CHEMICAL AND PHYSICAL ASPECTS OF THE BLACKWATER RIVER IN NORTHWESTERN FLORIDA

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INTRODUCTION

Although it is one of the most interesting streams in Florida, if not in the entire United States, the distinctive qualities of the Blackwater River are not readily apparent upon casual observation. Certainly streams with shifting sand bottoms are widespread within the Southeastern Coastal Plain Province but the shifting sands of the Blackwater are biologically productive; most others are not. Acid, soft, moderately to highly colored waters such as we find in the Blackwater are extremely common in Southeastern United States. But the Blackwater is different. In some aspects it resembles the rain-forest streams of the upper Rio Negro basin that are strikingly low in dissolved electrolytes (FITTKAU, 1964). In other aspects if differs.

Some of the distinctive features of the Blackwater River are known at present, others remain to be discovered. The River is the object of long range and intensive study by the staff of the Laboratory of Aquatic Entomology. Each visit to this stream is most rewarding.

BLACKWATER BASIN

Blackwater River is a youthful stream that came into existance at the end of the ice age. The stream traverses a number of Pleistocene marine terraces that are composed of very permeable sand. The permeable nature of the terrace sand gives rise to an unusual feature exhibited by many of the streams in the area — steepness of the heads of the tributary streams. The heads remain steep longer than they would otherwise because there is little surface erosion and the headward growth of the streams is caused by perennial springs, which gradually eat back into the upland, never rising above the level of the zone of ground-water saturation.

MUSGROVE *et al* (1965) have described the drainage basin quite adequately. "Blackwater River heads in southern Alabama, north of Bradley. The river enters Florida north of Baker, flows across the northwestern corner of Okaloosa County, and winds southward along the Santa Rosa-Okaloosa county line for a distance of about 4 miles. At Bryant Bridge, at the county line, the river turns to the southwest and is joined by Big Juniper Creek and Big Coldwater Creek, and then continues toward Milton. At Milton it turns southward and flows into Blackwater Bay.

"The basin is well dissected by tortuous stream channels that wind their way through a thick forest of pine and juniper trees. Except during floods, the water is clear and flows in clean channels of sand and gravel.

"The following discussion of streamflow is by tributary basins, proceeding upstream in the following order : Pond Creek, Big Coldwater Creek, Big Juniper Creek, and upper Blackwater River.

