, Leon-Ridgeland-Wesconnett, and Tisonia. Approximately 75 percent of the soils belong to the D hydrologic soil group, and the remaining 25 percent belong to the A hydrologic soil group (CDM 1989) (Table 2.2).

Most of the land is still undeveloped. The developed part is mostly residential with a significant amount of commercial and industrial development.

Both water quantity and water quality problems are encountered in the basin.

LSJR-U/S. This basin is located in Duval County, upstream of the Trout River basin outlet. The total area includes approximately 92 square miles. Elevations range from near sea level to nearly 30 ft NGVD. Thus, in general, there is little topographic relief. This basin includes many of the urbanized streams and ditches in downtown Jacksonville, such as McCoy Creek, Hogan Creek, Long Branch, Deer Creek, Big Fishweir Creek, Little Fishweir Creek, Deep Bottom Creek, Goodbys Creek, Christopher Creek, Craig Creek, and Miller Creek.

The St. Johns River itself covers approximately 40 percent of the tributary basin area. The remaining part is residential or commercial and industrial. It is anticipated that by the year 2010 the basin will be completely developed (CDM 1989).

Three soil mapping units were identified in the basin, producing a basin composite of 28 percent A soils, 9 percent B soils, and 63 percent D soils (CDM 1989) (Table 2.2).

Both water quantity and water quality problems (i.e., flooding, poor water) exist in the basin, especially along McCoy Creek and Hogan Creek (CDM 1989).

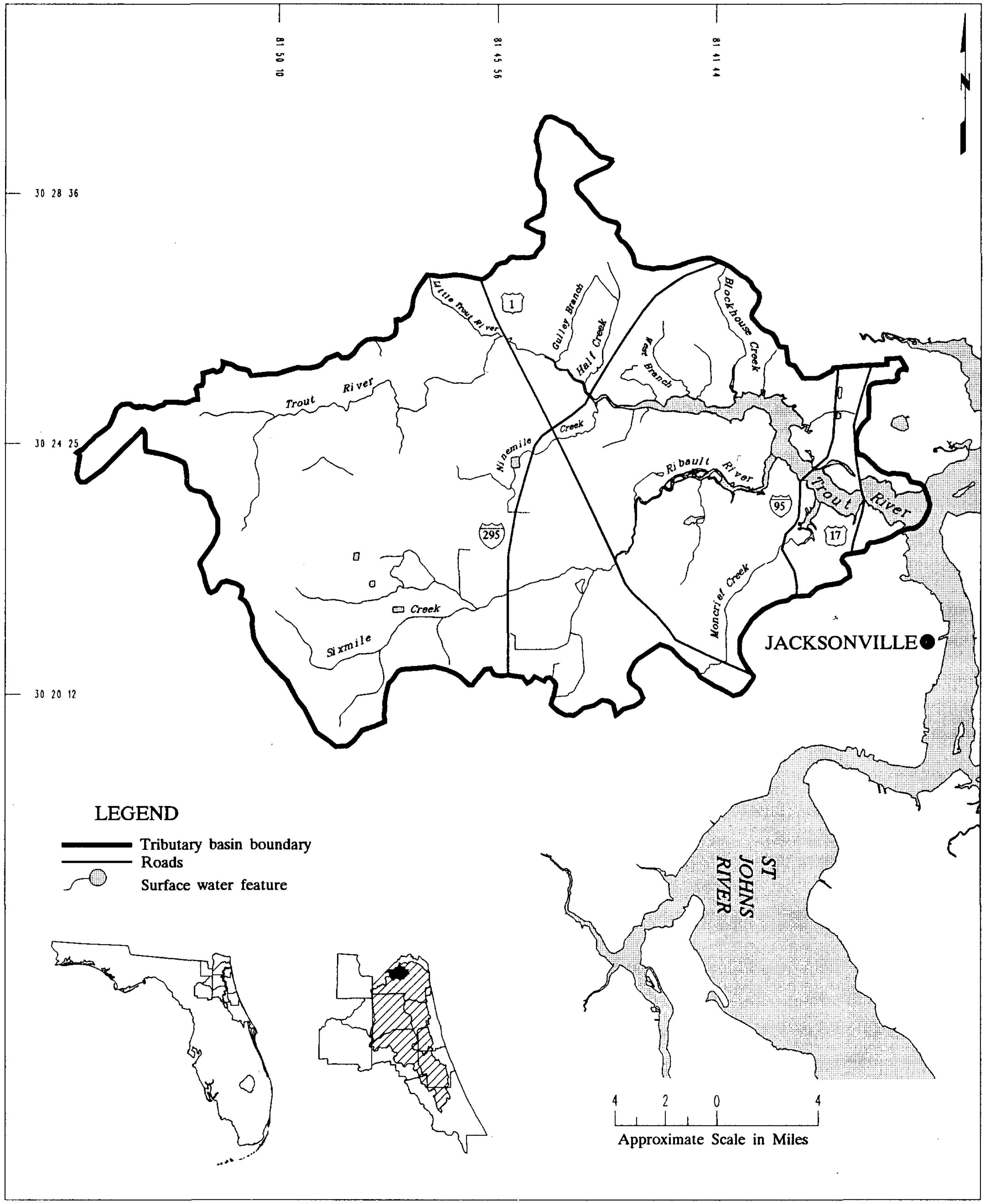

FIGURE 2.12
The Trout River tributary basin of the lower St. Johns River basin

Trout River Basin (Figure 2.12)

The Trout River basin lies west of the St. Johns River and joins the river when it turns east toward the Atlantic Ocean (CDM 1989). The total drainage area is approximately 94 square miles. Elevations range from near sea level to about 100 ft NGVD. The basin is heavily influenced by tidal fluctuations. Physiographically, it belongs to the Dinsmore Plain, which is a physiographic subdivision of the Northern Coastal Strip. Major tributaries are Little Trout River, Moncrief Creek, Ribault River, Sixmile Creek, Blockhouse Creek, West Branch, Half Creek, and Gulley Branch.

Soil types in the basin belong to the Leon-Ridgeland-Wesconnett series or to the Pelham-Mascotte-Sapelo series. The basin average hydrologic soil group percentages are 11 percent A soils, 13 percent B soils, and 76 percent D soils (CDM 1989) (Table 2.2).

Present land uses are residential and agricultural, with more residential and commercial development expected in the future.

Some flooding problems exist in the basin (CDM 1989). Water quality problems are, generally, related to the presence of septic tanks along the river system (CDM 1989).

HYDROLOGIC AND HYDRAULIC DATA

PRECIPITATION

The SJRWMD makes extensive use of rainfall data in its management of surface water and ground water basins in the District, in its engineering studies, and in its permit activities. The existing network of rainfall stations is expanded continuously, based on particular needs and programs.

Precipitation in the lower St. Johns River basin occurs primarily as rainfall. The large number of stations throughout the basin makes the organized collection of historical rainfall data possible. One of the main sources of rainfall data is the publications of the National Oceanic and Atmospheric Administration (NOAA), which was called the U.S. Weather Bureau until 1965, and the Environmental Science Service Administration from 1965 to 1970. Daily rainfall data are published in *Climatological Data*, together with information on daily temperatures, soil temperatures, evaporation, and wind. Hourly rainfall data are published in the *Hydrologic Bulletin* (1940-1948), in *Climatological Data* (1948-1951), and since 1951, in the monthly publications titled *Hourly Precipitation Data*. Other state and local agencies, including the SJRWMD and some private entities such as Palm Coast, also operate rainfall stations in the basin.

Rainfall Monitoring Network

The locations of NOAA rainfall stations, which are significant to the LSJRB, are listed in Table 2.3. All these stations collect daily data, except for Jacksonville Airport, Raiford State Prison, Jacksonville City, and Marineland, which collect hourly data. In addition, in Duval County, daily rainfall data are also reported at twelve forest service towers, and at some United States Navy owned stations (CDM 1989). Data from all these stations are available in digitized format. In addition, the District and some private parties also

Table 2.3. National Oceanic and Atmospheric Administration rainfall stations in and near the lower St. Johns River basin

STATION	ID	LATITUDE	LONGITUDE	RECORD
Crescent City	1978	292600	813100	1898 - present
Daytona Beach Airport	2158	291100	810400	1914 - present
De Land	2229	290100	811800	1903 - present
Federal Point	2915	294500	813200	1892 - present
Fernandina Beach	2944	303900	812800	1897 - present
Gainesville	3321	293800	822200	1897 - present
Glen St. Mary	3470	301600	821100	1896 - present
Hastings ARC	3874	294300	813000	1902 - 1944 1977 - present
Jacksonville Airport (*)	4358	303000	814200	1867 - present
Jacksonville Beach	4366	301700	812400	1942 - present
Jacksonville City (*)	4371	302000	814000	1948 - 1956
Marineland (*)	5391	294000	811300	1942 - present
Palatka	6753	293900	813800	1927 - 1984
Raiford State Prison (*)	7440	300400	821100	1931 - present
St. Augustine	7812	295300	812000	1872 - 1973
St. Augustine Radio Tower	7826	295400	811900	1973 - present
Starke	8527	295600	820600	1896 - 1984

Source: Rao and Clapp 1986
* Hourly Data

maintain a number of rainfall stations. These stations are of the recording (tipping bucket gage) or non-recording type. A complete listing of rainfall stations in the lower St. Johns River basin, their owners, and record lengths is given in Appendix A.

During the fiscal year 1989-1990, the District, in cooperation with the City of Jacksonville and the U.S. Geological Survey (USGS), installed a number of rainfall gages in Duval County (Table 2.4). These stations are to assist in the calibration and validation of the hydrologic models developed within the framework of the Master Stormwater Management Plan (MSMP).

Many different statistics can be computed from the set of collected rainfall data, depending on particular needs. For instance, one may be interested in the daily, monthly, and/or yearly averages, the seasonal averages, and regional averages. Other interests may concern extreme events, such as daily, monthly, yearly, and seasonal maxima. On a smaller time scale one may be interested in storm duration, total storm depth, storm distribution, and the average time between events. On a regional level, correlations between rainfall events at various locations may be studied. The information extracted from the rainfall data can be used in various studies, for instance in the determination of water balances, hydrologic modeling, drought analysis, and the design of rainfall networks.

Normal Rainfall

Normal rainfall is the average of rainfall over the period 1951-1980. Normal rainfall data for a number of stations in the basin are listed in Table 2.5. The annual normal rainfall varies between 54.06 in. at De Land and 46.71 in. at Marineland. The average of all stations is 51.77 in. Monthly normal rainfall data are plotted in Figure 2.13. Clearly, the months June through September constitute the main rainy season, while November through April are the dry months. The highest monthly normal rainfall was recorded at Starke, 8.24 in for August, and the lowest monthly normal rainfall was recorded at Jacksonville Airport, 1.7 in for November. Figure 2.13 also shows that two rainfall cycles per year exist, one that peaks around February, and a second one that peaks around July. Table 2.6 presents the seasonal normal rainfall for the summer season (June through September) and for the winter season (December through March).

Table 2.4. Rainfall stations installed 1989-1990, Duval County

DRAINAGE BASIN	LATITUDE/LONGITUDE	STATION NUMBER	GAGE LOCATION
Lower St. Johns River, upstream of Trout River	302036/813943	302036081394301	Hogan pump station on Broad Street
	301940/814158	301940081415801	*McCoy lift station on Leland Street
	301743/813058	301743081305801	*Sandalwood pump station on Saints Rd
	301407/812842	02246828	*Pablo Creek rain gage
Trout River	302218/814635	302218081463501	Trout lift station on Prichard Road
	302530/814556	302530081455601	*Trout River at Dinsmore
Ortega River	301728/814626	301728081462601	Ortega lift station at Normandy Village
Arlington River	301528/813503	301528081350301	Arlington lift station on Belfort Road
	301943/813338	301943081333801	Arlington lift station on Millcreek Road
Julington Creek	300558/812909	300558081290901	*St. Johns Greyhound Park on S.R. 27
	301019/813449	301019081344901	Mandarin lift station on Losco Road

*Discontinued since 10/1/91

Table 2.5. Monthly normal rainfall (inches), 1951-1980

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR
Crescent City	2.90	3.76	3.82	2.71	3.86	6.06	7.42	7.10	7.11	3.72	2.32	2.80	53.58
Daytona Bch Airport	2.37	3.09	2.99	2.25	3.38	6.41	5.52	6.34	6.68	4.27	2.55	2.19	48.04
De Land	2.60	3.48	3.43	2.42	4.06	7.20	7.54	7.77	6.76	4.44	2.32	2.04	54.06
Federal Point	2.98	3.48	3.47	2.49	4.09	5.91	6.76	7.09	7.19	3.93	2.41	2.93	52.73
Fernandina Beach	2.96	3.65	3.58	2.64	3.91	5.27	5.97	6.36	7.59	3.77	2.82	2.70	51.22
Gainesville	3.27	3.91	3.61	2.94	4.18	6.63	7.09	7.99	5.60	2.33	2.04	3.19	52.78
Glen St. Mary	3.58	3.87	3.94	3.20	5.09	6.46	7.87	7.95	6.52	2.23	2.12	3.29	56.12
Jacksonville Airport	2.91	3.62	3.45	3.02	4.36	5.73	6.41	7.54	6.68	3.55	1.70	2.46	51.43
Jacksonville Beach	2.96	3.68	3.41	2.67	4.21	5.66	5.76	5.28	6.96	4.75	1.95	2.78	50.07
Marineland	2.61	3.43	3.12	2.15	3.26	4.86	5.06	6.15	6.94	4.21	2.38	2.54	46.71
Palatka	3.05	3.61	3.45	2.64	3.84	5.93	6.61	6.95	6.74	3.88	2.09	2.71	51.50
St. Augustine	3.05	4.11	3.69	2.33	3.83	5.38	5.83	5.99	7.68	4.89	2.67	3.14	52.59
Starke	3.12	3.59	3.29	2.96	4.64	5.91	7.24	8.24	5.61	2.38	2.01	3.21	52.20
AVERAGE	2.95	3.64	3.48	2.65	4.05	5.95	6.54	6.98	6.77	3.72	2.26	2.77	51.77

Source: Jenab et al. 1986

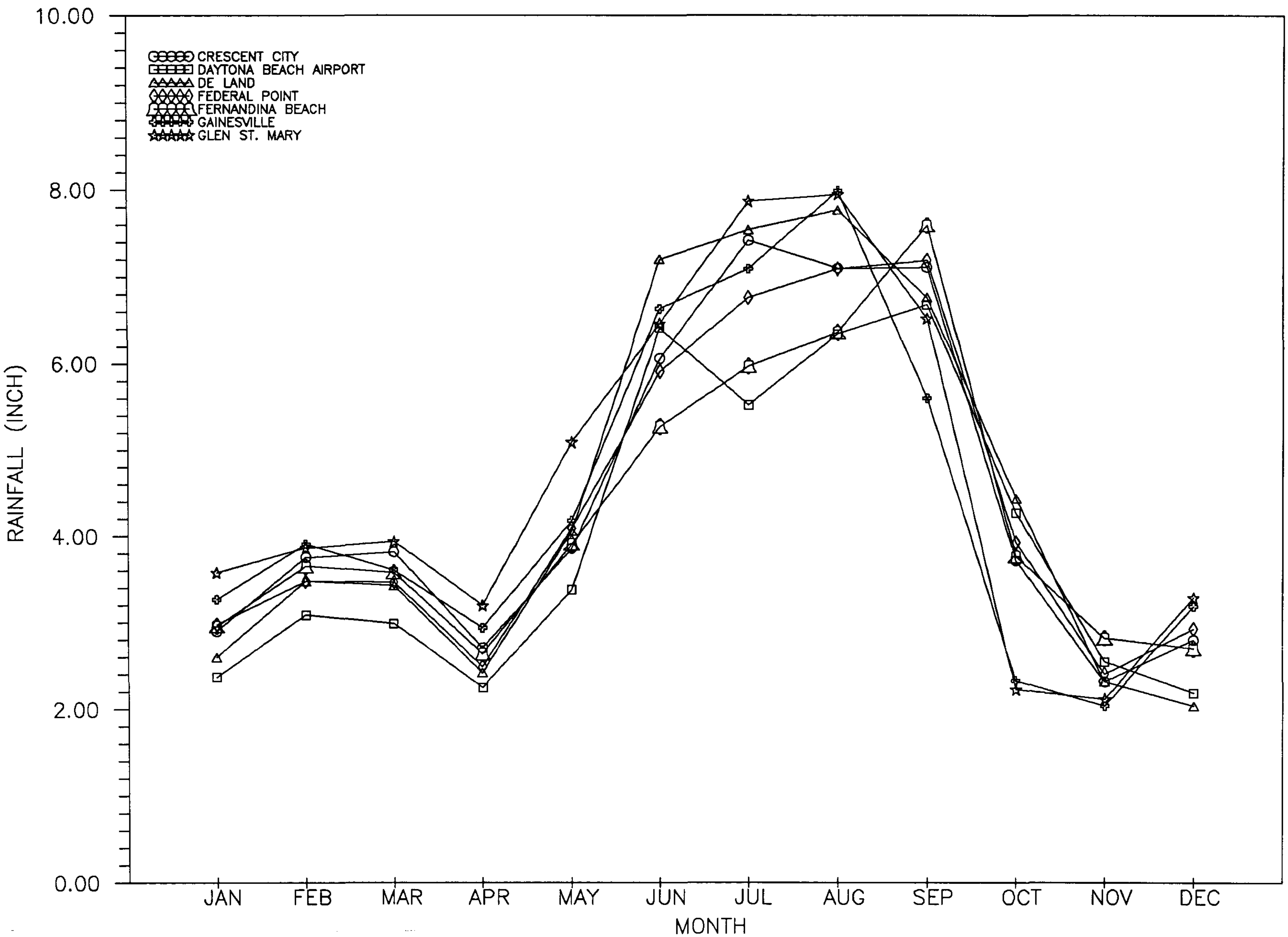

Figure 2.13 Monthly normal rainfall (inches)

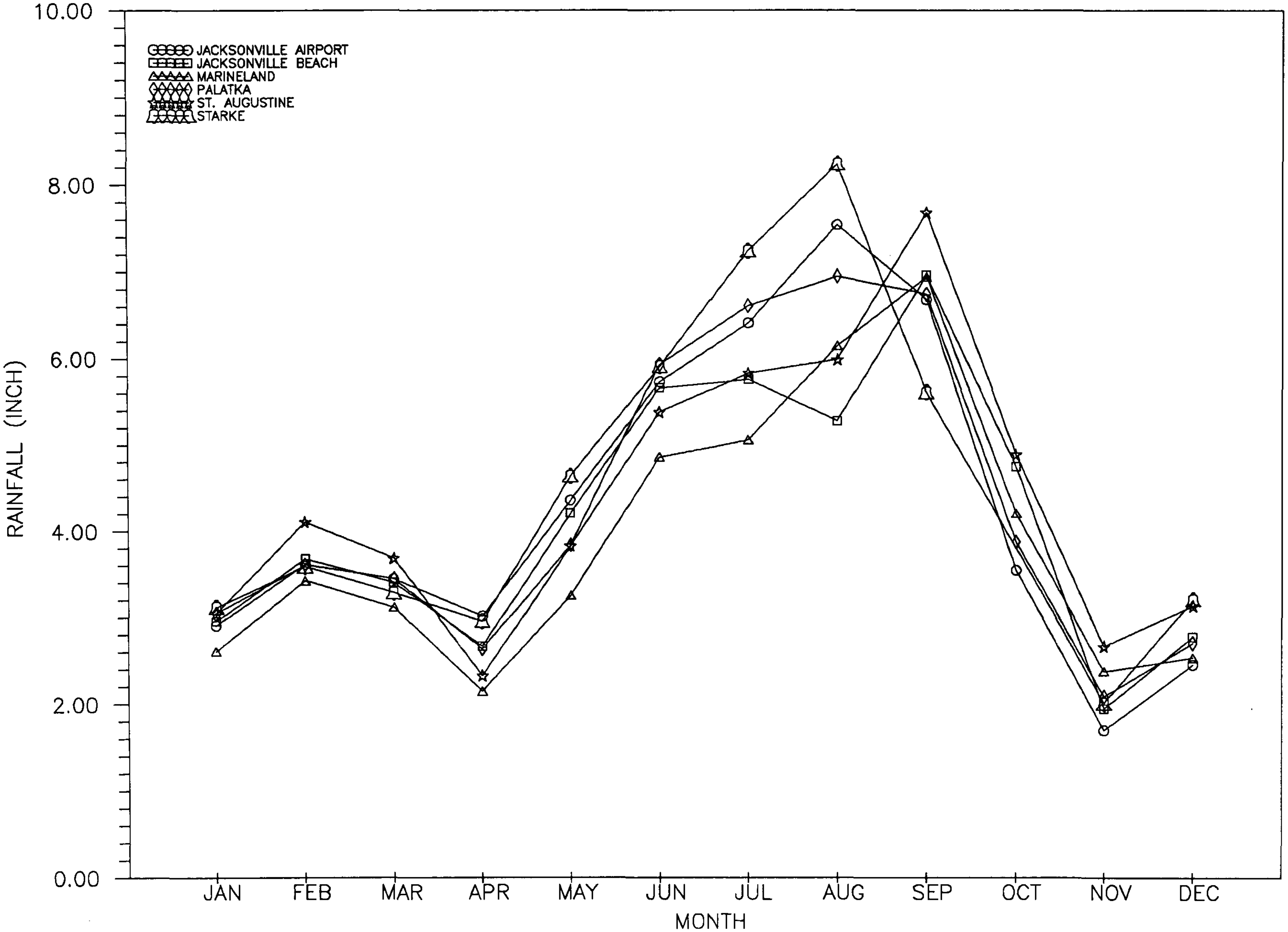

Figure 2.13 Continued

Table 2.6. Seasonal normal rainfall (inches), 1951-1980

STATION	ANNUAL	SUMMER SEASON (JUN-SEP)	WINTER SEASON (DEC-MAR)
Crescent City	53.58	27.69	13.28
Daytona Beach Airport	48.04	24.95	10.64
De Land	54.06	29.27	11.55
Federal Point	52.73	26.95	12.86
Fernandina Beach	51.22	25.19	12.89
Gainesville	52.78	27.13	13.98
Glen St. Mary	56.12	28.80	14.68
Jacksonville Airport	51.43	26.36	12.44
Jacksonville Beach	50.07	23.66	12.83
Marineland	46.71	23.01	11.70
Palatka	51.50	26.23	12.82
St. Augustine	52.59	24.88	13.99
Starke	52.20	27.00	13.21

To account for spatial variation in rainfall, a Thiessen network has been fitted over the complete St. Johns River basin (Figure 2.14). Monthly normal rainfall data were averaged using Thiessen weights. The results of these manipulations for the lower St. Johns River basin are presented in Table 2.7. It can be seen that the basin average rainfall and the Thiessen weighted basin average rainfall differ only slightly: 51.77 in versus 51.88 in. Figure 2.14 shows that the rainfall measured at Jacksonville Airport, Jacksonville Beach, Starke, Federal Point, Palatka, and Crescent City make the largest contributions to the weighted normal rainfall over the basin. On the other hand, stations like Marineland, St. Augustine, Glen St. Mary, Gainesville, De Land, Daytona Beach Airport, and Fernandina Beach have considerably less weight. Federal Point is the most centrally located station in the basin. Its annual normal rainfall is 52.73 in (Table 2.5).

The correlation between the monthly normal rainfall at Federal Point and other stations in the basin can be seen from Figure 2.15, while the various correlation coefficients are listed in Table 2.8. It can be seen that:

- Overall, there is a rather high correlation between the monthly normal rainfall at Federal Point and other stations.
- The correlation coefficients are relatively low for stations located in the western part of the basin.
- Palatka and Crescent City correlate the strongest with Federal Point.
- Correlation in the north-south direction is relatively higher than in the east-west direction.

