GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: November 14, 1979 Revised

Project Title: Potential for Industrial Water Conservation in Georgia: Major Water Consumption Groups

Project No: B-539

Project Director: ~~L.P. Fisher~~ Gary Richardson

Sponsor: U.S. Department of the Interior; Office of Water Research & Technology

Agreement Period: From 9/15/79 Until ~~9/14/80~~ 6/30/81

Type Agreement: Grant No. 14-34-0001-9453, dated 9/28/79

Amount: $36,462 OWRT
36,679 (E-152-201)
$73,141 Total

Reports Required: Quarterly Progress Report; Summary Report; Draft Final Report; Final Report

Sponsor Contact Person (s):

Technical Matters

Assistant Director, Research
Office of Water Research and Technology
U.S. Department of the Interior
Washington, D.C. 20240

ATTN: Mr. John T. Campbell
Ohone: 202-343-2076

Contractual Matters
(thru OCA)

U.S. Dept. of the Interior
Office of Water Research & Technology
Chief, Contracts and Grants Center
Washington, D.C. 20240
Phone: 202-343-6992

Defense Priority Rating: None

Assigned to: TAL/ECD (School/Laboratory)

COPIES TO:

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- Project File (OCA)
- Project Code (GTRI)
- Other ______

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 8/7/81

Project Title: Potential for Industrial Water Conservation in Georgia: Major Water Consumption Groups

Project No: B-539 (subproject is E-19-607/Hartley/ChE)

Project Director: Craig Wyvill

Sponsor: U.S. Dept. of the Interior

Effective Termination Date: 6/30/81

Clearance of Accounting Charges: ______

Grant/Contract Closeout Actions Remaining:

- _ Final Invoice and Closing Documents
- x Final Fiscal Report
- x Final Report of Inventions
- x Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ______

Assigned to: TAL (School/Laboratory)

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Other: E-19-607 file

B-539

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

December 19, 1979

Mr. John T. Campbell
Office of Water Research and Technology
U.S. Department of the Interior
Washington, D. C. 20240

Re: OWRT Grant No. 14-34-0001-9453

Dear Mr. Campbell:

This letter is intended to serve a dual purpose: to report the progress of the above referenced grant, and to formally propose the change in scope we have discussed several times since our meeting on November 1st. As you recall, on that same day I met with Connie Kollar and Pat McAuley of the Bureau of Domestic Business Development, U.S. Department of Commerce, concerning a possible change in project direction. We agreed then that it would be desirable to select a single industrial sector in Georgia and then to collect and present data on that industry's consumptive water use.

The pulp and paper industry appeared to be the logical choice, in that it represents about 60 to 70% of the industrial process water usage in Georgia. The question that had to be resolved was whether or not we could gain the cooperation of the individual plants in sharing their operational data. Dr. Ed Hartley of the Georgia Tech School of Chemical Engineering has contacted a number of these plants, and has received a generally favorable response. Dr. Hartley has a great deal of expertise in pulp and paper, as well as a substantial number of personal contacts within the industry and a position on the 1979-1980 Southeastern Technical Association of the Pulp and Paper Industry's Board of Directors. He has agreed to assist on this project, and will certainly be a valuable addition.

Based on the tentative expressions of cooperation secured from these various plants, I feel that the pulp and paper industry ought to yield sufficient data to be the basis for a worthwhile study, should you concur in the revised project scope.

While we haven't yet finalized our list of pertinent plants, there appear to be about 30 that use significant quantities of water in pulp, paper, and paperboard mill operations, and should therefore be included in this study. The proposed new project scope will entail a mail survey followed by plant visits for purposes of gathering water consumption data. Information will be sought on intake water sources and quantities, as well as on a cataloguing and quantification of the exit streams from the plant, i.e., discharge to the stream, evaporation, steam leakage, condensate discharge to sewers, and containment in the product. Data on employment and production levels will also be solicited, and water consumption figures correlated with both. Also, where feasible, process water recycle rates will be documented and related to water consumption.

The end product of the study will be a presentation of the data collected as described above, as well as a bibliography of water conservation and recycle/reuse in the pulp and paper industry. A draft version will be prepared by September 1, 1980, and the final report should be ready for dissemination by November 1, 1980. The initial survey work will begin during the second week of January, 1980, and plant visits will start the end of that month, with your approval. The proposed staffing will be as follows:

Lawrence Fisher (Principal Investigator)
William Himes
Dr. Edwin Hartley
George Battaglia.

An undergraduate student assistant will also be utilized.

If this plan is acceptable to you, I would appreciate it if you would send a brief letter to our Office of Contract Administration stating your approval of the change in scope. Please address the correspondence to:

Mr. L. R. Scott
Office of Contract Administration
Georgia Institute of Technology
Atlanta, Georgia 30332.

Please let me know if your administrative procedures requires a different approach.

I look forward to hearing from you at your earliest convenience. If you need any additional information to facilitate this approval, I'll be glad to help. Thank you for your continuing interest in this project.

Sincerely,

Lawrence P. Fisher
Principal Investigator

LPF/mro

B-539

Quarterly Progress Report

Office of Water Research and Technology

January 1, 1980 - March 31, 1980

OWRT Grant No. 14-34-0001-9453

Ga. Tech Project No. B-539

March 31, 1980

Engineering Experiment Station
Georgia Institute Of Technology
Atlanta, Georgia 30332

FIRST QUARTER ACTIVITY

Reporting Period: January 1, 1980 - March 31, 1980

A. Project Team and Scope of Project:

- Gary Richardson - Principal Investigator
  William Himes
  George Battaglia
  Edward Hartley

- The project scope has been narrowed to include the largest industrial water consumer in the state -- The Pulp and Paper Industry. The pulp and paper industry represents about 60 to 70% of the industrial process water usage in Georgia.

B. Plant Surveys:

Plant Code	Date of Visit	Status
W-2600 7	2/29	Complete
W-2600 8	2/6, 3/24	Complete

C. Other Activities:

- Efforts are being made to obtain more accurate estimates of water flow rates. Water flow rates for large use areas are difficult to get, and the lower flow internal streams are very difficult to find. The use of a non-invasive flow meter would make this information much easier to obtain.

D. Plans for Second Quarter:

- Approximately 21 plant surveys will be conducted.

SUPPLEMENT TO QUARTERLY PROGRESS REPORT

January 1, 1980 - March 31, 1980

OWRT GRANT NO. 14-34-0001-9453

GEORGIA TECH PROJECT

No. B-539

May 6, 1980

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

I. Summary

This report presents initial work for a study of water usage in Georgia's pulp and paper industry under OWRT Contract #14-34-0001-9453. The contract covers the period from September 15, 1979 through September 15, 1980. During the first quarter of 1980, Georgia's pulp and paper industry was selected as the target of a program that would identify specific opportunities for water conservation. This objective would be accomplished by making water usage surveys of individual pulp and paper mills. This information combined with Georgia Tech's expertise in the field of water use and management, will be used to prepare a report on the state of water conservation and recycle/reuse in Georgia's pulp and paper industry.

The pulp and paper industry represents 60 to 70% of the industrial process water usage in Georgia. The three chemical processes used are kraft pulping, sulfite pulping, and soda pulping. In chemical pulping lignin is separated from the cellulose fibers by cooking the chips in aqueous liquid. Sulfite pulping uses a solution of calcium, magnesium, sodium or magnesium bisulfate. Soda pulping uses sodium hydroxide and a recent development includes oxygen. Over 80% of the chemical pulp is made by using the kraft process.

The pulp and paper industry uses water for many of their processing operations. The water is obtained from two sources: ground water and river water. The most common processing operation is the kraft process. Some of the major water uses in this process are evaporation from the paper machine, black liquid recovery, and cooling tower evaporation.

There are two major factors to consider when choosing survey locations. The size of the mill, and their willingness to cooperate. These two factors have been used to pick nineteen mills for the water use survey. In addition to these, we expect another 6 to 8 mills to come from referrals.

The two plants surveyed to date have been very cooperative in providing water usage information, and we do not anticipate any problems in completing the survey as planned.

II. Objectives of Program

The objective of this program is to identify specific opportunities for water conservation within Georgia's pulp and paper industry. This objective will be accomplished by making water usage surveys of individual pulp and paper mills. This information, combined with Georgia Tech's expertise in the field of water use and management, will be used to prepare a report on the state of water conservation and recycle/reuse in Georgia's pulp and paper industry.

III. Kraft Pulping, Bleaching and Paper Making

Introduction

Kraft pulping, sulfite pulping, and soda pulping (including soda oxygen) are the three principal chemical pulping processes. In chemical pulping, the lignin is separated from the cellulose fibers by cooking the chips in aqueous liquor. Sulfite pulping uses a solution of calcium, magnesium, sodium or magnesisum bisulfite. Soda pulping uses sodium hydroxide and a recent development includes oxygen. The kraft process uses sodium hydroxide and sodium sulfide which protects the cellulose from attach by the alkali. Kraft pulp is characteristically stronger, darker, more difficult to bleach, and has a higher versatility of wood species than the other processes. The bleaching of kraft pulp is predominantly accomplished in five or more stages using chlorine, chlorine dioxide, hypochlorite and caustic extraction. A newer process, displacement bleaching, uses the same bleaching chemical continuously in a single vessel rather than in stages. Papermaking is generally done on the fourdrinier machine. Twin wire formers are a later development in sheet formation and are used to a large extent for tissue production and mechanical pulp newsprint production. Generally, kraft mills are integrated, that is, the wood preparation, pulping, bleaching and papermaking operations are continuous at the same site. The overall flow sheet for the integrated kraft mill is shown in Figure 1. Over 80% of the chemical pulp is made by the kraft process.

Kraft Pulping

Wood Preparation

The wood is received at the mill either as chips or roundwood (logs), which is subsequently debarked and chipped. The bark and chip fines from the chip screening operation are usually burned as fuel in the mill boilers. Extensive outside roundwood and chip storage insures a steady wood supply for pulping.

Pulping

The chips are cooked batchwise in batch digesters and also in continuous digesters. The sodium hydroxide, sodium sulfide cooking liquor, called

BLEACHED KRAFT PULPING
PROCESS FLOW DIAGRAM

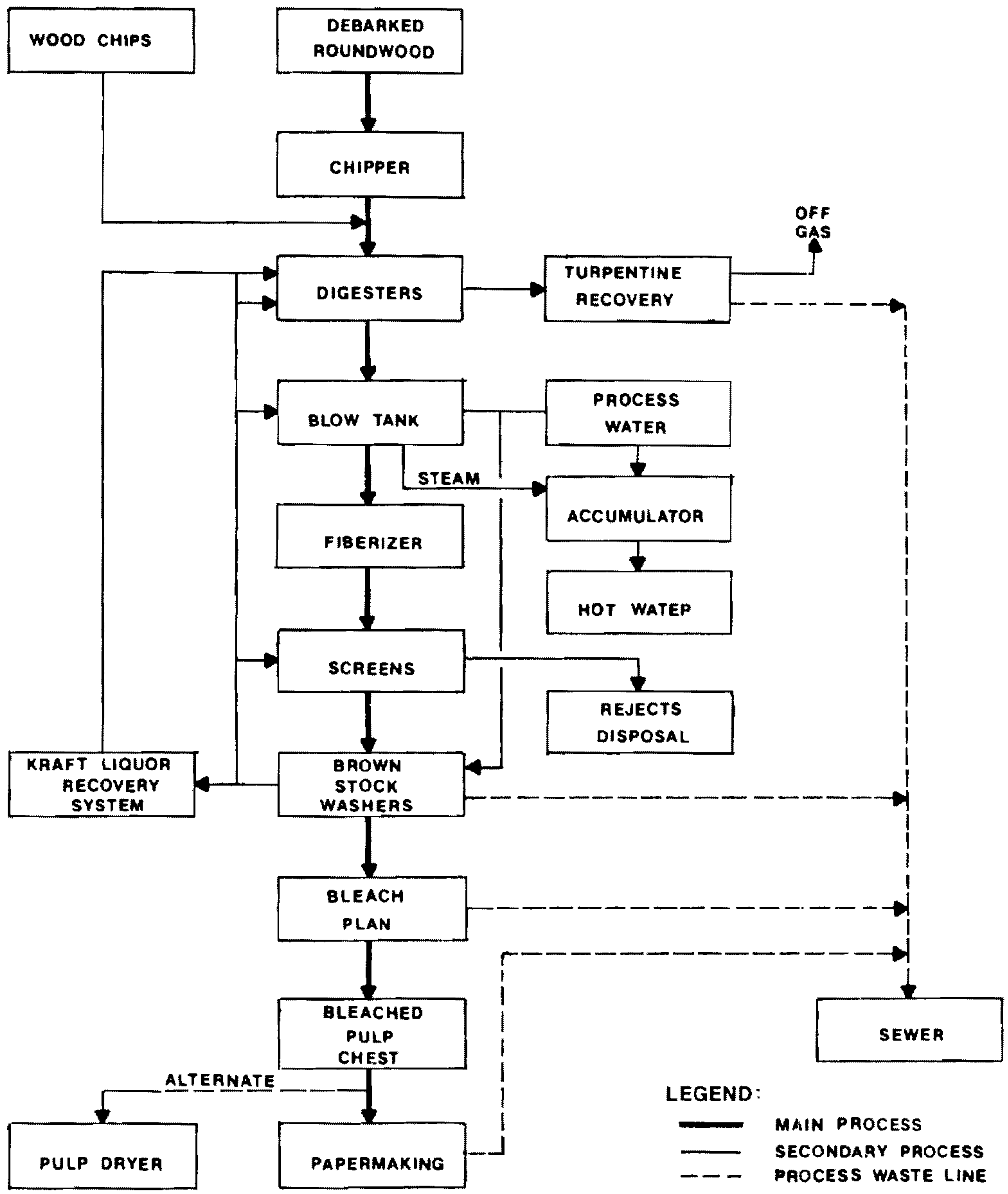

FIGURE - 1

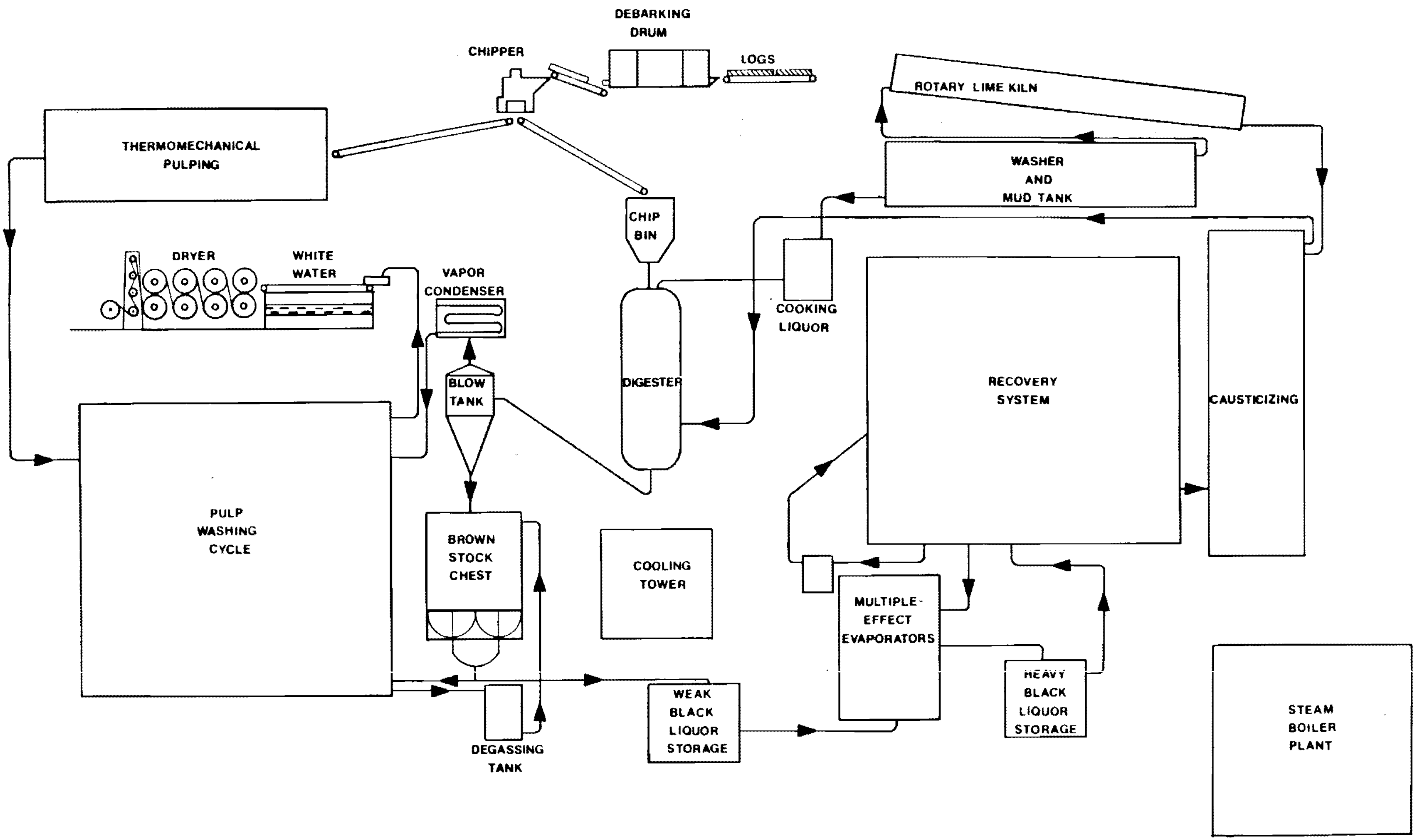
DEBARKING
DRUM
CHIPPER
LOGS
ROTARY LIME KILN
THERMOMECHANICAL
PULPING
WASHER
AND
MUD TANK
CHIP
BIN
DRYER
WHITE
WATER
VAPOR
CONDENSER
COOKING
LIQUOR
BLOW
TANK
DIGESTER
RECOVERY
SYSTEM
CAUSTICIZING
PULP
WASHING
CYCLE
BROWN
STOCK
CHEST
COOLING
TOWER
MULTIPLE-
EFFECT
EVAPORATORS
HEAVY
BLACK
LIQUOR
STORAGE
WEAK
BLACK
LIQUOR
STORAGE
DEGASSING
TANK
STEAM
BOILER
PLANT

FIGURE - 2

white liquor and chips are charged to the digester and held at 100 psig, 338°F, for 1-2 hours with steam. From the batch digesters the charge is released to a blow tank at atmospheric pressure where a large quantity of water vapor flashes off which is recovered in the accumulator. From the blow tank, the pulp and cooking liquor, called black liquor, are fed continuously to the washers where the pulp and black liquor are separated. Either before or after the washers, the pulp may be refined to break up fiber bundles and screened to remove knots, partially cooked chip fragments and foreign material. The pulp is stored then in high density (H.D.) tanks prior to delivery to the bleach plant or paper machine. The black liquor which contains the lignin and other wood organics is evaporated down to a range of 35% water content and burned as fuel in the recovery boiler. In addition to generating steam from the black liquor the recovery boiler also facilitates recovery of the sodium and sulfur inorganics for reuse in the white liquor. In the bottom of the boiler, the reducing zone, a pool of molten smelt of sodium carbonate and sodium sulfide forms which is tapped off and dissolved in water. The solution of the sodium salts, green liquor, is reacted with calcium oxide to produce sodium hydroxide and calcium carbonate precipitate. After filtration and clarification, the sodium hydroxide-sodium sulfide solution is returned as white liquor to the digester for cooking. The calcium carbonate filtrate is burned in the lime kiln to calcium oxide and reused for reaction with the green liquor in the slaker-causticizers. The recovery fo the inorganic salts and generation of energy from the black liquor is essential to the economics of the kraft process.

Bleach Plant

The washed pulp is mixed with chlorine in the first state of bleaching to remove residual lignin. Caustic extraction, the second state, is used to remove the chlorinated lignin components from the pulp. Successive stages involve the bleaching of the pulp with chlorine dioxide, hypochlorites, and other bleaching agents. Usually caustic extraction stages are intermittent with bleaching stages to remove the color bodies and other products of the bleaching stages from the pulp. Drum washers are used after each stage for washing the pulp. In the displacement bleaching process, the bleaching stages are performed in a single tower by successively displacing the bleaching chemical or caustic by the agent used in the next step rather than each stage being done in a separate tower. Displacement bleaching is a relatively new development and claims to save energy, space, manpower and bleaching chemicals and has the requirement of a higher accuracy of process control. Kraft pulp is more difficult to bleach than sulfite pulp, requiring more stages for the same degree of brightness. Five stages will result in G.E. brightness in the high eighties and up to 10 stages are required for the high nineties. Chlorine dioxide is usually manufactured on site because it is too unstable for shipment.

Papermaking

The bleached or unbleached pulp is first diluted to 3-4% consistency and mechanically treated by refiners in the stock preparation area. The refiners abraid the surface of the fibers, softening them and creating more surface for contact when formed into a sheet. Typically, two stages of refining are used. In the stock prep areas additives for water repellancy and strength are mixed with the stock. The stock is then diluted to about 1/2% consistency, screened, cleaned centrifugally and pumped to the head box of the paper machine. On the fourdrinier machine the stock is delivered onto the forming fabric, and endless moving screen. The water drains through the fabric leaving the fibers deposited on the top surface of the flat screen. In the cylinder forming machine, the sheet is deposited on the surface of a wire screen covered revolving cylinder. After being formed, the sheet is transferred to the press section where additional water is mechanically pressed out of the sheet between two rolls. Up to three presses are typically used. The sheet is next dried to finish product moisture content by wrapping a series of steam heated drums in the dryer section. In the dryer section, the sheet may be coated and redried. At the end of the machine the sheet is smoothed in the calender stack and wound into rolls.

IV. Major Water Uses in the Pulp and Paper Industry

Based on preliminary studies of the pulp and paper industry in the State of Georgia, the major water consuming process is the kraft process producing linerboards. In addition to this, less significant amounts of water are used for recycling paper and newsprint and in mechanical pulping.

Unlike other raw materials used in the manufacture of paper, the large quantities of process water necessary cannot be economically transported to the mill site. Therefore, it is essential that pulp and paper mills be located near a readily available water supply. The source of this water is primarily from two sources -- surface water and groundwater.

Surface water is that water obtained from rivers, ponds, lakes and impounding reservoirs. Ground water is obtained from springs and wells. Except for four paper mills located on the southeast Georgia coast, the remainder of the industry throughout the state relies almost exclusively on surface water. This surface water is supplied by the abundant river system flowing through Georgia. The coastal mills use well water since the river water is brackish.

Another source of water into a mill is with the raw wood. Fresh cut timber is approximately 50% water and a mill producing 1300 tons of kraft linerboard per day could use as much as 5000 tons of wood per day. At 50% moisture content, 2500 tons of water or 600,000 gallons of water enters the mill each day with the wood.

Wood is debarked and the bark is generally burned to produce steam. In the process of burning the bark, the water content of the bark is lost. This loss in an average mill is around 100,000 gallons per day.

The debarked wood is chipped and fed into a digester where the fibers are separated from the lignin in the wood. The spent chemicals or black liquor as it's known in the industry, is processed through a recovery system to form fresh cooking liquor. The black liquor begins the recovery process at 12-18% solids and proceeds through evaporators to remove some water and is eventually incinerated in the recovery furnace. This process typically releases approximately 500,000 gallons per day of water into the atmosphere.

Another major loss of water is in cooling towers. In many instances process water must be cooled in order to reuse it. Evaporation losses in these towers may be as high as 400 gallons per minute or 576,000 gallons per day.