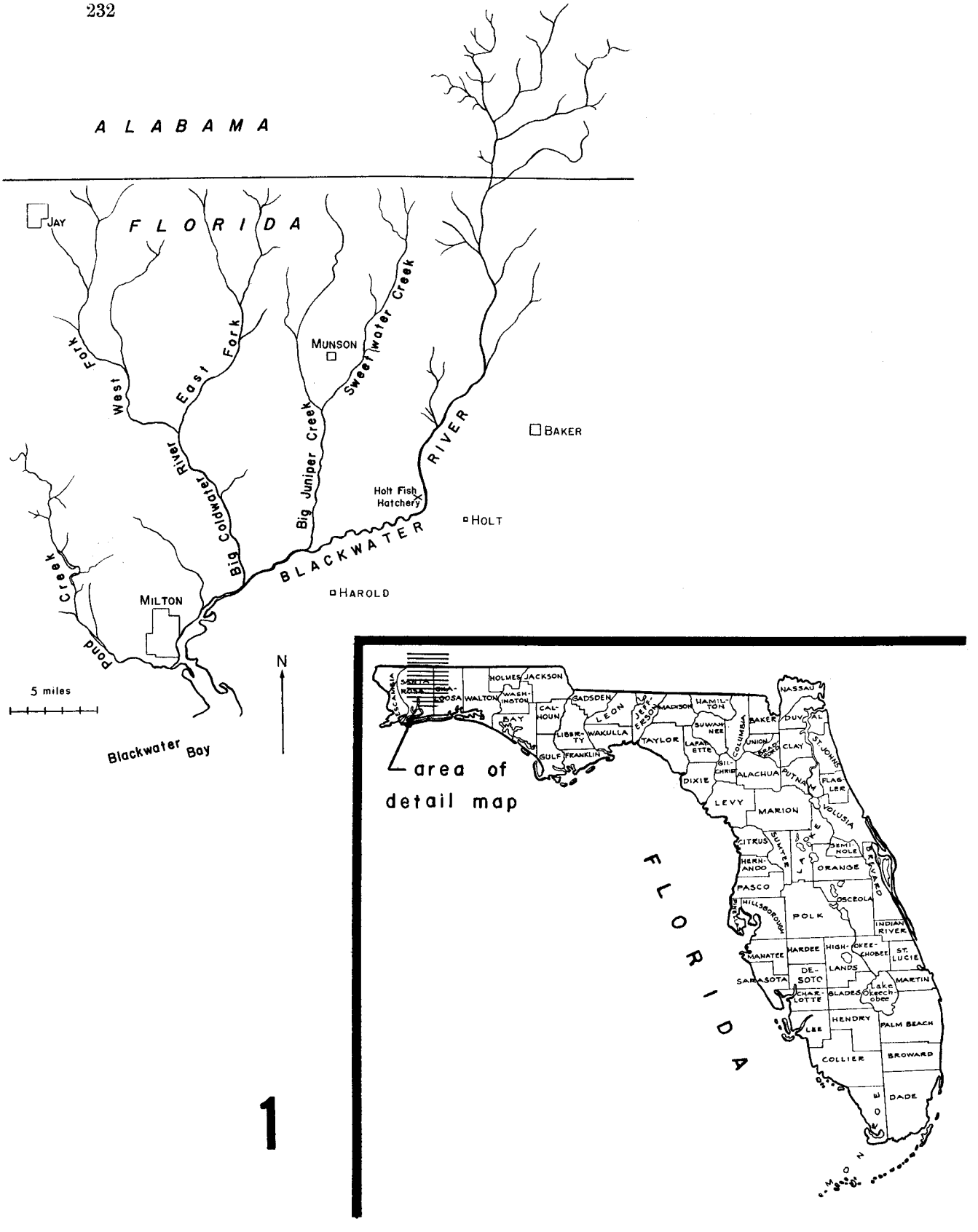

FIGURE 1. Map of the Blackwater River drainage basin, Northwestern Florida.

"Pond Creek drains an area of 88 square miles. The creek flows southward and empties into the Blackwater River just south of Milton. The basin has an elongated shape with relatively short tributaries that drain directly from the steep hills. The land along the basin divide is flat and is from 1 to 2 miles wide. From the flat divide, however, the land slopes steeply to the stream channel.

"Pond Creek has two channels within the lower three-fourths of its flood plain. One of these is the natural channel which is very crooked while the other is a straight channel dug many years ago for transporting logs. The valley slope is steep, with a total fall of about 200 feet from the headwaters to the mouth, a distance of 24 miles.

"The estimated unit runoff from Pond Creek is 1.4 cfs (cubic feet per second) per square mile, which is equivalent to an average flow of 123 cfs from the basin. The minimum daily flow measure at the gauging station during a 4-year period ending 1961 was 43 cfs, or 0.7 cfs per square mile. About 75 percent of the total flow is derived from the ground as base flow and 25 percent is direct runoff by overland flow.

"Big Coldwater Creek is the largest tributary feeding the Blackwater River. The total area drained by this tributary is 241 square miles. All except the smallest streams in the Big Coldwater Creek basin have perennial flows. The average flow from the basin is estimated to be 542 cfs.

"The unit runoff of East Fork and West Fork, the two main tributaries of Big Coldwater Creek, is slightly lower than that of the main creek. The unit runoff from the upper 64 square miles of East Fork is 2.0 cfs per square mile; that from the upper 39.5 square miles of West Fork is 1.9 cfs per square mile; and that from the 237 square miles above State Highway 191, below the confluence of the two forks, is 2.2 cfs per square mile. The intervening drainage area of 133.5 square miles between the two gauging stations on the forks and the gauging station on State Highway 191 has a unit runoff of 2.5 cfs per square mile. About 60 percent of the flow of West Fork Coldwater Creek is base flow and 40 percent is direct runoff from overland flow.