The complete correlation matrix of the monthly normal rainfall in the basin is shown in Table 2.9. It can be seen that all the correlation coefficients are relatively high. Correlation of daily rainfall was investigated for two situations: between Federal Point and Crescent City and between Jacksonville Beach and Jacksonville Airport. No significant correlation exists (Figure 2.16).

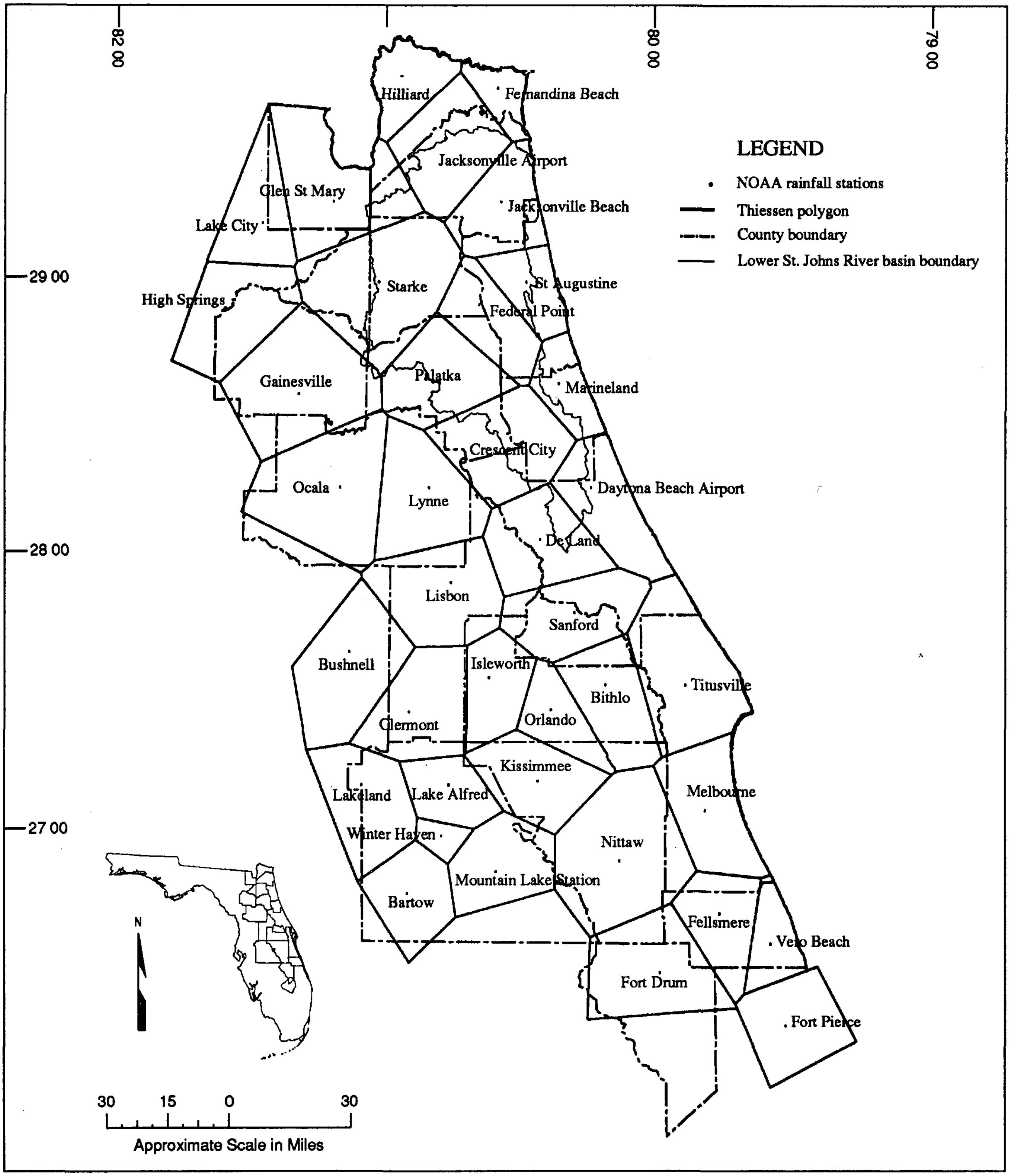

FIGURE 2.14

National Oceanic and Atmospheric Administration rainfall stations and Thiessen polygons covering the St. Johns River Water Management District

Table 2.7. Thiessen weighted monthly normal rainfall (inches)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR
Crescent City	2.90	3.76	3.82	2.71	3.86	6.06	7.42	7.10	7.11	3.72	2.32	2.80	53.58
Daytona Bch Airport	2.37	3.09	2.99	2.25	3.38	6.41	5.52	6.34	6.68	4.27	2.55	2.19	48.04
De Land	2.60	3.48	3.43	2.42	4.06	7.20	7.54	7.77	6.76	4.44	2.32	2.04	54.06
Federal Point	2.98	3.48	3.47	2.49	4.09	5.91	6.76	7.09	7.19	3.93	2.41	2.93	52.73
Fernandina Beach	2.96	3.65	3.58	2.64	3.91	5.27	5.97	6.36	7.59	3.77	2.82	2.70	51.22
Gainesville	3.27	3.91	3.61	2.94	4.18	6.63	7.09	7.99	5.60	2.33	2.04	3.19	52.78
Glen St. Mary	3.58	3.87	3.94	3.20	5.09	6.46	7.87	7.95	6.52	2.23	2.12	3.29	56.12
Jacksonville Airport	2.91	3.62	3.45	3.02	4.36	5.73	6.41	7.54	6.68	3.55	1.70	2.46	51.43
Jacksonville Beach	2.96	3.68	3.41	2.67	4.21	5.66	5.76	5.28	6.96	4.75	1.95	2.78	50.07
Marineland	2.61	3.43	3.12	2.15	3.26	4.86	5.06	6.15	6.94	4.21	2.38	2.54	46.71
Palatka	3.05	3.61	3.45	2.64	3.84	5.93	6.61	6.95	6.74	3.88	2.09	2.71	51.50
St. Augustine	3.05	4.11	3.69	2.33	3.83	5.38	5.83	5.99	7.68	4.89	2.67	3.14	52.59
Starke	3.12	3.59	3.29	2.96	4.64	5.91	7.24	8.24	5.61	2.38	2.01	3.21	52.20
WEIGHTED AVERAGE	2.98	3.62	3.46	2.71	4.17	5.90	6.67	7.05	6.68	3.67	2.14	2.84	51.88

Source: Rao et al. 1989

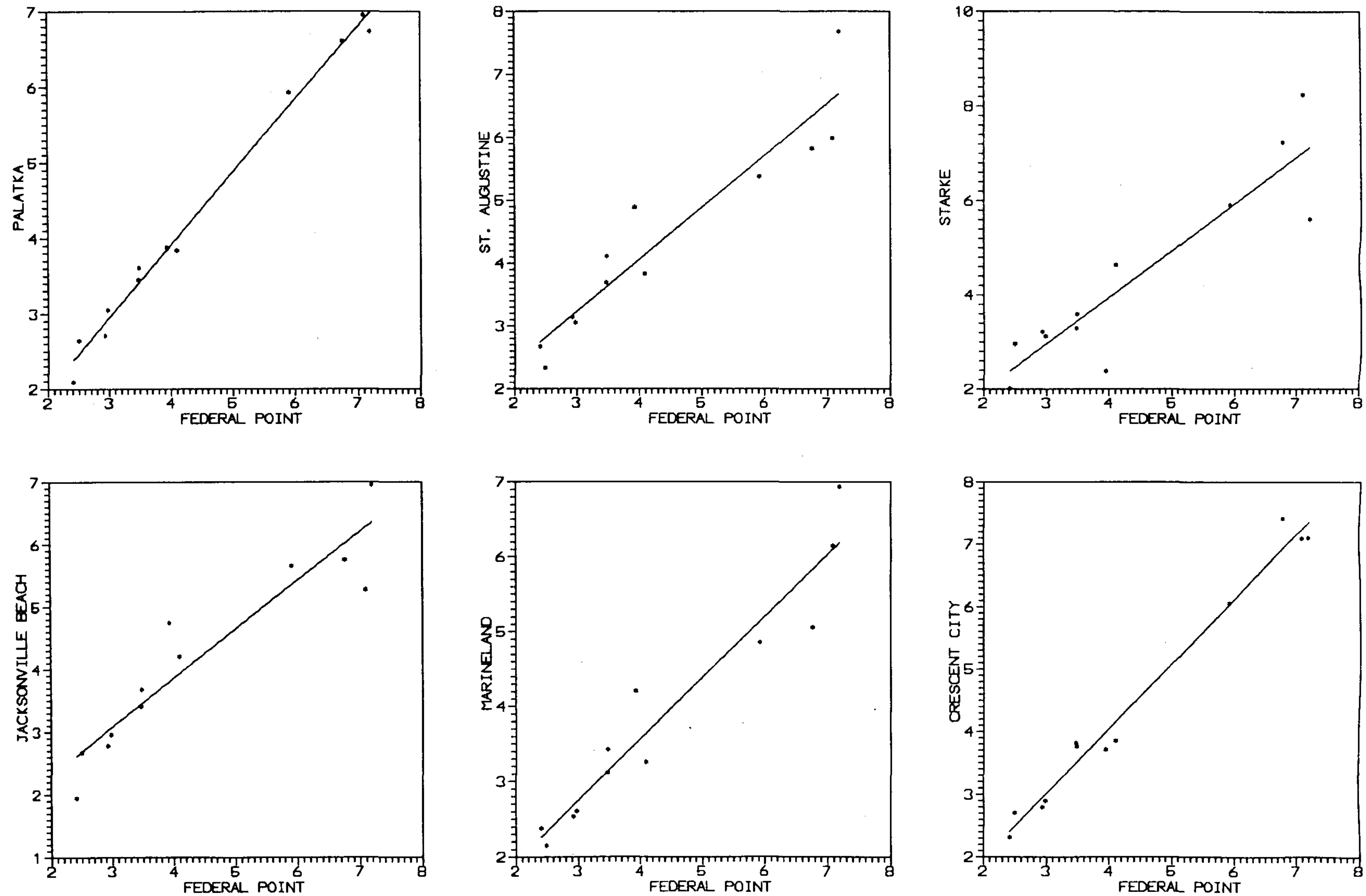

Figure 2.15 Correlation of monthly normal rainfall with normal rainfall at Federal Point

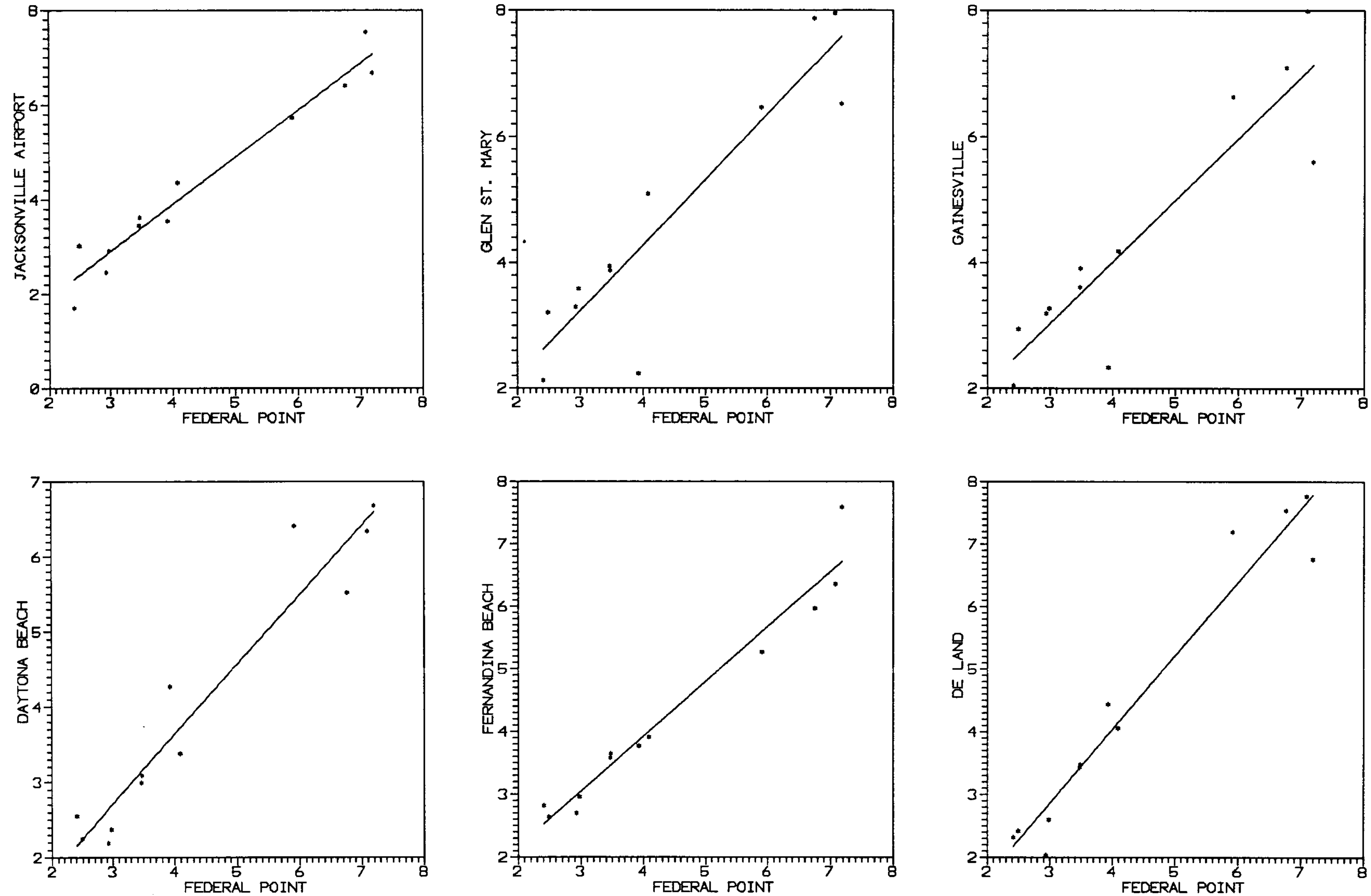

Figure 2.15 Continued

Table 2.8. Correlation between monthly normal rainfall at Federal Point and various stations in the lower St. Johns River basin

STATION	DISTANCE FROM FEDERAL POINT (MILES)	CORRELATION COEFFICIENT
St. Augustine	16	0.944
Palatka	9	0.995
Starke	38	0.913
Jacksonville Beach	39	0.938
Marineland	21	0.961
Crescent City	32	0.991
Jacksonville Airport	52	0.977
Glen St. Mary	53	0.921
Gainesville	48	0.911
Daytona Beach Airport	48	0.961
Fernandina Beach	64	0.977
De Land	50	0.973

Table 2.9. Correlation matrix of monthly normal rainfall

	Federal Point	Augustine	Palatka	Starke	Jacksonville Beach	Marineland	Crescent City	Jacksonville Ap	Glen St. Mary	Gainesville	Daytona	Fernandina	De Land
Federal Point	1.												
St. Augustine	0.944	1.											
Palatka	0.995	0.931	1.										
Starke	0.913	0.740	0.922	1.									
Jacksonville Beach	0.938	0.968	0.937	0.756	1.								
Marineland	0.961	0.986	0.951	0.790	0.944	1.							
Crescent City	0.991	0.920	0.993	0.922	0.920	0.933	1.						
Jacksonville Airport	0.977	0.889	0.985	0.947	0.905	0.924	0.973	1.					
Glen St. Mary	0.921	0.761	0.929	0.986	0.789	0.794	0.938	0.946	1.				
Gainesville	0.911	0.745	0.927	0.988	0.764	0.791	0.928	0.940	0.982	1.			
Daytona Beach Airport	0.961	0.939	0.960	0.820	0.940	0.959	0.942	0.927	0.824	0.840	1.		
Fernandina	0.977	0.969	0.964	0.837	0.939	0.979	0.962	0.943	0.862	0.835	0.947	1.	
De Land	0.973	0.893	0.981	0.905	0.914	0.916	0.974	0.961	0.903	0.917	0.970	0.924	1.

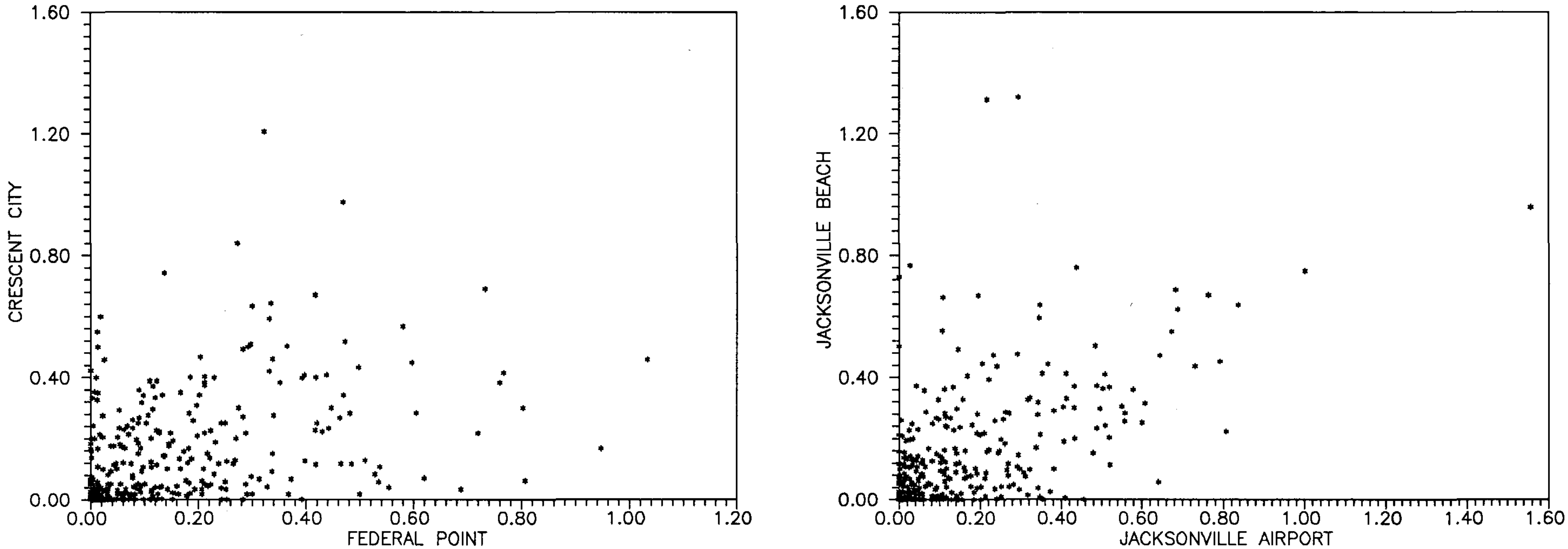

Figure 2.16 Correlation between daily mean rainfall at Federal Point and Crescent City and at Jacksonville Airport and Jacksonville Beach

Long-Term Mean Rainfall

Comparison of long-term average monthly and yearly rainfalls at various stations in the basin (Table 2.10) with normal rainfall data (Table 2.5) shows that:

- For five stations, normal and long-term averages differ less than one inch
- The largest difference between normal and average yearly rainfall occurred at Glen St. Mary (2.27 inch)
- The smallest difference between normal and average yearly rainfall occurred at Daytona Beach Airport (0.12 inch)
- For the basin as a whole, there was a difference of less than one inch between normal and long-term average rainfall for the periods of record

Seasonal Rainfall

In the LSJRB, there are two distinct seasons: the summer season, lasting from June through September, and the winter season, lasting from December through March. Long-term average rainfall, received during those two seasons, is not significantly different from the normal rainfall amounts (Table 2.11). The highest average rainfall during the summer season was observed in De Land (30.05 inch), and the lowest average rainfall during the same season in St. Augustine (24.18 inch).

Maximum Rainfall

Maximum recorded rainfall for different durations at various locations in the lower St. Johns River basin is presented in (Table 2.12). The highest 24-hour rainfall was recorded at Fernandina Beach (22.22 inch), starting November 1, 1969, while the lowest 24-hour rainfall was recorded at Starke (6.89 inch), starting on August 29, 1968. In general, maximum daily rainfall occurred in all months except December and February, but over 60 percent

Table 2.10. Long-term rainfall (inches)

STATION (Period)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR
Crescent City (1897-1984)	2.46	3.26	3.50	2.89	4.04	6.73	7.23	7.04	6.51	3.97	2.06	2.75	52.44
Daytona Beach Airport (1923-1984)	2.12	2.78	3.22	2.67	3.36	6.35	5.96	5.83	6.64	4.63	2.28	2.32	48.16
De Land (1909-1984)	2.28	2.93	3.37	2.90	4.13	7.88	7.99	7.46	6.81	4.70	2.07	2.29	54.81
Federal Point (1892-1984)	2.68	3.30	3.45	2.80	3.88	6.54	6.90	6.98	7.18	4.47	2.10	2.90	53.18
Fernandina Beach (1902-1984)	2.77	3.15	3.66	2.88	3.52	5.48	6.25	5.77	7.39	4.10	2.40	2.80	50.17
Gainesville (1897-1984)	3.00	3.53	3.54	3.03	3.54	6.67	7.21	7.16	5.43	2.91	1.86	3.13	51.01
Glen St. Mary (1896-1984)	3.07	3.72	4.04	3.06	4.14	6.61	7.84	7.20	5.82	3.10	1.96	3.29	53.85
Jacksonville Airport (1867-1984)	2.82	3.19	3.42	2.83	3.89	6.09	6.64	6.54	7.29	4.34	1.95	2.73	51.73
Jacksonville Beach (1945-1984)	2.88	3.54	3.80	2.80	3.89	5.46	5.76	5.36	7.62	5.16	2.25	2.87	51.39
Marineland (1942-1984)	2.35	3.29	3.62	2.52	2.99	5.12	5.20	5.95	7.45	4.39	2.32	2.53	47.73
Palatka (1923-1984)	2.63	3.31	3.79	3.13	3.73	6.59	7.17	6.91	6.78	3.91	1.90	2.74	52.59
St. Augustine (1877-1984)	2.75	3.48	3.36	2.86	3.49	5.58	5.83	5.68	7.09	5.18	2.44	2.93	50.67
Starke (1896-1984)	2.77	3.45	3.62	3.03	3.91	6.24	7.61	7.20	5.53	3.05	1.84	3.19	51.44
AVERAGE	2.66	3.30	3.57	2.88	3.73	6.26	6.74	6.54	6.73	4.15	2.11	2.81	51.48

Source: Jenab et al. 1986

Table 2.11. Comparison of seasonal long-term rainfall with seasonal normal rainfall (inches)

STATION	LONG-TERM AVERAGE SUMMER SEASON (JUN-SEP)	LONG-TERM AVERAGE WINTER SEASON (DEC-MAR)	NORMAL SUMMER SEASON (JUN-SEP)	NORMAL WINTER SEASON (DEC-MAR)
Crescent City (1897-1984)	27.51	11.97	27.69	13.28
Daytona Beach Airport (1923-1984)	24.78	10.44	24.95	10.64
De Land (1909-1984)	30.05	10.87	29.27	11.55
Federal Point (1892-1984)	27.60	12.33	26.95	12.86
Fernandina Beach (1902-1984)	24.89	12.38	25.19	12.89
Gainesville (1897-1984)	26.47	13.20	27.13	13.98
Glen St. Mary (1896-1984)	27.47	14.12	28.80	14.68
Jacksonville Airport (1867-1984)	26.56	12.16	26.36	12.44
Jacksonville Beach (1945-1984)	24.20	13.09	23.66	12.83
Marineland (1942-1984)	28.11	11.79	23.01	11.70
Palatka (1923-1984)	27.45	12.47	26.23	12.82
St. Augustine (1877-1984)	24.18	12.52	24.88	13.99
Starke (1896-1984)	26.58	13.03	27.00	13.21
AVERAGE	26.60	12.34	26.24	12.84

Source: Jenab et. al. 1986

Table 2.12. Maximum rainfall (inches) in the lower St. Johns River basin, for different time periods

STATION	MAXIMUM RAINFALL (INCHES) 24-HOUR	48-HOUR	72-HOUR
St. Augustine Radio Tower (1931-1983)	11.08	13.49	14.72
Palatka (1931-1983)	11.86	14.58	16.81
Starke (1942-1983)	6.89	10.80	12.49
Jacksonville Beach (1945-1983)	10.79	13.80	14.83
Marineland (1942-1983)	14.63	15.45	15.55
Crescent City (1931-1983)	8.09	8.89	9.43
Jacksonville Airport (1931-1983)	10.75	13.25	14.87
Glen St. Mary (1931-1983)	9.27	11.82	13.86
Gainesville (1903-1983)	7.54	9.82	10.92
Daytona Beach Airport (1931-1983)	9.32	10.32	11.83
Fernandina Beach (1931-1983)	22.22	22.50	22.63
De Land (1931-1983)	9.25	10.97	12.25

Source: Rao and Clapp 1986

occurred in September and October. Some of the extreme daily values were associated with hurricanes and weaker tropical storms, but many were not. For rainfall durations over 24 hrs, the highest 48-hour and 72-hour rainfalls were recorded in Fernandina Beach, while the lowest rainfalls were recorded at Crescent City (Table 2.12).