Another large evaporation loss occurs in the dryer section of the paper machine. The fibers start into the machine in a solution that is only 3-4% solids or 96-97% water. The solid content is increased until the sheet leaves the machine with a moisture content of around 7%. In the process of drying the paper, 400,000 gallons per day of water is evaporated into the atmosphere.

Several other areas contribute to the total water consumption in the plant. The end result is the consumption of approximately 1200-1500 gallons of water per ton of linerboard production or 2,000,000 gallons per day in an average kraft mill.

V. Previous Quarter Performance

The Georgia pulp and paper industry was surveyed to determine the most desirable candidates for a water usage survey. Several factors played an important part in this decision making process. The most important factor was the size of the plant. Since plant size is directly related to the amount of water used, we wanted the largest plants in the state to participate in this program. However, the individual pulp and paper mills are very concerned about maintaining their competitive edge by protecting their propietary operating method. This could produce a reluctance on the part of some mills in participating in our program. Since we have no interest in the propietary technique used in the paper making process, we felt that once the paper mills understand our objectives that they would allow us to visit their plants to gather water usage data. This has been the case with the mills and plants that we have contacted to date. We have received a great deal of cooperation from the pulp and paper industry in participating in our program.

From these two considerations, the plant size and our ability to gain entry into the paper mill, we have formulated a list of nineteen major pulp and paper producers within the State of Georgia. Using referrals from these nineteen major producers we expect to gain entry into another six to eight smaller producers. These plants will form the data base for our water use survey.

In order to maintain the confidential nature of the water survey information each plant will be given a code number and all references will be made by plant code number.

The two plant surveys conducted to date have focused on all aspects of water usage. The first plant W-26007 is a large manufacturer of linerboard located in the northern part of the state. This paper mill is typical of what we expect to see of linerboard manufacturers. No problems were encountered, and plant personnel were very cooperative. The second plant W-26008, also located in the northern part of the state, is a manufacturer of paper tubes which are used in the carpet industry. Water usage patterns in this plant were about what we expected. As more plants are surveyed in the second quarter, our data base will start to develop. A summary of the data base will be given in next quarter's report.

VI. Objectives for Next Quarter

The primary focus for second quarter activities will be the acquisition of plant water usage data. We expect to complete surveys on most of the major water consumers during the next quarter. In addition to this, a computer search of current literature is being conducted to identify state of the art water conservation techniques in the pulp and paper industry.

B-539

QUARTERLY PROGRESS REPORT

March 31, 1980 - June 30, 1980

OWRT Grant No. 14-38-0001-9453

Georgia Tech Project

B-539

July 8, 1980

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

I. Summary

This report presents work done during the second quarter of 1980 for a study of water usage in Georgia's pulp and paper industry under OWRT Contract #14-34-0001-9453. The contract covers the period from September 15, 1979 through September 15, 1980.

Georgia's pulp and paper industry ranks first in pulp and paper production and in acres of pulp wood forest land. In addition to this, Georgia has the two largest unbleached kraft paper mills in our country, and the largest producer of bleached kraft pulp. A year round growing season provides an adequate supply of raw material for these giant mills. There are fourteen large integrated mills in Georgia employing either chemical or mechanical pulping.

The primary focus of activities during this quarter has been the acquisition of plant water usage data. A total of nine plants have been surveyed to date. Of these nine, three have been the smaller cylinder board process. After surveying historical water usage data for these smaller cylinder board processes we have decided to exclude them from our survey. These small plants represent less than one-percent of all the water consumed in the pulp and paper industry in Georgia. Because of this, we will focus our attention on the fourteen major producers in the pulp and paper industry.

Next quarter's activities will focus on completing the plant surveys and preparation of a rough draft on the final report.

II. The Pulp and Paper Industry in Georgia

The pulp and paper industry of Georgia is unique in several respects in the United States. Union Camp Corporation's Savannah, Georgia, unbleached kraft mill is the largest mill in terms of tons of production. The mill has a capacity of over one million tons per year of linerboard, paper, and corrugating medium and has produced over one million tons during these years when the market demand was high. Great Southern Paper Company's Cedar Springs unbleached kraft mill is the second largest mill. Brunswick Pulp and Paper Company at Brunswick, Georgia is the largest producer of bleached kraft pulp. The largest dissolving pulp mill is ITT Rayonier's mill at Jesup, Georgia. Among the fifty states, Georgia ranks first in pulp and paper production and ranks first in acres of pulp wood forest lands. Southeast Paper Manufacturing

Company at Dublin, Georgia, was the only mill producing newsprint from 100% waste raw material but has recently added some mechanical pulping. As is typical of the Southeastern United States, Georgia pulpwood forests are predominately southern pine; the loblolly pine being typical of the fast growing, tall, straight softwood species. With an almost year round growing season, southern pine can be harvested every 20 years or less and is indeed a renewable resource. With this adequate supply of raw material there is a large production of unbleached kraft linerboard, a product which is characterized by high tonnage rate per paper machine. The resinous nature of the southern pine makes it undesirable for the sulfite process and consequently there are no sulfite chemical pulp mills in Georgia. The forests will typically contain 10% hardwoods, oak and gum, and these are blended with the pine in many of the kraft mills. The hardwood is also used exclusively for corrugated medium production in several mills. Because of the resins in southern pine mechanical pulp mills have been scarce in Georgia. With the development of TMP, thermal mechanical pulp, mechanical pulp production is increasing in Georgia. Most mills in Georgia are integrated, that is, the wood preparation, pulping, and paper production are continuous at the same location. Integrated mills are generally more efficient in terms of energy and water use. The kraft processes, both unbleached and bleached, which has a high tolerance of wood species is the predominant pulping process in Georgia. There are fourteen large integrated mills in Georgia employing chemical pulping and/or mechanical pulping and several smaller mills using the cylinder board process.

The fourteen large mills include the new Buckeye Cellulose Mill near Oglethorpe, Georgia, which will start up in September and produce dissolving pulp.

III. Previous Quarter's Performance

The primary focus of activities during the second quarter has been the acquisition of plant water usage data. The basic philosophy in gathering data has been to perform a mass balance on the water systems with particular interest in the area of water conservation. There are a number of input and output variables that must be considered when performing a mass balance on a complicated pulp and paper mill. Many of these variables are mentioned in the 1st quarterly report of 1980.

Initial plant surveys were begun in the 1st quarter of this year. Our plan was to mix surveys of the large pulp and paper mills with surveys of the smaller specially operations. This would give us an opportunity to evaluate the impact of the different size plants on the total water consumption. The initial surveys indicated that there were large differences in the amount of water being used by the different manufacturing sites. This was to be expected, since the smaller mills are only producing a fraction of the pulp and paper tonnage produced by the larger mills. In general, the water usage at the smaller plants has been between 1/2 and 1% of the water usage in the large pulp and paper mills. As you can see in Table I, the consumption in the smaller plants is a very small percentage of what is consumed in the larger plants. Table I lists the data for several of the large and small mills.

The relatively small amounts of water being used in the specialty pulp and paper operations has caused us to exclude them from our study. The amount of water used by these small operations represents less than 1% of the water being consumed in the larger mills. Table II lists major producers in the pulp and paper industry along with water usage data.[(1)] As you can see, the small companies are only a fraction of the large pulp and paper mills.

In light of this data we focus our attention on fourteen of the largest pulp and paper consumers in the state. Of these fourteen, we have completed six surveys to date. The balance of the surveys will be completed in the third quarter.

We are continuing our computer search for current literature in the area of water conservation in the pulp and paper industry. To date, we have not found any significant research on the pulp and paper industry in Georgia.

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(1) Carter, R. R., and Johnson, A. M. F., 1974, Use of Water in Georgia, 1970, with Projections to 1990.

TABLE I

Company	Total Water Usage Mgd
W-26012	5.4
W-26013	35.2
W-26014	5.7
W-26015	75.2
W-26016	8.5
W-26008	26.3
W-26007	0.03
W-26010	0.03
W-26011	0.01

TABLE II

Company	County Location	Total Water Use Mgd	% of Total Usage
ITT Rayonier Inc.	Wayne	91.75	16.42
St. Mary's Kraft	Camden	71.93	12.9
Abitibi Southern Corp	Richmond	7.16	1.28
Cedartown Paper Board Company	Polk	7.45	1.33
Georgia Kraft Company	Floyd	26.3	4.7
Georgia Kraft Company	Bibb	16.9	3.02
Great Southern Paper Company	Early	31.1	5.56
Interstate Paper Company	Liberty	11.12	1.9
Owens Illinois Inc.	Lowndes	17.41	3.11
American Can Company	Coweta	13.45	2.4
Mead Container Div.	Fulton	0.03	0.005
Union Camp Cor.	Chatham	145.34	26.0
Continental Forest Ind.	Chatham	15.21	2.7
Continental Forest Ind.	Richmond	25.62	4.5
Brunswick Pulp & Paper Co.	Glynn	75.21	13.48
Kraft Bag Div.	Camden	0.53	0.09
St. Regis Paper	Fulton	0.28	0.05
Atlantic Envelope Company	Fulton	0.11	0.02
U.S. Envelope Company	DeKalb	0.08	0.01
Owens Illinois Inc.	Lowndes	0.30	0.05
Union Carbide Corp.	Bartow	0.53	0.09
Georgia Factory for the Blind	Decatur	0.02	<0.01
Package Corp. of America	Bibb	0.01	<0.01
Charmin Paper Products Co.	Doughtery	0.09	0.02
Mead Products Div.	Fulton	0.08	0.01
Union Camp Corp.	DeKalb	0.01	<0.01
Mead Packaging Div.	Fulton	0.15	0.03
Austell Box Board	Cobb	0.03	0.01
Container Corp. of America	DeKalb	0.02	<0.01
Continental Can Co., Inc.	Fulton	0.01	<0.01
Gaylord Container Div.	DeKalb	0.02	<0.01
Inland Container Corp.	Floyd	0.03	0.01
Inland Container Corp.	Bibb	0.03	0.01

Company	County Location	Total Water Use Mgd	% of Total Usage
Union Camp Corp.	Clayton	0.02	<0.01
Wayerhaeuser Company	DeKalb	0.01	<0.01
Dairy-Pak	Clarke	0.02	<0.01
Lily Division Owens Illinois Inc.	Richmond	0.04	0.01
Continental Can Co.	DeKalb	0.01	<0.01
Greif Bros. Corp.	DeKalb	0.01	<0.01
Sonoco Products Co.	Fulton	0.02	<0.01
Mid-South Container Corp.	Richmond	0.02	<0.01
		TOTAL	558.56

IV. Next Quarter's Activities

The primary focus of activities next quarter will be on the completion of plant surveys and preparation of the rough draft of the final report. In addition to this, the literature search will be completed. We do not foresee any problems in completing the project on the scheduled completion date.

Kuch

EES

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

October 31, 1980

Mr, John T. Campbell
Assistant Director, Research
Office of Water Research and Technology
U. S. Department of the Interior
18th and C Street, N. W.
Washington, D. C. 20240

Dear Mr. Campbell:

As we discussed by phone today, enclosed please find a draft copy of our final report entitled "An Evaluation of the Potential for Water Conservation and Reuse in the Georgia Pulp and Paper Industry. This report contains the findings of our work under Grant No. 14-34-0001-9453.

This submission is in agreement with the Clause 9 reporting requirements of our agreement.

If you have any questions regarding any aspect of the study or this report, please do not hesitate to call.

Sincerely,

J. Craig Wyvill
Project Director

JCW/lj

cc: Dr. Bernd Kahn

Enclosure

Draft Final

ERC -80 November 1980

AN EVALUATION OF THE POTENTIAL FOR WATER CONSERVATION AND REUSE IN THE GEORGIA PULP AND PAPER INDUSTRY

by

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Final Report
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ABSTRACT

KEY WORDS: Water Conservation, Water Reuse, Pulp and Paper Industry, Georgia

This study culminates one year of research into the potential for water conservation and reuse in the Georgia Pulp and Paper Industry. Specifically, the study conducts an in depth investigation of water usage patterns in 14 of the largest mills in Georgia responsible for nearly 85 percent of all production in the state. Further consideration is given to water supply and water quality which the industry must address and an identification is made of feasible conservation and reuse techniques which the industry should consider. The effort concludes with the tabulation of potential water withdrawal savings in Georgia if this industry practices both normal and potentially feasible conservation and reuse measures.

LIST OF FIGURES

SECTION I

PROSPECTIVE

The objective of this research effort is to identify specific opportunities for water conservation and reuse in Georgia's pulp & paper industry. Industry is the second largest user of water in Georgia. If electric utility usage is excluded, industry accounts for 59% of the remaining usage.[1] The pulp and paper industry accounts for nearly 70% of this industrial water usage.[2]

The research specifically focuses on water usage patterns to:

- survey actual water intake and discharge
- search for potential areas of water conservation
- assess the potential for water reuse

It is hoped that the information contained in this report will assist industrial and governmental planners alike in limiting water usage by this industry. Without careful planning for the future, Georgia's abundant water resources may quickly become limited.

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SECTION II

AN OVERVIEW OF GEORGIA'S PULP AND PAPER INDUSTRY

The pulp and paper industry is a significant sector of Georgia industry providing 7.7% of all industrial shipments in 1977.[1] It is composed of 27 plants who primarily produce kraft liner board and pulp.

In 1977, Georgia produced 4,720,000 tons of paper and paper board constituting 7% of the total national output for this category.[2] However, nearly 85% of Georgia's total tonnage was provided by 13 plants. These thirteen mills plus a 14th major facility scheduled for startup this year are the focus of our in depth water usage survey. The plants are listed in Table 1 and their location in the state are presented in Figure 1.

Actual visitations were made to each of the mills to gather, first hand, information on water intakes and outtakes. Balances were made on each plant's flow to insure all major streams were accounted. Figure 2 shows the total balance achieved for all 14 plants studied. Less than a 3% error was found.

TABLE 1

Major Pulp and Paper Facilities Visited in Georgia

1. Brunswick Pulp and Paper Co., Brunswick, GA
2. Great Southern Pulp and Paper, Cedar Springs, GA
3. St. Mary's Kraft Div., Gilman Paper Co., St. Mary's, GA
4. Georgia Kraft Co., Mead Div., Macon, GA
5. Georgia Kraft Co., Krannert Div., Rome, GA
6. Owens Illinois, Inc., Valdosta, GA
7. Southeastern Paper Co., Dublin, GA
8. I.T.T. Rayonier, Inc., Jessup, GA
9. Interstate Paper Corp., Riceboro, GA
10. Union Camp Corp., Savannah, GA
11. ABITIBI Southern Corp., Augusta, GA
12. Continental Forest Industries, Augusta, GA
13. Continental Forest Industries, Port Wentworth, GA
14. Buckeye Cellulose, Inc., Oglethorpe, GA

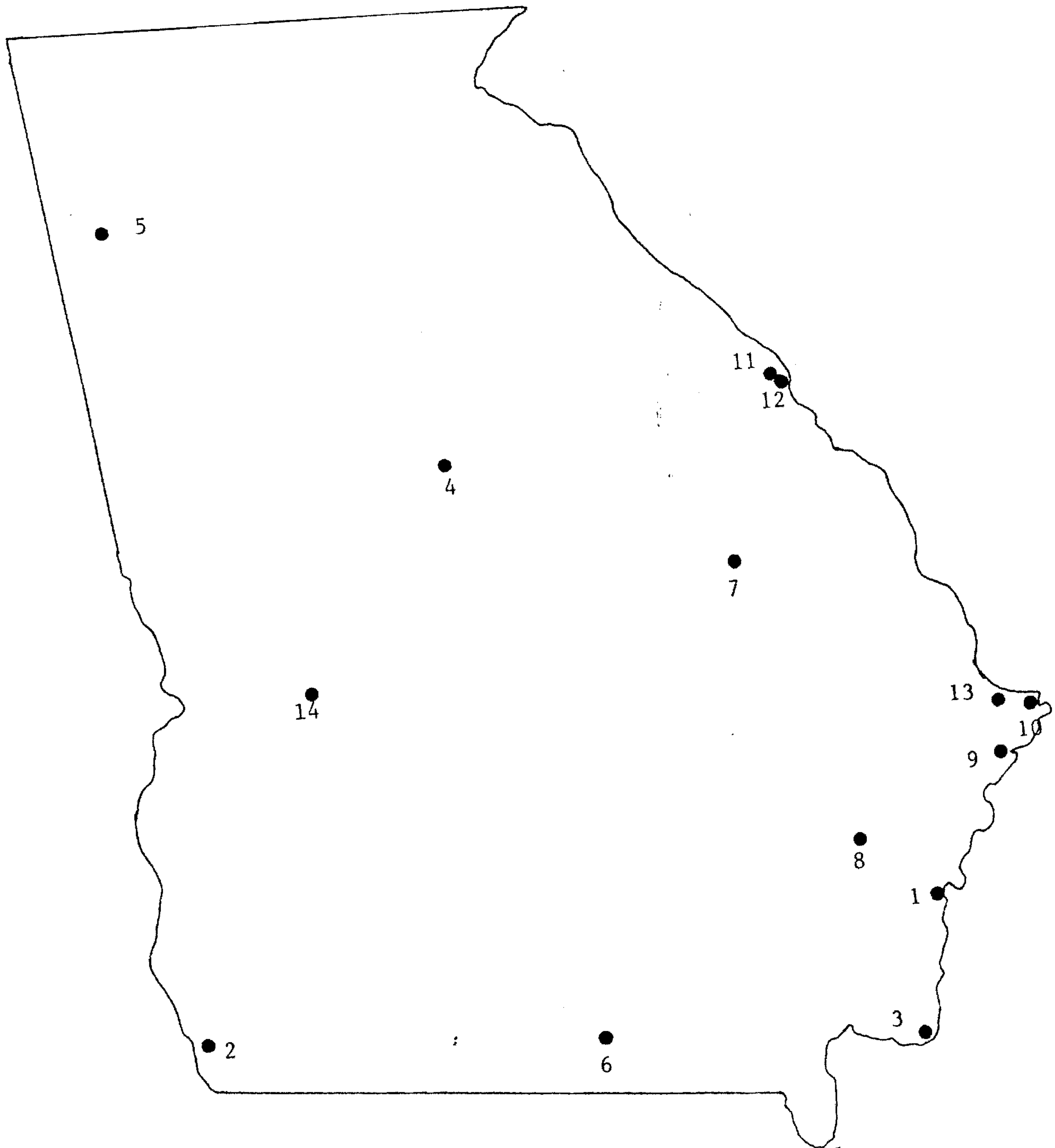

Figure 1 - Location of 14 Pulp and Paper Mills Visited in Survey

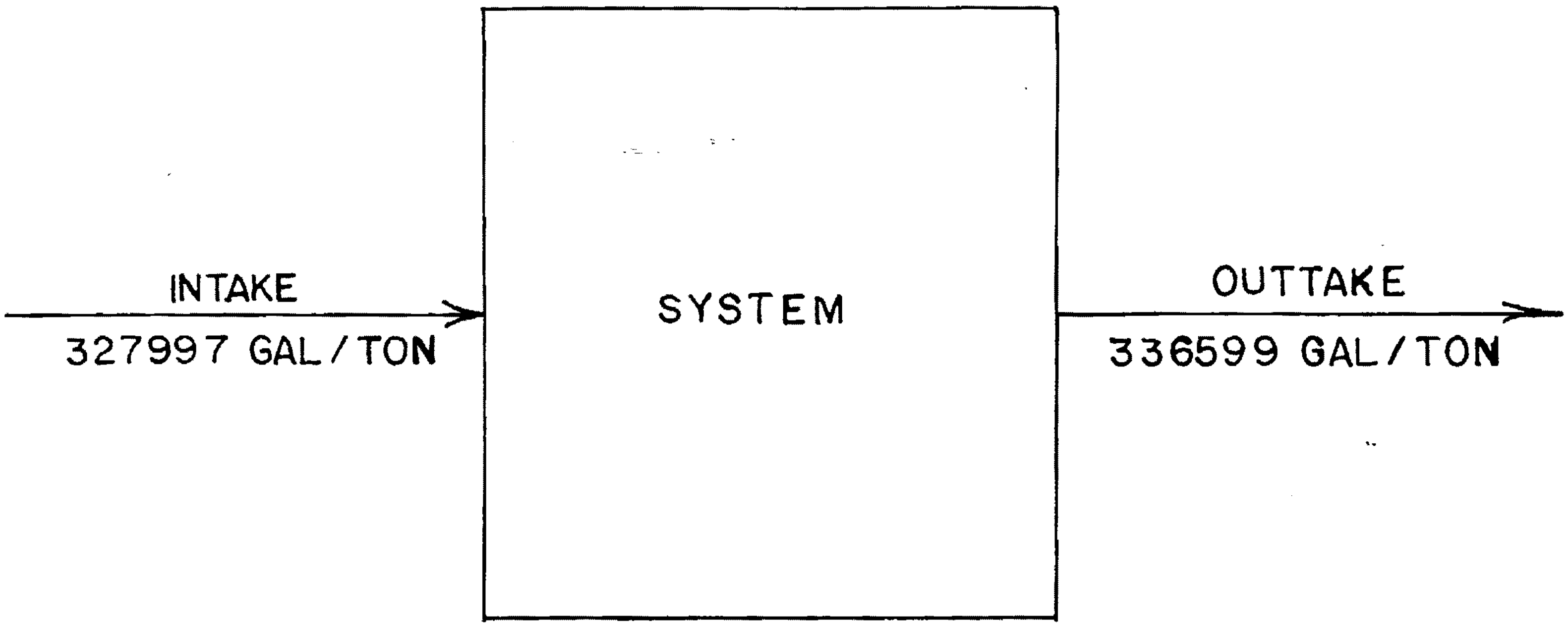

Figure 2 - Flow Balance for 14 Plants Surveyed

REFERENCES

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SECTION III

WATER USAGE IN GEORGIA'S PULP AND PAPER INDUSTRY

As mentioned in Section II, most of Georgia's pulp and paper production is by the kraft process. Figure 3 provides a detailed overview of the general krafting process while Figure 4 provides a simplified block diagram of the general systems.