"Streamflow records have been collected for 32 years (1938-70) on Big Coldwater Creek. The gauging station near Milton is located on State Highway 191 and measures flow from 237 square miles. Because of the rolling topography and steep slope of the basin, flood waters drain rapidly. Ground-water seepage sustains the base flows at rather high rates during dry weather.

"The seasonal distribution of runoff in Big Coldwater Creek basin follows very closely the pattern of rainfall. Heavy spring rains cause high runoff, thus March and April have the highest average flows. High intensity rainstorms in July and August cause high peak flows. October is the month of lowest flow.

"Big Juniper Creek, which joins the Blackwater River 5 miles upstream from Big Coldwater Creek, drains 146 square miles. The streambeds in this basin are composed of loosely packed sand and gravel, and the banks are steep and heavily wooded.

"The average flow from the Big Juniper Creek basin is estimated to be 260 cfs, or 1.8 cfs per square mile. Flow was measured at the three sites within the basin : Big Juniper Creek at State Highway 4, near Munson; Sweetwater Creek at State Highway 4, near Munson; and Big Juniper Creek near Harold. Runoff characteristics are similar at these three sites. Slightly over one-half of the flow is base flow; the remaining is direct runoff from overland flow.

"The Blackwater River drains 860 square miles, and discharges an average of 1,490 cfs into Blackwater Bay.

"The lower 6 miles of the Blackwater River channel varies in depth from 10 feet to as much

as 60 feet in holes. At least 6 holes in the lower river are 35 to 60 feet deep. These deep holes trap salt water moving in from the Gulf and could be a source of contamination of the surrounding ground water if large capacity wells are located nearby and pumped heavily enough to cause major drawdowns. The salt front during extreme high tides extends upstream about 6 miles from Blackwater Bay."

Physical Features

Gradient. In Table I are listed gradients and lengths for selected Florida streams. It will be noted that the streams are divided into three groups.

Table I

Comparison of gradients and lengths of selected Florida streams

Stream	*Gradient Ft. per Mile*	*Length, Miles*
Apalachicola River	0.4	100
Choctawhatchee River	1.4	125
Escambia River	3.8	91.8
St. Johns River	0.1	318
Suwannee River	0.5	245
Blackwater River	3.4	58.4
Big Coldwater River	6.5	27.0
Big Juniper Creek	7.6	24.2
Pond Creek	9.2	21.3
Sweetwater Creek	6.5	18.2
Barrel Branch	117.0	1.5
Bethel Branch	158.1	0.6
Dogwood Branch	100.0	0.5
Yellow Water Creek	112.9	3.1

The first, or top, group consists of the five largest streams of Florida. The St. Johns, which has been referred to as a river, a series of connected lakes, or a fossil lagoon, has the lowest gradient of all, 0.1 ft/mile and a length of 318 miles. The Suwannee is considered a rather swift stream by Florida standards, yet only has an average gradient of 0.5 ft/mile.

The second group consists of the Blackwater River and its main tributaries, all of the latter having steeper gradients than the main stream. A gradient of 3.4 ft/mile for the Blackwater is indicative of the swiftness of the stream and also indicative of the source of energy keeping the shifting sands in almost constant motion.

It is the third group, however, that reveals one of the truly distinctive features of the sand-bottomed streams of the panhandle of Florida. The four examples are for "steepheads", mentioned above. These will be discussed more thoroughly below.

Geological Deposits. The entire Blackwater system is bedded in the Citronelle formation. Although the term "Citronelle formation" is somewhat subject to debate at present, it seems best to retain the term here because of its widespread use in Florida literature.

Table II

Discharge of the Blackwater River (in cubic feet/second) recorded near Baker, Florida, in 1968

1968	*CFS*
MAXIMUM	1660
MINIMUM	73
MEAN	211
JUNE 4, 1969	18,600*

* 32 year maximum

The following quotation from MARSH (1966) is a very thorough description.

"Type locality. — The Citronelle Formation was named by MATSON (1916) for exposures at the town of Citronelle in northern Mobile County, Alabama, and especially northward along the Mobile and Ohio Railroad for a distance of 3 to 4 miles. At the type locality the formation consists predominantly of light-yellowish brown to reddish-brown, very fine to very coarse, pebbly sand with some white clay as thin layers and pellets scattered throughout. Only the lower part of the formation is present at the type locality, the upper part having been removed by erosion.