Recorded Daily Rainfall

For all stations (Table 2.3), daily rainfall has been recorded by NOAA. At Marineland, Jacksonville Airport, and Jacksonville City hourly rainfall is recorded. For some of the stations, the rainfall recording program was initiated in the second half of the 1800s (e.g., the station now located at Jacksonville Airport), while other stations were initiated more recently. All data are made available by NOAA in its monthly publications, and can be obtained on magnetic tape upon request. SJRWMD maintains a data base which contains climatological data pertaining to stations in the basin. The daily rainfall data collected by NOAA are also stored in this data base and are, therefore, readily accessible for use in projects, in decision making, and as public information. The District makes an effort to update the climatological information in its data base as it becomes available. Some of the records are incomplete and sometimes large gaps in the data make it difficult to perform various analyses. In this case, some of the missing data may have to be estimated from nearby stations in order to obtain records that are continuous for certain periods designated for analytical evaluation. This could, for instance, occur in the evaluation of a water budget or in rainfall studies.

In addition to the daily rainfall from NOAA, the District's data base also contains daily rainfall data obtained from private climatological stations and from stations operated by the District. These stations are included in Appendix A.

STREAMFLOW

Streamflow Monitoring Network

The USGS has systematically collected water surface data, including stage, discharge, and water quality of the streams in the lower St. Johns River basin. A schematic of the permanent gaging network to assist in this effort is shown in Figure 2.17. A listing of these stations is given in Appendix B, together with their

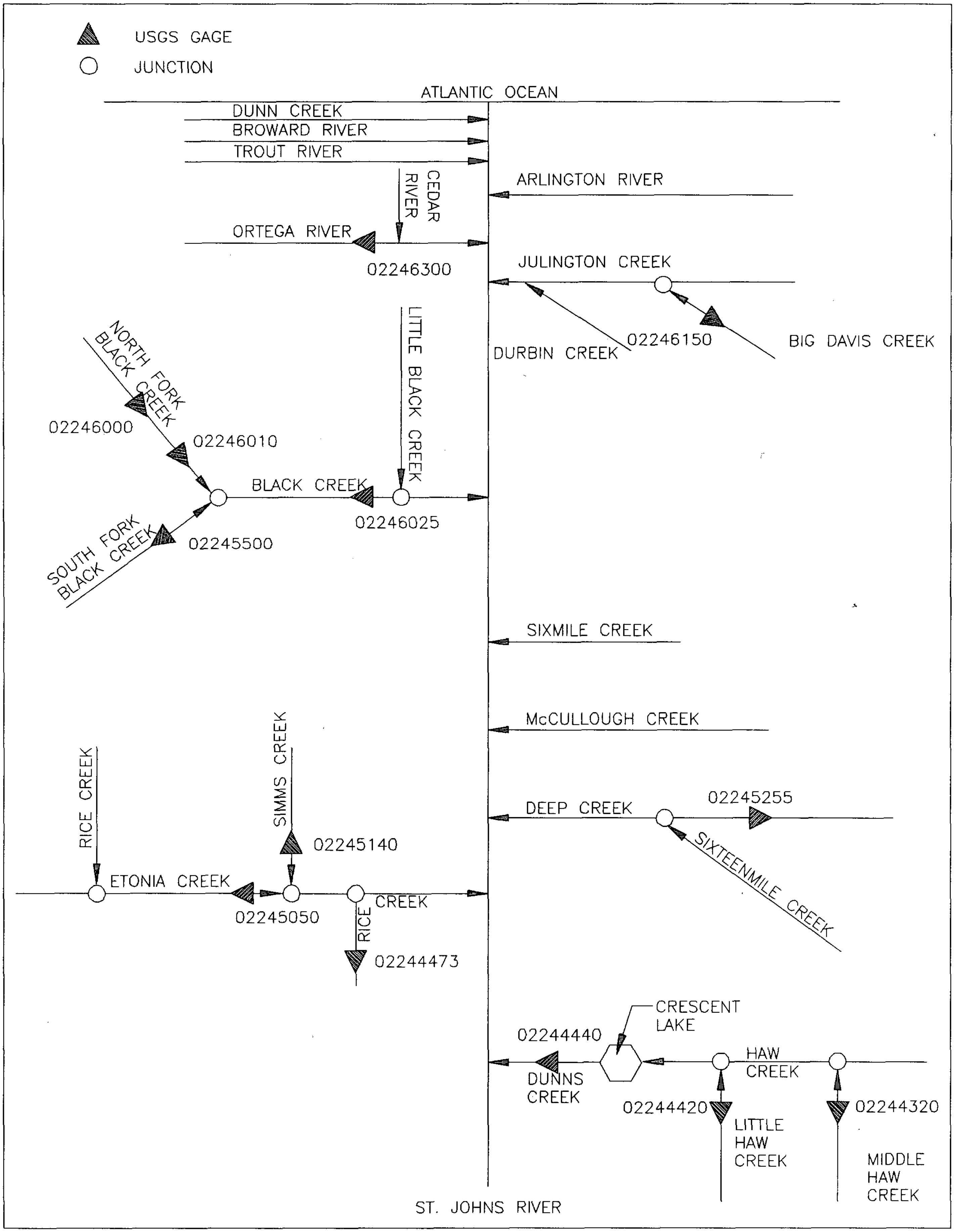

Figure 2.17 Schematic of U.S. Geological Survey streamflow gaging network

location, station identification number, and length of record. Some stations have been discontinued, for instance 02244300 (1966), 02245000 (1951), and 02245200 (1973), while other stations have interrupted records. Basins like McCullough Creek, Sixmile Creek, and Trout River have not been monitored at all. The Deep Creek basin has only one gaging station, which has been in operation since 1975. In Duval County several of the smaller watersheds have not been monitored, while other creeks and streams have been equipped with crest-stage recorders (Table 2.13).

One of the LSJRB SWIM projects is to extend the existing hydrologic monitoring network in the various watersheds composing the lower basin. The objective is to monitor tributaries for evaluation of their impacts on the St. Johns River and calibration and validation of stormwater models developed for the tributary basins. Within this framework, the District, in cooperation with the USGS and the City of Jacksonville, installed a number of streamflow gaging stations in Duval County, during the period 1989-1990. Table 2.14 provides a summary of these stations. Additional gaging stations in the lower St. Johns River basin may be installed in the future.

Daily Streamflow

Daily streamflow data have been collected by the USGS at the stations listed in Appendix B. Some of the records are incomplete, while others have been discontinued. A brief discussion of the observed daily flows follows. Average daily discharges at the gage refer to the period of record (USGS 1989), including water year 1988, which ends September 30, 1988.

Black Creek. This basin has a drainage area of approximately 496 square miles. The major tributaries are Little Black Creek, the North Fork Black Creek and the South Fork Black Creek. The last two tributaries join at Middleburg to form the Black Creek. The following USGS streamflow gages are currently active.

- Gage 02245500 on South Fork Black Creek is located upstream of State Highway 16. This station has been in operation since October 1939. The drainage area is 134 square miles (USGS 1989). The average discharge over the period of record is 156 cubic feet per second (cfs), or 15.81 in/yr. The maximum observed flow is 13,900 cfs on October 19, 1944, while the minimum observed flow is 9.4 cfs on June 24, 1955. For a plot of the recorded data, see Figure 2.18.

Table 2.13. U.S. Geological Survey crest stage recorders

WATERCOURSE	TRIBUTARY BASIN	GAGE NUMBER
Julington Creek	Julington Creek	02246100
Red Bay Branch Tributary	Arlington River	02246522
Jones Creek	LSJR-Downstream	02246820
Little Sixmile Creek	Trout River	02246700
Williamson Creek	Ortega River	02246460
South Fork Wills Branch	Ortega River	02246455
McCoy Creek	LSJR-Upstream	02246497
Dunn Creek	Dunn Creek	02246800
Big Branch	Black Creek	02246029
Greens Creek	Black Creek	02245470
Durbin Creek	Julington Creek	02246200
Cedar River	Ortega River	02246360
Long Branch	LSJR-Upstream	02245850

Source: CDM 1989

Table 2.14. U.S. Geological Survey streamflow stations installed 1989-1990, Duval County

TRIBUTARY BASIN	GAGE NUMBER	LATITUDE/LONGITUDE	GAGE LOCATION
Lower St. Johns River	02246502	302027/813942	Hogan Creek at Broad Street
	02246498	301939/814128	McCoy Creek at Stockton Street
	02246835	301822/812732	Hogpen Creek at Hodges Road
Trout River	02246600	302551/814607	Trout River at Old Kings Road
	02246602	302623/814621	Little Trout River at Old Kings Road
	02246700	302151/814416	Little Sixmile Creek at Old Kings Road
	02246650	302214/814447	Sixmile Creek at Old Kings Road
Ortega River	02246359	301850/814513	Cedar River at Ramona Blvd
Broward River	02246750	302730/814049	Cedar Creek at Duval Road
Arlington River	02246520	301926/813400	Strawberry Creek at Century Drive
	02246515	301550/813525	Pottsburg Creek at Bowden Road
Julington Creek	02246200	300557/813134	Durbin Creek at Racetrack Road*
	02246201	300933/813422	Oldfield Creek at Loretto Road**
	44444444	301002/813347	Julington Creek at I-295

* stage measurement only
**discontinued since 10/1/91

- Gage 02246000 is located on the North Fork Black Creek, near Middleburg, 0.3 miles upstream of Big Branch. The creek drains 177 square miles (USGS 1989). This station has been in operation since October 1931. The average discharge over the period of record is 194 cfs, the maximum discharge is 12,600 cfs, and the minimum discharge is 3.6 cfs. The data are plotted in Figure 2.19.

- Gage 02246010 is the second station located on the North Fork Black Creek, just upstream of Middleburg where the South Fork and the North Fork combine into the Black Creek. The contributing drainage area is 197 square miles. The period of record extends from October 1981 to the present year. Only stage elevations are being measured.

- Gage 02246025 is located on the bridge over Black Creek on State Highway 209. The drainage area is 403 square miles. Measurements started in October 1981. However, the records are incomplete, of poor quality, and tidally affected.

Two other stations were only in operation during the period October 1957 - September 1960. The first station, USGS 02245400, was located on the South Fork Black Creek near Camp Blanding along State Highway 21. The second station, USGS 02245800, was located at the intersection of the North Fork Black Creek and State Highway 218.

<u>Crescent Lake</u>. The drainage area of the basin is 605 square miles. Dunns Creek, Haw Creek, Middle Haw Creek, and Little Haw Creek are the major water courses in the watershed. Crescent Lake is a major Florida lake. Two USGS stream gages are in operation.

- Gage 02244320 is located on Middle Haw Creek, which drains an area of 78.3 square miles, according to the USGS (1989). The average discharge amounts to 76.5 cfs. Flow monitoring started in July 1975.

- Gage 02244420 is located on Little Haw Creek, which drains an area of 93.0 square miles. Flow measurements were started in 1951 and are being continued. The average discharge over the period of record is 85.1 cfs or 12.43 in/yr.

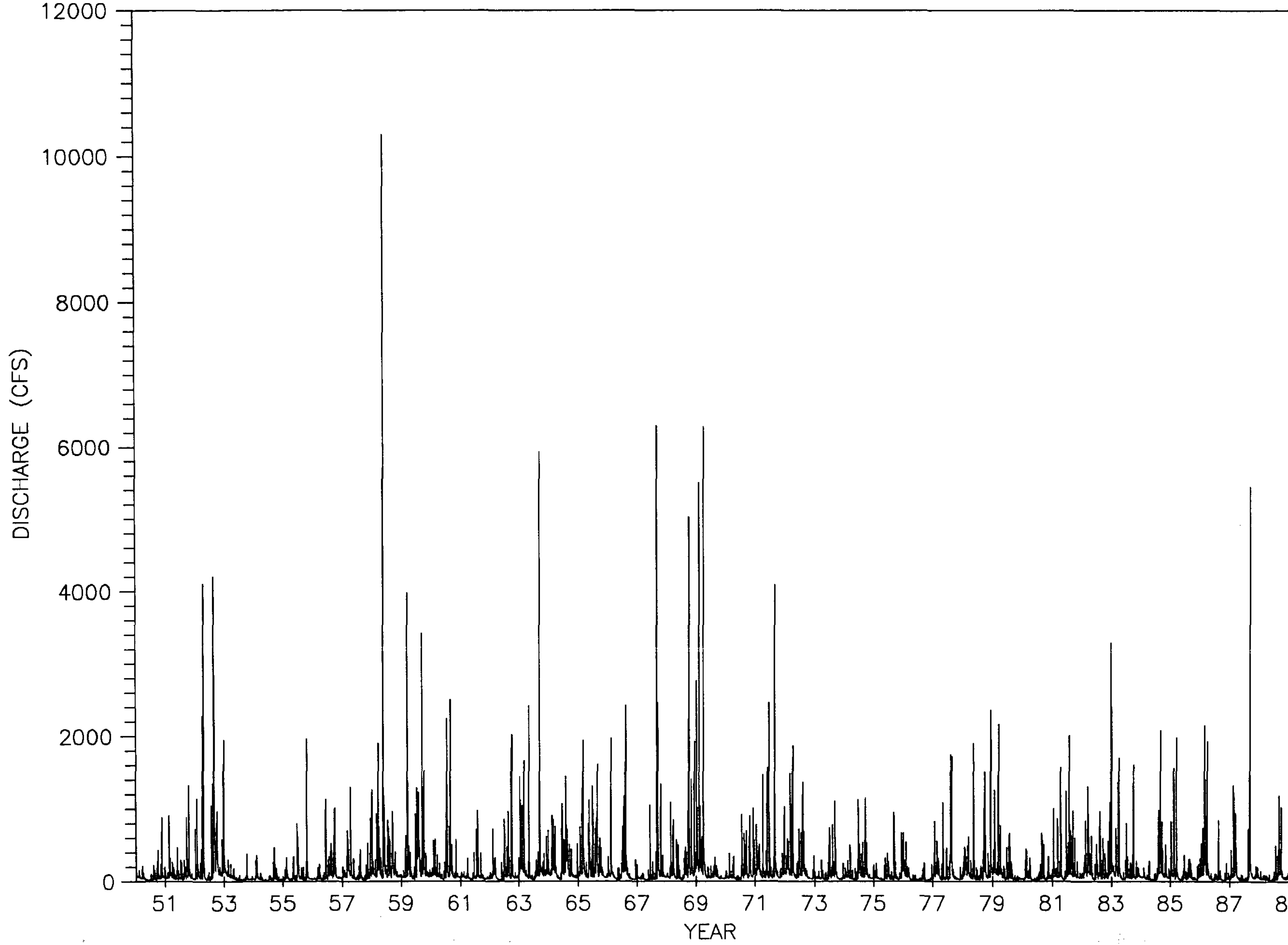

Figure 2.18 Daily discharges of the South Fork of Black Creek (USGS 02245500), 1/1/1951 - 2/28/1990

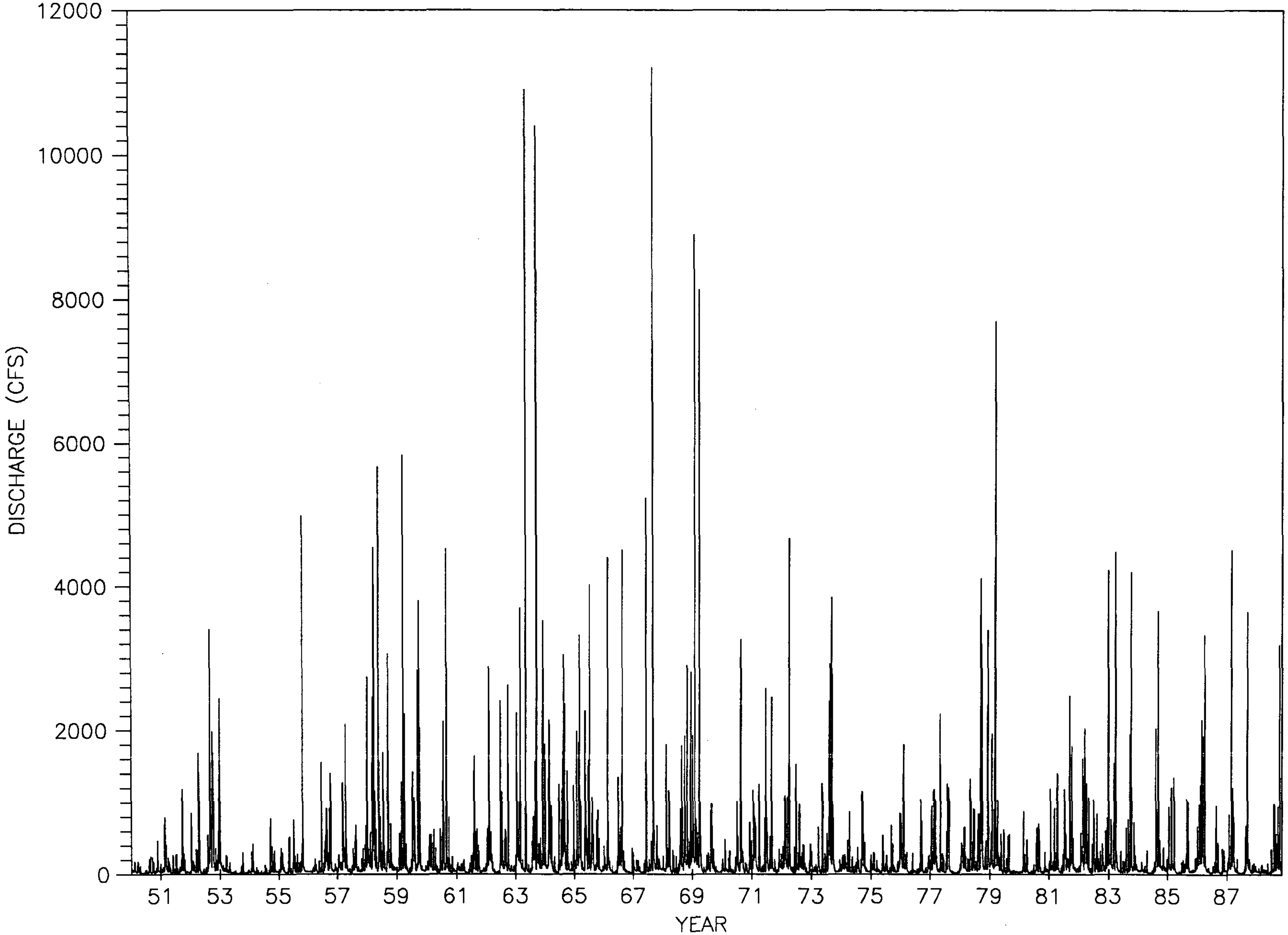

Figure 2.19 Daily discharges of the North Fork of Black Creek (USGS 02246000), 7/1/1951 - 10/31/1989

Graphs of the recorded data are shown in Figures 2.20 and 2.21, respectively.

Deep Creek. This basin covers a drainage area of approximately 76 square miles. The major watercourse is Deep Creek, and a major tributary is Sixteenmile Creek. Only one streamflow gage is located in the basin: USGS 02245255, on Deep Creek, 1.3 miles upstream from Sixteenmile Creek. Measurements were started in June of 1975, and are being continued. The average recorded discharge is 8.47 cfs, or 5.56 in/yr. The contributing drainage area at the gage is 20.7 square miles. A plot of the discharges is shown in Figure 2.22.

Etonia Creek. This basin covers a drainage area of 355 square miles. Streamflow gages are located on Rice Creek (02244473), Etonia Creek (02245050), and Simms Creek (02245140).

- Gage 02244473 on Rice Creek was put into operation in October 1973. Its precise location is on the downstream side of the bridge on State Highway 100, 1.8 miles northwest of Springside. The average recorded flow is 45.0 cfs, or 14.14 in/yr. The contributing drainage area is 43.2 square miles.

- Gage 02245140 on Simms Creek is located about 2.7 miles upstream from its confluence with Etonia Creek (near Bardin). According to the USGS, measurements started in October 1973 and continued to September 1975. Then the measurements were interrupted until March 1976, but have resumed since then. The drainage area upstream of the gage is 47.3 square miles. The average recorded discharge is 47.4 cfs, or 13.61 in/yr.

- Gage 02245050, located on Etonia Creek, also started recording in October 1973. It drains an area of 219 square miles. The average recorded discharge is 99.6 cfs. The records show an appreciable amount of base flow, 60 cfs, which can be attributed to the production wells of the Georgia-Pacific Paper Corporation.

The recorded discharges are plotted in Figures 2.23, 2.24, and 2.25, respectively.