Background

Kraft pulping began in the United States in 1909. Since that time it has grown into the major process for producing paper pulp in the United States. The kraft process can be summarized by the following steps:

- Entering logs are first debarked and then chipped.
- These chips are carried by conveyor from storage silos to a digester, where the chips are cooked in a liquor broth for a prescribed period under the proper temperature and pressure (usual cooking time is about 2 to 4 hr., at about 100 to 110 p.s.i.).
- While the wood is cooking, turpentine and other volatile constituents distill and are condensed for sale as by-products.
- At the end of the cook, the pulp and liquor are "blown" into the blow tank by pressurized steam. The steam from the blow is utilized to heat water for mill use.
- While in the blow tank the pulp and the black liquor are diluted and pumped through de-knotters to the brown-stock washers, where the liquor, which contains soluble residue from the cook, is washed out of the pulp.
- The washed pulp is then screened and rewashed. A portion of the black liquor from the washers is used as a dilution for the cooking liquor and blow-tank stock. The remainder is sent to the recovery unit of the pulp mill, where the cooking chemicals are reclaimed.[2]

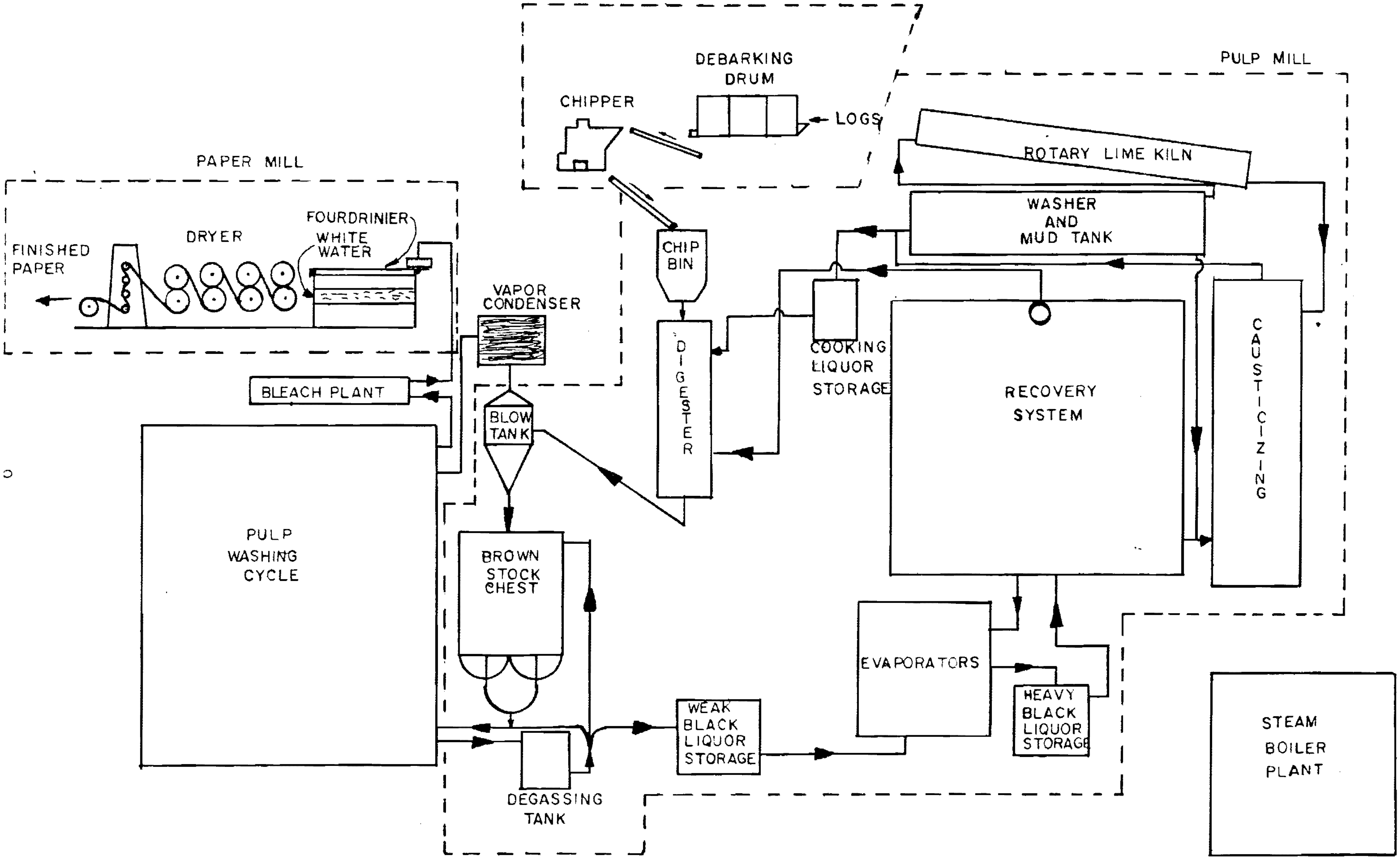

Figure 3 - Typical Bleached Kraft System

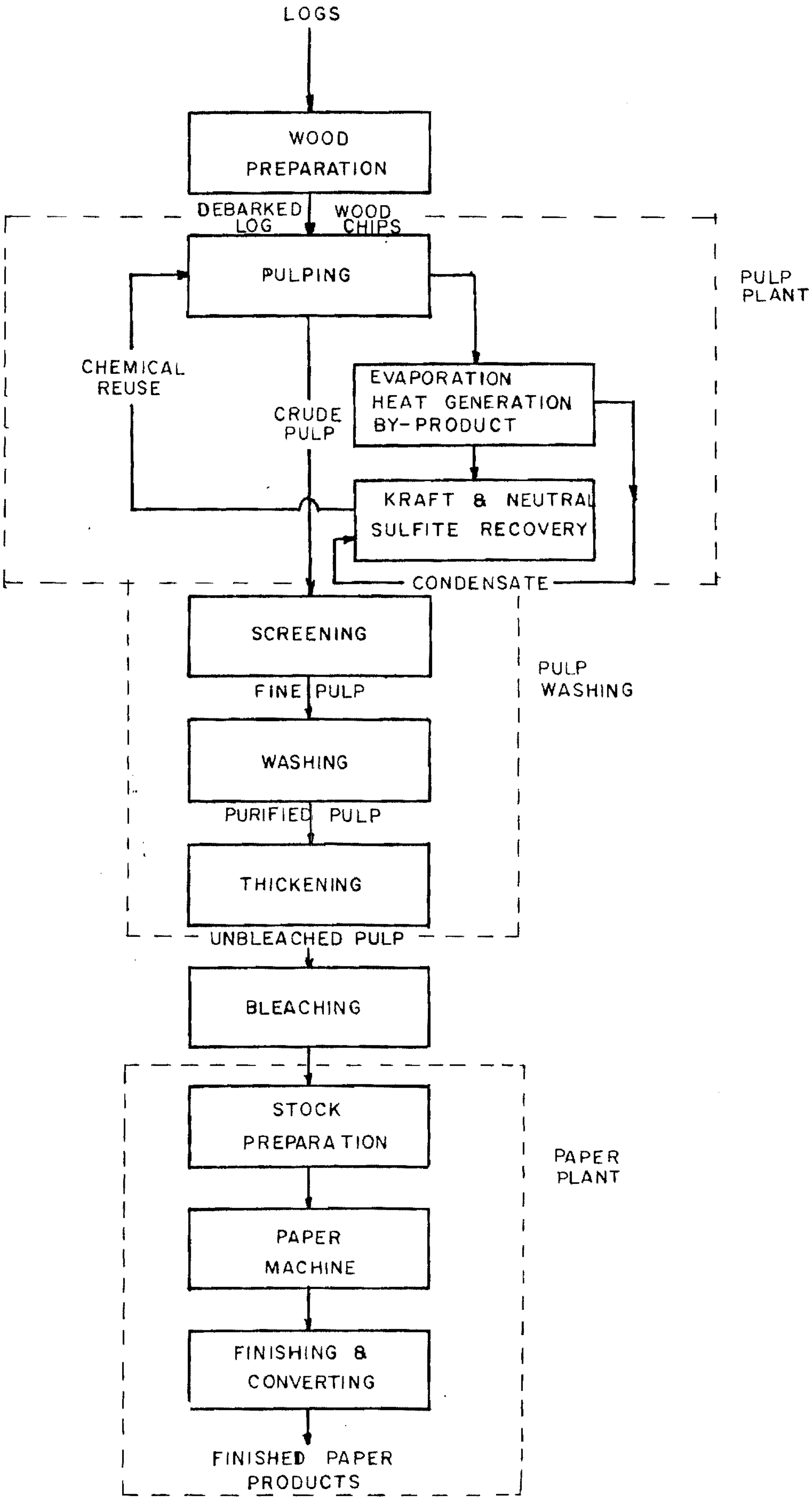

Figure 4 - Simplified Flow Diagram of a Typical Bleached Kraft System

- The washed pulp is slurried with water to a consistency of .5 to 3% solids and sent to the paper machine. It flows out of the head box onto a wire screen and is formed into a sheet. The sheet is mechanically and thermally dewatered and exits the paper machine with between 5 and 10% moisture content. If bleaching is required, it is performed prior to preparing the stock for the paper machine.

Water Usage Survey

If system boundaries are drawn around the wood yard, pulp mill, pulp washing, bleach plant and paper mill, an examination of the points where water enters and leaves the systems can be performed. In essence, this is treating the system as a "black box" and a water balance on the flows entering and leaving the mill can be made. Complete accounting of all flows is difficult however for several reasons.

- Typically the accuracy of the measuring devices used on the major intake and effluent streams is uncertain. At one mill, for instance, no meters were used at all on intake water.

- The point at which the effluent is measured affects the accuracy of the water balance. If the reading is taken at the point of entry into the river then the gains and losses from rainfall, infiltration, leaking, and evaporation in the treatment pond system must be estimated and accounted for.

- There are virtually no flow meters on the piping in the processes themselves; therefore losses must be calculated using information such as percent solids, pounds of fiber, and percent yield. Assumptions about the average moisture content of wood entering the mill, saturation of flows exhausted in stacks, and other data that is not available, can lead to errors.

However, even with these uncertainties and the presence of miscellaneous leaks, spills, and steam losses, a water balance of reasonable accuracy is attainable as pointed out by our less than 3% balance error (see Figure 2).

There are 13 major flow streams common to kraft pulp mills in Georgia where water enters or exits the system. They are:

- General water intake
- Water entering with pulp wood
- Effluent discharge
- Chemical recovery evaporation
- Smelt tank vent evaporation
- Lime kiln evaporation
- Cooling tower evaporation
- Cooling water discharge
- Blow tank evaporation
- Paper dryer evaporation
- Water leaving as part of the finished product
- Miscellaneous significant flows (intake and discharge)

In addition, in three of the plants studies, mechanical pulping was used in addition to or as a replacement for kraft pulping. For these mills a single evaporative flow was determined for the pulp mill section of the plant.

Each of the above flows is briefly described below along with a presentation of flow quantity data collected from each mill. For purposes of presenting this survey information, the mills are catagorized as unbleached kraft, bleached kraft and other (if the plants primarily employ specialized techniques such as mechanical pulping). This grouping allows the reader to make usage comparisons between members in each general category.

°General Water Intake - Process water is taken either from surface water supplies provided by the rivers or ground water provided through deep wells which tap the plentiful aquifers 800 to 1000 feet below the surface of the ground. In some instances water from municipal water systems is used; however, because of cost, this usage is typically confined to drinking water. Figure 5 displays the mix of sources utilized by the 14 mills studied. Figure 6 displays the amount of water intake identified for each of the plants.

°Water Entering With Wood - Green wood typically contains approximately 50% water by weight. This is a significant quantity of water brought into the process and must be considered when manufacturing pulp. In addition, significant quantities of water are soaked up by the logs when sluicing rather than mechanical means are used to deliver wood to the preparation area. Figure 7 displays the amount of water brought into each of the plants surveyed.

°Effluent Discharge - The primary manner in which water is discharged from plants is in a liquid state (see Figure 8) as effluent. Most of the mills visited metered effluent flow both into and out of their treatment facilities. Knowing before and

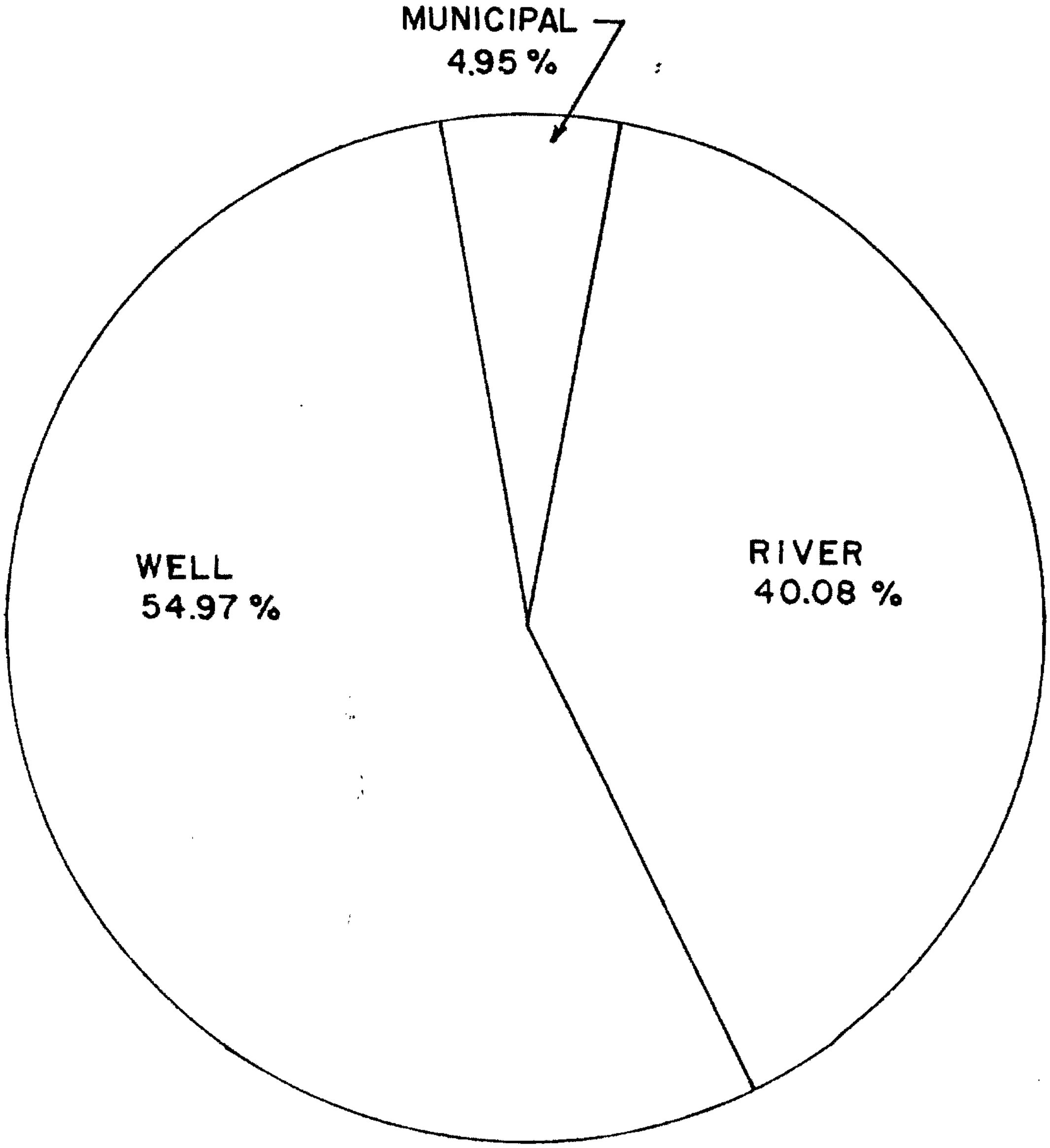

Figure 5 - Sources of General Water Intake for 14 Plants Surveyed.

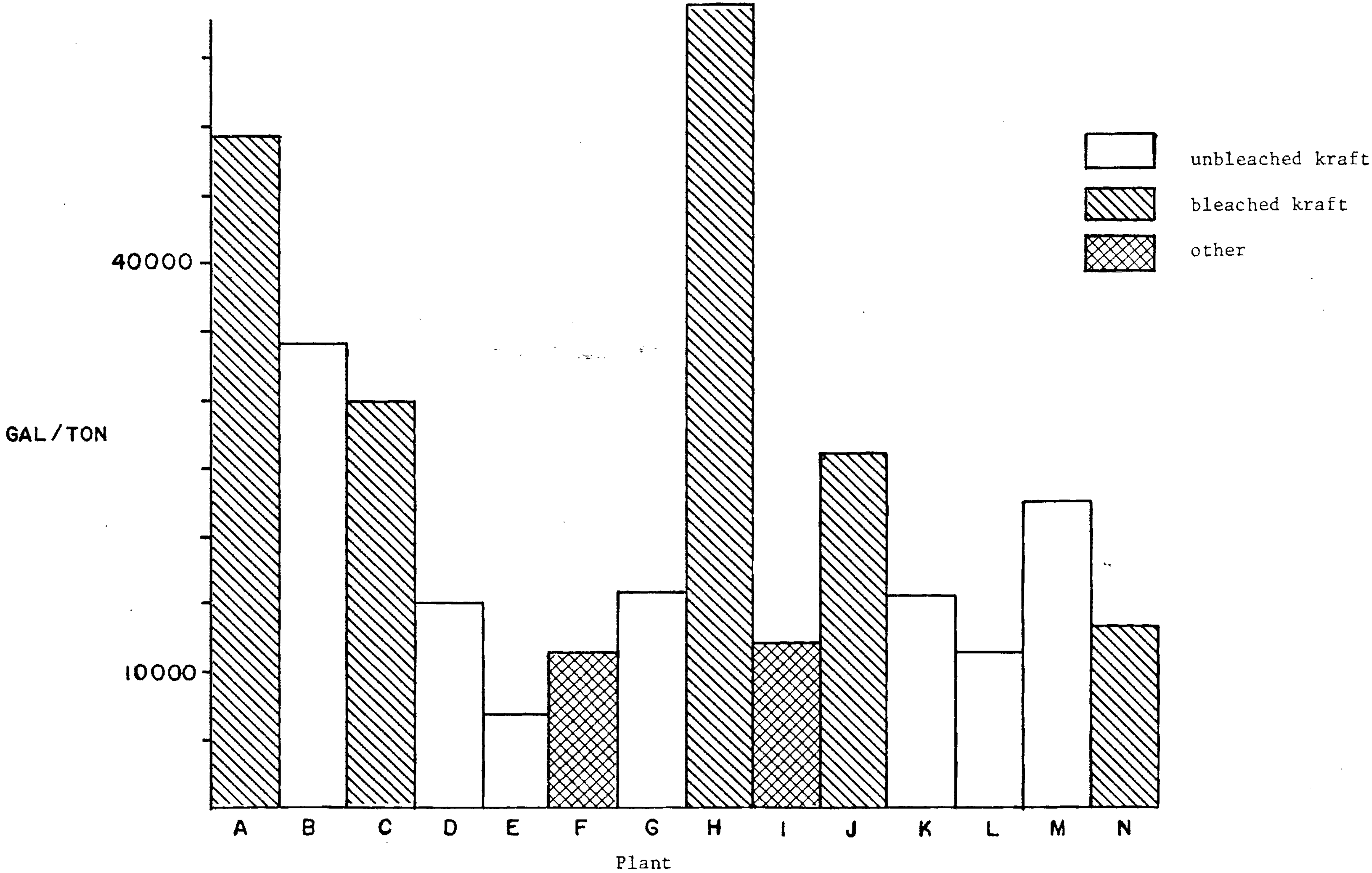

Figure 6 - General Water Intake

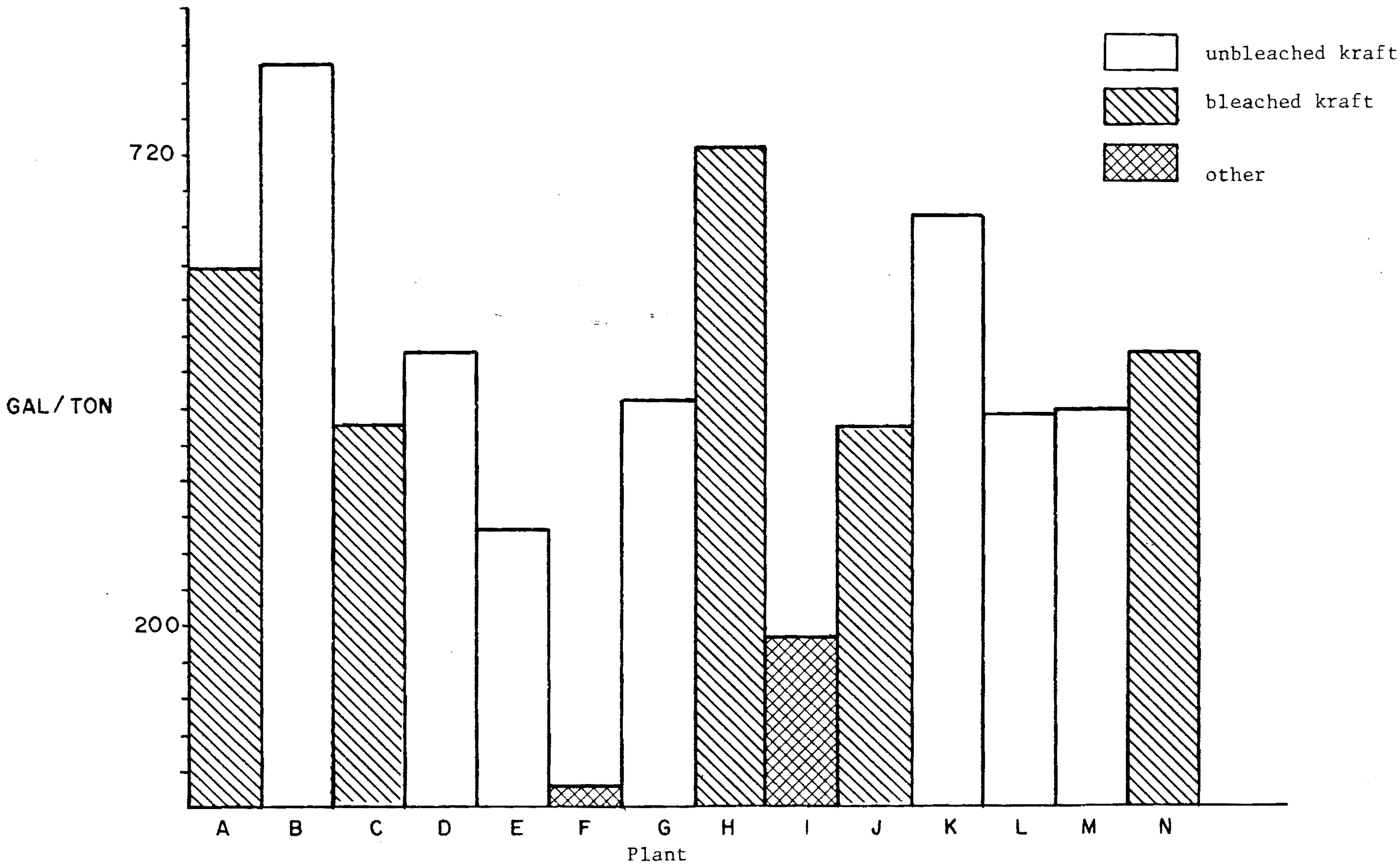

Figure 7 - Water Entering with Wood

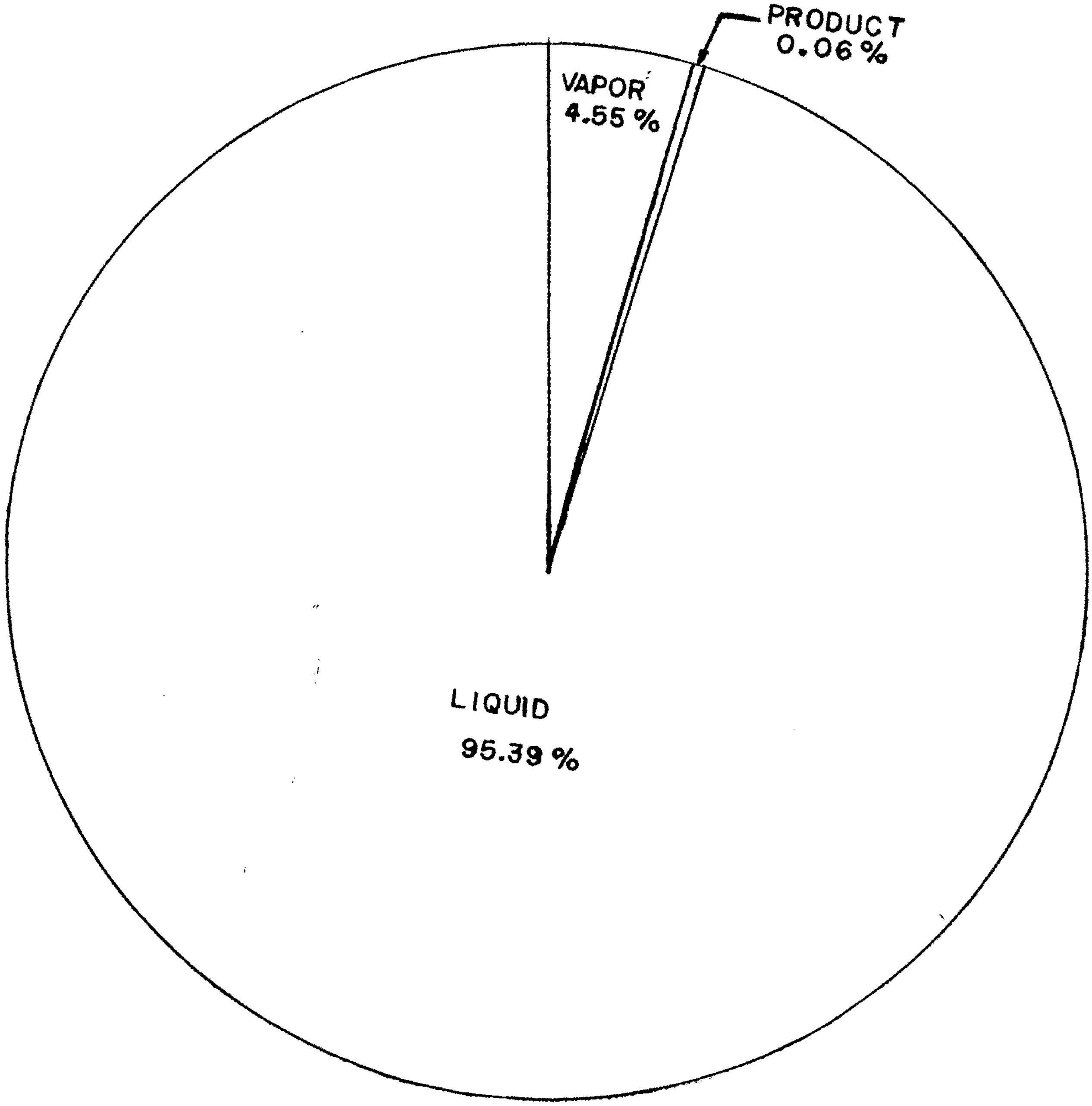

Figure 8 - Manner in which water exited 14 plant s surveyed

after treatment flows is important in determining treatment facility variations. For example, the evaporation loss on a hot Summer day for a 650 acre treatment pond system can be as great as 5 million gallons per day. Likewise, one inch of rain on a treatment pond system of 650 acres is over 18 million gallons of added load. Figure 9 displays effluent values for the plants surveyed.