Table III

Water chemistry of the Blackwater River, recorded near Baker, Florida

	Minimum	*Maximum*
pH	5.0	6.3
Color, mg/l	10	20
Chlorides, mg/l	2.8	3.2
Hardness, Carbonate, mg/l	2.	6
Hardness, Non-Carbonate, mg/l	0.	3
Total Dissolved Solids, mg/l	15	17
Alkalinity, Bicarbonate, mg/l	2	3
Phosphate (PO^4), mg/l	0.00	0.00
Nitrate (NO^3), mg/l	9.2	0.6
Dissolved Oxygen, mg/l	6.8	9.7

"Distribution. — The Citronelle extends eastward and south-eastward from the type locality into Florida where it underlies all of Escambia and Santa Rosa counties and continue eastward

across the Panhandle for an undetermined distance. How much of the virtually unfossiliferous sand-gravel-clay sequence that is found in the rest of the State should be included in the Citronelle is yet to be resolved. PURI and VERNON (1959) included the "unnamed coarse clastics" of the eastern Panhandle in the Hawthorn Formation of early and middle Miocene Age. COOKE (1945) and PIRKLE (1960) correlate the kaolinitic sands exposed in the central ridge of the peninsula with the Citronelle.

"Thickness. — The thicknesses given here for the Citronelle Formation in Escambia and Santa Rosa counties include the Pleistocene terrace deposits because, as CARLSTON (1950) points out, "it is virtually impossible to differentiate Pleistocene sand and gravel of the marine terraces from the Citronelle sand and gravel." However, the terrace deposits are probably relatively thin, and therefore, their inclusion would not greatly alter the general thickness figures. Together the Citronelle and the terrace deposits range in thickness from about 30 feet at the southern border of Santa Rosa County to about 799 feet in northwestern Escambia County. The combined thickness of these two units in Escambia and Santa Rosa counties is quite variable for two reasons : (1) The base of the Citronelle appears to be an irregular surface of unconformity, and (2) the top of the terrace deposits coincides with an irregular topography of considerable relief.

"Carlston remarks that "the Citronelle formation ... ranges from 40 to 130 feet thick in coastal Alabama, vecause of pre-Citronelle relief and a general thickening toward the Gulf." MATSON says that the formation may be more than 250 feet thick in southern Alabama and that west of Mobile it may have a maximum thickness of 340 feet. COOKE believes that "in Florida the thickness is probably of the same order of magnitude" as that given by MATSON. The results of the present study do not appear to agree with the thickness figures of either CARLSTON or MATSON, although those obtained for Escambia and Santa Rosa counties are closer to MATSON's figures. Despite the gulfward thickening of the Citronelle in coastal Alabama reported by CARLSTON, just west of the area of this report the Citronelle apparently thins southward (toward the Gulf) as well as eastward in Escambia and Santa Rosa counties, Fla.

"Lithology. — In Escambia and Santa Rosa counties, the Citronelle consists principally of quartz sand which contains numerous lenses, beds, and stringers of clay and gravel. The lithology changes abruptly over short distances.

"The sand is typically light yellowish brown to reddish browns, although some is white or light gray. The grains are mostly angular to subangular and very poorly sorted, ranging from very fine to very coarse. Muscovite is abundant throughout. In places the sand grades into gravel composed of quartz and chert pebbles up to an inch in diameter. A few pebbles of silicified oölitic limestone were noted in samples from the northern part of the area. Elsewhere the sand grades into siltstone and clay. The siltstone is light gray to light yellow and in places contains abundant carbonized plant remains. The clay occurs in lenses as much as 60 feet thick and is chiefly white or gray, although some is lavender, yellow or brown. Fragments of carbonized wood are common in the gray clay. At Molino in Escambia County, clay for making bricks is mined from a lens that is 50 feet thick. Although it is difficult to ascertain the horizontal extend of the clay beds within the Citronelle, they probably range from a few feet to 2 or 3 miles in length.

"A distinctive rock type that occurs in the Citronelle Formation throughout western Florida and southern Alabama is a limonite-cemented sandstone called "hardpan."