Julington Creek. This basin drains approximately 104 square miles. Major tributaries are Durbin Creek, Sampson Creek, and Big Davis Creek. USGS gage 02246150 is located on Big Davis Creek at the downstream end of the culvert on

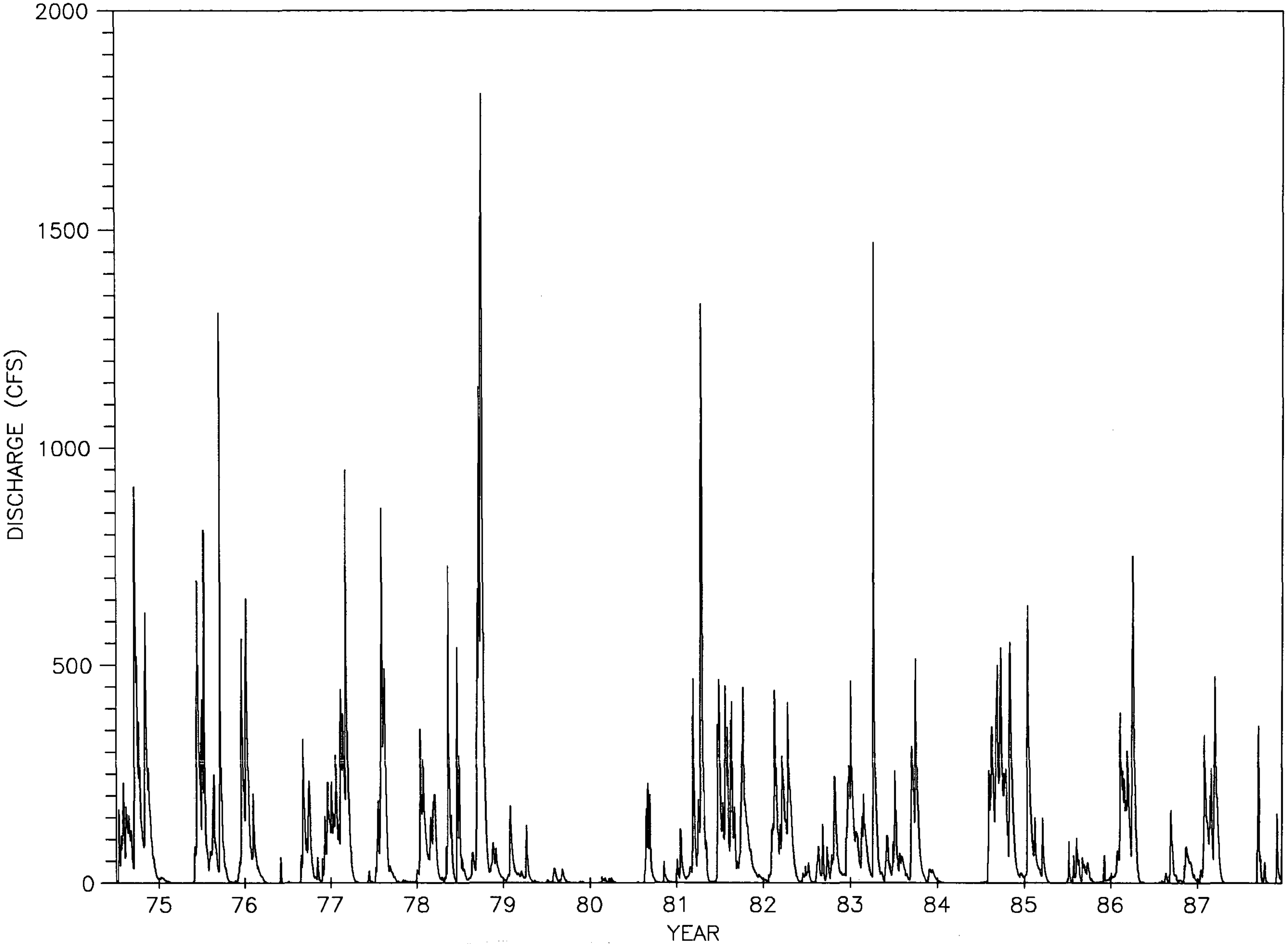

Figure 2.20 Daily discharges of Middle Haw Creek near Korona (USGS 02244320), 7/1/1975 - 12/15/1988

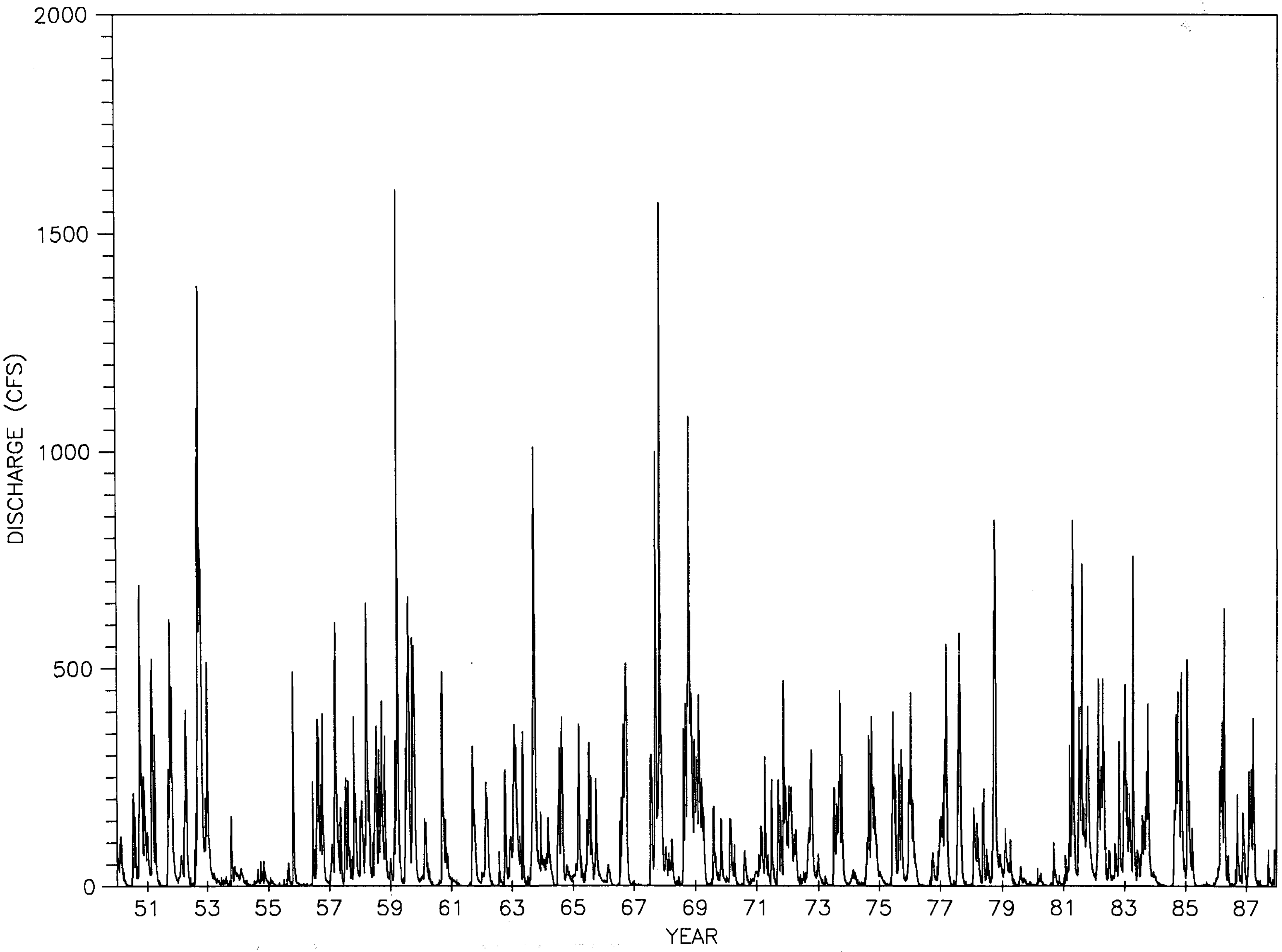

Figure 2.21 Daily discharges of Little Haw Creek near Seville (USGS 02244420), 1/1/1951 - 12/15/1988

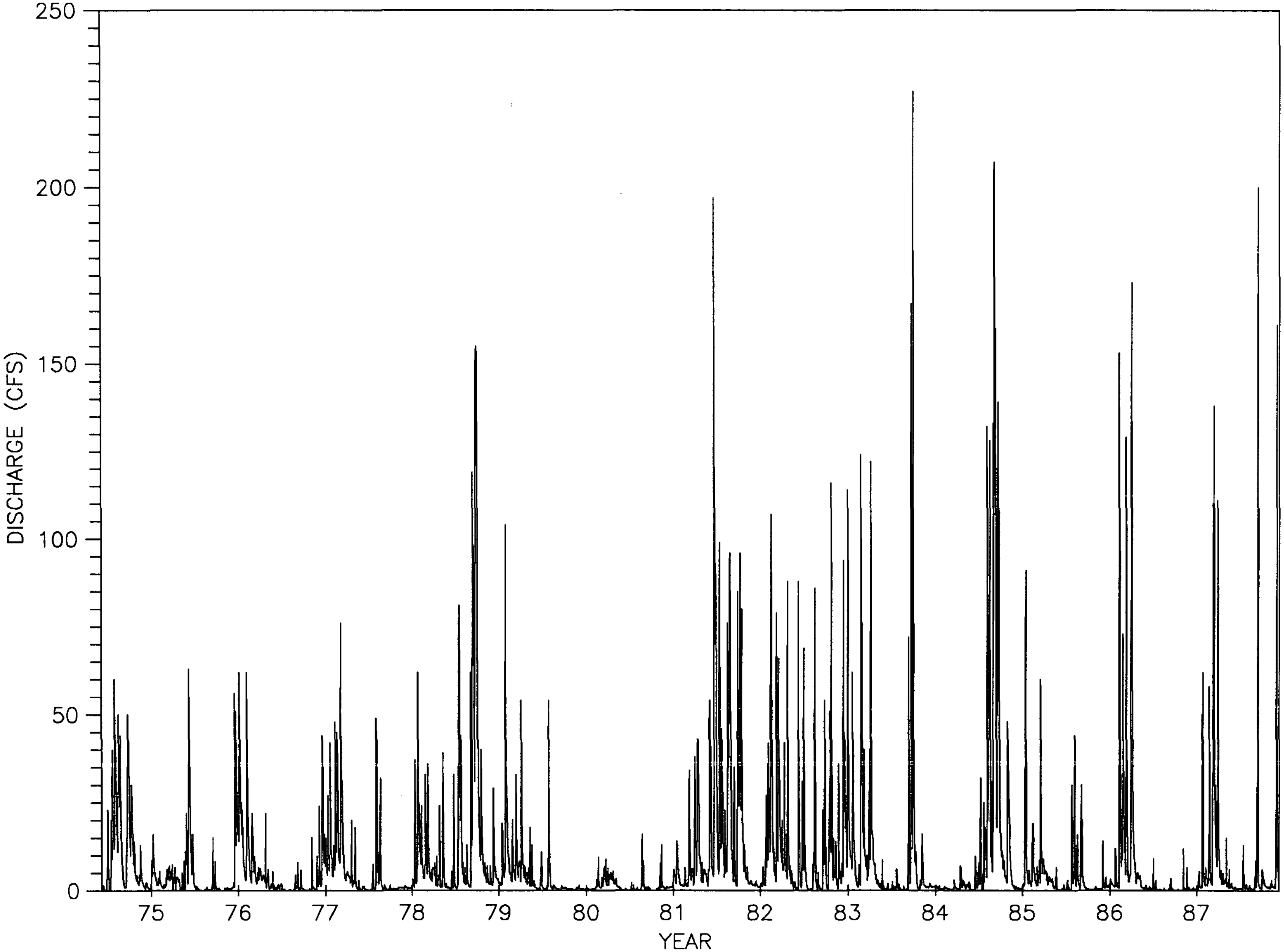

Figure 2.22 Daily discharges of Deep Creek near Hastings (USGS 02245255), 6/1/1975 - 12/5/1988

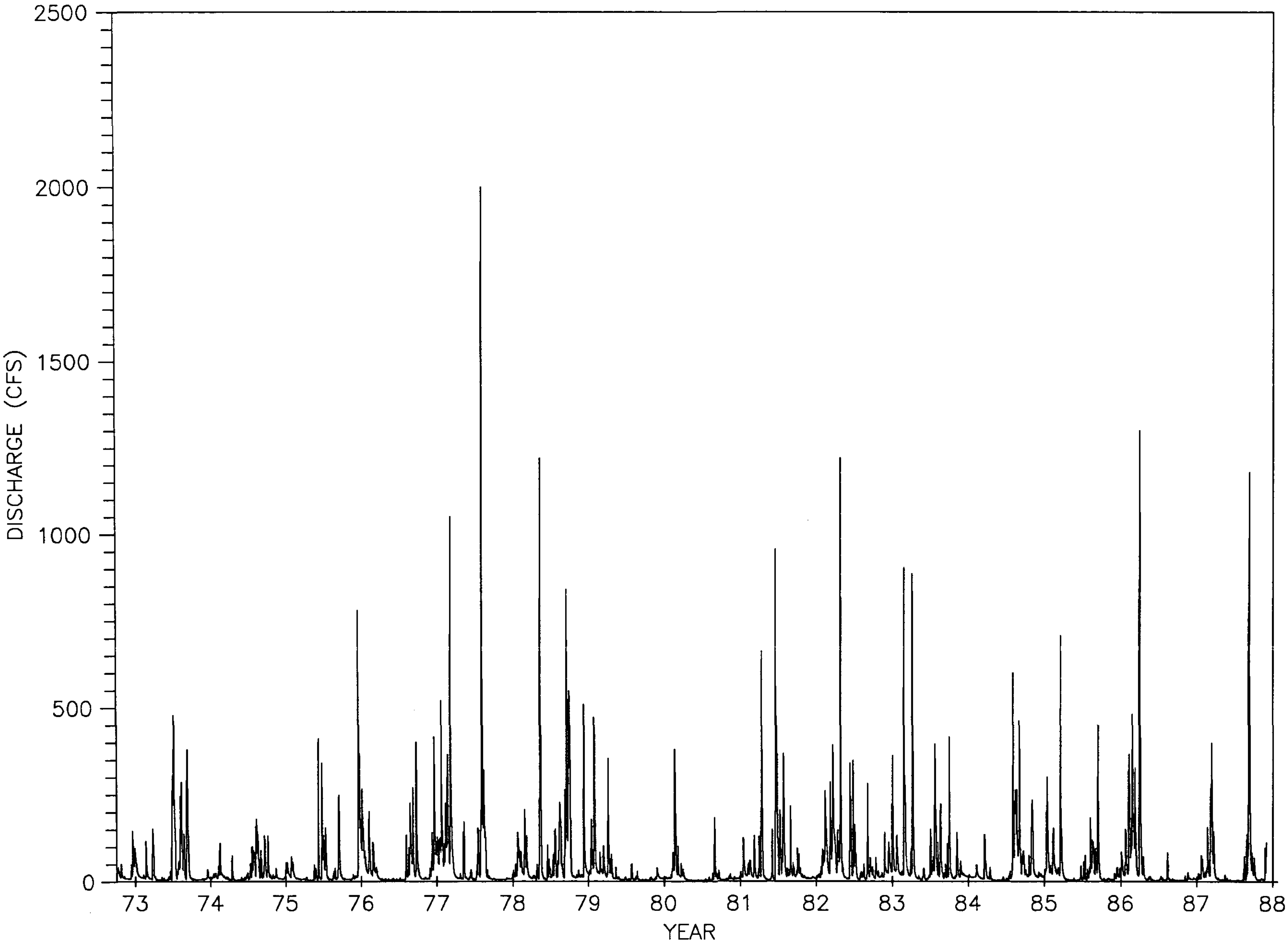

Figure 2.23 Daily discharges of Rice Creek near Springside (USGS 02244473), 10/1/1973 - 11/30/1988

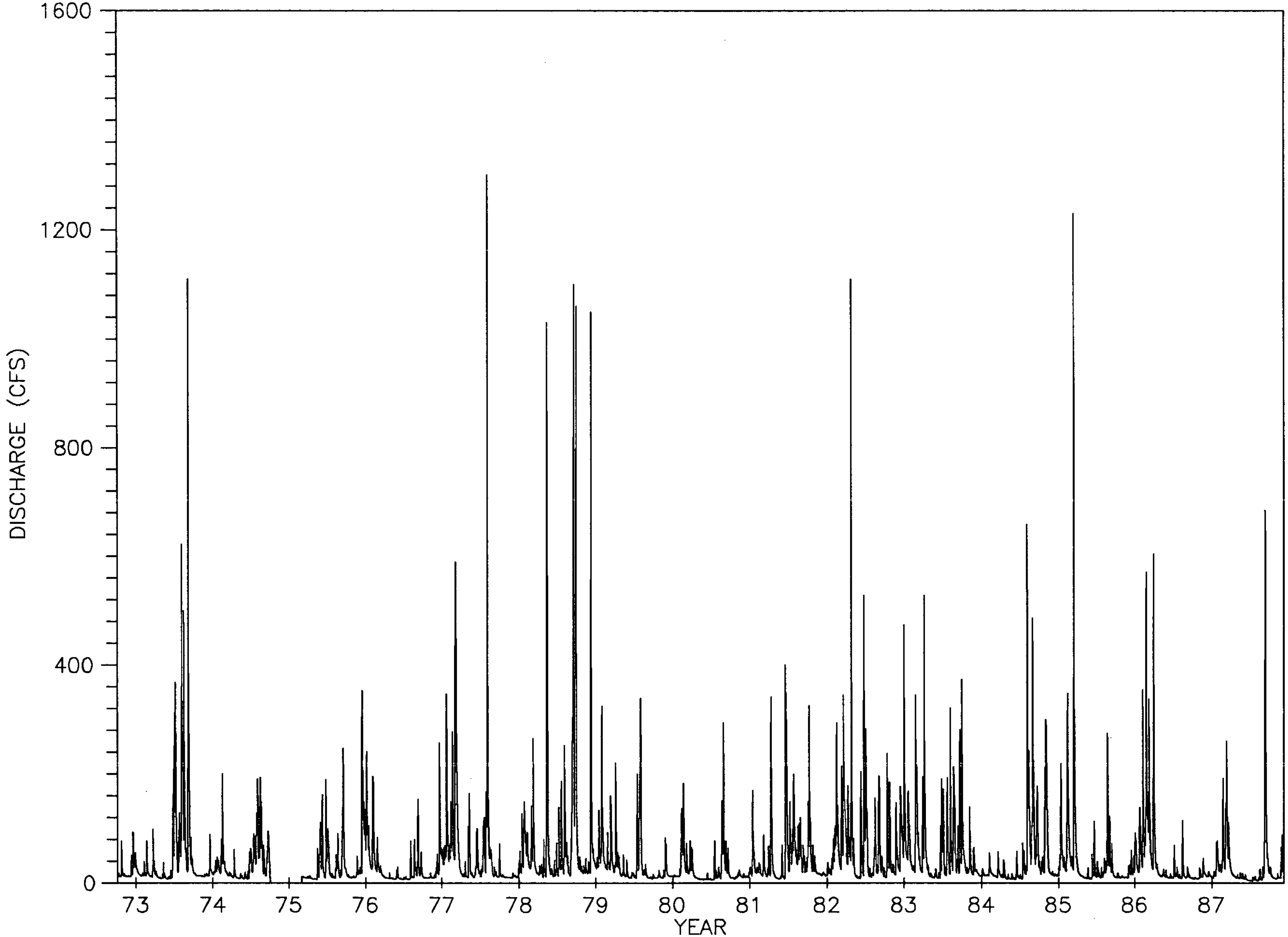

Figure 2.24 Daily discharges of Simms Creek near Bardin (USGS 02245140), 10/1/1973 - 12/6/1988

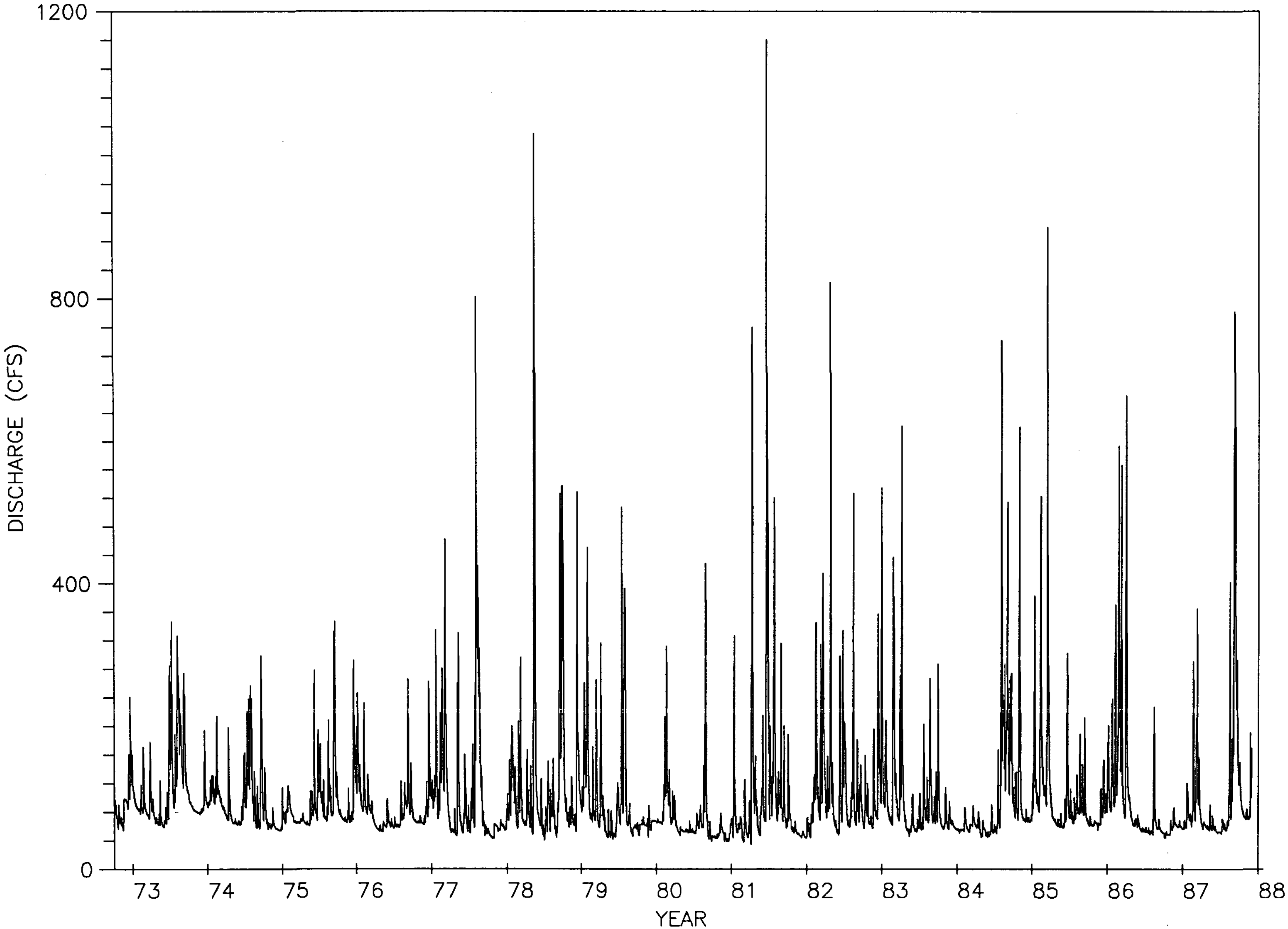

Figure 2.25 Daily discharges of Etonia Creek near Bardin (USGS 02245050), 10/1/1973 - 11/30/1988

U.S. Highway 1, 0.8 miles northwest of Bayard (USGS 1989). The drainage area totals 13.6 square miles. The average recorded discharge equals 10.7 cfs, or 10.68 in/yr. The discharges are plotted in Figure 2.26. From June of 1970 to November of 1987, the USGS has also collected daily rainfall data at this station.

Station 02246100, located on Julington Creek, was in operation from January of 1965 to August of 1966, and has been discontinued since then.

Ortega River. This basin has an area of approximately 100 square miles. Major tributaries are McGirts Creek, Cedar River, Wills Branch, Butcher Pen Creek, and Fishing Creek. USGS gage 02246300 is located on the downstream side of the bridge on S.R. 134. The Ortega River upstream of the gage drains 30.9 square miles (USGS 1989). Although prior to 1965 some occasional flow measurements were made, for all practical purposes the recording of data was started in January 1965, with an interruption from July 1983 to July 1984 due to bridge construction. The average recorded discharge over 22 years (USGS water years 1966-1983, 1985-1988) was 36.0 cfs, or 15.82 in/yr. For a plot of the discharges, see Figure 2.27.

A statistical summary of the various streamflow records is shown in Table 2.15.

EVAPOTRANSPIRATION

Evapotranspiration is the combined loss of water due to direct evaporation from land and water surfaces and transpiration of water by plants. Transpiration occurs mostly during the daylight hours, through the process of photosynthesis.