°Chemical Recovery Evaporation - Although the primary function of a pulp mill is the production of pulp, in kraft pulping the spent liquors and muds cannot just be disposed of, but must be recovered as completely as possible. The cost of chemical recovery is typically as high as or higher than the combined cost of all other operations.[2] If all the spent cooking chemicals were sewered, the cost of the process would be prohibitive, and stream pollution would be severe enough to preclude continued operation on inland waters.

The chemical recovery process is complex and involves many operations. The primary area where water is lost to the atmosphere is in the incineration of the spent cooking liquor or "black liquor" in the recovery furnace. The liquor is separated from the pulp after the digesters and washers containing approximately 16% to 18% solids. This liquor is passed through multiple effect evaporators and is increased to approximately 50%-55% solids. The last step prior to incineration is a direct contact evaporator to bring the solids content to 63%-70%. This is a

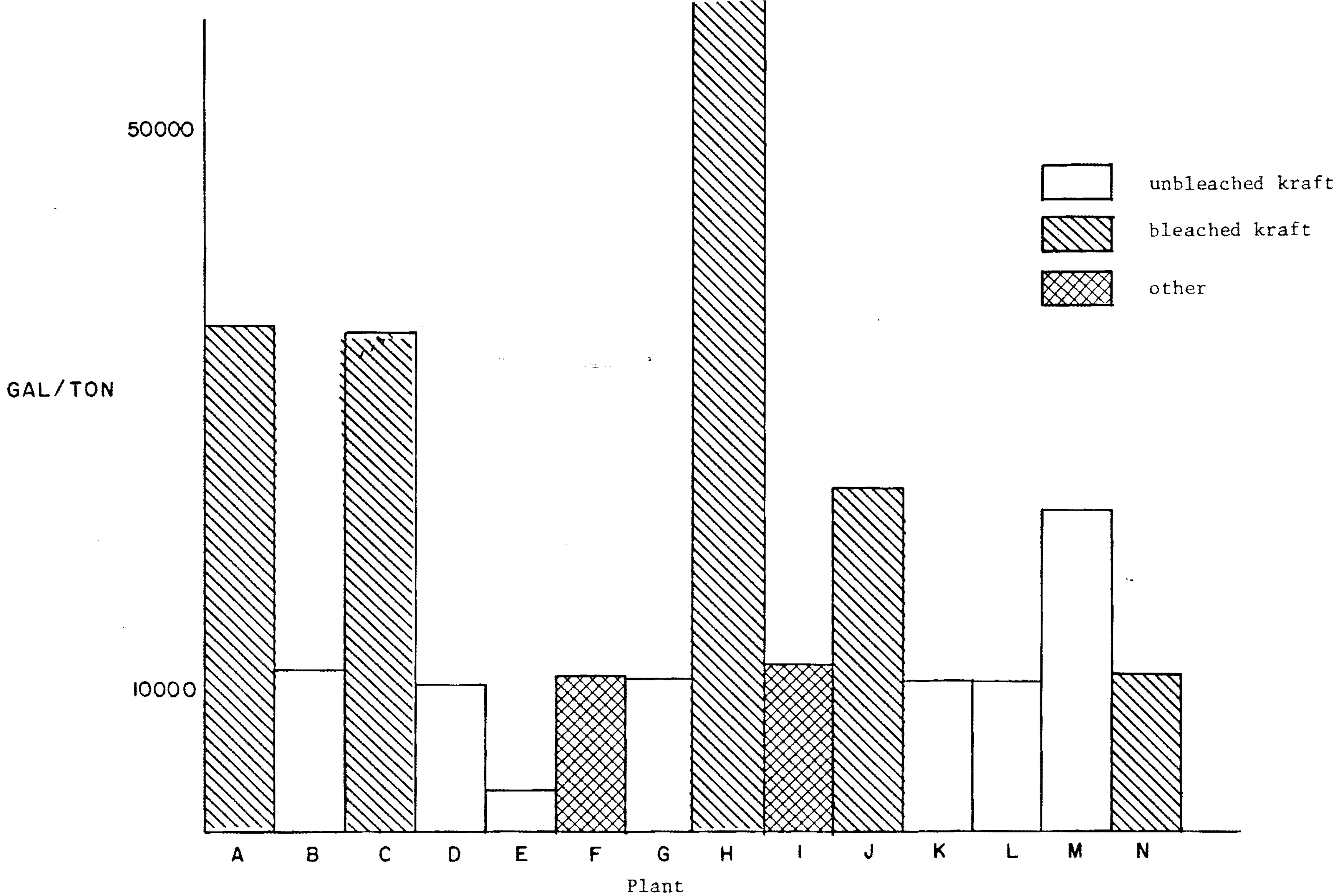

Figure 9 - Effluent Discharge

level which will support combustion. During combustion the remaining water is evaporated off. Figure 10 displays the evaporation loss calculated for the plants surveyed.

°Smelt Tank Vent Evaporation - The principal zone of chemical recovery is on the hearth of the furnace. There the residual carbon in the black liquor is burned out and the inorganic sodium salts are melted and flow over the hearth to the water-cooled smelt spouts. The molten smelt falls from the smelt spouts into a dissolving tank. It is a common practice to supply a steam shatter jet to break the smelt into small pieces before entering the liquid. Steam and gases formed in the smelt-dissolving tank are removed through a vent pipe to the atmosphere.[2] This vent is another point of water loss in the chemical recovery process. Figure 11 displays the values gathered for the plants surveyed.

°Lime Kiln Evaporation - Recovery of lime mud from the causticizing process is performed because the cost would be very high if only fresh lime were used in the cooking liquor. Consequently, the lime mud is burned in a kiln to produce lime.

Today's rotary kilns used to burn lime mud vary in diameter from 7 to 11 feet and in length from 100 to 350 feet. They are inclined from feed end to discharge end and rotated about the longitudinal axis. Mud entering the kiln is 40 to 45% water.[2] This moisture is evaporated by the 1200 to 1600°F temperature in the kiln. Figure 12 displays the evaporative losses calculated for the plants surveyed.

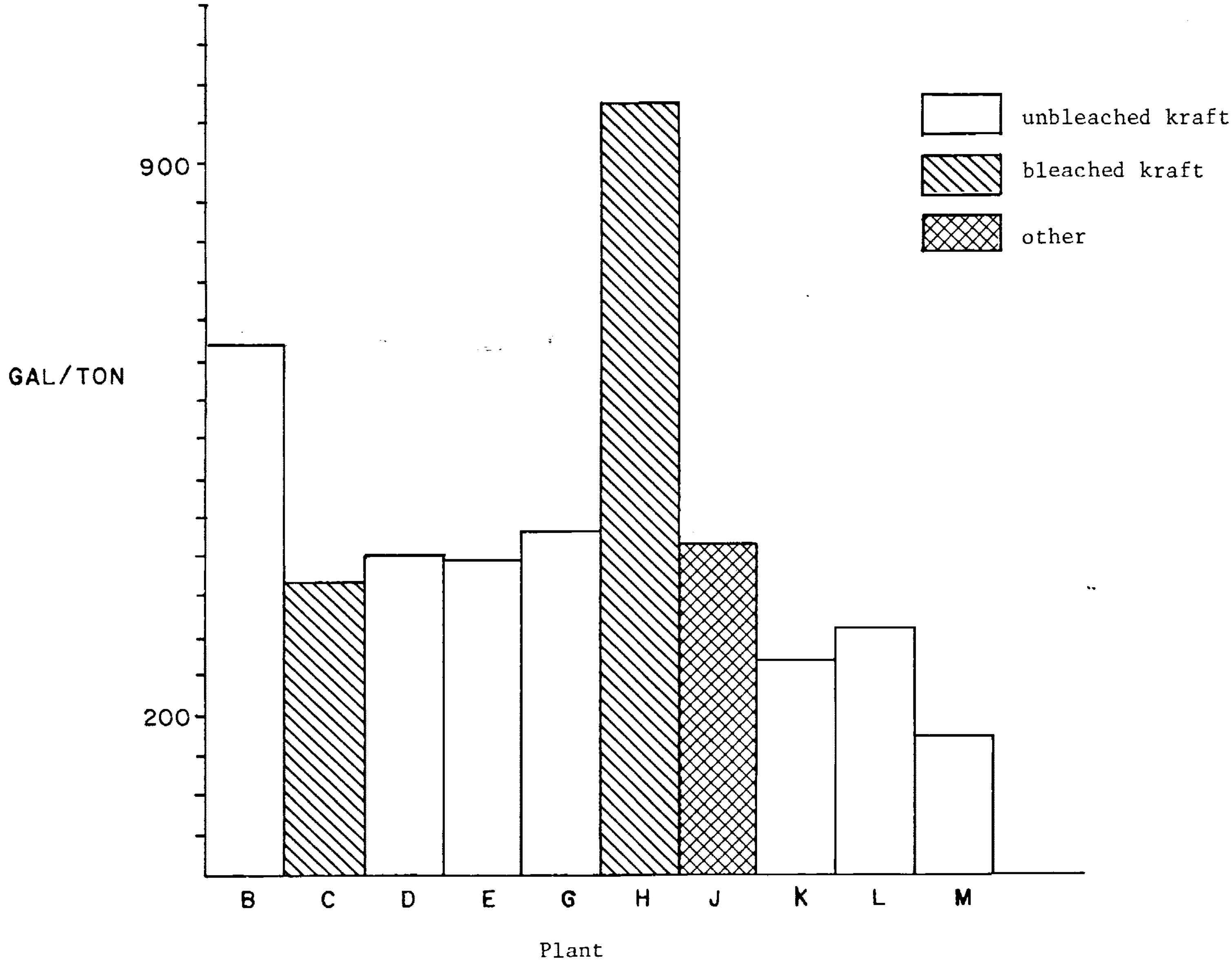

Figure 10 - Chemical Recovery Evaporation

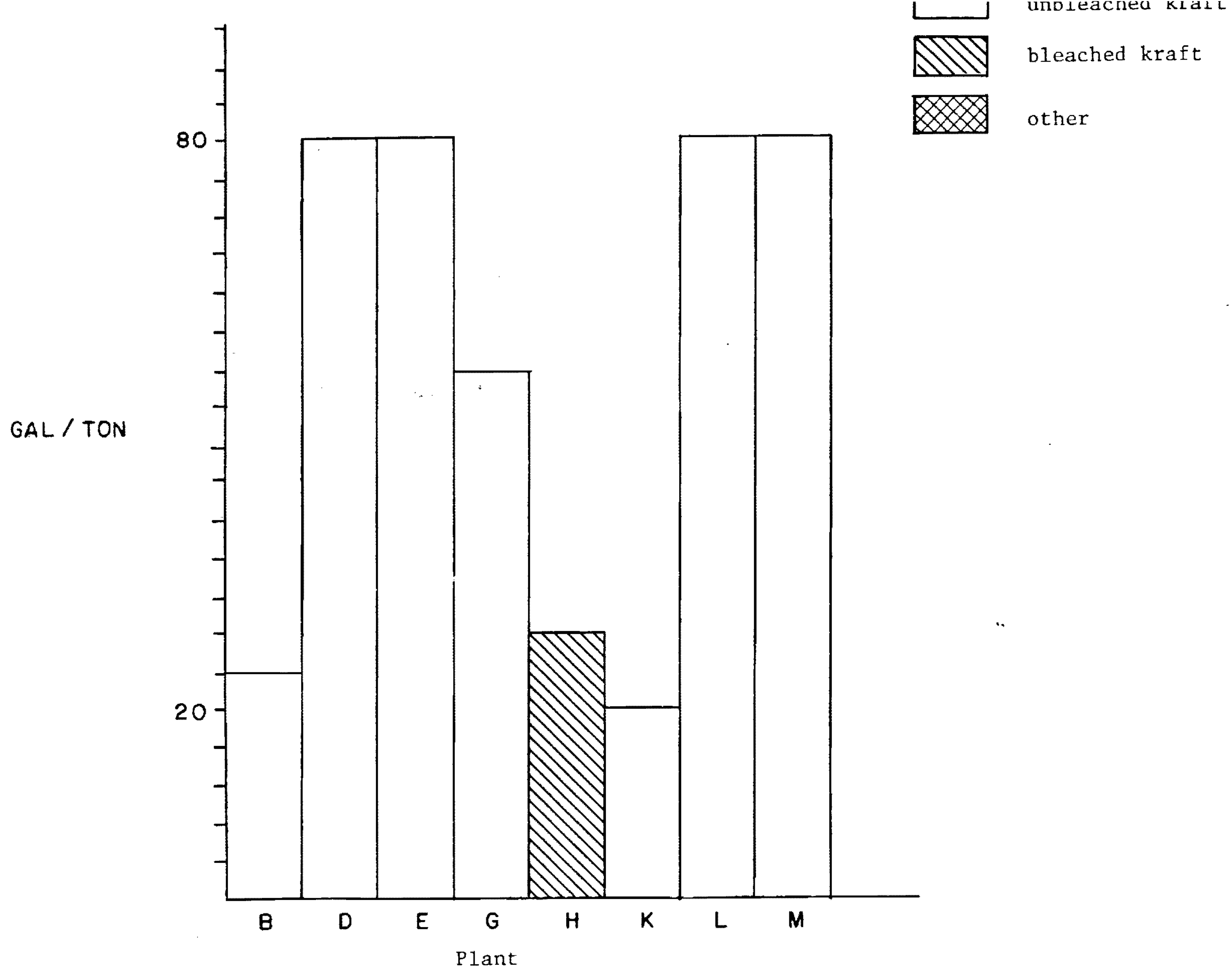

Figure 11 - Smelt Tank Vent Evaporation

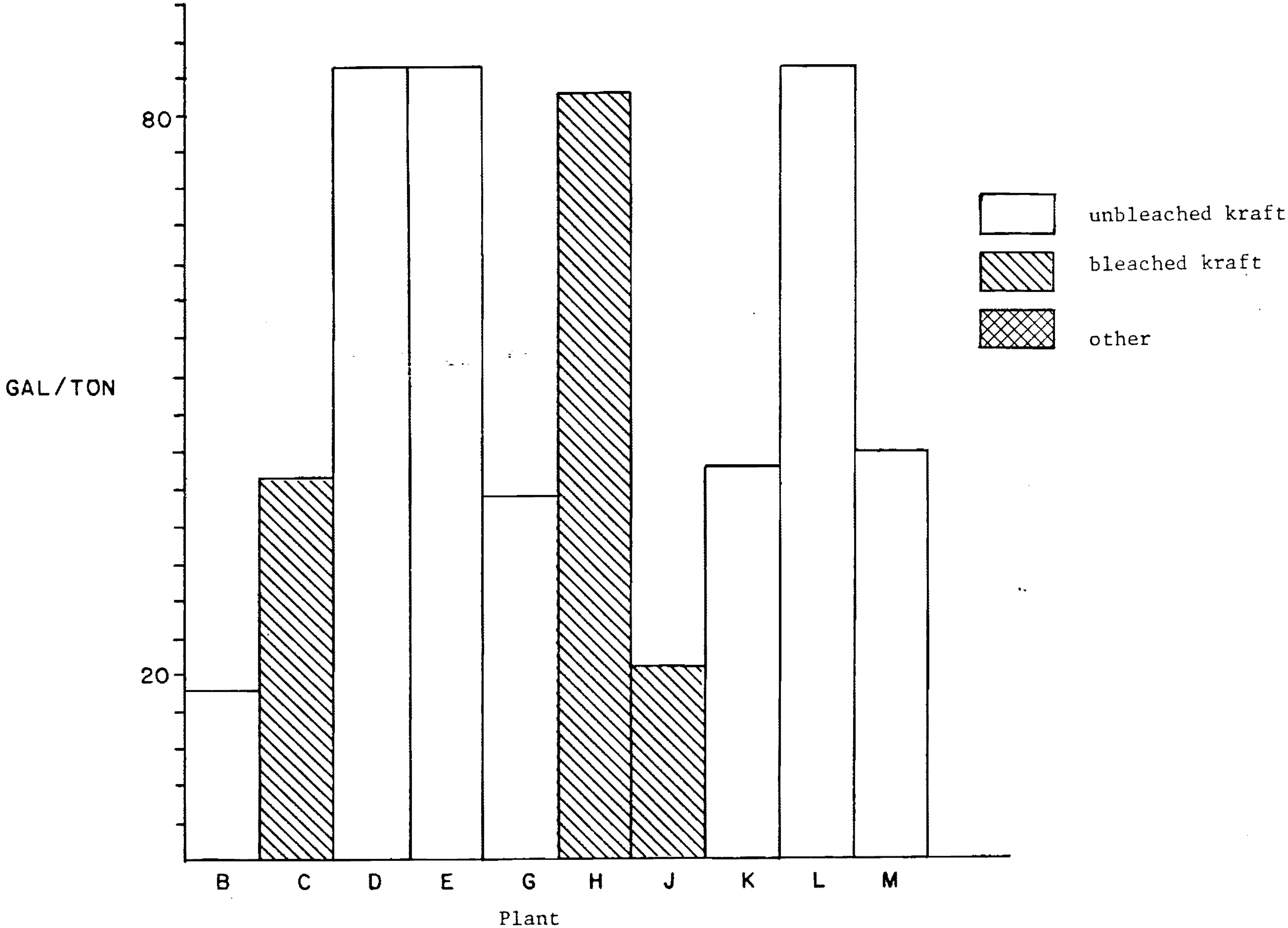

Figure 12 - Lime Kiln Evaporation

°Blow Tank Evaporation - The final step in the cook cycle is the clearing of the digester. A valve in the bottom of the digester is opened and the cooked wood and spent liquor are blown under pressure into the blow tank. The sudden decrease in pressure around the cooked chips causes them to explode and make a fiber pulp. Some heat in the blow steam is recovered in heat exchangers which heat water for the stock washers and for other mill use. A cyclone separator at the top of the blow tank allows the steam to pass out to the heat exchangers while keeping the pulp and spent liquor in the blow tank.[2]

The final temperature and pressure in the digester at the end of the cook just prior to the blow are in the range of 150-180°C and 90-105 PSIG. During the blow the pressure drops to atmospheric pressure and some of the liquid is lost as vapor. Figure 13 displays the evaporative losses calculated for the plants surveyed.

°Cooling Tower Evaporation - Cooling towers are used in some plants to reduce temperature in certain process water streams so that they may be reused. The stream is cooled both by the warming of the air as it passes through and the evaporation of a portion of the water. Figure 14 displays the evaporative losses for the plants surveyed.