"This rock, formed by cementation of sand with iron oxides probably precipitated from ground water, is dark rusty brown and is generally extremely hard, although some may be rather

soft. The "hardpan" most commonly occurs as layers that parallel the bedding of the enclosing sediments. These layers range from a fraction of an inch to 3 or 4 feet in thickness. In places, the "hardpan" is filled with peculiar curving tubular structures of uncertain origin, from a fraction of an inch to severeal inches in diameter.

"These tubular structures parallel the bedding and are filled with the same loose sand that encloses the "hardpan" layers. Little is known concerning the lateral extent of these hardpan layers, but it is unlikely that any given layer extends for more than a few thousand yards. Escambia and Santa Rosa counties are dotted with hundreds of ponds, many of which probably owe their existence to "hardpan" layers at or near the surface.

"Fossils. — Parts of the Citronelle Formation of the western Panhandle contain abundant remains of trees and other woody plants. This material occurs in two forms : as zones of charcoal and carbonaceous material, and as logs and twigs that have not been carbonized. Samples from well W-4312 in north-eastern Escambia County contain soft black carbonaceous lumps at 190 and 280 feet; in the interval 340-360 feet, an estimated 50 percent of the unwashed samples consists of carbonized wood fragments. A thin, carbonaceous layer may be seen in roadcuts, stream banks, and railroad cuts at many places throughout Escambia and Santa Rosa counties. Whether this actually represents a single, regionally extensive layer or several different layers could not be determined. The thickest carbonaceous zone observed was at an altitude of about 50 feet on the north side of Canoe Creek about 4 miles south west of Century in northeastern Escambia County, where U.S. Highway 29 crosses the creek. Here, a zone of highly carbonaceous clayey earth and gravel containing bits of coal and twigs was exposed in the side of a small artificial drainage cut until later construction work obliterated the exposure. The zone was 2 feet thick, with a sharp but irregular upper contact, and graded downward into sparcely carbonaceous sand at the bottom of the cut. About 8 miles northeast of this locality, a 1-foot carbonaceous zone containing abundant charcoal is exposed at an altitude of about 200 feet along both sides of a deep railroad cut where U.S. Highway 29 crosses the Louisville and Nashville Railroad northeast of Flomaton, Ala. It is not unreasonable to suppose that this this bed and the one at Canoe Creek may be the same; if so, it would have a southwestward dip of about 18 feet per mile, which agrees quite well with the regional dip of the Citronelle in Escambia and Santa Rosa counties. Well driller Lehmon ("Tex") SPILLERS (oral communication, April 1961) of Pensacola stated that at Escambia Farms in northern Okaloosa County he drilled through a layer of "burnt wood or charcoal hard as a brick" at a depth of 100-125 feet. He added that most wells in that general area encounter this same carbonaceous zone. These zones of carbonaceous material may have been the result of ancient forest fires.

"The second type of fossil wood in the Citronelle of west Florida is uncarbonized material. At a few places, notably south of Munson in Santa Rosa County, fragments of wood and twigs replaced by limonite were found among lag gravel on the surface of the ground. Of considerably more interest, however, are the numerous logs that well drillers encounter during the drilling of water wells in western Florida. SPILLERS (oral communication, April 1961) reports that he has drilled through many fossil logs in Okaloosa, Santa Rosa, and Escambia Counties, Fla.. and in southern Baldwin County, Ala. In the Pensacola area, he says, logs are generally encountered at a depth of about 200 feet and are commonly embedded in a "fine, silty, muddy sand like an old lake bottom." Near Robertsdale in southern Baldwin County, Ala.. SPILLERS drilled through a log 3 feet thick between depths of 80 to 100 feet, and "enough pulp to fill a couple of washtubs" came up the drill hole, clogging the mud pit and stopping

up the pump. Other drillers have reported drilling into logs at depths of 50 to 100 feet at various places in the western panhandle.