The energy required for the evapotranspiration process is supplied by the incoming solar radiation, which depends on the specific location and the time of the year. Micro-climatological factors such as wind speed, temperature, and vapor pressure affect the evaporation process. Maximum evapotranspiration occurs when the supply of water to both the plant and land surface is unlimited. This state of evapotranspiration is also called potential evapotranspiration and is approximately equal to the evaporation from a free-water surface such as a lake. Depending on the soil moisture content and micro-climatological conditions, water loss to the atmosphere may be less than potential evapotranspiration and is then called actual evapotranspiration.

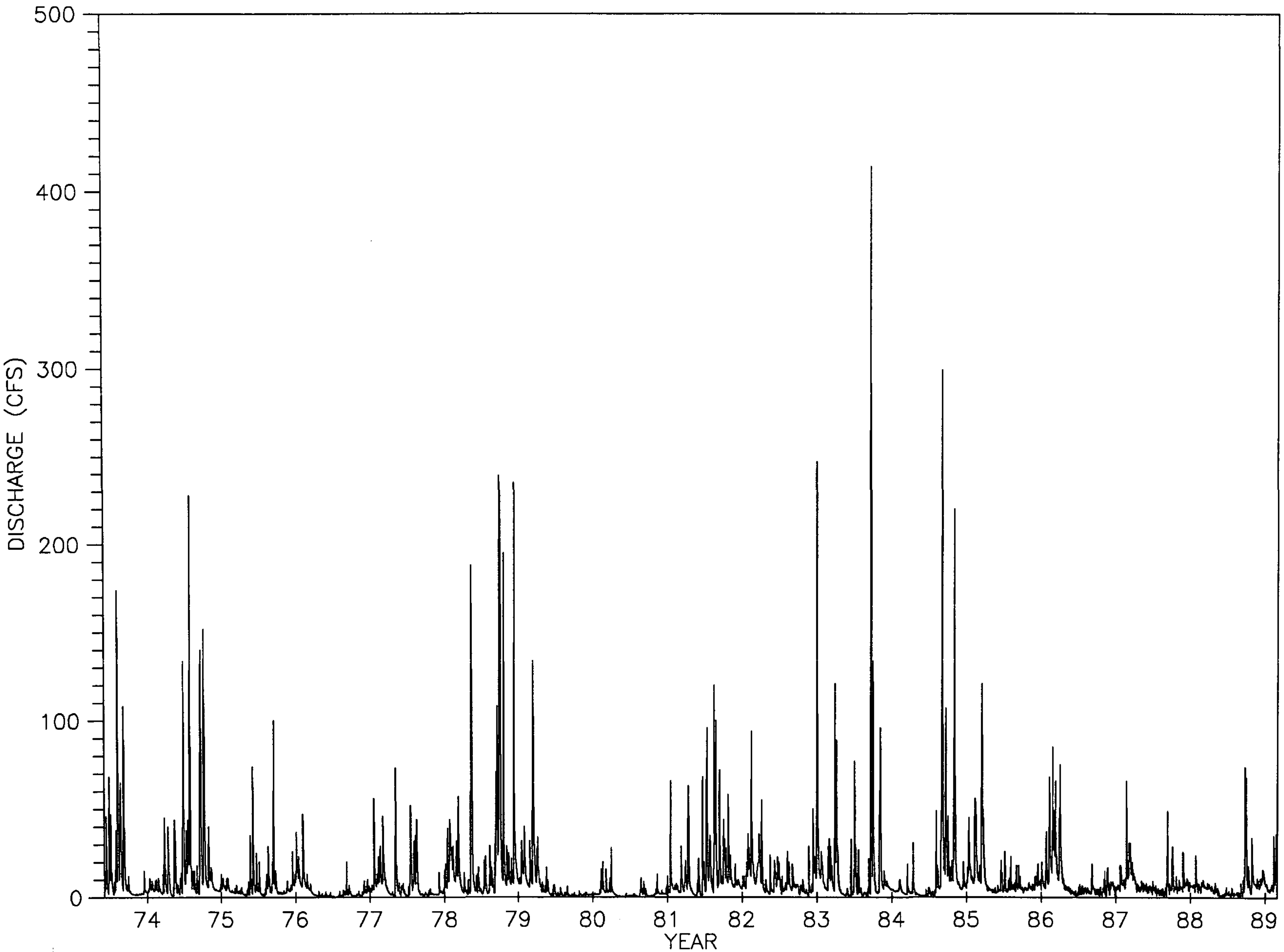

Figure 2.26 Daily discharges of Big Davis Creek (USGS 02246150), 6/1/1974 - 2/28/1990

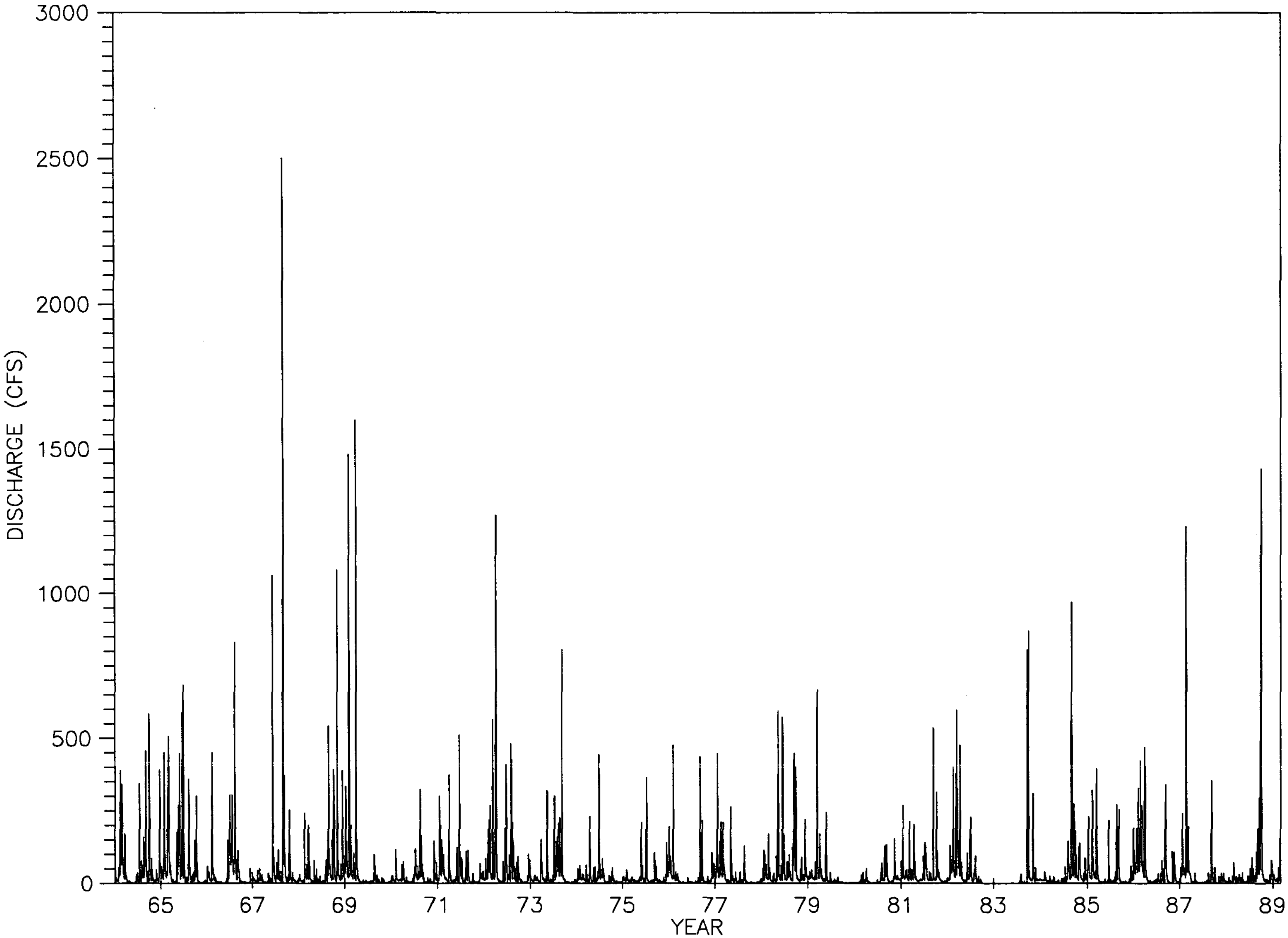

Figure 2.27 Daily discharges of Ortega River (USGS 02246300), 1/1/1965 - 2/28/1990

Table 2.15. Statistical description of daily streamflow data (cfs)

USGS STATION	AREA SQ MI	LENGTH OF RECORD	NUMBER OF DATA	MEAN	MEDIAN	MINIMUM	MAXIMUM	STANDARD DEVIATION	COEFF. OF VARIATION	SKEWNESS	KURTOSIS
South Fork Black Creek 02245500	134.0	1/1/1951-2/28/1990	14304	148.2	70.0	10.0	10300.0	290.2	1.96	10.9	214.9
North Fork Black Creek 02246000	177.0	1/1/1951-10/31/1989	14184	199.7	78.0	3.9	11200.0	454.9	2.28	9.5	142.6
Middle Haw Creek near Korona, 02244320	78.3	7/1/1975-12/15/1988	4917	77.3	18.0	0.0	1810.0	146.4	1.89	4.4	33.2
Little Haw Creek near Seville, 02244420	93.0	1/1/1951-12/15/1988	13865	84.1	29.0	0.0	1600.0	131.9	1.57	3.3	16.4
Deep Creek near Hastings 02245255	20.7	6/1/1975-12/5/1990	4937	8.6	1.8	0.0	227.0	19.6	2.28	4.8	29.8
Rice Creek near Springside, 02244473	43.2	10/1/1973-11/30/1988	5540	44.7	14.0	2.2	2000.0	95.5	2.14	7.2	84.7
Etonia Creek near Bardin, 02245050	219.0	10/1/1973-11/30/1988	5540	99.5	73.0	35.0	1160.0	80.3	0.81	4.4	28.4
Simms Creek near Bardin, 02245140	47.3	3/1/1976-12/6/1988	4664	47.1	20.0	4.1	1300.0	81.2	1.72	6.3	62.5
Pablo Creek 02246828	25.8	3/1/1974-12/31/1989	5785	32.5	17.0	1.8	959.0	55.2	1.70	6.5	62.2
Cedar Swamp Creek 02246832	3.4	3/1/1974-2/28/1990	5844	8.1	4.4	0.1	293.0	15.4	1.90	7.6	83.7
Big Davis Creek 02246150	13.6	6/1/1974-2/28/1990	5752	10.5	5.2	0.1	735.0	20.1	1.91	7.5	85.8
Ortega River 02246300	30.9	1/1/1965-9/30/1983	6847	36.4	12.0	0.1	2500.0	90.9	2.50	10.2	175.2

Various relationships exist to estimate the potential evapotranspiration. A well-known method is, for example, the Penman equation, which incorporates radiation, vapor pressure, wind velocity, and air temperature. Other methods were developed by Thornthwaite, Turc, and Blaney-Criddle (Bedient and Huber 1988). Also, evaporation can be measured from a standard weather bureau Class A pan (Bedient and Huber 1988). Pan evaporation rates are higher than lake evaporation rates, and should be adjusted to obtain estimates of the potential evapotranspiration. This adjustment factor is called the pan coefficient, which ranges from 0.64 to 0.81 (Bedient and Huber 1988).

In the lower St. Johns River basin, no daily evaporation measurements are being made on a systematic basis. The closest station where evaporation data are being collected is Gainesville. This station has been operated by NOAA (index 3321) since 1960. Monthly pan evaporation in June-July may amount to 8 in. Lake City is the second nearest station where NOAA measures evaporation.

FLOODING

The National Flood Insurance Program (NFIP) was established by the National Flood Insurance Act of 1968 and further defined by the Flood Disaster Protection Act of 1973. The objective of the act was to provide flood insurance to communities that were willing to adopt floodplain management programs to mitigate future losses caused by floods. The act also required the identification of all floodplain areas within the United States and the establishment of flood-risk zones within those areas.

One of the requirements to qualify for NFIP is the completion of a flood insurance study of the particular community. A flood insurance study involves an appraisal of a community's flood problems, estimation of the flood flow frequency of flooding sources, computation of flood elevation profiles for various frequencies (10-, 50-, 100-, and 500-year events), delineation of flood boundaries and floodways, and computation of flood hazard factors.

Table 2.16 lists the communities in the lower St. Johns River basin that are participating in the National Flood Insurance Program.

Table 2.16. Participating communities in the National Flood Insurance Program

COMMUNITY NUMBER	COMMUNITY NAME	DATE OF ENTRY	DATE OF CURRENT EFFECTIVE MAP
120086	Bunnell, Flagler County	3/26/1975	3/26/1975
120064	Unincorporated Areas, Clay County	7/2/1981	8/1/1983
120408	Crescent City, Putnam County	12/18/1979	12/18/1979
120307	De Land, Volusia County	12/22/1980	NSFHA*
120085A	Unincorporated Areas, Flagler County	9/17/1975	2/25/1977
120065	Green Cove Springs, Clay County	3/1/1979	3/26/1982
120282	Hastings, St. Johns County	7/2/1981	7/2/1981
120078B	Jacksonville Beach, Duval County	3/15/1977	3/15/1977
120077	Jacksonville, Duval County	12/1/1977	12/15/1983
120066	Orange Park, Clay County	3/18/1980	3/18/1980
120273	Palatka, Putnam County	6/4/1980	6/4/1980
120418	Pomona Park, Putnam County	12/4/1979	12/4/1979

Source: U.S. Army Corps of Engineers 1986
* NSFHA - No Special Flood Hazard Area

HYDRAULIC STRUCTURES

CDM did an extensive field survey of the hydraulic structures in the various drainage basins in Duval County (CDM 1989). A similar inspection was done in Putnam, Flagler, Volusia, and St. Johns counties (Table 2.17). It was observed that in most of the watercourses the flow was seriously obstructed by trees, brush, and vegetation growing along the lakes, stream banks, and in the floodplains. Due to poor maintenance, heavy and prolonged storms may cause serious flooding of roads, utilities, and residential areas. Litter and trash along the roads and streets also ultimately cause pollution of surface and ground waters. Because the restoration of these waters is costly and time consuming, preventive measures, like regular street cleaning and public awareness, should be undertaken.

Another source of information on hydraulic structures in the study area is FEMA. However, only a few FEMA studies were done in this area, mostly pertaining to lake elevations. Therefore, little is known about the cross-sectional geometry of the streambeds in the study area, with the exception of Dunns Creek downstream of Crescent Lake and Acosta Creek.

Table 2.17. Summary of field survey of hydraulic structures

TRIBUTARY	COUNTY	QUAD	TRIBUTARY	HIGHWAY	DESCRIPTION
Crescent Lake	Putnam	Satsuma	Dunns Creek	Hwy 17	Large concrete bridge, USGS gage 02244440
	Flagler	Bunnell	Haw Creek	Hwy 100	Box culvert with 2 openings, ~ 10x7 ft (wxh)
	Flagler	Bunnell	Haw Creek	Hwy 100	Box culvert with 3 openings, ~ 9x5 ft (wxh)
	Flagler	Bunnell	Black Branch	Hwy 11	Small concrete bridge on timber piles
	Flagler	Codys Corner	Middle Haw Creek	Hwy 11	Medium concrete bridge on timber piles
	Flagler	Codys Corner	Middle Haw Creek	Hwy 304	Medium concrete bridge with concrete piles
	Flagler	Codys Corner	Middle Haw Creek	Hwy 11	Box culvert with 1 opening, ~10x5 ft (wxh)
	Flagler	Codys Corner	Middle Haw Creek	Dirt Road	Timber bridge near hunting camp
	Flagler	Codys Corner	Middle Haw Creek	Dirt Road	Approx. 30" dia. culvert in dirt road
	Flagler	Codys Corner	Middle Haw Creek	Dirt Road	Culvert in dirt road, half silted
	Flagler	Codys Corner	Little Haw Creek	Hwy 11	Small concrete bridge on timber piles
	Volusia	Lake Dias	Little Haw Creek	Hwy 40	Medium concrete bridge with concrete piles
	Volusia	Lake Dias	Lake Dias	Hwy 11	Box culvert with 2 openings, ~10x4 ft (wxh)
	Flagler	Seville	Little Haw Creek	Hwy 305	Small concrete bridge on timber piles
	Flagler	Bunnell	Middle Haw Creek	Hwy 305	Medium concrete bridge on timber piles, 13 tons
	Flagler	Bunnell	Haw Creek	Hwy 305	Medium concrete bridge on timber piles, 25 tons
	Volusia	De Land	Little Haw Creek	Hwy 44	2 - 24" culverts
	Volusia	De Land	Little Haw Creek	Hwy 430	1 - 24" culvert
	Volusia	De Land	Little Haw Creek	Minnesota Av.	Small concrete box shaped bridge, between Blue Lake and South Lake Talmadge
	Volusia	De Land	Little Haw Creek	Hwy 92	Box culvert with 3 openings, ~10x5 ft (wxh)
	Volusia	De Land	Little Haw Creek	Old Daytona Road	Small concrete/steel box shaped bridge
	Volusia	De Land	Little Haw Creek	Marsh Road	Small concrete bridge, very heavy vegetation
Sixmile Creek	St. Johns	Picolata	Sixmile Creek	Hwy 13	Large concrete bridge, no danger of flooding
	St. Johns	Picolata	Trout Creek	Hwy 13	Large concrete bridge, no danger of flooding
	St. Johns	Orangedale	Trout Creek	Hwy 16A	Medium concrete bridge, heavy vegetation
	St. Johns	Picolata	Sixmile Creek	Hwy 16A	Culvert, approx. 6' dia., to drain u/s swamp
	St. Johns	Picolata	Sixmile Creek	Hwy 16A	Culvert, approx. 6' dia., to drain u/s swamp
	St. Johns	Picolata	Sixmile Creek	Hwy 16A	Concrete box culvert, ~ 8x6 ft (wxh)
	St. Johns	Picolata	Sixmile Creek	Hwy 16A	Culvert, approx. 5' dia.
	St. Johns	Picolata	Sixmile Creek	Hwy 13	Two 8 ft culverts, heavy vegetation
Deep Creek	St. Johns	Hastings W	West Run Cracker Branch	Hwy 207	Small concrete bridge over dry channel bed
	St. Johns	Spuds	Sixteenmile Creek	Hwy 13	Medium concrete bridge over dry channel bed
	St. Johns	Spuds	Sixteenmile Creek	Dirt Road	Dirt road, 11 corrugated culverts, ~ 48"
	St. Johns	Spuds	Deep Creek	Hwy 207	Large concrete bridge
Etonia Creek	Putnam	Baywood	Etonia Creek	Dirt Road	Unknown hydraulic structure, not reachable
	Putnam	Palatka	Etonia Creek	Hwy 309C	Small concrete bridge, USGS gage 02245050
	Putnam	Palatka	Rice Creek	Hwy 309D	Small concrete bridge, heavy vegetation
	Putnam	Palatka	Rice Creek	Hwy 100	Small concrete bridge, USGS gage 02244473
	Putnam	Palatka	Branch of Rice Creek	Hwy 309	Set of culverts, 3 - 36"?, road easily flooded, heavy vegetation in creek bed
	Putnam	Palatka	Branch of Rice Creek	Hwy 100	Small concrete structure, 3 big openings, very heavy vegetation
	Putnam	Palatka	Rice Creek	Country Road	Small wooden bridge on property of Georgia Pacific
	Putnam	Palatka	Rice Creek	Hwy 19	Big concrete bridge over Rice Creek
	Putnam	Palatka	Rice Creek	Railroad	Railroad bridge over Rice Creek, d/s Hwy 17

RAINFALL-RUNOFF SIMULATION

RAINFALL-RUNOFF

The portion of the rainfall, minus losses, that flows over the land during and after a rainstorm, is called surface water runoff. In hydrologic analysis, the estimation of the amount of runoff and its temporal distribution (runoff hydrograph) is of primary interest.

The Soil Conservation Service (SCS) has developed a useful set of rainfall-runoff relations, based on soil type, land use, and initial losses (SCS 1972). A second method of estimating runoff from rainfall is the well-known Rational Formula. Only the peak runoff is computed by this method. For this method to be applicable, the size of the watershed should be smaller than 1 square mile (Bedient and Huber 1988), and application to urbanized areas is preferred. Hydrologic simulation as performed by software packages such as HEC-1, SWMM, HSPF, etc. offers a more accurate procedure for quantifying rainfall-runoff relations.

Losses

Losses, or reductions to the volume of runoff, are due to infiltration, evaporation, transpiration, and surface storage. Factors such as soils, geology, climate, topography, land use, and antecedent rainfall directly affect the magnitude of these losses. In general, runoff starts after some rain has accumulated. This amount is called the "initial abstraction" and is due mainly to depression storage and interception.

Interception refers to the quantity of water retained on the vegetal cover. It will, eventually, be lost by evaporation. Interception estimates may range from 0.03 to 0.16 in, depending on the type of vegetation and growth stage (Linsley et al. 1975).

Depression storage refers to the rainfall water retained in depressions in the soil surface. Initially, rain falling in these surface depressions will infiltrate until the rainfall intensity exceeds the infiltration capacity. When the depressions fill, the overland flow process begins.

In most hydrologic models, depression storage and interception are lumped into one parameter, which is the initial loss before overland flow sets in. In practical terms, this parameter may be difficult to quantify, and in those situations may be used as a calibration parameter. SCS offers a method to estimate the initial abstraction by determining the curve number (CN) of the drainage area. However, this method is very general and may lead to inaccurate results for certain applications.

The rate of infiltration of water into the soil can be estimated using various formulas, for instance Horton, Green-Ampt, and phi-index. Some of the infiltrated water may be recovered as streamflow through base flow (ground water discharge) or interflow, while another part is permanently lost to surface runoff as deep percolation. The mechanism of infiltration of water into the soil is a complicated one. Most equations describe the infiltration process after a certain amount of rainfall has accumulated on the soil surface (ponding), although actual infiltration starts at the beginning of the storm. Hydrologic models simulate this situation by setting the infiltration rate equal to the rainfall intensity during the period before ponding occurs. After ponding has occurred, the infiltration rate in the model is determined by the infiltration capacity.

In urbanized areas, the quantity of water that infiltrates can be considered insignificant. In the LSJRB, this is true, for instance, in the Jacksonville metropolitan area. The large percentage of impervious area will cause mainly surface runoff. However, many of the undeveloped areas in the lower basin have very flat topography combined with high ground water tables and sandy soils like those found in flatwoods. In these areas, infiltration can not be neglected and the effects of infiltration and available soil moisture storage on the surface runoff should be estimated. Infiltration parameters are site-specific and can be determined from field experiments. Rawls et al. (1983) presents generalized Green-Ampt parameters for locations throughout the United States. Characteristics of Florida soils have been tabulated by Carlisle (Carlisle et al. 1981). In addition, the SCS has prepared detailed soil surveys of all counties in Florida, at a scale of 1:20,000. Most soils have been classified into hydrologic soil groups A, B, C, or D, depending on infiltration characteristics (SCS 1972). A tabulation of Florida soils according to erodiblity and hydrologic groups can be found in Livingston et al. (1988). Saturated hydraulic conductivity for soils in group A is much higher than for soils in group D. Carlisle et al. (1981) reports that for Florida soils, saturated hydraulic conductivities range from 7 to 18 in/hr. These high infiltration rates will lead to relatively little overland flow, except where high ground water tables reach the surface.