°Cooling Water Discharge - Many of the mills use part of their general water intake for cooling purposes. Usually it makes one pass through the mill and is immediately returned to

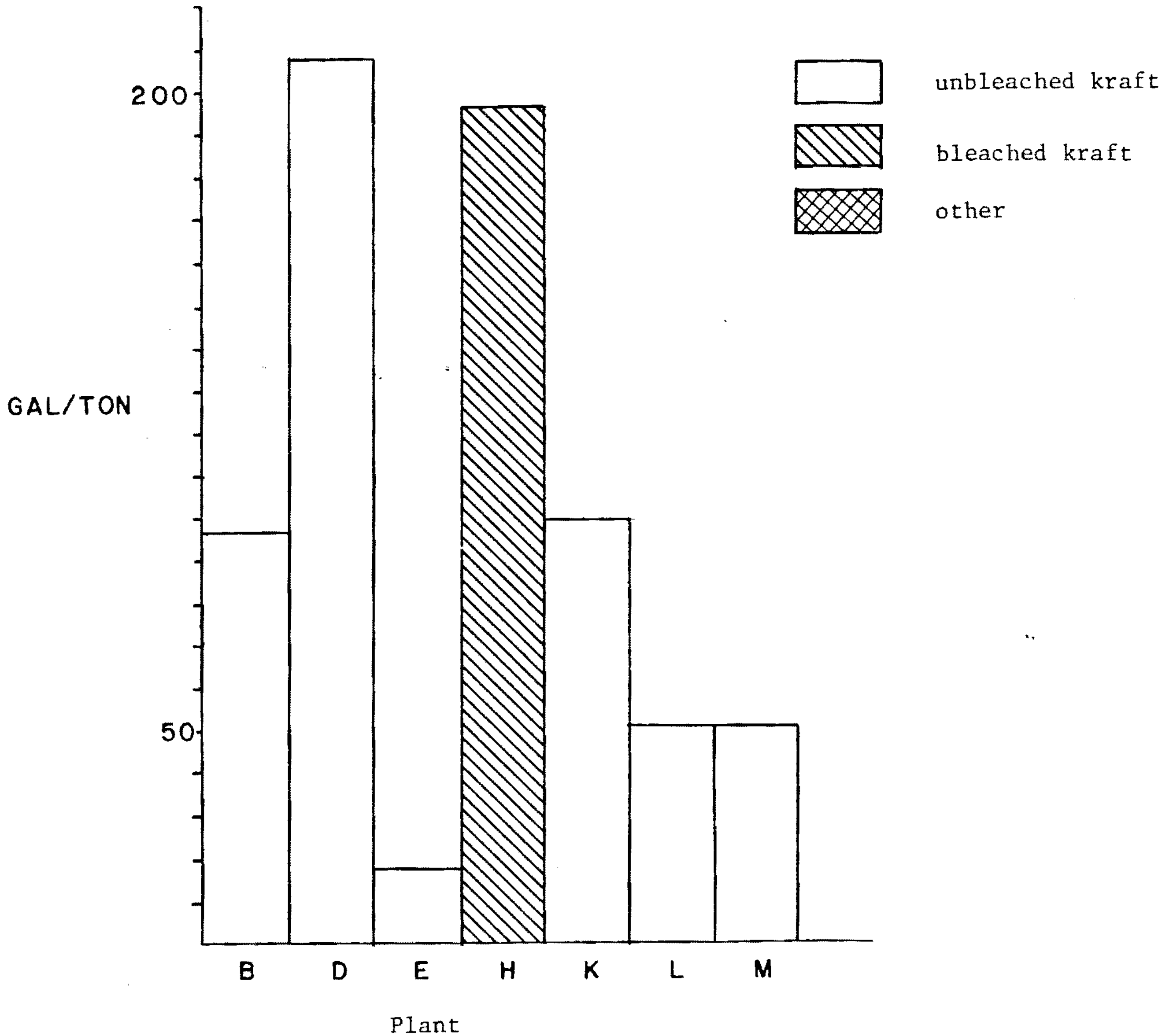

Figure 13 - Blow Tank Evaporation

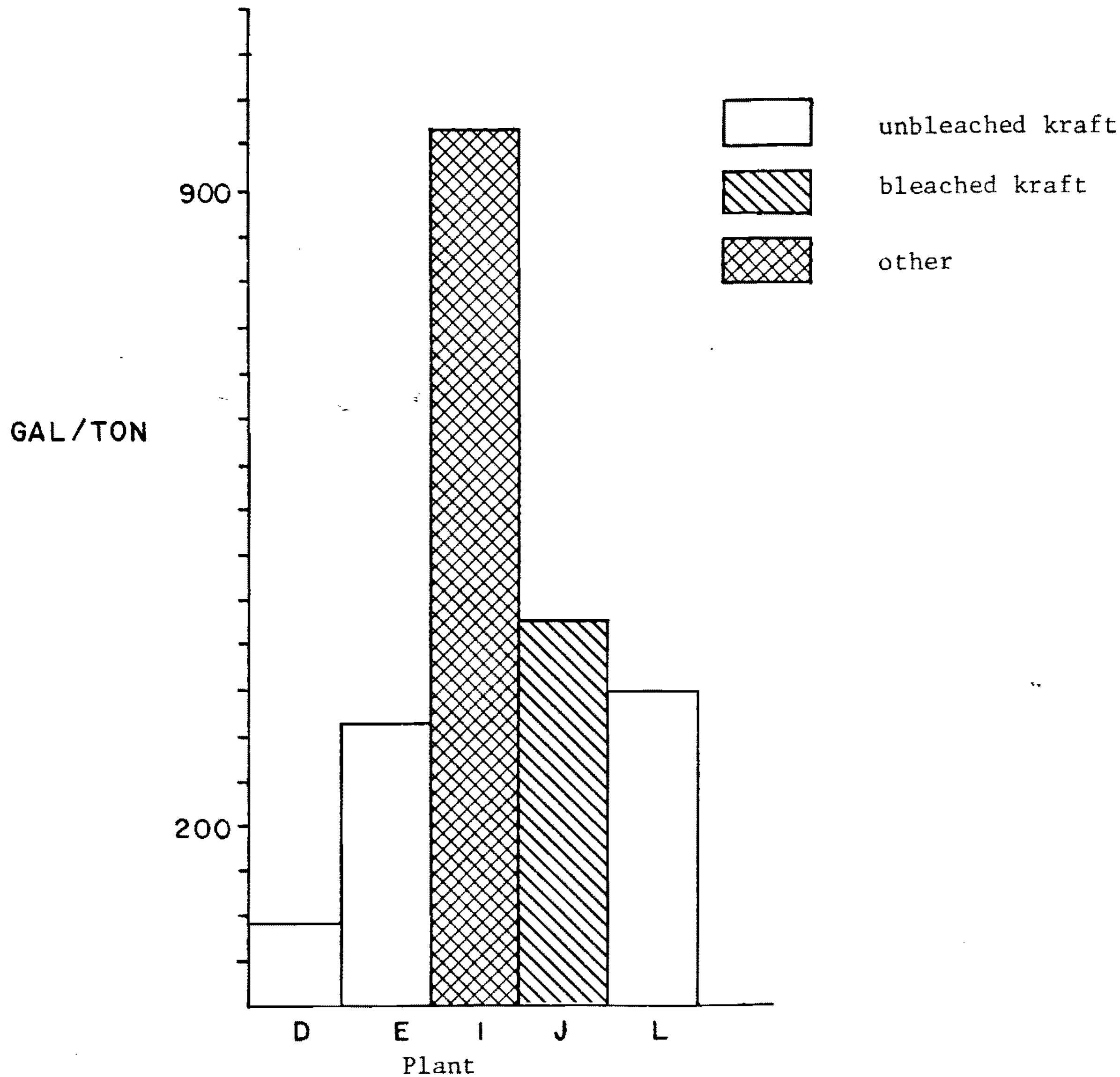

Figure 14 - Cooling Tower Evaporation

the river. The quality of the water is not significantly impaired except for a slight increase in temperature. Figure 15 presents the quantity of cooling water discharged by the plants surveyed.

°Paper Drying Evaporation - When the pulp slurry leaves the headbox and pours onto the fourdrinier wire to be formed into a sheet it is only ½ to 3 percent solids. To be useful, board or dry pulp normally requires a moisture content of less than 10%[3] After pressing, the sheet still contains approximately 60% moisture which must be removed in the dryer.

The dryer section of a paper machine consists of a number of hollow iron or steel cylinders over which the paper passes in a serpentine fashion. The cylinders are rotated in synchronization and heat is supplied by steam condensing inside the cylinders. This heat provides the evaporation necessary to bring the moisture content of the sheet to the required level. Figure 16 presents the calculated evaporation for the plants surveyed.

°Finish Product - Finished linerboard and pulp are typically 5 to 10% moisture content when it is wound up on the take-up reel. The exact moisture content depends on the specific product being made and can be very accurately regulated by the machine operator. Figure 17 presents the product water content gathered from the plants surveyed.

°Miscellaneous Significant Flows (intake and discharge) -Some mills have significant flows that are unique to their situation.

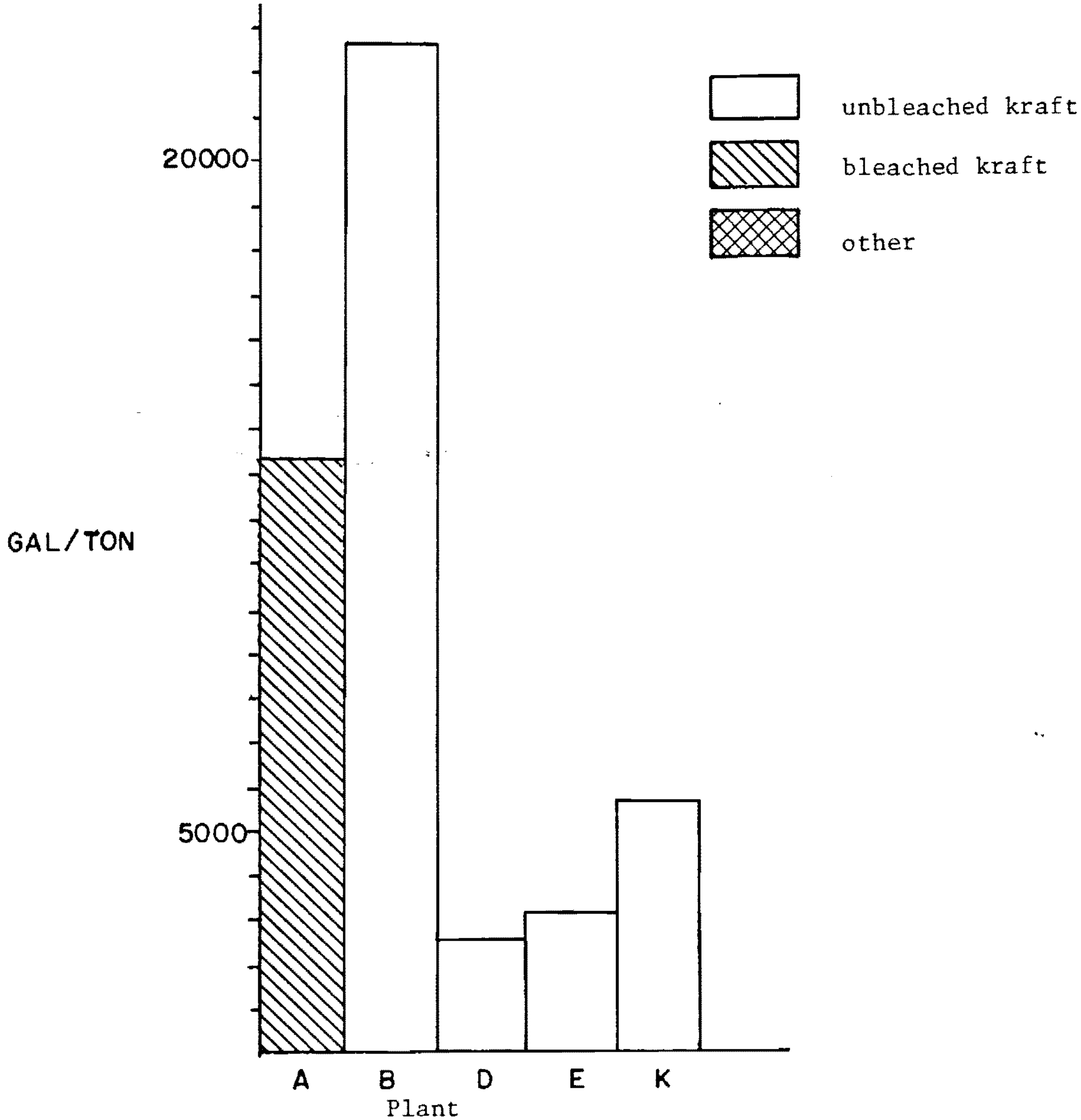

Figure 15 - Cooling Water Discharge

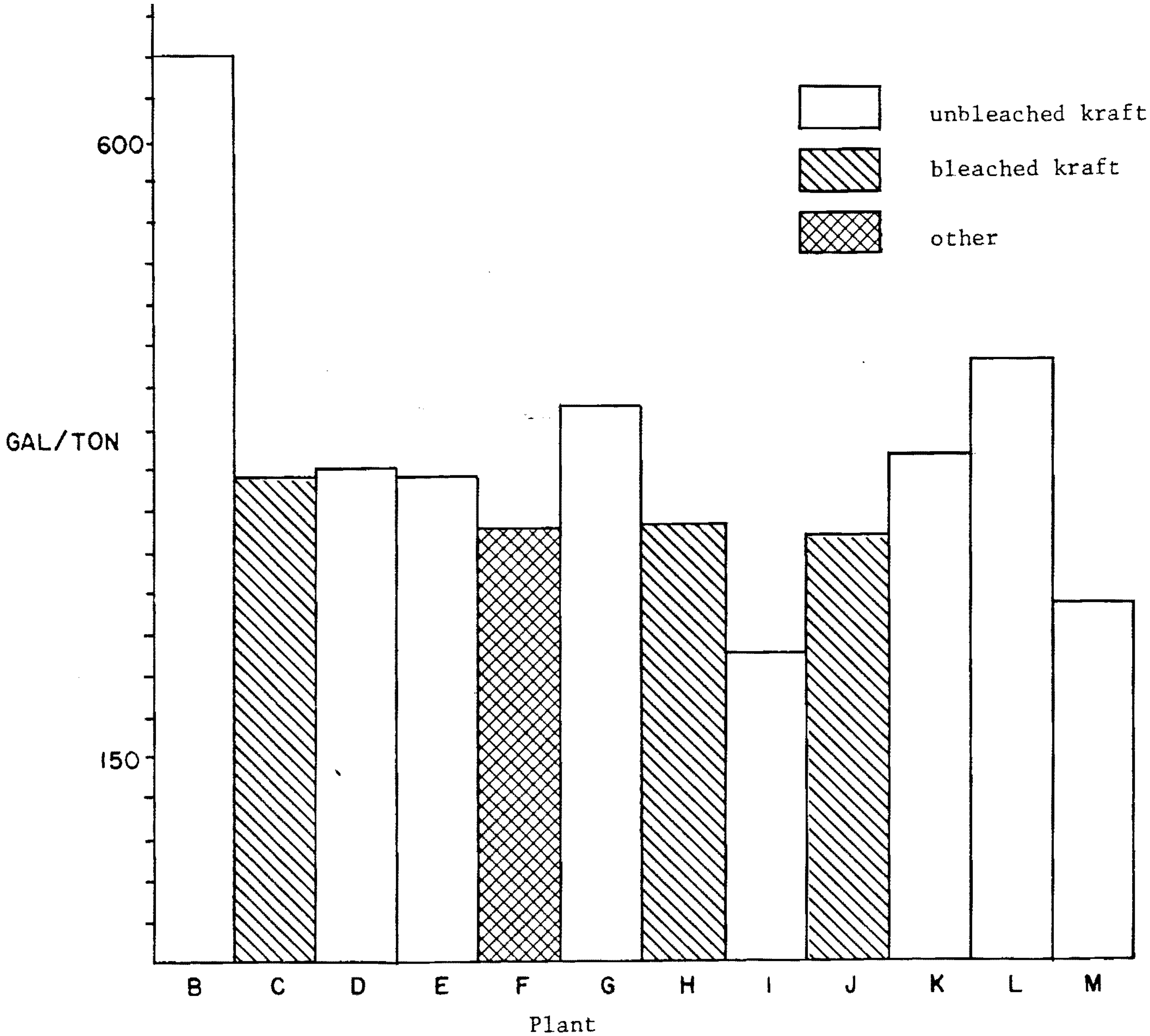

Figure 16 - Paper Drying Evaporation

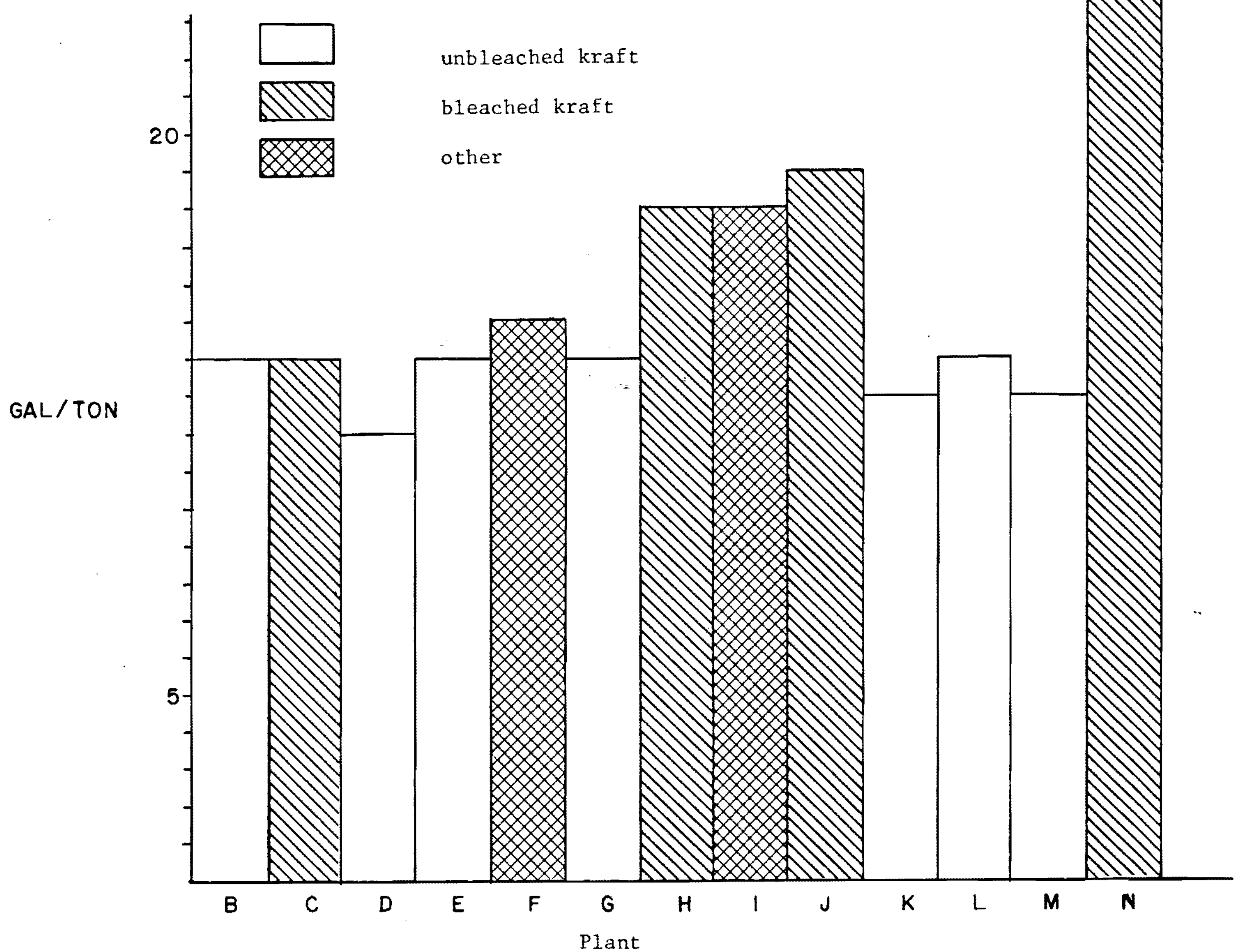

Figure 17 - Finished Product Water Outtake

These include neighboring mills that share wells or treatment facilities and mills that buy or sell pulp slurry. Figure 18 presents a listing of such extraordinary flows for those plants surveyed.

°Mechanical Pulping Discharges - Mechanical pulping (MP) is the process of converting pulpwood into pulp by mechanical rather than chemical means. The wood is forced against a rapidly revolving grindstone or refiners plate and the fibers are in effect torn from the pulpwood. This process utilizes practically all the wood fiber in the log both cellulose and lignin so that the yield of MP is about twice that of chemical or kraft pulping.[2]

Water is consumed in the process through evaporation caused by the heat from the friction between the wood and the grindstone. Water is injected continuously to keep the temperatures from reaching levels that would char the wood and damage the fibers. The rate at which water is injected varies with the type of mechanical refiner used, but is in the range of 30 to 70 gallons per minute. All of this water is not lost to evaporation since the dilution of the wood fiber is increased as the wood is processed. Figure 19 shows the amount of water evaporated from the MP in the mills surveyed.

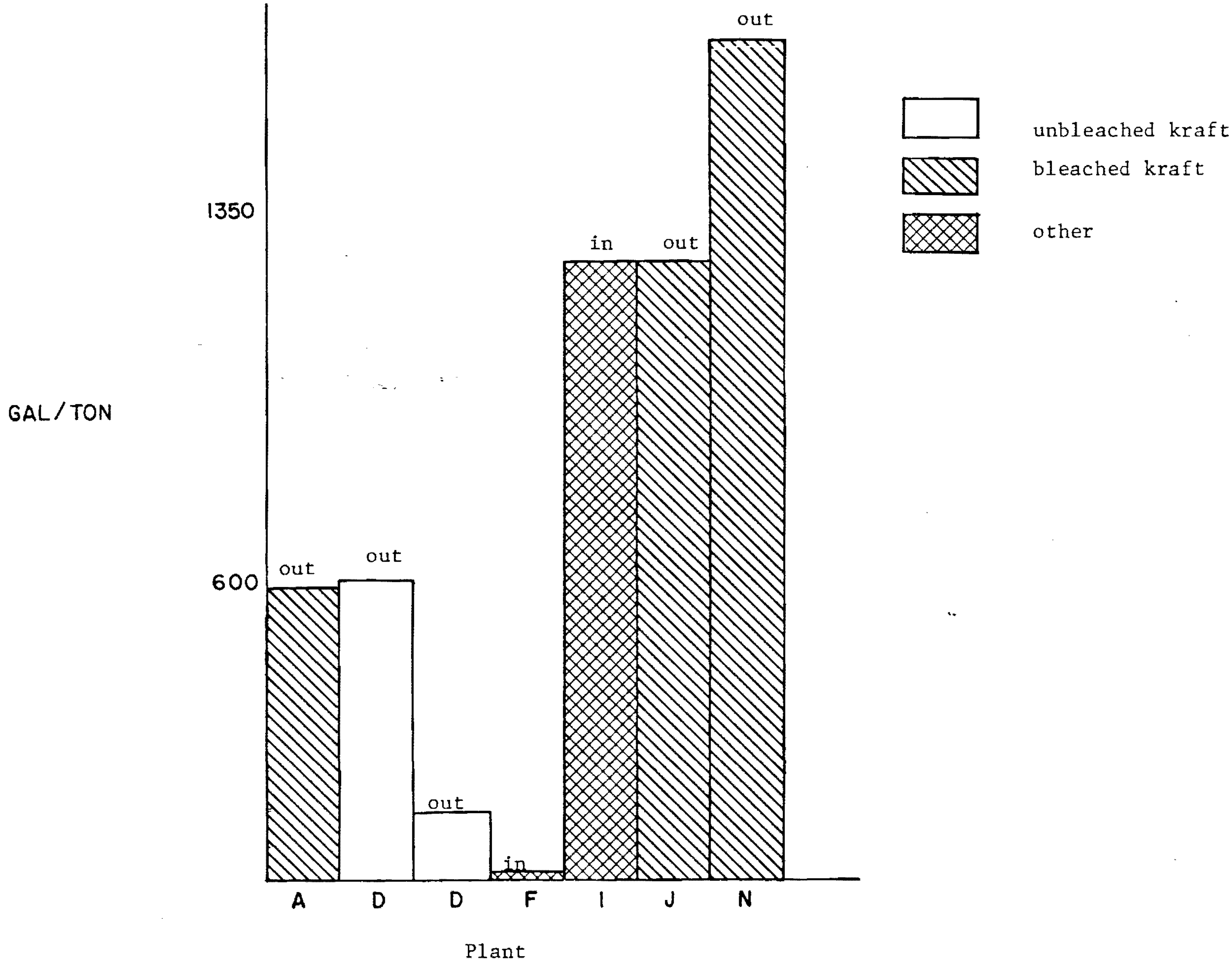

Figure 18 - Miscellaneous Significant Flows

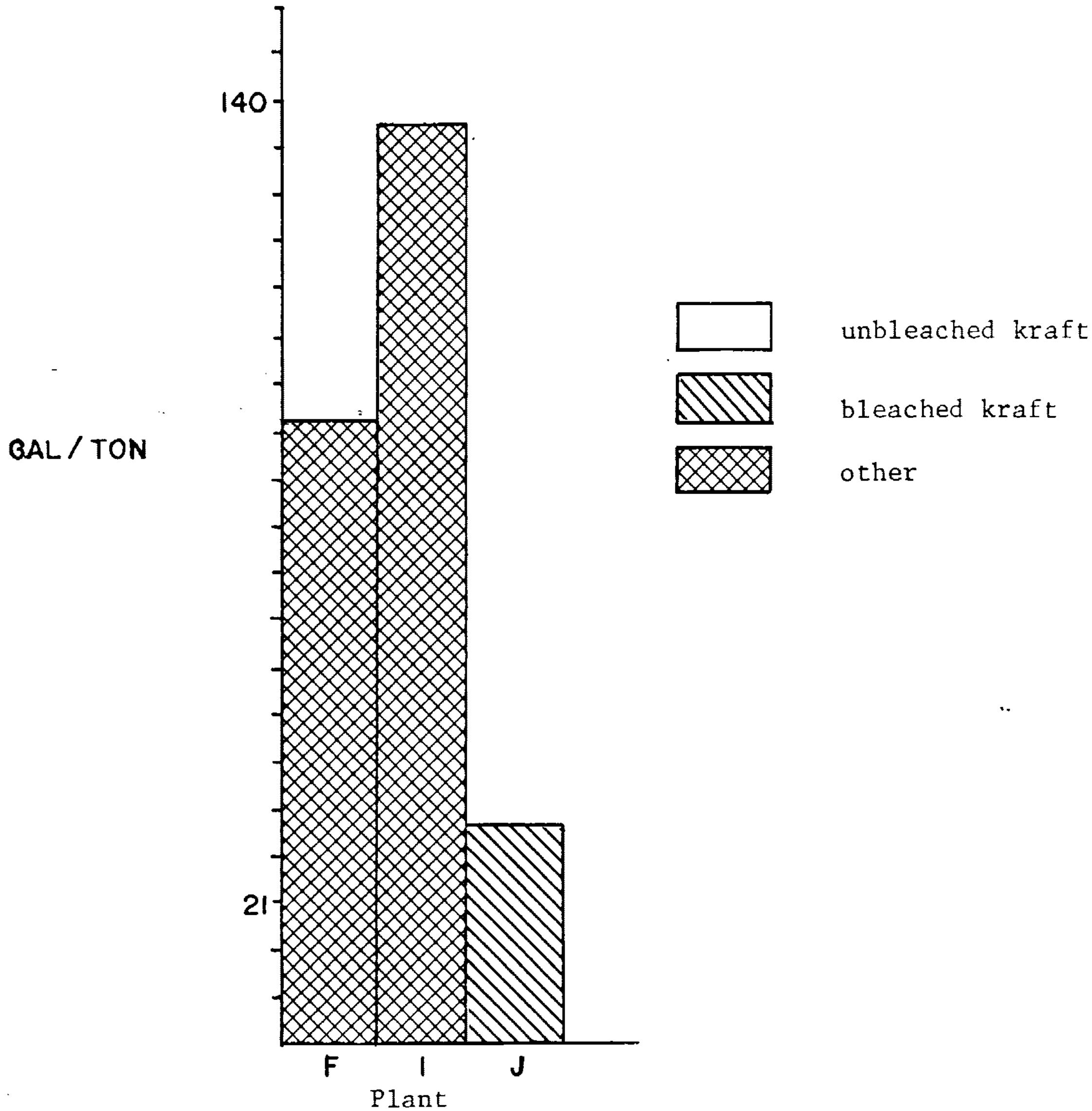

Figure 19 - Mechanical Pulping Discharges

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SECTION IV

GEORGIA'S WATER SUPPLY - A LIMITING CONSTRAINT?