"Invertebrate Fossils. — CARLSTON (1950) states that "no invertebrate or vertebrate fossils have been found in the Citronelle formation." It is largely for this reason that the age of the formation has never been conclusively established. In Escambia and Santa Rosa Counties, Florida, the great majority of well samples from the Citronelle Formation are nonfossiliferous. However, a few fragments of mollusk shells were noted in samples of the formation from wells in the central and northern parts of the area, at depths ranging from 20 to 300 feet below the surface. These shell fragments were too weathered and broken to permit identification. More significant is the occurrence near the Gulf of abundant fossils in sand and clay beds below about 25 feet. Because of the difficulty of distinguishing the sediments of the Citronelle from deposits formed during the latter part of the Pleistocene, such as the marine terrace deposits, exact correlation of these fossiliferous beds is uncertain. However, these beds may be the marine equivalent of the inland fluvial facies of the Citronelle. Unfortunately, time did not permit identification of the fossils from these beds which might have aided in their correlation."

Steepheads. — The following quotation from VERNON (1942) is the best general discussion of these features that I have found.

"SELLARDS applied the local name "steephead" to unusual amphitheater-shaped valley heads occurring in high sand areas. He attributed their origin to spring sapping along poorly indurated beds underlying more consolidated sands. SHARP agreed with SELLARDS and observed that drainage lines rarely lead from the upland surface into the steepheads. COOKE stated that some of these "steepheads" might result from the stream capture of sink holes.

"Steepheads are natural features and in this area apparently have not resulted from accelerated soil erosion brought about by misuse of land. Most of them are between 100 and 200 feet wide. Steepheads in Holmes and Washington counties occur cheifly at the junction of recent drainage with relatively high land topped by thick deposits of terrace sands. Broad areas of sand absorb large quantities of water, thereby preventing effective run-off. This water emerges at the base of escarpments along the ground water surface as springs, which gradually migrate into the terrace levels. The steepness of the walls of these steepheads depends upon the relative induration of the sediments, and along the Choctawhatchee River south of Hinson's Crossroad, Washington County, they show all gradations from gullies with steep gradients to the typical steephead. The shape of the steephead is also governed by the positions of the springs which produce it. An amphitheater shape is due to a major spring joined by many side, or tributary spings."

CHEMISTRY

Due, probably, to its relative isolation, there are rather few chemical analyses available for the Blackwater River. Table III is a summary of analyses from the files of the Florida State Board of Health, the Florida Department of Air and Water Pollution Control, and the United States Geological Survey.

The Blackwater River is chemically a rather typical West Florida sand-bottomed stream (BECK, 1965).

Writing of the area, MARSH (1966) says : "The most important natural resource of economic value in the area is ground water. Escambia and Santa Rosa counties enjoy an abundant

supply of the softest and least mineralized ground water in Florida — an important factor in industrialization of the area."

Climate

The following paragraph from Marsh (1966) summarized the climate of the area adequately.

"Western Florida has a humid, warm-temperature climate. Summers are warm and long, averaging about 80° F at Pensacola, although winds from the gulf make most of the nights comfortably cool. Winters are mild, averaging 55° F with rare cold spells of 15° or 20°. The average annual rainfall is 62 inches. March, July, August, and September are the wettest months, and October and November are the driest. Thundershowers of high intensity are common, with as much as 3 or 4 inches of rainfall during an hour period. Occasional tropical storms and hurricanes blow in from the Gulf of Mexico."

Concluding Remarks

The unusual biological features of the Blackwater River are a reflection of the combined chemical, physical, and geological features.

Chemically the river water is extremely soft and but slightly mineralized. This is due to the ground water flowing through siliceous sands between impervious layers of clay. The effects of this carry over into the stream itself, bedded, as it is, in the same sands and clays, thus having little opportunity to increase mineralization. The water is low in dissolved nutrients, a fact that is reflected in sparse growths of aquatic plants.

It is the physical factors, however, that some of the almost unique features are revealed. Steepheads have been discussed at some length. It is because of these that most of the normal flow of the River is ground water, not runoff water (surface drainage). This results in a temporing effect on extremes of temperature, keeping this stream cooler in summer and warmer in winter than waters of other origin (see Beck 1965 : 110-111 for observed data on this effect).

The shifting white sands in the bed of the River are also unusual in that they appear to support more burrowing organisms than normally found in most other areas of Florida. This needs further investigation.