Urbanization

Urbanization of a watershed is the process by which considerable areas of natural soil cover are replaced by impervious areas such as buildings, parking lots, and roads. The effects of urbanization on the hydrology of the watershed are an increase in the volume of runoff, and a decrease in the time of runoff. Runoff depends directly on the amount of precipitation and on the infiltration characteristics of the soil, such as soil type, antecedent moisture content, and percent impervious area. Travel time depends mainly on slope, length of flow path, depth of flow, and roughness of flow surface.

In urban developments, the construction of detention ponds is often employed as a measure to regulate the runoff from rainfall events, in particular to reduce flooding of downstream areas. In general, detention facilities do not reduce the total volume of runoff, but they redistribute the rate of runoff over a certain period of time by providing temporary surface storage to a portion of the overland flow. A major benefit, therefore, is the reduction of downstream flooding problems. Other benefits of detention ponds include reduction in the pollution loads of downstream receiving waters, reduction in cost of downstream drainage facilities, and improved aesthetics.

Detention ponds may be located throughout the watershed for flood prevention and water quality control. However, the location of such ponds should be planned carefully. The general assumption is that detention ponds reduce flooding of the downstream areas. However downstream flooding may be increased if the outflow hydrograph from the detention pond peaks simultaneously with the watershed hydrograph.

In the LSJRB, Duval County is the most developed area. Stormwater management in the Jacksonville metropolitan area is much needed. Heavily urbanized areas like Hogan Creek and McCoy Creek subbasins have a large percentage of impervious area and are frequently flooded. Building detention ponds could prove to be very useful for flood reduction, pollution control, and enhanced aesthetics. Future expansion of urbanized areas in Duval County may spill over to adjacent counties like Clay and St. Johns. Developments should occur according to the goals and directives of the counties, which are outlined in the local government comprehensive plans.

Rainfall-Runoff Modeling

Simulation of the rainfall-runoff process offers the opportunity to predict runoff in the basin under various development scenarios. Currently, many hydrologic and hydraulic models are available, and, depending on the particular application, the hydrologist has to select a model that most closely matches his needs in terms of reliability, cost, and simulation time.

Most hydrologic simulation models operate with the concept of subbasins. This means that the basin is subdivided into subbasins according to topography, stream confluences, locations of structures and streamflow gages, and specific project needs. Due to the very small relief in the flatwoods, the delineation of subbasins could be difficult, especially where headwaters originate in swampy areas. In fact, drainage patterns and subbasin boundaries could shift, depending on rainfall patterns and wind directions. Examples in the LSJRB are the connection between Pottsburg Creek and Julington Creek via Pottsburg Creek Swamp, and the connection between Big Davis Creek and San Pablo Creek. Each subbasin requires the measurement of various physical characteristics, such as area, slope, percent impervious area, surface roughness, soils, land use, and width. As a group, these physical characteristics define the system. In order to determine the response of the system, a system input has to be defined. Typically, an input to a hydrologic model is a time-defined event or series of events. For instance, a synthetic storm is an example of a single input event, while a time-series of rainfall events is an example of a continuous input. The model is calibrated by comparing the output of the model with an observed series and adjusting some of the model parameters.

In principle, the use of observed discharge records could provide the information to implement a hydrologic design such that the system operates according to specified criteria. However, not all drainage basins are gaged, and those that are gaged may have short records (less than 10 years), or interrupted records. Even when long-term records are available, the data may cover various stages of development in the basin, thereby making the record almost useless for statistical analysis. Moreover, when the record covers only a single stage of basin development, no data are available for use in assessing future conditions in the basin, and planning and implementation should be postponed until such data have been collected in the field.

Using hydrologic simulation, the hydrologist can predict the system's response under various scenarios of rainfall input and basin conditions.

Hydrologic Simulation Models

One of the responsibilities of a stormwater management plan is the development and use of simulation models to assess, evaluate, and quantify problems related to water quality and quantity; and to evaluate and recommend regional stormwater management alternatives.

Some of the available water quantity model packages, of possible interest to the LSJRB, are the following. A more comprehensive listing of frequently used hydrologic simulation models is provided in Table 2.18.

HEC-1. (Hydrologic Engineering Center 1981). The HEC-1 model is designed to simulate the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. Each component models an aspect of the precipitation-runoff process within a portion of the basin, called a subbasin. A component may represent a surface runoff entity, a stream channel, or a reservoir. Representation of a component requires a set of parameters that specify the particular characteristics of the component and mathematical relations that describe the physical process. The result of the modeling process is a set of hydrographs computed at desired locations in the basin.

HEC-2. (Hydrologic Engineering Center 1982). The HEC-2 program computes surface water profiles for steady, gradually varied flow profiles in natural or man-made channels. Both subcritical and supercritical flow profiles can be calculated. The effects of various obstructions such as bridges, culverts, weirs, and structures in the floodplain may be considered in the computations. The computational procedure is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated with Manning's equation. The computational procedure is generally known as the Standard Step Method. The program is also designed for application in floodplain management and flood insurance studies, to evaluate floodway encroachments and to designate flood hazard zones. Also, capabilities are available for

Table 2.18. Selected hydrologic simulation models

MODEL	AUTHOR	DATE	DESCRIPTION
Stanford	Crawford and Linsley	1966	Stanford Watershed Model
HEC-1	HEC	1973	Flood Hydrograph Package
HEC-2	HEC	1976	Water Surface Profiles
HEC-3	HEC	1973	Reservoir System Analysis for Conservation
HEC-4	HEC	1971	Monthly Streamflow Simulation
HEC-5	HEC	1979	Simulation of Flood Control Systems
TR-20	USDA SCS	1974	Hydrologic Simulation Model
HL-74	USDA ARS	1975	Model Of Watershed Hydrology
HSPF	Hydrocomp, EPA	1980	Hydrologic Simulation Program-FORTRAN
MITCAT	Eagleson et al.	1970	Event Rainfall-Runoff Urban Model
SWMM	Metcalf & Eddy; Camp Dresser and McKee; Univ. of Florida	1971, 1981	Storm Water Management Model
ILLUDAS	Illinois State Water Survey	1974	Illinois Urban Drainage Simulator
STORM	HEC	1974	Storage, Treatment, Overflow, Runoff Model
USGS	USGS, Dawdy	1975	Flood Routing in Urban Areas
Penn St.	Aron, Lakatos	1976	Urban Runoff Model
DWOPER	NWS, Fread	1978	NWS Operational Dynamic Wave Model

Source: Bedient and Huber 1988

assessing the effects of channel improvements and levees on water surface profiles. Input and output units may be in either English or metric units.

TR-20. (SCS 1975). The TR-20 computer program assists the engineer in hydrologic evaluation of flood events for use in analysis of water resource projects. The program is a single-event model which computes direct runoff resulting from any synthetic or natural rainstorm. There is no provision for recovery of initial abstraction or infiltration during periods of no rainfall. It develops flood hydrographs from runoff and routes the flow through stream channels and reservoirs. It combines the routed hydrograph with those from tributaries and computes the peak discharges, their times of occurrence, and the water surface elevations at any desired cross-section or structure. Any one of the above items can be printed out as well as discharge hydrograph elevations, if requested. The program provides for the analysis of up to nine different rainstorm distributions over a watershed under various combinations of land treatment, floodwater retarding structures, diversions, and channel work. Such analysis can be performed on as many as 200 reaches and 99 structures in any one continuous run. The program uses the procedures described in the SCS *National Engineering Handbook,* Section 4, Hydrology (NEH-4) except for the reach flood routing procedure.

All of the above packages are single-event models. In these models, often the assumption is made that the frequency of the output event (discharge) equals the frequency of the input event (rainstorm). However, there are a number of models available which can perform both event modeling and continuous modeling. Continuous models are capable of generating outflow hydrographs over long periods of time.

HSPF. (Johanson et al. 1980). HSPF (Hydrologic Simulation Program-Fortran) is a set of computer programs designed for the continuous or single-event simulation of hydrologic and water quality processes.

Included are the following simulation modules: PERLND, IMPLND, and RCHRES. The module PERLND simulates the pervious land segment, IMPLND simulates the impervious land segment, while module RCHRES simulates the hydraulic processes occurring in a reach or reservoir.

Additionally, the program provides a number of utilities to manipulate and plot data. HSPF has been applied most often to rural areas, but it is applicable to combinations of rural and urban areas as well.

SWMM. (Metcalf & Eddy et al. 1971). SWMM (Storm Water Management Model) is a hydrologic simulation model which was developed by several parties (Metcalf & Eddy, University of Florida, and Camp, Dresser, and McKee) over a number of years. Funding was provided by the EPA. It is capable of event simulation as well as continuous simulation of water quantity and water quality. SWMM consists of several modules, each of which is designed to perform specific tasks. It is usually applied to areas with substantial urban development.

- The Runoff module converts rainfall into runoff and performs simple flow routing. The watershed may be divided into a maximum of 200 subcatchments and 200 channel/pipes plus inlets. Subsurface flow routing is possible.

- The Transport module performs flow routing by the kinematic wave approach. No downstream effects are incorporated in the computations.

- The Extran module performs flow routing by solving the complete St. Venant's equations. Backwater effects and downstream controls are included in the computations. This module does not provide for pollutograph routing.

- The Storage/Treatment module simulates the routing of flows and pollutants through storage units.

- The Statistics module performs simple statistical analyses on continuous-event or single-event data. Both quality and quantity data may be analyzed.

Model Calibration and Verification

Calibration is the adjustment of the model parameters to a particular set of data. Verification is testing these model parameters using an independent set of data. Continuous models are usually calibrated and verified by comparing the output generated by the model with historical streamflows, measured at significant locations in the basin. Continuous models like SWMM may also be calibrated by using specific storms. However, technically, there is no difference between continuous and event calibration. Both methods require an input series, which is usually a time history of rainfall, and an output series, which is usually a time history of measured streamflows (hydrograph).

Geographic Information Systems

Computer based geographic information systems (GIS) enable the user to develop, store, and process many of the physical characteristics of a watershed that are required for stormwater management practices, all with references to locations in the basin. The advantages of GIS over a numerical data base are:

- Data can be extracted from GIS by selecting a specific location or set of locations, either numerically or graphically.
- Data can be analyzed with spatial statistics.

Before GIS can be used, data have to be entered into its data base in digitized format. A widespread range of data can be entered, but typical data for stormwater management are soil type, land use, hydrologic soil group, drainage basin boundaries and area topography, and natural drainage system data. Digitizing basic data and entering it into the GIS data base does not require extensive training. However, operation of the geographic information system requires a good level of understanding of the system. After development of the data base, the data can be retrieved and manipulated, statistical analyses can be performed upon the data, and maps can be drawn. This applies to the basin as a whole, and to selected parts. Mapping can be done with various levels of detail, depending upon the specific application.

In combination with hydrologic simulation, geographic information systems can be used as an excellent source of basic physical watershed information. Subbasin boundaries are transferred to polygons, which are stored in digital form in the data base. Each polygon is labeled with an identification symbol, to which are assigned the physical properties of the area enclosed by the polygon. By interaction between GIS and the hydrologic simulation model, an efficient and speedy retrieval of data and subsequent data processing results. Because different hydrologic simulation models employ different formats of their input data, it would be advantageous to develop software which prepares data files in the format required by the models, using GIS as the basic source of data. In addition, software could be developed for the computation of specific information required by the simulation model. For instance, composite curve numbers for each subbasin could be computed, for various stages of development in the basin.

SYNTHETIC STORMS

For hydraulic design, accurate prediction of peak discharge is essential. This could be accomplished by long-term streamflow monitoring and a subsequent frequency analysis. However, in ungaged watersheds such a procedure is not possible, and the peak discharge may be computed from rainfall-runoff models using design storms as input. Design storms can be based on historic storm data collected at one or more rain gages in the basin, or on synthetic storms which reflect certain design criteria. Elements describing a synthetic storm are: depth, duration, frequency, temporal distribution, and spatial distribution. Of these elements, the spatial distribution is the most difficult to define. In practice, therefore, storms are assumed to be uniformly distributed in space.

The SCS has developed generalized rainfall distributions, which are applicable to specific regions in the United States. However, due to the general nature of these distributions, they may lack accuracy for certain applications. For instance, it was found that none of the SCS rainfall distributions could be uniformly applied to the area within the District. Therefore, site-specific synthetic storm distributions were developed (Rao 1988b).

Basic data for storm synthesis are supplied by the following sources:

- Hershfield (1961) provides accumulated point rainfall amounts for storm durations ranging from 30 minutes to 24 hours, and frequencies ranging from 1 to 100 years

- Miller (1964), extends the duration range of Hershfield (1961) to 10 day

- NOAA (1977), provides accumulated point rainfall amounts for storm durations of 5-minute, 15-minute, and 1-hour for the 2- and 100-year frequencies. It supplies semi-empirical formulas for other storm durations and frequencies.

- Rao (1988a) includes rainfall data available through 1983, and is specifically designed for the District. For the 24-hour, 48-hour, and 96-hour durations, rainfall depths from this document should be used.

The general procedure for the development of a site-specific rainfall distribution involves the following steps:

1. Maximum rainfall depths for various durations are determined, corresponding to the particular site. The 15-minute, 30-minute, and 60-minute rainfall depths are derived from NOAA (1977), the 3-hour and 6-hour durations are derived from Hershfield (1961), and the 24-hour, 48-hour, and 96-hour depths are derived from Rao (1988a).

2. Point rainfall data are reduced to take the size of the drainage basin into consideration. A set of area-depth curves is supplied in Hershfield (1961).

3. The mass curve of the reduced rainfall data is interpolated for time increments corresponding to the time interval used in the computation of the flood hydrograph. A common value is 15 min.

4. Incremental rainfall depths are computed for each of the time periods. The incremental depths are the differences between successive cumulative depths.

5. Incremental rainfall depths are rearranged according to a specified rainfall distribution.

Rao (1988b) presents charts with maximum rainfall depths from NOAA (1977), Hershfield (1961), and Rao (1988a). These charts are very helpful with the construction of synthetic storms in the LSJRB. As an example, Figure 2.28 shows the 10-year, 25-year, and 100-year synthetic storm distributions, respectively, for a 24-hour storm duration in the Etonia Creek tributary basin.

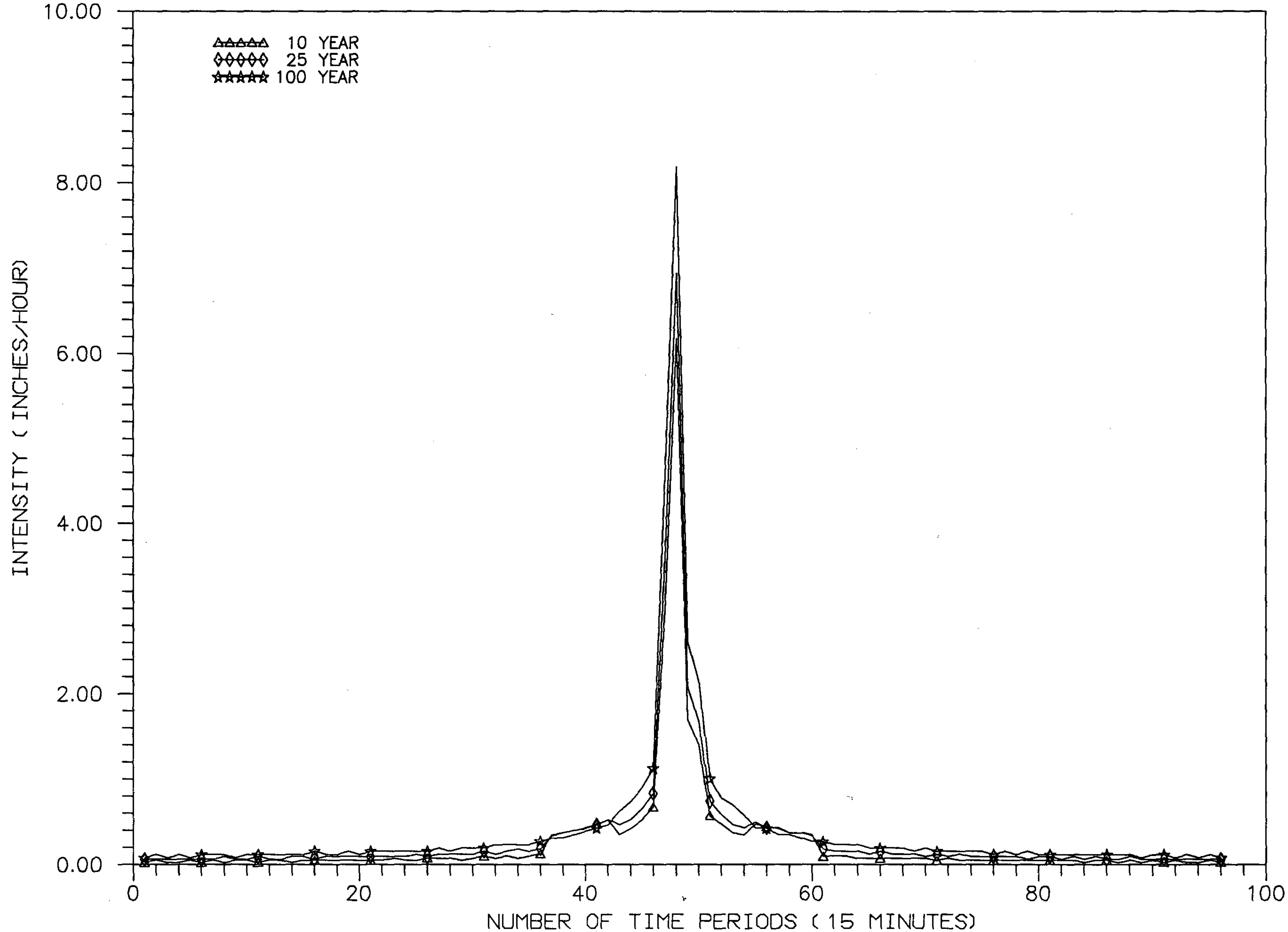

Figure 2.28 10-, 25-, and 100-year 24-hour storm distributions, Etonia Creek tributary basin

EXAMPLE OF STREAMFLOW ANALYSIS

In this section, a stochastic model of a streamflow process is formulated. It serves as an example to illustrate the detailed analysis of a measured streamflow hydrograph. Because the technique used is statistical, it can be applied to many different time series, for instance a series of water quality data.

GENERAL

Natural hydrologic systems are extremely complex. The processes, mechanisms, and interactions that make up such systems vary over a wide range of spatial and temporal scales. These processes and interactions cannot practically be combined in a single representation. Therefore, the behavior of such systems, e.g. the behavior of a watershed, can only be approximated by models, which are simplified representations of the true systems. In this chapter, "model" implies mathematical model. Regardless of the structure of the model, each model transforms a given quantitative input into a quantitative output. In watershed modeling, the inputs are precipitation, evaporation, and land use. The outputs are discharge, flood elevations, and lake elevations.

The model itself may be described by a set of equations that approximately formulate the physical processes and their interactions of the hydrologic system. This type of model is deterministic, and applies the principles of hydrodynamics to describe the physical mechanisms of the hydrologic system. However, because of the uncertainty involved in hydrologic processes, their true behavior is difficult to predict and application of the laws of probability may be required. Models that include probabilistic terms in their structure are stochastic. Chow (1978) distinguishes between models where the input and output are stochastic but the model itself is deterministic, and models where input, output, and the model itself are stochastic. In his terminology, the first type of model is quasi-stochastic, while the latter is called stochastic.

BASIC STATISTICS

The series used for this analysis is the historical record of daily streamflows of Etonia Creek at Bardin, Florida. Bardin is located about 2 miles north of Springside on Etonia Creek (Figure 2.7). The data have been recorded by USGS since October 1973, and are listed under station number 02245050 (Figure 2.17). For the analysis, daily data over the period 1978-1987 were used. Some basic statistical properties of the data are presented in Table 2.19. From this table it can be seen that the mean discharge of the sample was 101.2 cfs, the median discharge was 70 cfs, and the standard deviation approximately 90 cfs.

The skewness is a measure of the asymmetry of the probability distribution of the streamflow data. It indicates if, relative to the mean value (101.2 cfs), low flows or high flows are more likely to occur. For a perfectly symmetrical distribution, the coefficient of skewness equals zero. The coefficient of skewness computed for this series (4.1) is positive and indicates that flows smaller than the mean are more likely to occur.

The coefficient of kurtosis is a measure of the flatness of the probability distribution in comparison with the normal distribution. It is known that for a normal distribution the kurtosis equals three. For the given series, the kurtosis is 27.00, so the excess kurtosis equals 24.00. This high kurtosis indicates that large deviations from the mean exist. A graph of the discharges is shown in Figure 2.29.

Daily mean discharges, monthly mean discharges, and yearly mean discharges, all in cfs, were computed from the recorded data and are plotted, respectively, in Figures 2.30 through 2.32. The monthly mean discharges indicate the presence of two wet seasons per year, the first one around February-March and the second one during the summer season. The yearly mean discharges, as plotted in Figure 2.32, indicate the relative dryness or wetness of a particular year. It appears that the year 1981 was relatively dry, and the years 1979, 1982, and 1983 were relatively wet.