Georgia is blessed with an abundance of water resources. However in recent years these resources have become taxed in some areas of the state, emphasizing a need for concern by industrial and governmental planners alike. An in depth discussion of water flows in all major river basins and aquifers around the state follows in Appendix A. Due to the vast quantities of water needed by the pulp and paper mills, and increasingly stringent water constraints, there has been a reduction in the availability of new plant sites. As seen in Figure 20 the northern half of the state has neither sufficient river flow nor ground water flow capacities to support a new mill. The same is generally true for the western border of the state, although here it is more a problem of insufficient flow for wastewater assimilation. A typical example of these limiting constraints is the new Buckeye Cellulose plant due to start up in the near future. Preliminary sites for the mill were to be further north on the Flint River, but due to wasteload calculations and water quality degradation the site was moved to Oglethorpe where the necessary assimilative capacity of the river existed. Even the water rich southern and southeastern parts of the state have begun to see the possibility of an end to unlimited tapping of the principal artesian aquifer (see Appendix A). Over 50% of the mills studied rely on drilled wells in this aquifer to provide all or most of their water needs (214 mgd). However the phenomenon of salt water intrusion has

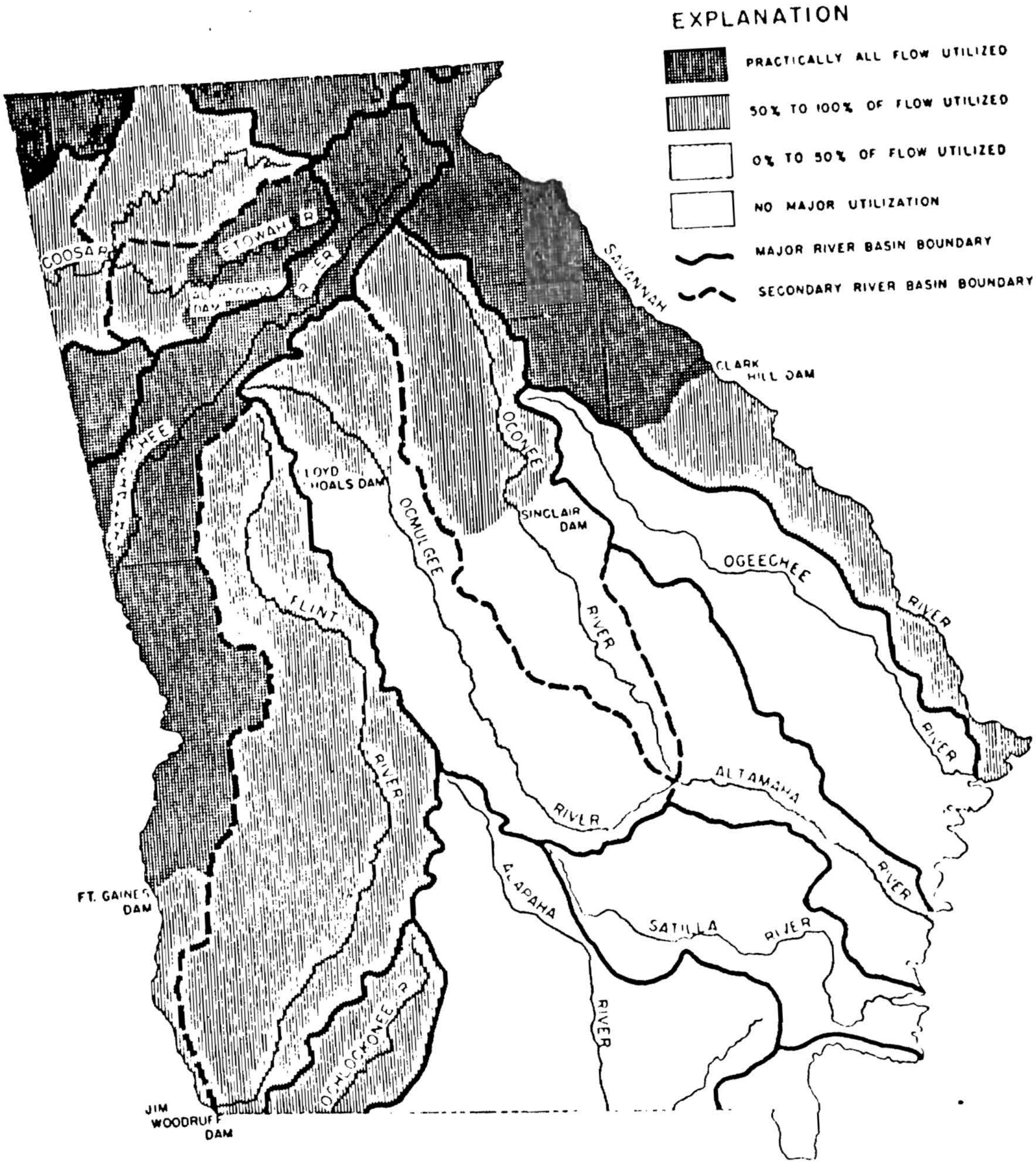

Figure 20 - Estimate of Percent Utilization of Average Flows in Georgia River Basins

Source - Reference 1

begun to take place along the coastal shores of the aquifer, which could spell severe problems for both industry and municipalities in the not too distant future. This intrusion is caused from a depletion of the fresh water aquifer reducing its static head and allowing salt water to infiltrate the coastal ground water supplies. Already the city of Brunswick, home of one of the world's largest mills, has experienced the problems caused by salt water intrusion.

With the shrinking of available plant sites on the western, northern and eastern regions of the state, there remains abundant ground water supplies in the central and southern sections of Georgia. Yet here is where planners must carefully take into consideration the needs of all potential water consumers. The agricultural heart of the state lies within this region and any usage of water resources must be balanced to take into account the ever increasing requirements of irrigation. This is particularly critical given the fact that irrigated land has been doubling at a five year rate.

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SECTION V

WATER QUALITY CONSIDERATIONS

In general, paper and allied product industries are located in areas with adequate supplies of water. Water conservation measures incorporated by the pulp and paper mills have typically been initiated because of economic considerations related to product, energy, or process chemicals recovery and water quality considerations, rather than a shortage of water.

The issue of water quality effects the pulp and paper industry in two ways. First, the water used in the manufacturing process must be of suitable quality not to adversely affect the product. Secondly, the wastewater discharged from the mills must be of acceptable quality to meet state and federal effluent discharge requirements.

The properties which must be considered regarding water used by the paper industry are hardness, alkalinity, turbidity, pH, color, iron, suspended solids, manganese, dissolved gases, algae and bacteria. Suspended solids and turbidity in the water decrease brightness, affect colors, interfere with textures and uniformity, clog wire screens and favor slime growth. High hardness interferes with washing operations, causes fouling in resin sizing and digesting processes and results in the precipitation of calcium carbonate. Color can have an adverse effect on paper brightness. Control of pH and dissolved gases is necessary to avoid corrosion of equipment.

Standards for the chemical composition of process water accepted by the majority of the paper mills are shown in Table 2.[1] If the source of water used by the mill is of inferior quality it must be treated before entering the mill. Water treatment costs, to insure quality standards, can become the overriding factor in determining between use of surface or groundwater sources. In general, groundwater sources are usually of good quality but sometimes requires pretreatment for hardness. But additional expenses are occured in the drilling of wells, and must be compared to treating surface sources. The higher the cost of suitable quality supply water to the mill, the more incentive the mill has to reduce its intake of water through conservation or reuse.

A prime example of water conservation measures incorporated because of concern over wastewater discharges is the use of the Rapson-Reeve closed-cycle process at the Great Lakes Forest Products Limited 'B' mill in Thunder Bay, Ontario. Conventional wastewater treatment systems were not feasible at this location because of space limitations.[2] The Rapson-Reeve system was well suited for this plant because, when taken to its ultimate, it does not have any organic discharge to receiving waters. Water reuse is maximized within the process to reduce load to recovery system. Many of the water saving techniques used in this process

Table 2

Summary of the recommended water supply quality guidelines for the pulp and paper industry.

Parameter	Fine Paper	Kraft Paper Bleached	Kraft Paper Unbleached	Groundwood Papers	Soda and Sulfite Pulp
Alkalinity	75	75	150	150	75
Calcium hardness	50	-	-	-	50
Carbon dioxide, free	10	10	10	10	10
Chlorides	-	200	200	75	75
Chlorine, residual	2.0	-	-	-	-
Hardness, total	100	100	200	200	100
Iron	0.1	0.2	1.0	0.3	0.1
Magnesium hardness	-	-	-	-	5.0
Manganese	0.03	0.1	0.5	0.1	0.05
Silica	20	50	100	50	20
Solids, Total Dissolved	200	300	500	500	250
Turbidity	10	40	100	50	25

can be employed in conventional mills. This process is the only proven feasible technology that can meet the 1985 goal of the Water Pollution Control Act Amendments (1972) which is to eliminate the discharge of pollutants. Public Law 92-500 (WPCAA of 1972) and Public Law 95-217 (The Clean Water Act of 1977) have an indirect influence on wastewater reuse. These acts improve the quality of industrial wastewater discharges thereby reducing the incremental costs for renovation and recycling.

Water reuse practices that also reduce the wasteload discharged into receiving waters are benefical because of the reduced demand placed on the assimilative capacity of the receiving body of water. Two recent experiences in Georgia related to limited water for the assimilation of treated wastewater can best depict the conflict pertaining to instream use. In siting two pulp and paper industry operations on two different rivers in the state, the available assimilative capacities of the rivers have been exhausted. Consequently, while these two operations will be able to meet their water needs and comply with all federal and state water quality requirement, they have also prevented any additional significant industrial user from building or expanding in these areas. In both cases, other industrial representatives have already been refused a request to located a plant in the same areas because the water resources simply are unavailable to meet the needs.[3]

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SECTION VI

WATER CONSERVATION POTENTIAL IN THE PULP AND PAPER INDUSTRY

In considering the absolute water usage of the integrated kraft pulp mill it is important to realize that mills have the potential to be a net producer of water. The raw material to the mill, roundwood or chips, typically contain 50% water by weight and the typical final product contains only about 50% of the dry wood introduced to the plant. Combining these two figures results in a water input to the mill of 2 lb. of water for each lb. of finished fiber. The paper or board product produced by the mill typically contains about 0.06 lb. water for each lb. of fiber. Therefore, the difference of 1.94 lb. water per lb. of fiber is the theoretical quantity of produced water. For a "typical" mill producing 1000 adt* per day, the water production would be 440,000 gallons per day or 440 gallons per ton of product. But quite the contrary, the pulp and paper industry is a heavy user of water.

In the early history of papermaking, when paper was made by hand, water was used at a rate of up to a third of a million gallons per ton of paper. By the turn of the century when the paper machine was being developed, water use had been reduced to 150,000 gallons per ton. In the 1950's the water usage rate was down to 35,000 gallons per ton.[1] Today typical figures for mills who have still not undertaken intensive water conservation programs are 12,000 gallons per ton for unbleached kraft mills and 23,000 gallons per ton for bleached kraft mills. Some nonintegrated paper mills have reduced their water use to 8000 gal/adt and the Rapson Process has reduced the bleach plant water effluent from one integrated mill to zero. However, it appears as though typical mills could reduce these rates to 8000 gallons per ton for unbleached plants and 11,000 gallons per ton for bleached plants.

Taking the integrated mill subprocesses one at a time, the use of water and possible decreases in this use are discussed below:

° Wood preparation area[2]: In this operation, often called the "Woodyard", entering raw material to the mill is processed. Purchased wood chips are screened and conveyed to storage for use by the pulp mill. Roundwood is stored, debarked, cut to shorter lengths, if necessary, and chipped. Water use here is minimal. Some mills use a water flume to convey the roundwood from storage to the barking drums and have a small makeup water requirement to replace evaporation, leakage, and wood retention. Other uses can include fresh water for hydraulic drives, and for lubrication, cooling, and/or flushing of bearings on chain conveyors and chip blowers. Water which is not required to be clean may be used for bark sluicing, grit sluicing and log showers. The total water requirement may be on the order of 3000 gal/ton with about 80 gal/ton required as fresh water.

Replacing the sluices with conveyors will eliminate much of the process water requirement. Log showers on the other hand must remain. Fresh water requirements can be reduced by replacing hydraulic drives and chip blowers. All of these items have energy, maintenance and capital cost considerations in addition to water conservation considerations. Based on our findings in this study we estimated that the typical woodyard water requirement need not exceed a maximum use of 800 gal/ton of which 40 gal/ton is fresh or clean water.

° <u>Pulp mill</u>[3]: The integrated pulp mill first converts the wood chips to a slush pulp, which is a water solution of wood fibers. The slush pulp is then cooked in either a batch or continuous digester using a water solution of inorganic reagents such as sodium hydroxide and sodium sulfide for the kraft process and various combinations of sulfurous acid, bisulfites and sulfites of sodium, ammonium, or magnesium for sulfite processes.

In the digester, the cooking liquor is maintained in the range of 900 gal/ton of pulp for batch processing and there is not a great deal of potential for decreasing this volume unless the requirement that the chip charge must be covered by liquid, is removed by the successful development of vapor phase pulping. Continuous digesters however require about 40% less water than batch digesters, because of reduced steam requirements and liquor volume. As with most of the subprocesses, however, the choice between batch and continuous digesters is based on a great many more factors than just water use. Some examples are:

1. Flexibility - With batch digesters the pulping can be changed with each batch. With continuous digesters, pulping changes necessitate a slow gradual process shift.

2. By-product recovery - The turpentine yield is typically higher with batch digesters because of the venting configuration and technique.

3. Complexity - The continuous digester is drastically more complex because of the higher number of heat exchangers, pumps, screens, and control valves. The batch digester with direct steam injection is the ultimate in simplicity and therefore offers higher reliability, continuity and low maintenance costs.

4. Corrosion - Because of the temperature cycle, corrosion is more of a problem with batch digesters.

5. Space requirement - The single, continuous vertical digester vessel requires far less real estate than does an equivalent bank of batch digesters.

6. Environmental - A distinct advantage is held by the continuous digester because gaseous effluents from the recovery system are continuous and therefore much more amenable to control.

7. Energy - The specific energy requirement of the continuous digester is lower because of a lower liquor to wood ratio.

Also the alternate heating and cooling of the batch digester is avoided in the continuous digester.

8. Chip quality - The batch digester is more tolerant of off-quality chips.

° Pulp washing[3]: After the chips are cooked, the mixture of fibers and spend liquor (black liquor) are separated by the pulp washers. The conventional three stage vacuum drum washer and the displacement washers require the same dilution factor. This factor is defined as "pounds of water put into the liquor system per pound of airdry pulp". The optimum value is a balance between the cleanliness of the pulp and the degree of black liquor dilution which affects consequent load on the evaporators. Dilution factors of 2-3 are common (600 gal/ton, avg.). Other water uses in the pulp mill include pump seals, bearing cooling, washup hoses, turpentine condenser (200 gal/ton) and other miscellaneous uses. This total requirement can be in the range of 1400 gal/ton. Pump seal water can be reduced by changing to mechanical seals but the impact on water consumption is minimal.

° Bleach plant: Bleaching, as it is typically carried out, could be considered a continuation of the pulping process because it also involves the removal of lignin rather than simply decoloring the pulp. The process of bleaching pulp is required to produce a high brightness pulp such as that used in the manufacture of white paper. The general procedure involved in bleaching pulp is to treat the washed pulp from the digester alternately between a stage where an aqueous solution of a bleaching agent is applied and an alkaline stage where the products formed in the oxidation stage are extracted from the pulp. Commonly used bleaching agents are chlorine, hypoclorite, chlorine dioxide, peroxide, and oxygen while sodium hydroxide is typically used as the alkaline source in the extraction stage. Between these stages the pulp is usually washed to remove the residual chemicals and dissolved lignin degradation products resulting from the proceeding stage. Multistage bleaching, starting with a chlorination stage, is considered to be the "conventional" method of bleaching pulp but can be carried out in many different combinations. All bleaching methods have certain requirements in common. Among these are mixing of the pulp and chemicals and washing of the pulp. Most of the following comments are for the "conventional" method but many of the same principles can be applied to other methods.

In a fully intergrated mill, the bleach plant is one of the subprocesses that uses the largest amount of water. The volume of fresh water used in the bleaching process has been significantly reduced during the seventies. A key ingredient to the reduction has been the implementation of countercurrent washing systems. Countercurrent washing involves recycling water from the final stage of the bleaching to the earlier stages. Figures vary but in the sixties fresh water useage by the bleach plant was reported as high as 50,000 gallons/adt, while today the typical usage is about 11,000 gallons/ton.[4] Countercurrent washing reduces freshwater consumption but not necessarily water usage. Water usage and consumption could be further reduced if the pulp was bleached at a higher consistency. Research is being done in this area but problems have prevented full scale application. Water usage has also been reduced by eliminating some of the washing between stages when it can be applied without seriously effecting the product.

Other significant water using processes in the bleach plant do not directly involve the washing system, including chemical makeup and pump gland water (using 1000 gallons/ton and 1200 gallons/ton respectively). Water usage could be reduced by 400 gal/ton for chemical make-up by using wash water effluent where applicable and pump seal water could be eliminated by using mechanical seals.

Displacement bleaching is another method used to bleach pulp. The process takes place within a single tower and there is no washing between stages. The reaction products from one stage are displaced by the chemical solution of the next stage. Wash water is added only after the last stage. The pulp enters the washer at a somewhat higher density than required in conventional bleaching thereby resulting in a decrease in both the total water useage and freshwater consumption. Water consumption is reportedly one-fifth that of conventional bleaching.

° Paper Mill[5]: The pulp, entering the paper mill at about 16% consistency, is immediately diluted to about 3% consistency for stock prep refining. Subsequently it is further diluted to about 1/2% consistency prior to the paper machine headbox. The total water requirement for these phases is on the order of 20,250 gal/ton. In addition, vacuum pump seal water and various showers on the paper machine headbox, fourdrinier and the presses will require about 4500 gal/ton.

There is no potential for reducing any of the intermediate dilution prior to the paper machine because the high dilution is necessary to achieve good formation of the sheet in the fourdrinier forming section. This high water requirement will remain necessary until a better fundamental understanding of interfiber forces is achieved. If the electrokinetics of the stock were controllable to the extent that a high consistency feed could be provided with minimum fiber flocs, considerable water useage would be avoided. Some research is being done on dryforming, but results so far are not applicable to paper-linerboard grades. Vacuum pump seal water on the order of 900 gal/ton for the water ring vacuum pump can be eliminated by changing to water free vacuum equipment.

° <u>Energy Systems</u>: Steam production for electricity generation, digester heating, evaporators, paper machine dryers, etc. may result in a boiler feed water requirement of 2000 gal/ton. Steam reduction for digesters and evaporators hold little promise. The digester temperature can be reduced only a the expense of cooking time as related by the H factor. Since the rate constant for the reaction of the cooking liquor with the wood components rises exponentially with temperature their is a disproportionate increase in cooking time with temperature decreases. As mentioned in the discussion of pulp washers, the only way to reduce the load to the evaporators is to use less wash water. This of course, results in a lowering of the product quality and an optimum must be reached. Water conservation is practiced in the evaporator operation by the universal use of multiple effect evaporators.

Steam condensers on turbine exhausts typically use 12,000 gal/ton[6] of cooling water but this water is not contacted by any polluting medium and the temperature rise is insignificant. Therefore it can be returned to its source with little net change in the ecosystem. An exception would be if the water were taken from wells and the water table endangered.

Steam requirements for the paper machine dryers can be reduced when and if pressing technology is advanced to the point that the maximum theoretical water removal by mechanical means is achieved. Extended nip presses which are now being developed should enhance wet pressing considerably.

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SECTION VII

WATER RECYCLE AND REUSE POTENTIAL IN THE PULP AND PAPER INDUSTRY

In the paper mill, reuse has been a standard procedure for many years in that the white water drained from the fourdrinier stock to the wire pit has been recycled to the fan pump. The paper machine and stock prep areas of the paper mill present a unique situation. The stock in the pulp mill is at 16% consistency in the high density storage tank. However, it is subsequently diluted to ½-3% consistency and has size, alum, and other additives added to it prior to the paper machine. The stock leaves the paper presses at about 40% consistency. The water (called white water) removed at the paper machines, in concentrating the stock from its initial consistency to 40% consistency, can be recycled countercurrently to the fiber flow back as far as the high density storage dilution. Typically however, because of the additives, this liquid cannot be used in pulp washing. An exception to this is Neutral Sulfite Semi Chemical processing (NSSC), or a corrugating medium process in which typically no additives are used. With the NSSC process about 4 lb. water per lb. of fiber is available for limited recycle potential.

In addition to the white water, 20 lb. of paper machine shower water is typically mixed with and "contaminated" by white water. This water has typically been sewered. But part of this stream is often diverted to uses where white water is acceptable, such as in the woodyard for log showers. If the material balances were favorable to reuse all white water, the problem would be far from solved because of contaminant concentrations and increased system temperature.