It is anticipated that we will have an automatic sampler, analyzer and recorder installed in the Blackwater within a few months, giving us 24 hours per day measurement of such factors as water temperature, dissolved oxygen, pH, alkalinity, and conductivity. Perhaps then we will have a much greater understanding of this truly fascinating stream.

Résumé

Aspects chimiques et physiques de la rivière Blackwater dans le nord-ouest de la Floride

La rivière Blackwater prend sa source dans le sud de l'Alabama, coule en direction du sud, puis du sud-ouest, à travers les comtés de Okaloosa et de Santa Rosa, vers la baie Blackwater, et à travers les baies de l'Est et de Pensacola vers le golfe du Mexique. Son cours d'eau principal a 58,4 miles de long et sa pente moyenne est de 3,4 pieds par mile. La rivière et ses affluents

ont creusé leur lit assez profondément dans des formations du Citronelle, dépôt de sables rougeâtres, d'argile et de gravier remontant au Pleistocène. Cette formation a une épaisseur variant de 30 à 350 pieds et couvre à peu près 860 miles carrés en Floride et en Alabama.

La rivière est un exemple typique de cours d'eau à fond sableux du nord de la Floride, avec un pH légèrement acide (pH 5,0-6,3), une faible concentration en sel (concentration en carbonate 2-6 mg/l), et une faible concentration en particules solides (15-17 mg/l). La teneur en oxygène de ces eaux est assez élevée (6,8-9,7 mg/l) et elles sont faiblement colorées (10-20 mg/l).

A basses eaux la majeure partie des eaux provient des sources constituées par ce que l'on appelle en Floride "steepheads", c'est-à-dire des ravins profonds avec un suintement sur la partie supérieure des parois.

Le débit du cours d'eau principal en 1967 a varié de 73 à 1663 cubic feet par seconde (cfs) avec une moyenne annuelle de 211 cfs. Le plus fort débit pendant une période de 32 ans d'observation a été relevé le 4 juin 1969 et a atteint à peu près 18600 cfs.

L'un des caractères les plus remarquables de cette rivière est le fond de sable blanc constamment renouvelé, ce qui en fait quelque chose d'unique du point de vue biologique.

Zusammenfassung

Chemisches und physikalisches Aussehen des Blackwater Flusses in Nordwest-Florida

Der Blackwater Fluss entspringt in Süd-Alabama, fliesst in einer südlichen dann südwestlichen Richtung durch die Bezirke Okaloosa und Santa Rosa zur Blackwater Bucht, und durch Ost- und Pensacola-Buchten zum Golf von Mexiko. Der Hauptstrom ist 54.8 Meilen lang, und der gewöhnliche Gradient 3.4 Fuss pro Meile. Der Fluss und alle seine Nebenflüsse schneiden ziemlich tief in die Citronelle Formation, eine Pleistocene Ablagerung von rötlichem Sand, Lehm und Kies. Die Formation wechselt in Dicke von 30 bis 350 Füssen und bedeckt zirka 860 Quadratmeilen von Florida und Alabama.

Der Fluss ist ein typisches Exemplar von Sandboden-Flüssen im Pfannenstiel von Florida, ein wenig sauer (pH 5.6-6.3), mit aussergewöhnlich weichem Wasser (Carbonat-Härte 2-6 mg/l) und schwacher Festkörperlöslichkeit (15-17 mg/l). Er ist gut mit Sauerstoff durchzogen (6.8-9.7 mg/l) und hat eher wenig Farbe (10-20 mf/l).

Das meiste langsam fliessende Wasser hat seinen Ursprung in Quellen, die in Florida "steepheads" (Steilköpfe) genannt sind. Diese sind tiefe Einschnitte mit Sickerungen aus dem "head" (Kopf).

Entleerung des Hauptstromes in 1967 variierte von 73 zu 1663 Kubic-Fuss pro Sekunde (cfs), ein Durchschnitt von 211 cfs in Jahr. Die grösste Entleerung in 32 beobachteten Jahren kam am 4. Juni 1969, und war 18,600 cfs.

Eine der hervorstechendsten Merkmale dieses Flusses ist der stets wechselnde weisse Sandboden, welcher für die biologische Einmaligkeit verantwortlich ist.

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