ANALYSIS

In this analysis, the original streamflow series is divided into a deterministic and a stochastic part. The deterministic part represents trends and periodic components. The stochastic part is further divided into a dependent and

Table 2.19. Statistical properties of daily discharges Etonia Creek, 1978-1987

Number of data	3652
Minimum discharge	35.00 cfs
Maximum discharge	1160.00 cfs
Range of discharge	1125.00 cfs
Mean discharge	101.20 cfs
Median discharge	70.00 cfs
Standard deviation	89.73 cfs
Skewness	4.10
Kurtosis	24.00
Coefficient of variation	0.89

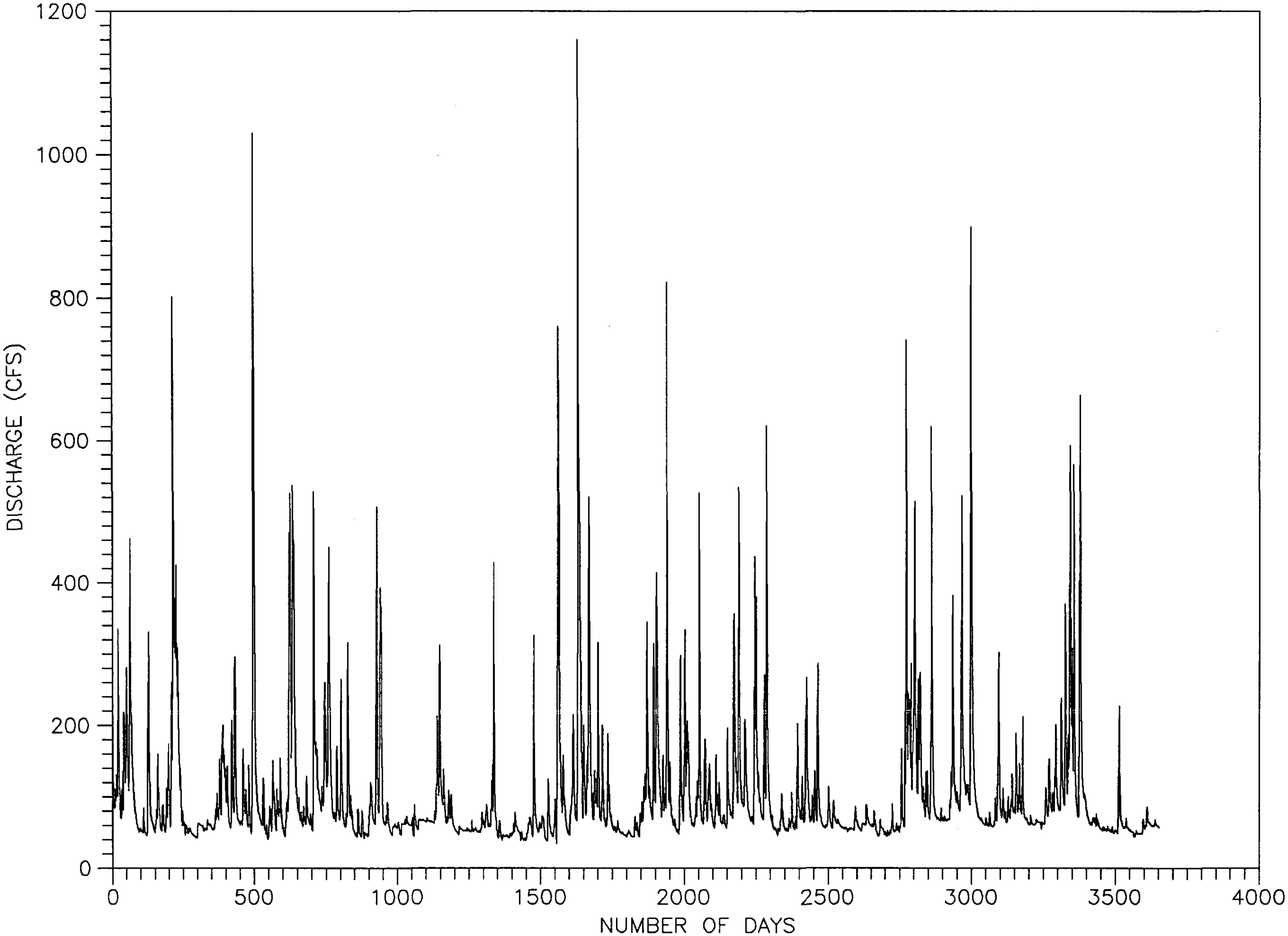

Figure 2.29 Daily discharges of Etonia Creek near Bardin (USGS 02245050), 1978-1987

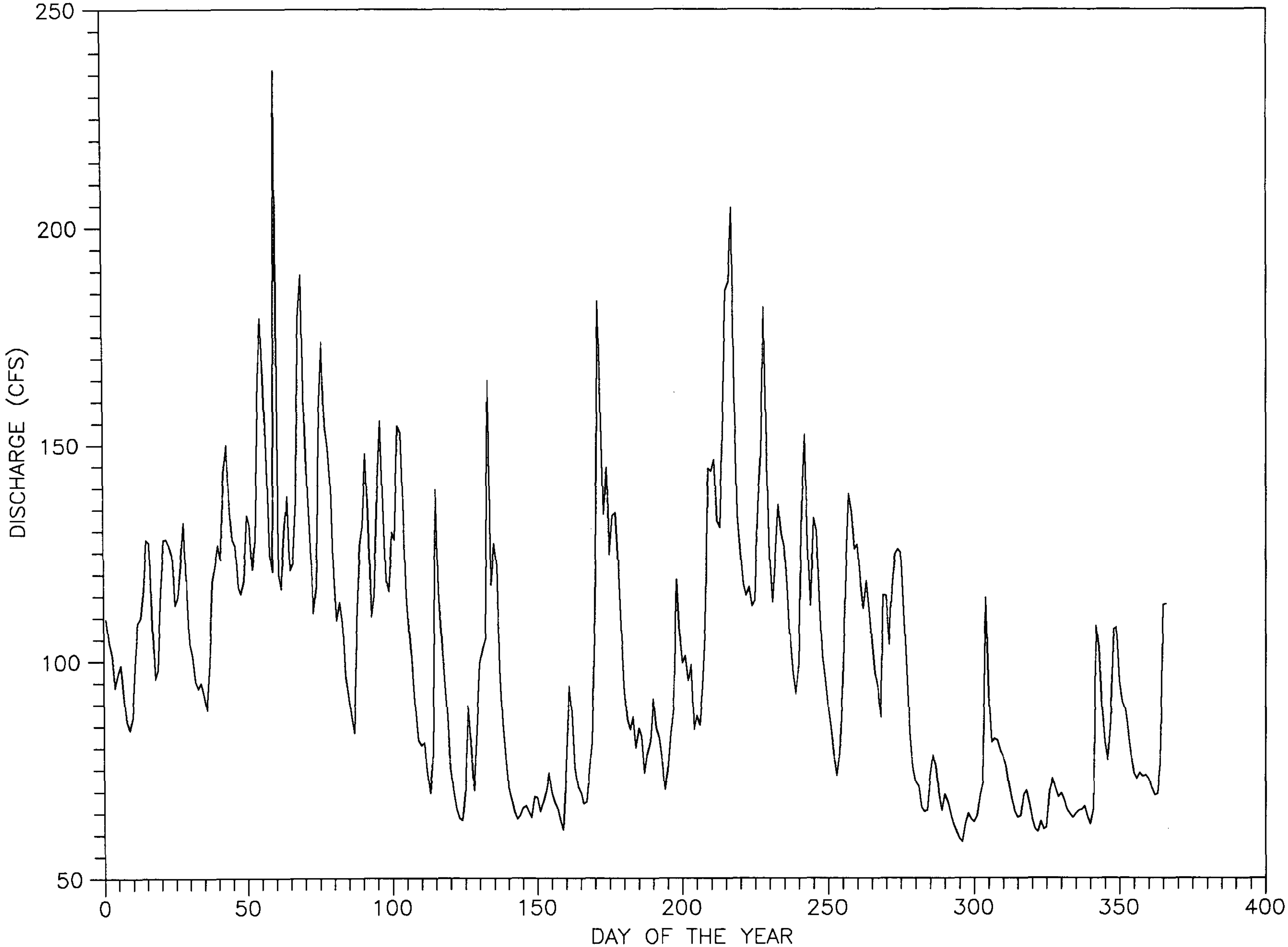

Figure 2.30 Daily mean discharges of Etonia Creek near Bardin (USGS 02245050), 1978-1987

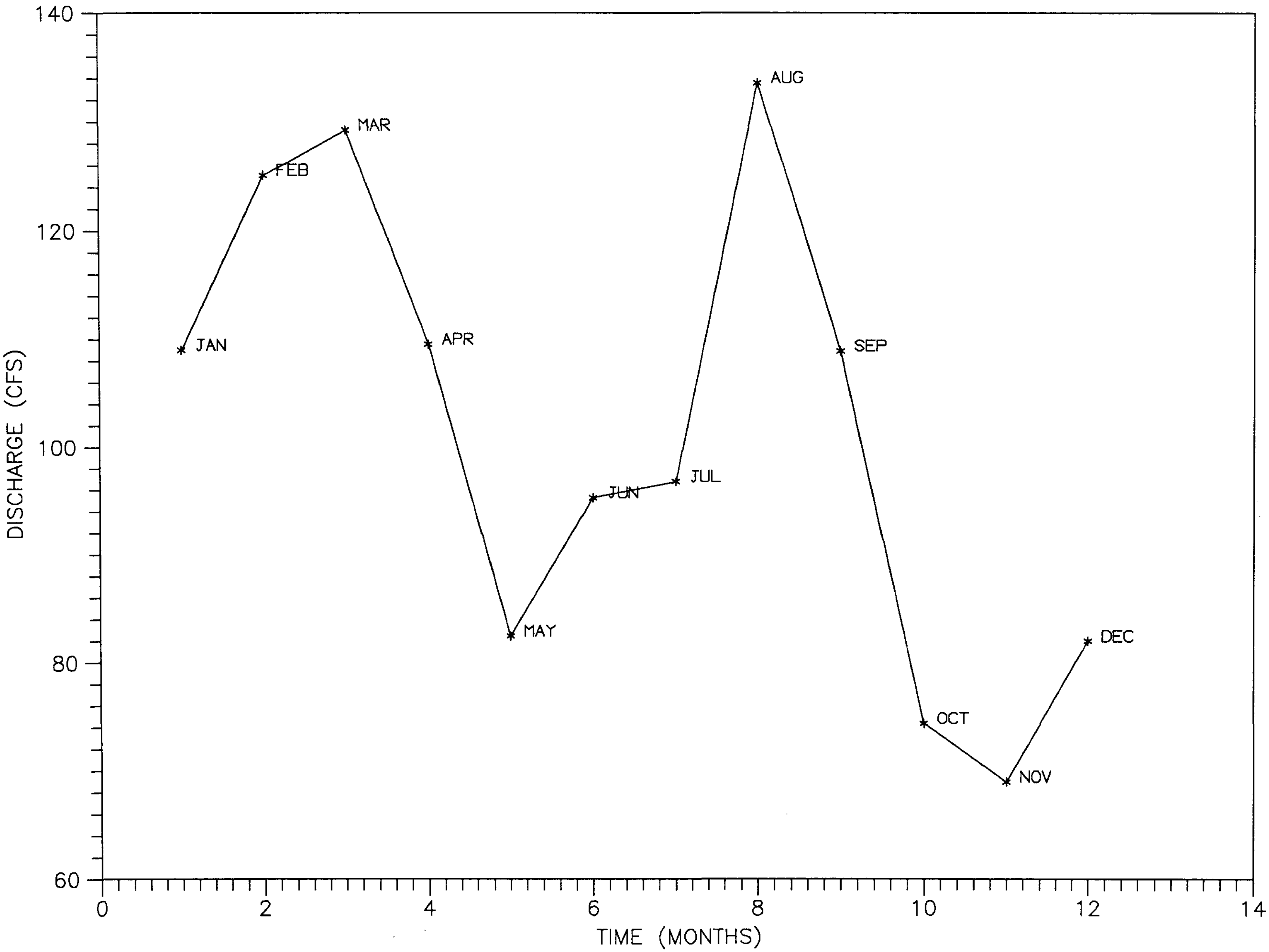

Figure 2.31 Monthly mean discharges of Etonia Creek near Bardin (USGS 02245050), 1978-1987

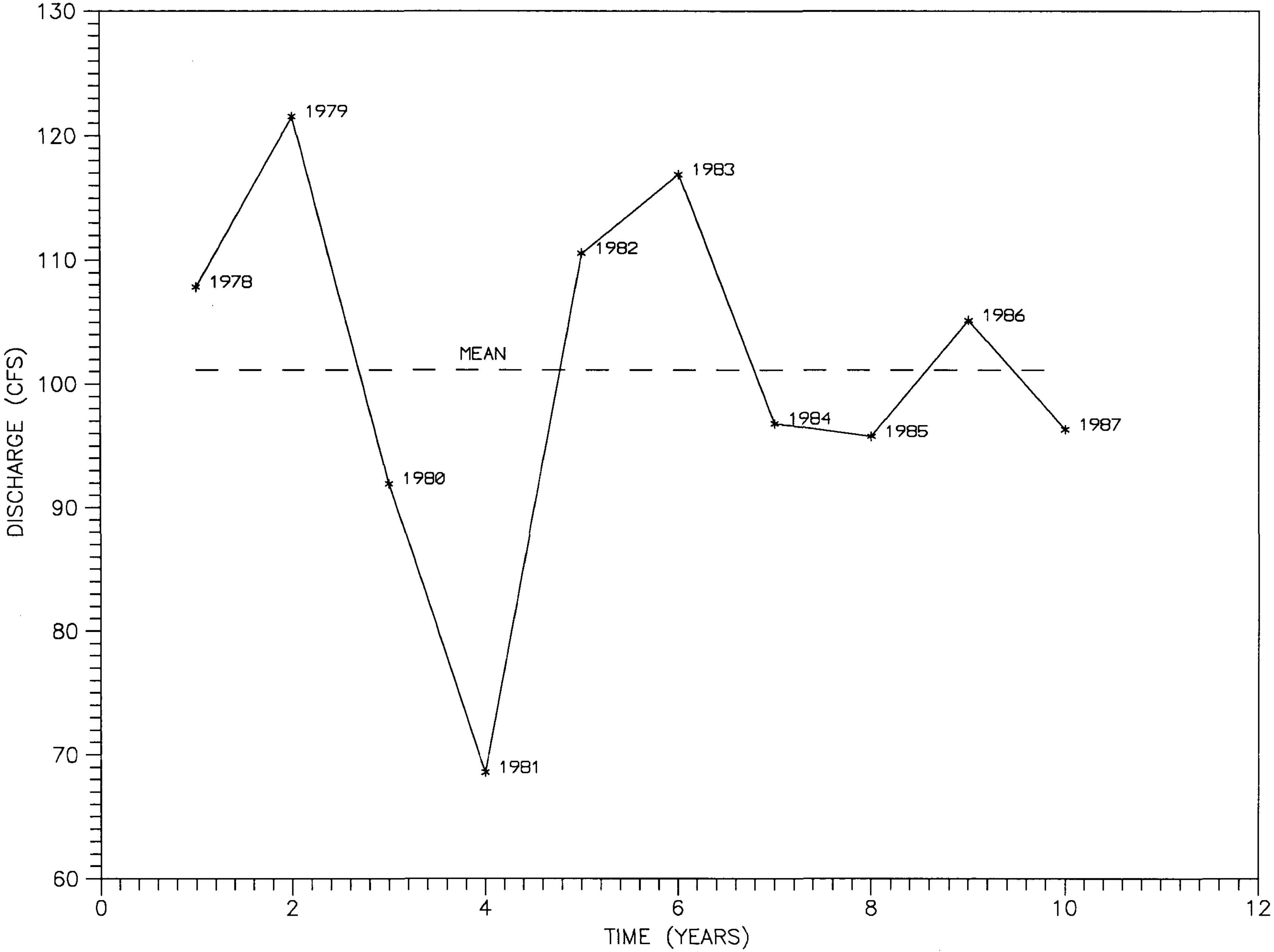

Figure 2.32 Yearly mean discharges of Etonia Creek near Bardin (USGS 02245050), 1978-1987

an independent component. A final synthesis of all components into one time series model, enables forecasting and generation of data series that preserve the statistical properties of the original series. The following set of computations is performed.

- Calculate the mean and standard deviation of the daily discharges for each day of the year.

- Determine the Fourier series of the mean daily discharges and the standard deviations of the daily discharges.

- Normalize the daily discharge data. These data represent the stochastic component of the series.

- Fit the stochastic series with an autoregressive-moving-average model: ARMA(p,q), where *p* represents the order of the autoregressive part and *q* represents the order of the moving-average part.

- Synthesize the Fourier series of the daily mean discharges and standard deviations, and the autoregressive-moving-average component into one model.

The first step in the analysis is the normalization of the data. In general, normalization is the process that subtracts the mean from the data and divides the result by the standard deviation. In this particular case, which deals with observed daily discharges, each day of the year has its own mean discharge and standard deviation. Therefore, a total of 365 daily mean discharges and standard deviations can be computed. In terms of modeling, each mean discharge and standard deviation represents a model parameter. One of the criteria in selecting a model is to use as few model parameters as possible. Therefore, to reduce the number of parameters in the model, the computed daily mean discharges and standard deviations are fitted with a number of sine and cosine functions of various frequencies (Salas et al. 1980). The harmonically fitted means and standard deviations are, in fact, the Fourier series of the daily mean discharges and standard deviations, which can be represented in the following general form (Equations 1 and 2):

Equation 1:

$$\text{mean}(t) = A(0) + \text{SUM}_j\ [A(j)\cos(2\pi jt/365) + B(j)\sin(2\pi jt/365)]$$

Equation 2:

$$\text{stdv}(t) = C(0) + \text{SUM}_j\ [C(j)\cos(2\pi jt/365) + D(j)\sin(2\pi jt/365)]$$

where:

mean(t)	=	harmonically fitted mean discharge at day t, t=1,2,3,....365
stdv(t)	=	harmonically fitted standard deviation of discharge at day t, t=1,2,3,....365
A(0)	=	mean of daily discharges
C(0)	=	mean of standard deviations of daily discharges
A(j)	=	coefficients of cosine terms in Fourier series of harmonically fitted daily mean discharges, j=1,2,...182
B(j)	=	coefficients of sine terms in Fourier series of harmonically fitted daily mean discharges, j=1,2,...182
C(j)	=	coefficients of cosine terms in Fourier series of harmonically fitted standard deviations of daily discharges, j=1,2,...182
D(j)	=	coefficients of sine terms in Fourier series of harmonically fitted standard deviations of daily discharges, j=1,2,...182

The normalization of the data is accomplished by applying the following equation:

Equation 3:

$$z(t,i) = [y(t,i) - \text{mean}(t)]/\text{stdv}(t)$$

where:

z(t,i)	=	normalized discharge at day t in year i, t=1,2,3...., 365; i=1,2,3,....,10;
y(t,i)	=	observed discharge at day t in year i

In principle, the summation in Equations 1 and 2 applies to all 182 harmonics. However, in practice the expansion may be developed by using only a small number of significant harmonics (Salas et al. 1980). In this case, the first 8 harmonics gave satisfactory results for this study. The coefficients A(0), C(0), A(j), B(j), C(j), and D(j), for j=1 through 8, in Equations 1 and 2 were estimated by the least squares method (Tables 2.20 and 2.21). The harmonically fitted means and standard deviations are shown in Figures 2.33 and 2.34, respectively.

The normalized data z(t,i), which were obtained by the application of Equation 3, represent the stochastic component of the series. Only the last five years of data were subjected to further analysis. An estimate of the autocorrelation function was made and partial autocorrelations indicated that an autoregressive model of order 3, ARMA(3,0) (Box and Jenkins 1976), was a good candidate for analyzing this data (Figure 2.35). The model coefficients were estimated from the data (Table 2.22).

Thus the stochastic component of the data can be described by the following ARMA(3,0) process:

Equation 4:

$$z(t) = 1.013\, z(t-1) - 0.278\, z(t-2) + 0.076\, z(t-3) + v(t)$$

where:

z(t) =	normalized daily discharge at day t
z(t-1) =	normalized discharge on the previous day
v(t) =	white noise

A test on the independence of the residuals indicated that the proposed model was adequate.

Table 2.20. Summary of Fourier analysis of mean daily discharges for Etonia Creek

HARMONIC (j)	A (j)	B (j)	$(A^2 + B^2)/2$
0	101.125		
1	-3.300	10.345	58.955
2	-5.045	27.060	366.122
3	0.479	-5.314	14.122
4	-0.577	-2.069	2.307
5	1.791	0.756	1.890
6	-1.230	-1.873	2.511
7	2.369	6.715	25.352
8	1.290	-6.831	24.163

A: coefficients of cosine terms in Fourier series of harmonically fitted means of daily discharges

B: coefficients of sine terms in Fourier series of harmonically fitted means of daily discharges

Table 2.21. Summary of Fourier analysis of standard deviations of daily discharges for Etonia Creek

HARMONIC (j)	C (j)	D (j)	$(C^2 + D^2)/2$
0	71.149		
1	-12.441	15.125	191.772
2	-9.276	21.556	275.353
3	3.337	-5.908	23.020
4	6.179	-4.221	27.998
5	0.556	-2.133	2.429
6	-2.302	-2.180	5.026
7	1.967	7.995	33.895
8	2.442	-19.030	184.052

C: coefficients of cosine terms in Fourier series of harmonically fitted standard deviations of daily discharges

D: coefficients of sine terms in Fourier series of harmonically fitted standard deviations of daily discharges

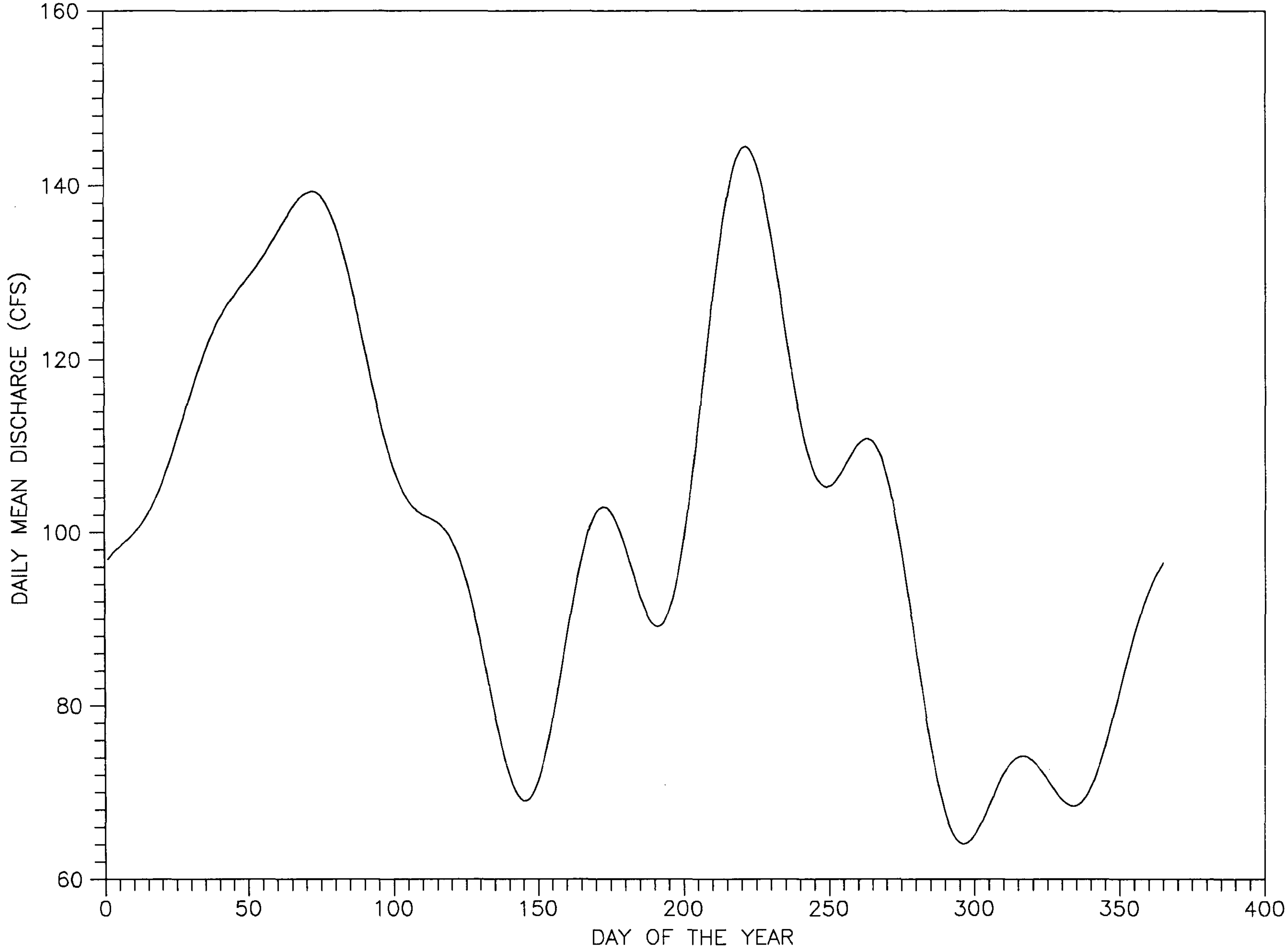

Figure 2.33 Fourier series of daily mean discharges, Etonia Creek near Bardin (USGS 02245050)