As the overall system temperature increases, microbiological activity changes. The aerobic microorganism population decreases but thermophilic organisms survive. Corrosion problems increase not only because of increased temperature but because of metabolic products of anaerobic microorganisms such as organic acids. Sulphate reducing bacteria and the low pH from alum addition plus formed acids results in the evolution of hydrogen sulfide thus causing a product odor problem. Odor problems also result from volatile acids formed such as lactic, succinic and oxalic. A rule of thumb for estimating corrosion rate as a function of stock temperature only (not accounting for the effect of acids formation) is that the corrosion rate will double for each 20°F increase in temperature above 110°F. By recycling water the temperature of the white water system can increase from 120°F to 140°F or possibly higher. The system temperature can be held at any desired temperature if the mill chooses to purchase and maintain heat exchange equipment. However holding the temperature down will not solve the problem. The equilibrium concentration of both dissolved and suspended solids will increase. As the pulp enters the system, contaminants such as dissolved salts, suspended organics from the black liquor, and fiber fines, will build in the system to an equilibrium value (controlled also by the "blowdown" rate). In the extreme case, solubility of the dissolved calcium, magnesium, barium and sodium salts will be exceeded and they will precipitate out causing localized corrosion, blinding, and scale. The extent to which a mill can close the loop on water usage therefore depends on the mills' tolerance of the following:

1. Corrosion and erosion increase
2. Foam increase
3. Increase in pitch, slime, dirt, scale, and odor in product and equipment
4. Machine room temperature
5. Felt, wire, shower plugging
6. Sizing problems from increased temperature

Extra costs result from the requirements for:

1. Increased use of expensive materials of construction such as stainless steel 316.
2. Increased use of higher quality defoamers.
3. Increased use of pitch dispersants and deposit control chemicals
4. Air conditioned control rooms
5. Filters and clarification equipment for the white water
6. Increased use of biocides
7. Better efficiency of the pulp washers
8. Increased use of retention aids on fourdrinier and savealls.

Closing up the water system does have benefits beyond reducing water supply costs. These benefits include decreased loss of fibers and filler, decreased waste treatment costs, and better water removal on the fourdrinier and wet presses at the higher temperature.

If excess white water is to be used where clean water is needed, the water must be treated. Mills with a fresh water use of 4000 gal/ton, as opposed to the average of 9000 gal/ton, utilize a water treatment operation for the white water. One mill visited uses a polymeric flocculating agent to clean up the suspended contaminants in the white water. It is then blended with fresh water to maintain dissolved solids concentration below saturation. This treated white water is suitable for many uses previously limited to only fresh water. These uses include showers on the paper machine, vacuum pump seal water, and decker spray nozzles. The typical mill however finds that maximum water reuse and white water clarification is not economical.

Water evaporation is another area where recycling may be possible. Current evaporative losses are in the range of 1500 gal/ton estimating from:

1. Blow tank accumular losses
2. Recovery boiler including direct contact evaporator
3. Smelt dissolving tank
4. Lime kiln
5. Cooling towers
6. Paper machine dryers.

This water varies from good quality, such as that lost from cooling towers to poor quality such a is lost from the recovery boiler. By recondensing these vapors, if only half of these streams could be reused, approximately 2% of the average water intake could be eliminated. In addition, there is a potential savings in heat recovery possible as well. Looking at other integrated mill operations:

° <u>Woodyard</u> - Clean water needs for pump seals, air conditions, cooling, sealing, flushing and lubricating will require top quality water and fresh water will no doubt continue to be used. This statement can generally be applied mill wide. Other wood yard uses can use recycled water with little problem.

° Pulp Mill - Blowing the digester to the blow tank traditionally results in 250 gal/ton of liquor and wood water being flushed to the atmosphere. Most mills have added accumulators to the blow tanks and most of this water is now recovered. This water can be used in the pulp washers. Dirty condensate from the evaporators also is recyclable to the washers.

° Bleach Plant - In a closed-cycle mill [such as that operated at Thunder Bay, Ontairo,] the main consideration is the recycle of bleachery filtrate. Basically, countercurrent washing through bleaching, screening, and brown stock washing, is employed in addition to other water conservation methods to reduce input water volume. The concept of the effluent-free kraft pulp mill requires that the fresh water input for process needs be minimal because whatever enters the process stream must be evaporated if closure is to be accomplished.

Water usage in a bleach plant designed or retrofitted to use the following methods could be a little as 4,000 gallons/adt or less.

1. Complete countercurrent flow from the final washer to the black liquor recovery furnace.
2. Substitution of other process streams or condensate for make-up or fresh water wherever applicable.

3. Vacuum pumps could be substituted for steam ejectors.

4. Wash down hoses should be off until required for use.

5. As in other subprocesses gland or sealing water could be recycled after cooling or replaced by mechanical seals.

° Energy Systems - The major clean water requirements for the power department are for boiler feedwater and cooling tower blowdown replacement. Water savings are maximized in the energy systems area when the steam used in the mill is condensed and the condensate returned to the boilers. This is typically the case for steam used in the paper machine dryers, evaporators and turbines. However, many batch digesters use direct steam injection for heating while indirect heating is chiefly used in the sulfite process batch digesters and in continuous digesters for all kraft pulping. In determining the potential for condensate recovery in batch digesters, it must again be stressed that there are many considerations, besides condensate recovery, involved in choosing the type of heating for batch digesters.

The cooling water for turbines and evaporators is generally noncontacting and typically will either be returned directly to the river or run through the turbine and evaporator condensers on the way to the treatment plant which supplies the mill with fresh water. Likewise, evaporation condensate is sometimes recycled through cooling towers.

SECTION VIII

CONCLUSION

Based on the extensive information gathered in our industry survey, we have been able to draw some general conclusions regarding the potential for water conservation and reuse in the Georgia pulp and paper industry. Primarily, it is obvious that there are certain plants in Georgia who have an enormous potential for reducing water withdrawal and who typically exceed industry average usage estimates. While it is agreed that no two plants are necessarily alike, nonetheless our research has found that a typical unbleached draft plant should draw approximately 12,000 gallons of water per ton of product produced while a bleached kraft plant should draw approximately 23,000 gallons of water per ton of product produced. These figures, it should be pointed out, reflect current industry practices of conservation and reuse.

Of the seven unbleached kraft mills studied in Georgia, if they were to approach this average withdrawal rate mentioned above, 70 million gallons of daily water withdrawal would be eliminated. Likewise for the five bleached draft mills studied, if they were to approach the average withdrawal rate mentioned above, 105 million gallons of daily water withdrawal would be eliminated. Since these plants represent the major production capacities of the pulp and paper industry in Georgia, it stands to reason that their withdrawal savings would account for most of the total savings potential for the Georgia pulp and paper industry. But the above discussion only addresses the potential savings possible in bringing Georgia's plants to a level typical of the industry today. What about those conservation and reuse measures mentioned in Sections VI and VII identifying additional savings potential? Based again on the production rates and makeup of the plants studied, we estimate an additional 97 million gallons of daily water withdrawal savings is possible.

It might be asked, why then are certain plants not taking even elementary steps, much less more deliberate measures, to reduce water withdrawal? While there are indeed a number of reasons often applicable to a particular plants position, a few common problems found in this study are:

1) The ready availability of clean water supplies with little additional cost attached to over withdrawal.

2) The availability of adequate existing wastewater treatment facilities to handle overdraft at little additional cost (typically these facilities are treatment lagoons which require very little operating cost).

3) The lack of knowledge and incentive to make expenditures which would preserve water resources for alternate uses.

The shear magnitude of the potential savings noted in this study clearly indicate that governmental and industrial planners alike must begin the educational process of making users water conscious, that is aware that there are no longer unlimited supplies of water. We feel the potential for water reuse improvements can be enhanced by:

1. The development of an economical process for cleaning the water of the myriad of dissolved and suspended solids, both organic from the wood and inorganic from the cooking liquor and wood.

2. The development of a computer model for determining the economic benefits and costs of reusing water to various extents.

3. An investigation of the economics of pressing high density pulp to recover water before dilution by white water prior to the stock prep area.

4. An investigation of the economics of recovering water vapor now lost in the atmosphere.

APPENDIX A

WATER RESOURCES OF GEORGIA

Surface Water Resources

Georgia has a north-south dimension of 320 miles and a maximum width of 250 miles. Over such a large geographic area, great variations in surface water resources are to be expected because of weather and physiographic factors.[2]

Georgia lies in four physiographic provinces -- the Blue Ridge, the Valley and Ridge, the Piedmont, and the Coastal Plain (See Figure 1A). The characteristics of streams differ among the provinces, and within the Coastal Plain great differences in runoff characteristics make it desirable to consider that area in two sections -- the upper and lower Coastal Plains.[3]

Physiographic Provinces

Blue Ridge Province. In this mountainous region of northeast Georgia the average annual rainfall ranges from 53 to 70 inches, while average runoff ranges from 27 to 37 inches. The forest-clad mountains, rising to elevations of 4,000 to 5,000 feet above mean sea level, are separated by narrow valleys in which lie the towns and most of the cropland. The rivers generally have small drainage areas but relatively high water yields.[1] They have steep, rocky channels and flow swiftly over many rapids and waterfalls. With the exception of the Chattooga River, most of the streams are the upper reaches of rivers, such as the Hiwassee

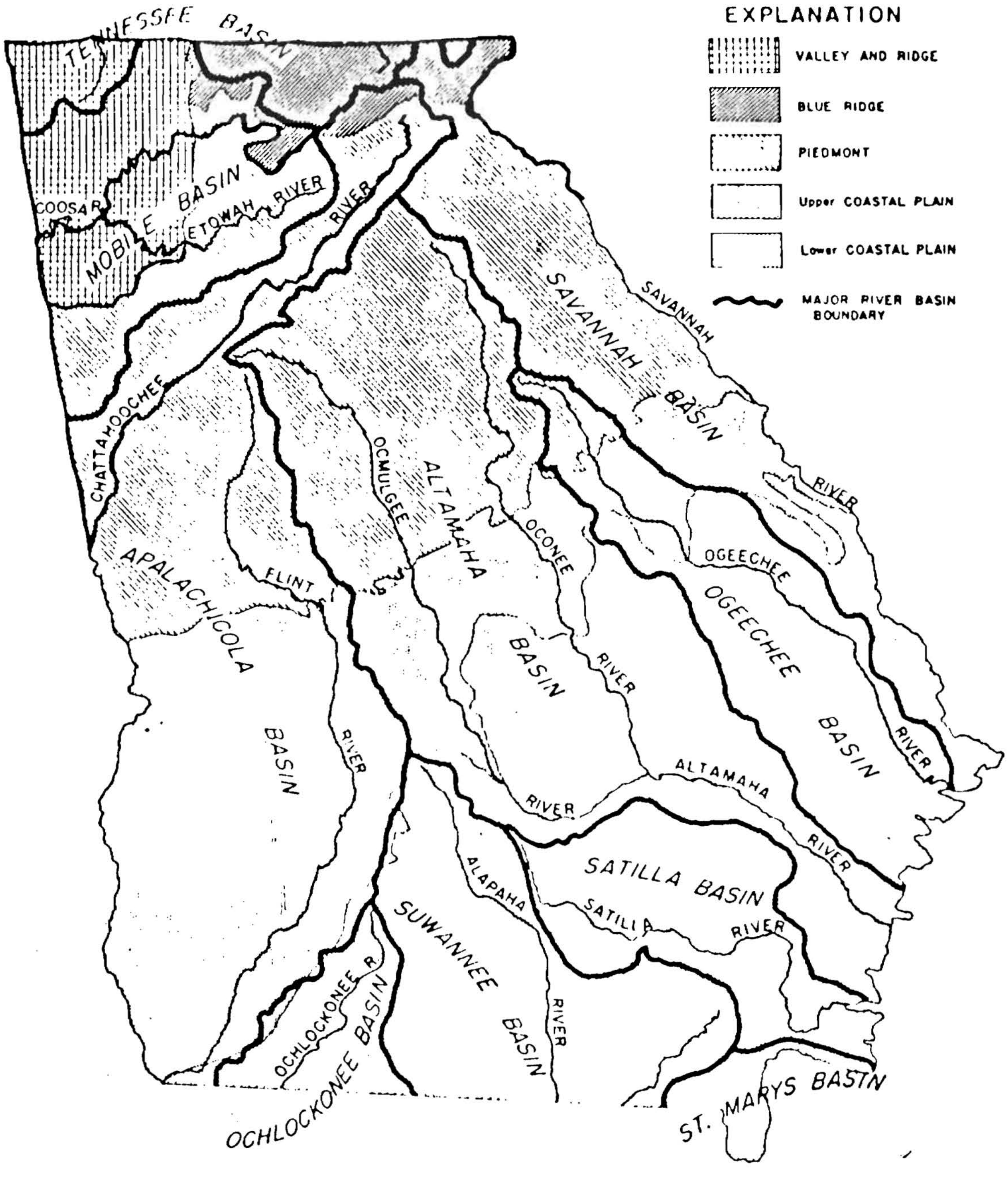

Figure 1A - Map of Georgia showing physiographic provinces and major river basins

Source - Reference 5

and Ocoee, that flow into adjoining Tennessee and drain into the Tennessee River Basin. The average surface water supply in this province is 3,400 mgd, but in the 1954 drought it fell to 650 mgd.[4,1]

There are no large cities and few industrial plants in this province. Average daily urban water use is just over 1 mgd, supplied largely by springs, and there is no large use by industry.[3] There are many water-power and reservoir sites, and hydro-power use of these waters presently amounts to over 2,000 mgd on the Tallulah, Toccoa, Nottely, and Hiwassee rivers. The power reservoirs have helped make the area a popular recreation center.

Valley and Ridge Province. This northwestern Georgia province has an average rainfall of 49 to 58 inches, while annual runoff ranges from 18 to 24 inches. The terrain, typically, consists of wide cultivated valleys at elevations ranging from 550 to 800 feet above mean sea level, separated by narrow and steep wooded ridges that range from 1,600 to 2,000 feet in elevation. Practically all of the towns and much of the cropland are in the valleys.[3]

The rivers generally flow in deep channels that meander in wide flood plains, but where they cut through the ridges, such water gaps are marked by shallow and swift waters with many rapids. The master stream is the Coosa River, formed at Rome by the junction of the Etowah and Ooostanaula rivers, both of which originate in the Piedmont. The average supply of river water in this province totals 4,350 mgd, against the 1954 drought record of 300 mgd.[4,1] Urban usage of water averages 15 mgd, mostly at Rome, and industry uses 360 mgd[3]; rivers and springs are the principal sources of supply. The largest users are Plant Hammond (steam power plant of Georgia Power Company) and the Rome Kraft plant, both on the Coosa River, west of Rome.

The major streams in this province have a few low-head power sites but few practical large-reservoir sites because of the farmland that would be flooded.[2] At present, there is no large hydro-power use in this province. There are many small dam sites in the water gaps that are suitable for minor power developments or small reservoirs.

Piedmont Province. This province, comprising the area south from the foregoing two provinces to the Fall Line, is characterized by both narrow and broad ridges, separated by relatively narrow valleys. Elevations range from 300 to 1,500 feet above mean sea level. The average annual rainfall ranges from 44 to 59 inches, while average annual runoff ranges from 10 to 39 inches. Nearly all the towns, highways, railroads, and farmlands are on the ridges. The steep hillsides and most river valleys are wooded, although some of the larger rivers have cultivated bottom lands.

The Chattahoochee River flows southwesterly across the northern third of this province, while the southerly-flowing headwaters of the Flint, Ocmulgee, Oconee, Ogeechee, and Savannah rivers drain the remainder of the province. These streams here "generally have moderate slopes interrupted by occasional rapids and waterfalls and flow in well-defined channels within valleys of varying widths. Stream beds are usually composed of silt or gravel overlying bedrock."[5] The average supply of river water in this province is 18,000 mgd, but in the 1954 drought this was reduced to 650 mgd. Urban usage in 1977 totaled over 200 mgd, the sum of waterworks capacities in the Atlanta area, Macon, Griffin, Athens, and Augusta -- there are several other additional small urban water plants. Industrial usage, mainly for steam-power generation on the Chattahoochee, Ocmulgee and Savannah rivers, was 720 mgd, which included re-use in large part of water used for urban and hydro-power purposes.[4,1] The rivers and small streams are principal sources of supply for the larger cities and industries, but wells are used by many small towns.

There are many water-power and reservoir sites, and in 1975 some 28,000 mgd were used by hydro-power developments, counting only the largest use on each river -- Allatoona on the Etowah, Bartlett's Ferry on the Chattahoochee, Jackson on the Ocmulgee, Sinclair on the Oconee, and Clark Hill on the Savannah.[3]

The potential irrigation demand of 1,370 mgd greatly exceeds the minimum supply of 650 mgd, thus creating a potentially serious situation for an urban population of over one million people who depend on river flow for their supplies and waste disposal, not to mention the industries and hydro plants also dependent upon these supplies. In addition, ground-water supplies in this province are limited.

Fall Line. Marking the boundary between the Piedmont and Coastal Plain provinces is the Fall Line, so called because of the steep fall of rivers as they cross this boundary. It is sometimes called the Fall Zone, since the boundary is discontinuous and both the Coastal Plain sediments and the Piedmont crystalline rocks may be exposed over a zone several miles wide. The Fall Line commonly is the head of navigation of large rivers and the site of water-power dams such as those at Augusta, Milledgeville, and Columbus.

Upper Coastal Plain. This section of the Coastal Plain extends south from the Fall Line over distances ranging from only a few miles up to practically the entire distance from the Line down to the Florida border in southwest Georgia (See Figure 1A). The average annual rainfall here ranges from 43 to 55 inches. The average annual runoff of the larger streams ranges from 12 to 28 inches.[1] Their flow is relatively uniform because of the small storm runoff and high yields during dry weather, due to inflow of ground water. Very small streams commonly have very little runoff because of rapid absorption of rain water by the pervious soil and inability to cut channels deep enough to intercept ground-water flows. The streams are generally sluggish, flowing in deep, meandering, low-banked, tree-choked channels, bordered by wide, swampy, densely wooded valleys. The intervening ridges are generally wide, with gentle slopes, and most of the cropland, transportation routes, and towns are on these ridges. The river water supply in this section of the Coastal Plain amounts to 27,800 mgd, while the minimum 1954 drought supply was only 3,600 mgd.[1,4]

Urban usage of surface waters is estimated at 1 mgd, mainly at Waynesboro where Brier Creek is the source; nearly all cities and many industries here, as well as elsewhere in the Coastal Plain, rely on artesian well water. The unusually large industrial usage of 1,350 mgd is due mainly to the demands of the nuclear energy plant on the Savannah River near Augusta and of the Georgia Power Company's Plant Mitchell on the Flint River near Albany.

On the larger streams of this section are some low-head water-power sites, but reservoir sites are few because of the flat terrain and pervious soil. Hydro-power generation, nevertheless, is the largest use for river water in this section, using 7,400 mgd at Jim Woodruff Dam in the extreme southwest corner of the state where the waters of the Flint and Chattahoochee rivers are impounded. The Walter F. George Dam at Fort Gaines, also impounds the waters of the Chattahoochee River for power generation, with this operation using over 18,000 mgd. In this upper Coastal Plain section is the first navigational use, 3,500 mgd on the Savannah River, "for which the hydro-power releases at Clark Hill Dam are reregulated by the Stevens Creek Dam to provide a uniform flow."[5]

From the standpoint of irrigation needs in the upper Coastal Plain, there is "an outstanding case of maldistribution" of the surface water supplies. Although the irrigation demand of 1,070 mgd in relation to the minimum supply of 3,600 mgd is a very favorable ratio, it is deceiving because most of this drought flow comes from springs or seepage which feed directly into the major rivers. On the other hand, streamflows are extremely poor close to the ridges where most of the irrigated lands are located.[5]

Lower Coastal Plain. This section, roughly embracing most of the southeastern two-thirds of the Coastal Plain province (Figure 1A), consists of very wide and very low flat ridges separated by very wide, swampy, heavily wooded valleys. Practically all of the towns and croplands are on the ridge tops. This section generally has the least runoff of any part of Georgia, partly because of higher temperatures and low flow-producing land characteristics and, also, possibly because of the high-consumption water demands of the dense swamp vegetation. The average annual rainfall ranges from 45 to 53 inches, but annual runoff averages only 9 to 14 inches.[1]

This section is drained by more streams than any other part of the state, the major rivers being the Savannah, Ogeechee, Satilla, Alapaha, Ochlocknee, Altamaha, Oconee, and Ocmulgee, the last two of which join to form the Altamaha. As a consequence, the river water supply here is the largest in the state, averaging 25,700 mgd. The minimum supply, as evidenced by the 1954 drought, amounts to only 200 mgd, the smallest flow of any section of the state.[1,4]

Urban usage in 1979 averaged 16 mgd, being mainly that used at Savannah. The industrial use of 200 mgd was principally that of the Georgia Power Company's Riverside and McManus steam plants at Savannah and Brunswick, respectively. Practically all other cities and industries, with exceptions above noted, rely on artesian water supplies in this section of the Coastal Plain.

There are few reservoir and low-head water power sites and, as a consequence, no hydro-power plants have been developed here.

Major River Systems

Inasmuch as the major rivers of Georgia each drain from two or more streamflow regions, the flow of a major river blends the regional flow characteristics as that river progresses through successive regions. Moreover, most of the major rivers are highly regulated by storage reservoirs and hydro-power plants. Thus, major rivers are best described by individual river basins and are so treated below in order to supplement the foregoing regional surface water discussion (see Figure 2A).

Savannah River. The Savannah River system begins with the rise of the Chattooga River in the mountains of northeastern

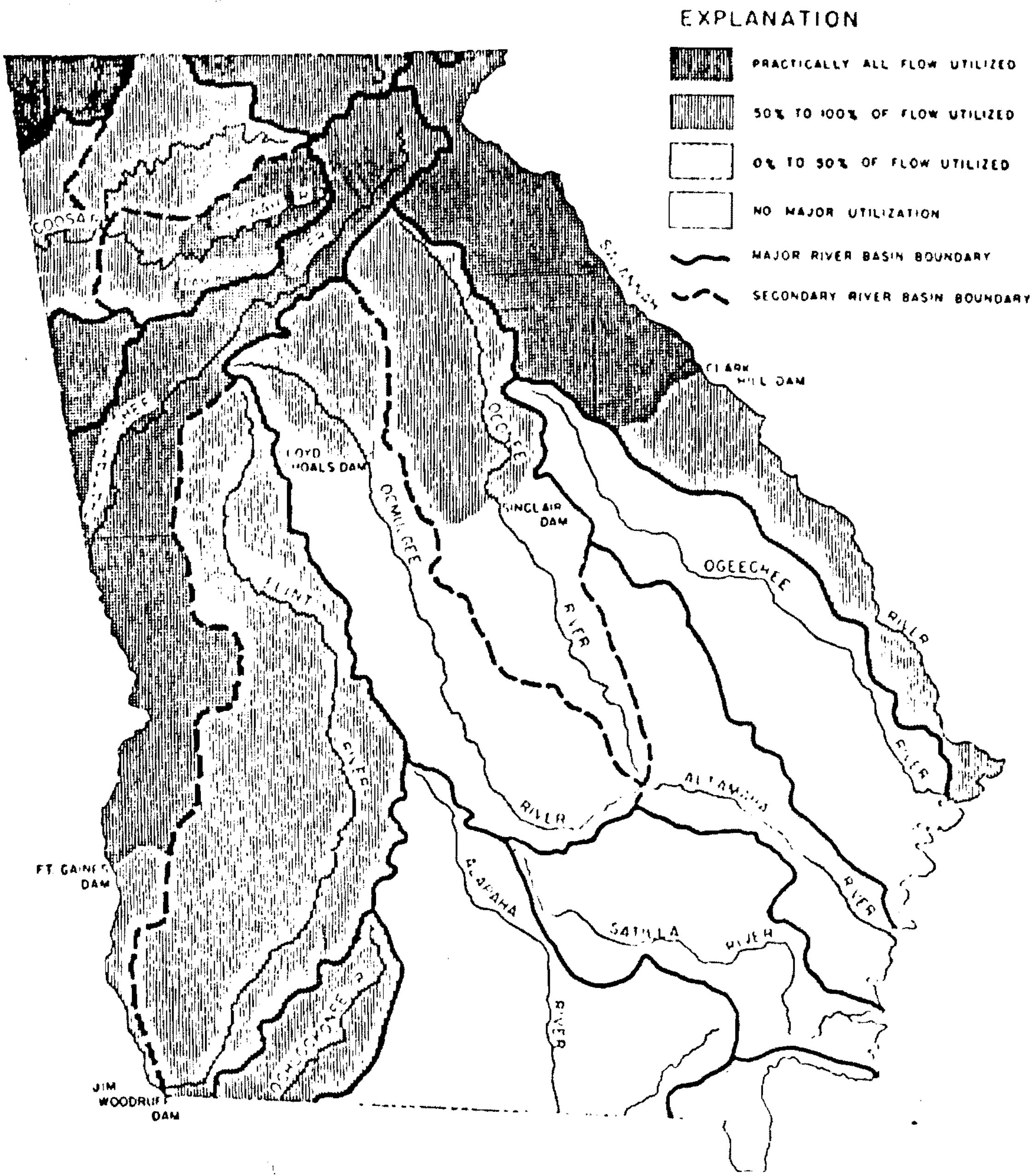

Figure 2A - Map of Georgia showing relation of proportionat utilization flows to average flow by river basins, based on 1965 data.