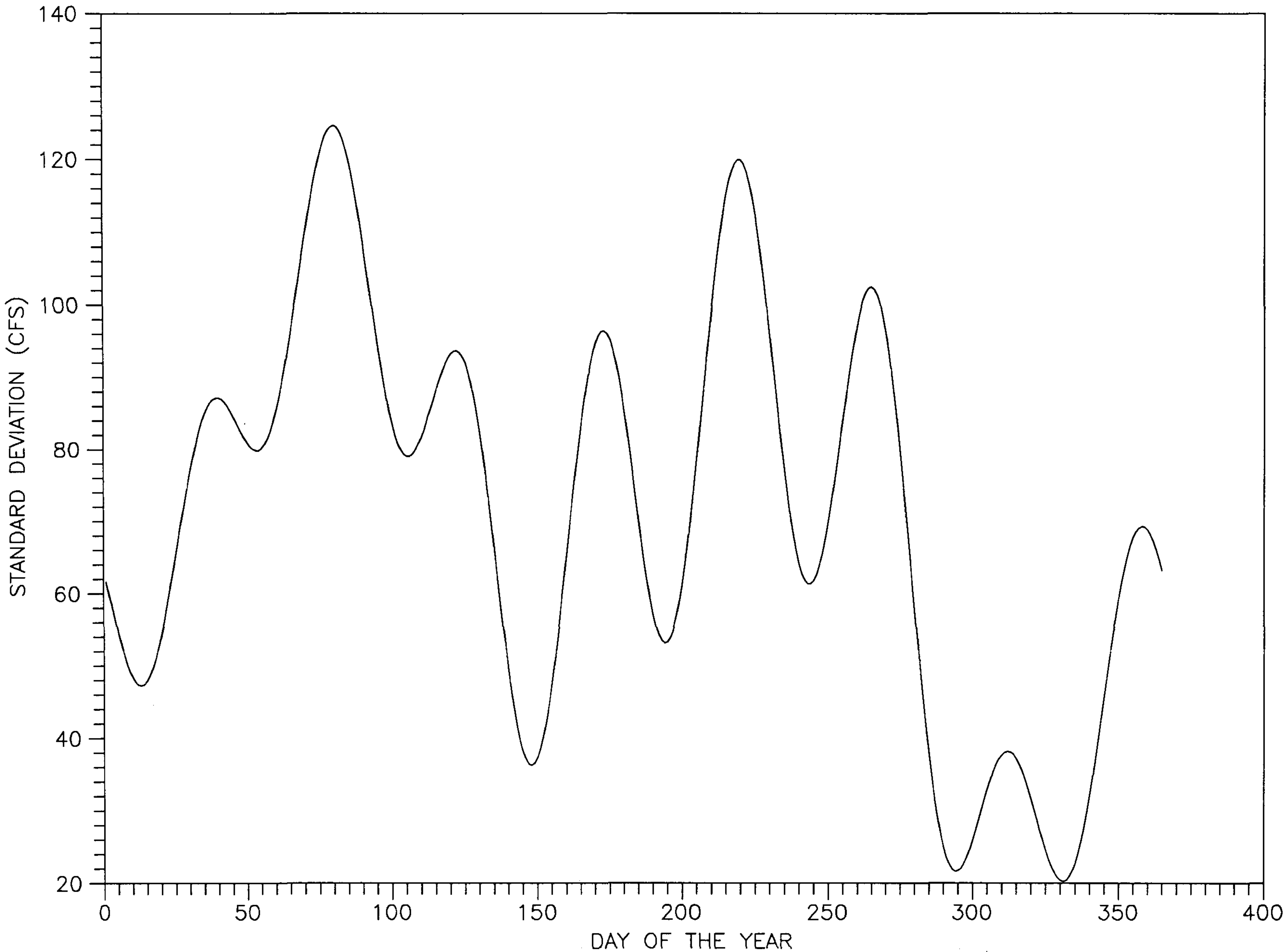

Figure 2.34 Fourier series of standard deviations of daily discharges, Etonia Creek near Bardin (USGS 02245050)

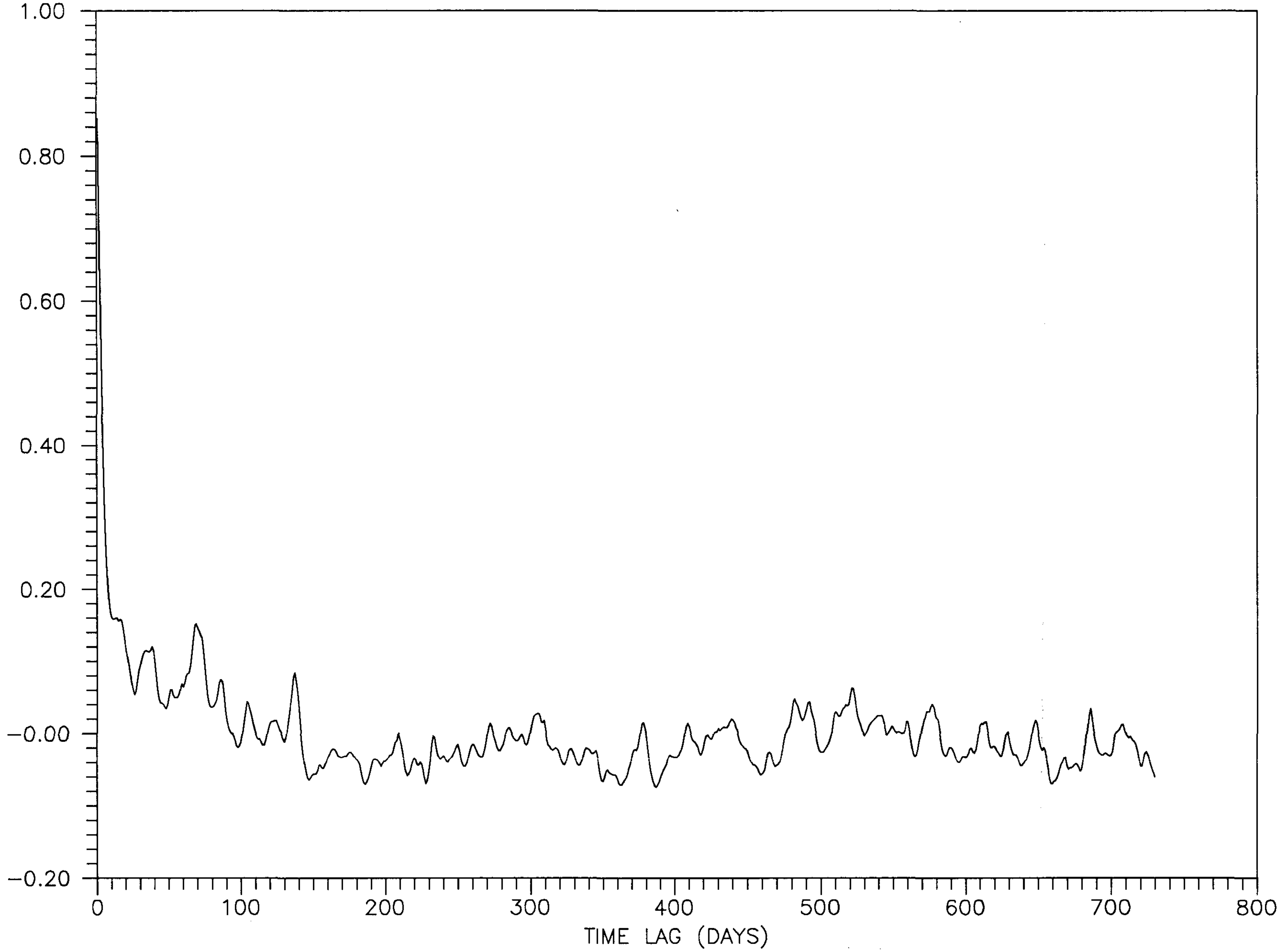

Figure 2.35 Estimated autocorrelations of normalized data, Etonia Creek near Bardin (USGS 02245050)

Table 2.22. Estimated model coefficients, ARMA(3,0) * for Etonia Creek

INDEX	TYPE	ESTIMATED COEFFICIENT	95% CONFIDENCE LIMIT LOWER	UPPER
1	AR	1.013	0.967	1.059
2	AR	-0.278	-0.342	-0.214
3	AR	0.076	0.023	0.122

* Box and Jenkins 1976

The final statistical model is a synthesis of Equations 3 and 4, with z(t,i) in Equation 3 replaced by z(t) of Equation 4, and mean(t) and stdv(t) of Equation 3 computed by their Fourier series. This model is used to forecast streamflows one day ahead, the results of which are shown in Figure 2.36.

Especially in the physical and environmental sciences, where the physical processes can be very complicated, time series analysis is an important tool. This example illustrates that the application of simple statistical techniques to observed time series can increase our knowledge of the behavior of a particular process and, therefore, could assist in the decision making process. The analysis of this particular series makes use of the correlation structure of the observed data points. More complicated statistical models could have produced superior results, such as a more accurate forecasting of the peak flows. However, simple models, like this example, can produce satisfactory results.

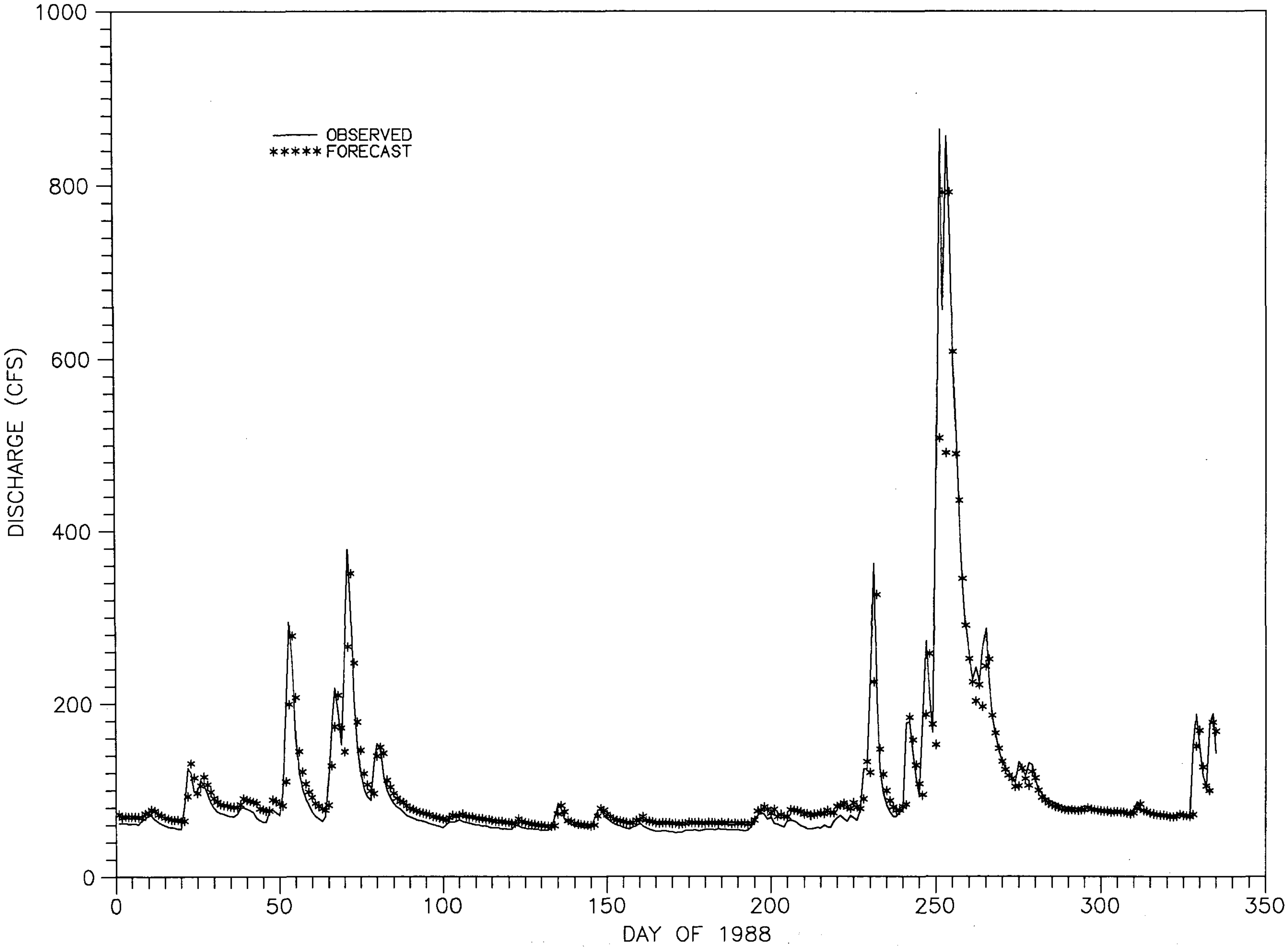

Figure 2.36 One day ahead forecasts and observed daily discharges, Etonia Creek near Bardin (USGS 02245050)

SUMMARY

This volume has given an overview of the surface water system and the existing rainfall and streamflow monitoring networks in the lower St. Johns River basin. The collection of hydrologic data, such as rainfall and streamflow, is vital to many activities of the District, because it provides the basic information needed for the management of surface waters.

Daily rainfall data in the LSJRB are being collected by NOAA, the District, other state agencies, and private parties. In general, NOAA stations have the longest period of record, sometimes dating back to the early 1900s. Only a few stations have collected hourly data: Marineland (NOAA 5391), Jacksonville Airport (NOAA 4358), Jacksonville City (NOAA 4371), and Raiford State Prison (NOAA 7440). A number of stations have been discontinued or have interrupted data records. One conclusion resulting from this study is that the existing rainfall network is not extensive. Table 2.4 is a listing of the temporary rainfall stations that the District installed during fiscal year 1989-1990. The main purpose of these stations is to assist in the calibration of the hydrologic models developed under the Master Stormwater Management Plan. A listing of permanent NOAA stations is provided in Table 2.3, while Appendix A supplies a listing of all rainfall monitoring stations in the lower basin that are currently in operation. At some stations data are collected manually (non-recording stations).

Daily streamflow data are being collected by the USGS. Data gaps in the various records were identified (Appendix B). Additional streamflow gages, installed during fiscal year 1989-1990 in Duval County, are listed in Table 2.14. These stations are temporary stations and were installed to assist in the calibration of water quantity and quality models that are being developed within the framework of the Master Stormwater Management Plan. A summary of the existing gaging stations in the study area is shown in Appendix B.

No evaporation data are being collected in the LSJRB. The nearest station is located in Gainesville, and is operated by NOAA (index 3321). The next closest station is located in Lake City, which is of little practical value to the LSJRB.

RECOMMENDATIONS

HYDROLOGIC MONITORING

An accurate picture of the freshwater inflow and outflow of the lower St. Johns River basin can be obtained by the systematic collection of rainfall, streamflow, and evaporation data. Within this context, the following activities are recommended.

- Maintain the existing hydrologic monitoring network: USGS stage/discharge stations, NOAA rainfall stations, and private rainfall stations. The collection of data from these stations should be continued.

- Install at least one new stage/discharge gaging station in each one of the following basins: McCullough Creek, Deep Creek, and Sixmile Creek. These should be permanent, long-term monitoring stations.

- Install new rainfall gaging stations in the McCullough Creek , Deep Creek, and Sixmile Creek basins. McCullough Creek and Deep Creek need at least one station and Sixmile Creek needs at least three.

- Calibrate the newly installed streamflow stations in Duval County (Table 2.14).

- Install at least three pan evaporation stations in the lower basin.

HYDROLOGIC MODELING

Collection, analysis, and processing of data and hydrologic model simulations should be coordinated as required by the hydrologic model.

- Develop hydrologic simulation models for the basins outside Duval County in the following order of priority: Etonia Creek, Crescent Lake, Deep Creek, Sixmile Creek, and McCullough Creek. Because agriculture is the major land use in these basins, these models should, in particular, address the effects of agricultural practices on the quantity or quality of surface runoff. Rank the problem areas in each of the basins based on the results of the hydrologic simulation, visual inspection, and other available information.

- Develop a basinwide geographic information system. This should enable the user to store and process many of the physical characteristics of each basin in the lower basin, such as soil type, hydrologic soil group, current land use, future land use, subbasin boundaries, subbasin area, topography, and natural drainage systems.

- Use the geographic information system (GIS) to locate cross-sections in the channel network of each basin and derive cross-sectional geometry (distance/elevation) from the topographic information stored in GIS.

- Develop specialized software to facilitate the transfer of data from the geographic information system to the simulation model in the appropriate format. This software should also be capable of the computation of specific model parameters from information stored in GIS.

INVESTIGATIONS

Here, *investigations* refers to a number of topics that should receive more attention. This type of investigation would be beneficial to the District by making the current data collection effort more effective. Further, the resulting hydrologic models will help in the decision making process.

- Analyze data collected by the District (water quantity, water quality) in a routine manner. Not all monitoring stations would be included, necessarily, but a small number of key-stations could suffice. The analysis should include plotting of the data; the computation of simple statistics, such as mean, median, standard deviation, skewness, and kurtosis; and trends, frequencies, and correlations. Simple computational techniques make it possible to update current statistics with the information available from new data. These evaluations would assist in a better resource management, and provide a better understanding regarding the location of new monitoring stations or the redundancy of existing stations.

- Implement optimization techniques to determine the adequate number of monitoring stations (water quantity, water quality) required to obtain specific monitoring goals, given a set of performance criteria.

- Develop stochastic models to assist in short-term and long-term forecasting and to provide useful information for management decisions.

- Develop and use lake circulation models to supplement the analysis of basin hydrology.

- Determine the transport and fate of discharges and pollutants to the mainstem of the river by means of hydrodynamic models.

Appendix A

RAINFALL MONITORING NETWORK
IN THE
LOWER ST. JOHNS RIVER BASIN

COUNTY NAME: STATION NAME	STATION INDEX	LATITUDE	LONGITUDE	STATION OWNER	PERIOD OF RECORD
ALACHUA:					
Gainesville	3321	293800	822200	NOAA	10/01/53-present
Gainesville (discontinued)	3316	293900	822100	NOAA	01/02/03-08/31/85
Gainesville (discontinued)	3326	293700	822100	NOAA	05/17/60-12/31/69
BAKER:					
Glen St. Mary	3470	301600	821100	NOAA	01/01/31-present
BRADFORD:					
Starke (discontinued)	8527	295700	822000	NOAA	02/01/58-03/31/85
DUVAL:					
Cecil Naval Air Station				USN	1946-1987
Jacksonville Airport	4358	303000	814200	NOAA	07/01/48-present
Jacksonville Beach	4366	301700	812400	NOAA	07/01/48-present
Jacksonville City (discontinued)	4371	302000	814000	NOAA	07/01/48-05/21/56
Jacksonville Naval Air Station				USN	1945-1987
Mayport Naval Station				USN	1959-1987

COUNTY NAME: STATION NAME	STATION INDEX	LATITUDE	LONGITUDE	STATION OWNER	PERIOD OF RECORD
FLAGLER:					
Marineland (discontinued)	5391	294000	811300	NOAA	08/01/48-09/30/51
Washington Oaks (recorder since 6/85)		293754	811219	SJRWMD	01/01/84-present
Hulett (discontinued)		293629	811633	PALM C	08/01/82-5/31/87
Black Branch		292451	811222	PALM C	08/01/82-present
Clubhouse		293316	811430	PALM C	08/01/82-present
Espanola		292856	811806	PALM C	08/01/82-present
Dave		293536	811912	PALM C	08/01/82-present
Beachfront		293444	811057	PALM C	08/01/82-present
NASSAU:					
Fernandina Beach	2944	303900	812800	NOAA	07/01/48-present
PUTNAM:					
Crescent City	1978	292600	813100	NOAA	01/11/31-present
Federal Point	2915	294500	813200	NOAA	01/01/31-present
Palatka	6753	293900	813800	NOAA	07/01/48-01/31/88
Banana Lake (non-recording)		292747	813523	SJRWMD	01/12/89-present

COUNTY NAME: STATION NAME	STATION INDEX	LATITUDE	LONGITUDE	STATION OWNER	PERIOD OF RECORD
PUTNAM:					
Lake Omega (non-recording)		292653	813155	SJRWMD	12/18/86-present
Oldfield Pond (discontinued)		294451	815928	SJRWMD	01/01/83-05/31/85
Swan Lake (recording)		294313	820018	SJRWMD	03/27/88-present
Dream Pond (non-recording)		292456	813114	SJRWMD	01/01/88-present
Lake Como (non-recording)		292836	813451	SJRWMD	05/10/88-present
Lake Marvin (non-recording)		292525	813629	SJRWMD	05/10/88-present
Levys Prairie (recording)		293824	820042	SJRWMD	01/01/84-present
District Hqtrs (recording)		293954	814143	SJRWMD	03/31/88-present
ST. JOHNS:					
Hastings ARC	3874	294300	813000	NOAA	01/01/78-10/31/88
St. Augustine	7812	295400	811900	NOAA	07/01/48-31/03/73
St. Augustine Radio Tower	7826	295400	811900	NOAA	04/01/73-present
UNION: Raiford State Prison	7440	300400	82110	NOAA	1931-present

COUNTY NAME: STATION NAME	STATION INDEX	LATITUDE	LONGITUDE	STATION OWNER	PERIOD OF RECORD
VOLUSIA:					
Daytona Beach	2158	291100	810300	NOAA	07/01/48-present
De Land	2229	290100	811800	NOAA	01/01/31-present
Lake Emporia (non-recording)		291153	812808	SJRWMD	12/26/86-present
Lake Pierson (non-recording)		291412	812837	SJRWMD	12/17/86-present
Shaw Lake (non-recording)		291402	812632	SJRWMD	01/04/82-present
Upper Lake Louise (non-recording)		292052	813025	SJRWMD	01/12/89-present
Lake Daugharty (non-recording)		290551	811627	SJRWMD	12/26/86-present
Cow Pond (non-recording)		292052	812947	SJRWMD	01/12/89-present
Lake Ashby (non-recording)		285600	810613	SJRWMD	07/16/86-present
Lake Purdom - Lambert (non-recording)		291214	812617	SJRWMD	10/20/88-present
Lake Purdom - Souza (discontinued)		291213	812842	SJRWMD	03/07/88-10/09/88
Lake Purdom - Todd (discontinued)		291227	812623	SJRWMD	12/18/86-10/05/88

Appendix B

USGS STREAMFLOW MONITORING NETWORK
IN THE
LOWER ST. JOHNS RIVER BASIN

SUBBASIN NAME: STATION NAME	STATION INDEX	LATITUDE	LONGITUDE	PERIOD OF RECORD
BLACK CREEK:				
South Fork Black Creek near Camp Blanding (discontinued)	02245400	295633	815352	10/01/57-09/30/60
South Fork Black Creek near Penney Farms	02245500	295845	815108	10/01/39-present
North Fork Black Creek near Highlands (discontinued)	02245800	300648	815900	10/01/57-09/30/60
North Fork Black Creek near Middleburg	02246000	300647	815424	10/01/31-present
North Fork Black Creek at Middleburg (stage only since 1988)	02246010	300431	815151	11/01/83-present
Black Creek near Doctors Inlet (discontinued)	02246025	300457	814834	06/16/81-09/30/90
CRESCENT LAKE:				
Middle Haw Creek near Relay Station (discontinued)	02244300	291822	811612	10/01/64-09/30/66
Middle Haw Creek near Korona	02244320	292135	811842	07/01/75-present
Little Haw Creek near Seville	02244420	291920	812310	01/01/51-present
Dunns Creek near Satsuma (incomplete)	02244440	293439	813735	01/01/78-09/30/88
DEEP CREEK:				
Deep Creek near Hastings	02245255	294052	812656	06/01/75-present
ETONIA CREEK:				
Rice Creek near Springside	02244473	294117	814432	10/01/73-present

SUBBASIN NAME: STATION NAME	STATION INDEX	LATITUDE	LONGITUDE	PERIOD OF RECORD
Etonia Creek near Florahome (discontinued)	02245000	294408	815147	01/01/50-09/30/51
Etonia Creek near Bardin	02245050	294300	814331	10/01/73-present
Simms Creek near Bardin (incomplete)	02245140	294407	814236	10/01/73-present
Rice Creek at Palatka (discontinued)	02245200	294157	813948	10/01/70-07/31/73
JULINGTON CREEK:				
Big Davis Creek at Bayard (incomplete)	02246150	300905	813135	08/22/66-present
ORTEGA RIVER:				
Ortega River at Jacksonville (incomplete)	02246300	301450	814749	01/01/65-present

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