Source - Reference 5

Georgia where it is joined by the Tallulah River to form the Tugaloo River, which, in turn, joins the Seneca River from South Carolina to form the Savannah River. At the gaging station nearest to its mouth (50 miles upstream from Savannah), the Savannah River has a drainage area of 9,850 square miles and an average flow of 7,142 mgd.[1,2]

The flow of the Savannah River is almost completely controlled by the great multi-purpose storage reservoirs of the Clark Hill and Hartwell dams in the Piedmont province, in conjunction with the Stevens Creek Dam below the Clark Hill reservoir and the regulation of the Tallulah River flow by the storage in Lake Burton and by four power plants. Thus is provided a relatively uniform flow for navigation in the Coastal Plain below Augusta.

The 20-year 1-day minimum flow was 10% to 15% of the Savannah River's average flow above Clark Hill Dam (Columbia County) prior to construction of Hartwell Dam, while below Augusta it was 21% to 25%, due to re-regulation at Stevens Creek Dam. Clark Hill Dam alone controls the flow so that the river at Augusta will rarely flood and the minimum flow will rarely be less than 3,000 cfs.[1]

Practically all of the flow from the area above Clark Hill Dam is used for hydroelectric power generation. Navigation below Augusta requires 60% of the average flow. The largest urban use in proportion to the minimum flow of the river, at Augusta, is only 2% of that flow.

The largest industrial use of the Savannah River at the plant of the nuclear energy plant near Augusta, is 720 mgd, or 20% of the regulated minimum flow (See Figure 3A). Combined surface-and ground- water uses by manufacturers only in the Savannah River basin, exclusive of the South Carolina part, in 1972 were estimated to total 218.5 mgd, with 33.5 mgd of that total being supplied from municipal water systems. The remaining 185 mgd is the usage by 44 manufacturers of water from their own private sources. The largest water users are pulp and paper plants; the three plants surveyed withdrew from the Savannah nearly 52 mgd.[6]

Ogeechee River. The Ogeechee River rises in the Piedmont province, but most of its dry-season flow is received in crossing the upper Coastal Plain. Its principal tributary, the Canoochee River, lies entirely within the lower Coastal Plain and has a drainage area of some 555 square miles and an average flow of 262 mgd, as measured at the gaging station nearest its mouth. The Ogeechee River, exclusive of the Canoochee, has a drainage area of 2,650 square miles and an average flow of 1,367 mgd, at the gaging station nearest its mouth.

There are no flow records for the Piedmont part of the Ogeechee River, but, in the Coastal Plain part, the 20-year 1-day minimum flow is about 7% of the average flow, or approximately 95.7 mgd. The river's water is not utilized for urban, industrial, power or navigation purposes, except for a few small mills within the Ogeechee River basin. Total water used by manu-

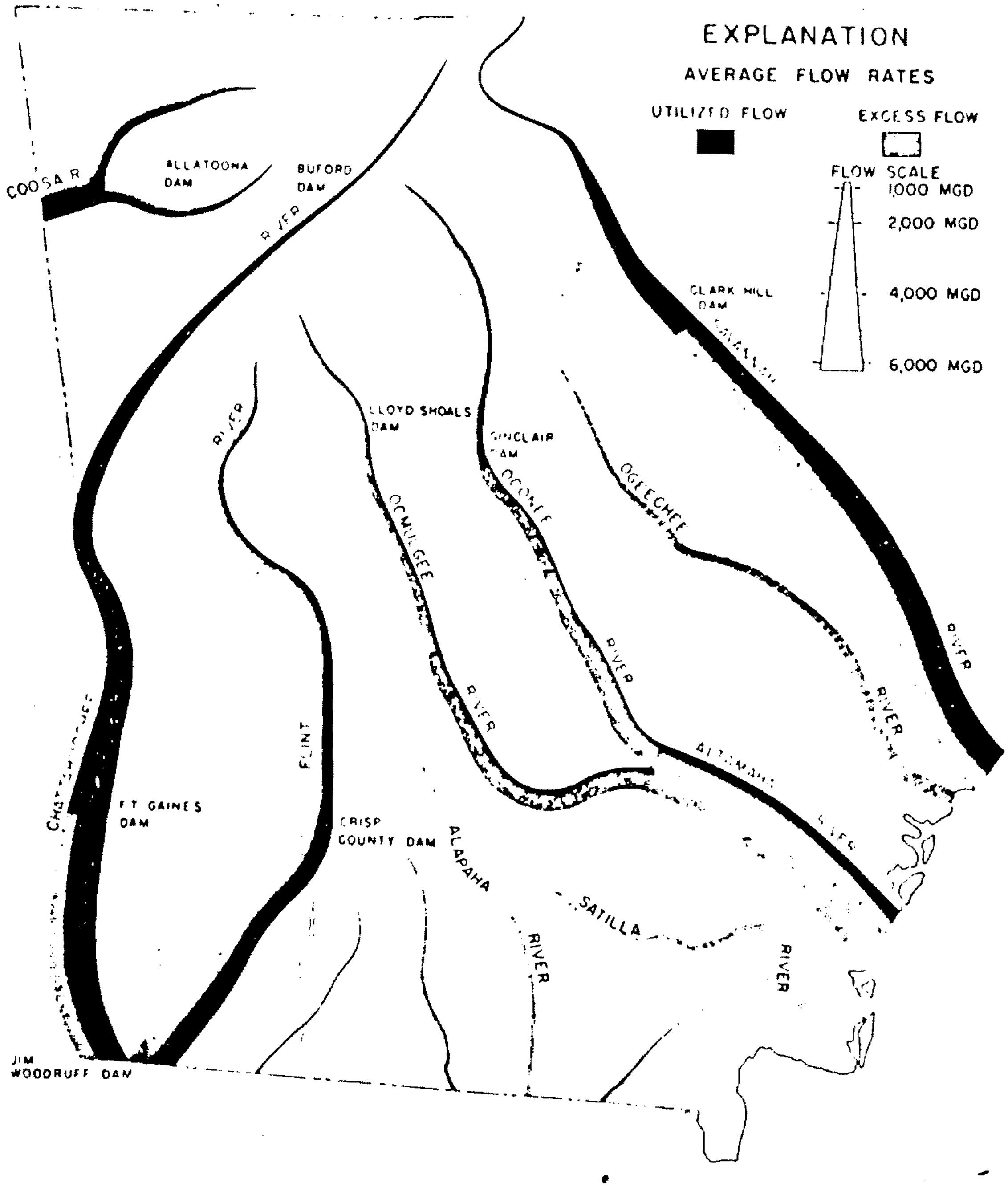

Figure 3A - Diagram of the average flow, average utilization flow, and excess flow on the major rivers of Georgia, in million gallons per day, based on 1965 data.

Source - Reference 5

facturers in the Ogeechee River basin in 1979 was estimated at under 2 mgd gallons daily, almost entirely from wells. Approximately one-third of that total was supplied from municipal water systems; the remaining gallons were used by eight manufacturers, six of which "depend entirely on their own sources for all water used while two industries supplement their supplies with municipal waters."[6]

"The Ogeechee River is unique among Georgia rivers in that a major railroad (Central of Georgia) runs along the greater part of the length of its valley. This combination of rail transportation and good industrial water supplies may in the future bring about the industrial growth of the small cities and villages in the valley."[7]

Altamaha River. The Ocmulgee and Oconee rivers, which rise deep in the Piedmont, join far south in the Coastal Plain to form the Altamaha River.

The Ocmulgee River, at the gaging station 12 miles upstream from its confluence with the Oconee River, has a drainage area of 5,180 square miles and an average flow of 3,415 mgd. The Oconee River, at its lowest gaging station 29 miles above the confluence, has a drainage area of 5,110 square miles and an average flow of 3,218 mgd. The Altamaha River, at the Doctortown gaging station 59 miles above its mouth, has a drainage area of 13,600 square miles and an average flow of 8,105 mgd, making this the largest flow of any river system within the state.[1]

Both the Oconee and Ocmulgee rivers receive substantial increments of flow in dry seasons as they cross the upper Coastal Plain. "South River, the head of the Ocmulgee River, receives a substantial part of its low flow from the Chattahoochee River through the Atlanta and DeKalb County waterworks and sewer systems."[2] This volume of sewage wastes in 1964 amounted to 24.5 mgd. As a consequence of this diversion from the Chattahoochee River, the 20-year 1-day minimum flow of South River was 10% of the average flow in 1955, while it was only 3% to 5% of the average flow at other stations in the Piedmont parts of the Ocmulgee and Oconee rivers. Since 1965, these percentages probably have increased. In the Coastal Plain, this minimum flow increases to 9%, 11%, and 15% on the Oconee, Altamaha, and Ocmulgee rivers, respectively. The low flow of the Ocmulgee River is regulated by Lloyd Shoals Dam and Jackson Lake, while the Oconee River has minor regulation below Barnett Shoals Dam and "severe regulation" below Sinclair Dam at Milledgeville. This latter regulation of the Oconee is discernible in low-water periods down to Doctortown on the Altamaha.[5] One paper plant located on the Oconee withdraws 5, 7 mgd.

The largest urban and industrial water usages in the Altamaha River system are at Macon, where 3% of the minimum flow of the Ocmulgee River is used for urban purposes and the Georgia Power Company's Plant Arkwright actually exceeds the river's minimum flow in its usage of 15% of the average flow. Usually, regulation of Jackson Lake provides a sufficient flow for Plant

Arkwright. In 1972, the combined use of surface and ground waters by manufacturers in the Altamaha River basin was estimated to total 93.75 mgd, with municipal water systems supplying 15.5 mgd of that total. The remaining 78.25 mgd represents usage by 36 manufacturers of water from their own water sources. The largest user, a pulp and paper plant in Bibb County using 9.5 mgd. depends mainly on the Ocmulgee River.

The largest average utilization for hydroelectric power on the Oconee River is at Sinclair Dam, near Milledgeville, where 83% of the average flow is used. On the Ocmulgee River, 67% of the average flow is used at Lloyd Shoals Dam, this being the largest such use on that river. Lake Sinclair and Jackson Lake, respectively impounded by the Sinclair and Lloyd Shoals dams, have a combined usable storage of 300,000 acre-feet.

The Altamaha River is navigable for three-foot draft vessels up to Doctortown, 59 miles upstream from the river's mouth, for about 80% of the time; for this navigation 16% of the average flow is required. In late summer, when the flow is less than 4,500 cfs, the controlling depth is less than three feet.[8]

Chattahoochee River. The Chattahoochee River rises in the mountains of northeast Georgia and flows west and south 436 miles to the Florida line, making it the longest river in Georgia. Its drainage area is 8,340 square miles and average flow is 6,954 mgd, as determined at Alaga, Alabama, 34 miles upstream from the Florida state line.[1]

There is little regulation of the Chattahoochee River from small mills on its upper reaches in the Blue Ridge province or on its tributaries in the Piedmont. On the main stream, regulation is effected by the Buford and Morgan Falls dams near Atlanta and, below West Point, by a series of eight power dams.[1/] The Jim Woodruff Lock and Dam and the Columbia Lock and Dam near Hilton (Early County), together with the Walter F. George Lock and Dam (with power generation facilities) near Fort Gaines, regulate the river in the upper Coastal Plain and provide for navigation up to Columbus.

Buford dam, built by the U.S. Corps of Engineers on the Chattahoochee River about 48 miles upstream from Atlanta, is a multi-purpose structure designed for flood control, navigation, and power. Prior to commencement of power operations in 1958, the minimum daily discharge of the Chattahoochee River at Atlanta was 340 cubic feet per second (cfs) on October 19, 1954, based on a 53-year record. Under present re-regulation of the flow, using reservoir facilities created at Georgia Power's Morgan Falls Dam below Buford Dam, a minimum flow of at least 700 cfs[2/] is maintained, providing some 450 mgd at the intake of the Atlanta Water Works. Even during periods of lowwater stage, the re-regulated flows from the Morgan Falls reservoir during the daytime can range up to 3,150 cfs, with nighttime and weed-end flows reduced to 1,050 cfs during any full week of operations.

Consumption of water in the Atlanta Metropolitan Area in 1979 was estimated at 140 million gallons per day. Approximately 120 million gallons of that total is being suppled from the Chattahoochee River through the Atlanta City Water Works, the DeKalb County system, and the Cobb County-Marietta Water Authority. The remainder of 20 mgd is obtained from springs, wells, and creeks for distribution through 35 other municipal and county systems in the five-county Metropolitan Area.

In 1979, daily consumption in the immediate Atlanta area alone amounted to 105 million gallons, not including water wholesaled to Hapeville, Union City, Fairburn, and Forest Park, and to the Fulton County Water System. By 1985, the Atlanta Metropolitan Area is expected to have a population of two million which will require over 200 million gallons of water daily. As early as 1970, the Atlanta, DeKalb County, and Cobb County systems alone were withdrawing water from the Chattahoochee River, in the stretch between Buford and Atlanta, at the maximum Summer rate of 150 mgd.

The Georgia Power Company's Plant Atkinson near Atlanta was the largest industrial user of water from the Chattahoochee River in 1979, the maximum rate being 450 mgd -- more than double the 20-year minimum daily flow record then prevailing. In 1979, average usage by the plant was 300 mgd. However, with the re-regulation effected through the Buford and Morgan Falls dams, as noted above, the lowest flow to be expected is 700 cfs, or some 450 mgd. This is more than adequate to supply a population of 2,500,000. Most of the water now withdrawn from the

Chattahoochee River for the Atlanta municipal system is returned by the sewer systems upstream from Plant Atkinson, so that the same water is re-used at the plant.

Recent expansion of Georgia Power's Plant Yates near Newnan has created a maximum water demand of 680 mgd for cooling and an average usage of 510 mgd, making this plant the largest user. The Fort Gaines Dam uses practically all of the flow above the dam for hydroelectric purposes, and 68% of the flow between that dam and Jim Woodruff Dam at the Florida state line will be used for that purpose.[2]

Combined use of surface and ground waters for manufacturing in the Apalachicola-Chattahoochee-Flint river basins, exclusive of Alabama and Florida usages, in 1962 was estimated to total about 150 mgd, of which municipal water systems supplied 34.4 mgd. Total municipal water consumption in these basins, excluding Alabama and Florida usages, amounted to about 185.8 mgd, including the above-noted 34.4 mgd used in manufacturing operations.[6] One pulp and paper mill uses 75 mgd for both process and cooling water.

Flint River. The Flint River rises far north in the Piedmont province and flows generally south-southwest to the extreme southwest corner of Georgia. At Bainbridge, 29 miles upstream from the Florida state line, the Flint River has a drainage area of 7,350 square miles and an average flow of 5,480 mgd. At the Florida state line, the Flint River joins the Chattahoochee River in the pool of Woodruff Dam to form the Apalachicola River.[1]

There is no regulation of the Flint River, except from small mills, until it is well down in the upper Coastal Plain (within which it lies entirely south of the Fall Line) where, in dry seasons, ground water contributes a large percentage of the river's flow, as it does to all streams. The flow here is regulated by power plants near Cordele and Albany.

The 20-year 1-day minimum flow of the Flint River is 2% to 5% of the average flow in the Piedmont province and 16% to 22% of that in the Coastal Plain, except where reduced to 3% by the above power plant operations. Below the Crisp County Dam near Cordele, on the lower Flint River, there is a rapid increase in minimum flow caused by springs and seepage from the limestone formations in that area.[1]

The largest urban use of the Flint River water, at Griffin, has taken all of the minimum flow at the pumping plant. A new plant due to start up in the next year will withdraw approximately 9.5 mgd from the Flint. The maximum industrial use of the river water is by the Plant Mitchell steam plant, below Albany, which requires 40% of the minimum flow at capacity operation and which averages 10% of the average flow. (Manufacturing usage of water in the Flint River basin is noted above under "Chattahoochee River.")

Coosa River. The Coosa River system starts with the Cartecay River, which joins the Ellijay River in the Blue Ridge province to form the Coosawattee River. This last-named river and the

Conasauga River meet in the Valley and Ridge province near Calhoun to form the Oostanaula River which, in turn, meets the Etowah River at Rome to form the Coosa River. The Etowah River rises in the mountains of the Piedmont province and flows generally westward through that province and the Valley and Ridge province.

At a gaging station two miles upstream from its confluence with the Oostanaula River in Rome, the Etowah River drains 1,810 miles and has an average flow of 1,630 mgd. The minimum recorded daily flow is 233 mgd. The Coosa River, at the gaging station west of Rome two miles upstream from the Georgia-Alabama state line, has a drainage area of 4,040 square miles and an average flow of 3,968 mgd, of which about 58% is contributed by the Oostanaula River. The Oostanaula River, at a gaging station 4.5 miles north of Rome, drains 2,120 square miles and has an average flow of 2,210 mgd. The minimum daily flow recorded since 1947 is 264 mgd.[1,9]

The lower Etowah River and the Coosa River are regulated by the Allatoona Reservoir, near Cartersville. The completion of the Weiss Dam on the Coosa River across the state line in Alabama created pool conditions in the river nearly to Rome. The 20-year 1-day minimum flow of the Coosa River system is 21% to 24% of the average flow in the Blue Ridge province, but diminishes to 11% to 14% in the Valley and Ridge province.

The largest urban use, at Rome, takes less than 1% of the minimum flow of the Oostanaula River, while the maximum industrial use, by Georgia Power's Plant Hammond and the Rome Kraft plant (both on the Coosa River west of Rome), averages 8% of the average river flow and 71% of the minimum flow during peak operations. These major usages in 1979 were as follows:

User	River	Average	Maximum
City of Rome	Oostanaula	10	13
Plant Hammond	Coosa	295	380
Celanese Rayon Plant	Oostanaula	10	13
Rome Kraft Plant	Coosa	24.5	28

The hydroelectric power plant at Allatoona Dam is the largest user in the system and requires practically all of the average flow of the Etowah River.

Lower Coastal Plain Rivers. In addition to the major streams that cross the lower Coastal Plain, there are several rivers that lie wholly within this section of the Plain -- the Satilla River, the St. Marys River, the Suwanne River system (including the Alapaha River and the Little River-Withlacoochee River system), and the Ochlockonee River.

The drainage areas and average flows for these rivers, at the nearest gaging station, as indicated, are as follows: the Satilla River at Atkinson -- 2,880 square miles and 1,335 mgd; the St. Marys River at Macclenny, Florida (far upstream from the mouth) -- 720 square miles and 427 mgd; the Suwanne River at Fargo (nearest station to the Florida state line) -- 1,260 square miles and 598 mgd; the Alapaha River at Statesville (nearest sdtation to Florida state line) -- 1,400 square miles and 598 mgd; the Withlacoochee River near Pinetta, Florida -- 2,220 square miles and 926 mgd; and the Ochlockonee River near Thomasville -- 550 square miles and 287 mgd. There is no regulation of these rivers within Georgia, excepting small mills and recreation ponds.[1]

The 20-year 1-day minimum flows of these lower Coastal Plain rivers range from zero to about 2% of the average flow. Urban and industrial water generally comes from deep wells, so these will affect the low flows only to the extent that waste waters from these uses may locally increase streamflows. There is no hydroelectric power usage of these rivers in Georgia.

Total water use by manufacturers in the Suwannee River basin, exclusive of Florida usages, in 1972 was estimated at 12.6 mgd, with only 1.7 mgd being supplied from municipal water systems. The other 10.9 mgd were obtained by 21 manufacturers from their own water sources. A pulp and paper plant in Lowndes County was the largest user, consumption being 8.750 mgd. In the Ochlockonee River basin, water use in manufacturing, excluding Florida usages, in 1962 was estimated to total 8.64 mgd, of which only 860,000 gallons per day were supplied from municipal water systems. Twelve manufacturers obtained the other 7.78 mgd from their own water sources. Mining operations in Decatur and Thomas counties, respectively, used 2.02 and 3.6 mgd. In the Satilla-St. Marys river basins, exclusive of the Florida part, water use by manufacturers in 1972 was estimated to total 113.338 mgd. This consumption was by 37 plants which obtained practically all of the water from their own sources. Pulp and paper plants in Camden and Glynn counties, respectively, used 35.0 and 70.9 mgd.[1,2,6]

Ground-Water Resources

When the moisture of cloud masses condenses and falls upon the land as rain or snow, some of this water runs off the land surface into ponds, lakes, creeks, and rivers and some of it enters the soil. Of the water that enters the soil, a part evaporates, a part is used by plants, and the rest percolates downward -- into the zone of saturation. This water is known as ground water, and the top surface of the zone of saturation is called the water table. Once in this zone, the water drains slowly toward springs or other natural outlets or towards wells. Water is a transient substance, always moving from one place to another. This movement is obvious in a flowing stream but not so obvious in the ground where it cannot be seen. Yet, the movement can be observed where water emerges from the ground to form springs that, in turn, form and supply many streams in Georgia. After a long period of drought, the only waters in the rivers and streams are those draining from the rocks.

The types of rocks and geologic structures of an area control the amount of water in the ground and the amount that will be yielded to wells. In Georgia, there are three distinct ground-water areas based on geology -- the Valley and Ridge province, the Piedmont and Blue Ridge provinces, and the Coastal Plain province (See map, Figure 4A).

In the Valley and Ridge province, the rocks are limestone, dolomite, marble, sandstone, quartzite, schist, and shale strata of Paleozoic age that have been folded and faulted by the earth movements that created the Appalachian Mountains.[11] In the Piedmont and Blue Ridge provinces, the rocks are igneous and metamorphic formations broadly classed as crystallines; they include granite, schist, gneiss, and slate. In the Coastal Plain are both consolidated rocks, such as limestone and sandstone, and unconsolidated sediments, such as sand, gravel, marl, and clay. All of these are much younger than the rocks northwest of the Fall Line and range from Upper Cretaceous to Recent.[11] Because of differences in physical characteristics, the rocks of the three areas vary widely in their capacities to store water and to yield such water to wells or streams.

<u>Valley and Ridge Province</u>

In the Valley and Ridge province, the rocks, with few exceptions, are low in permeability. Most important as aquifers (water-bearing rocks) are the limestones and dolomites. Ground water occurs in them in cracks and solution channels, some of

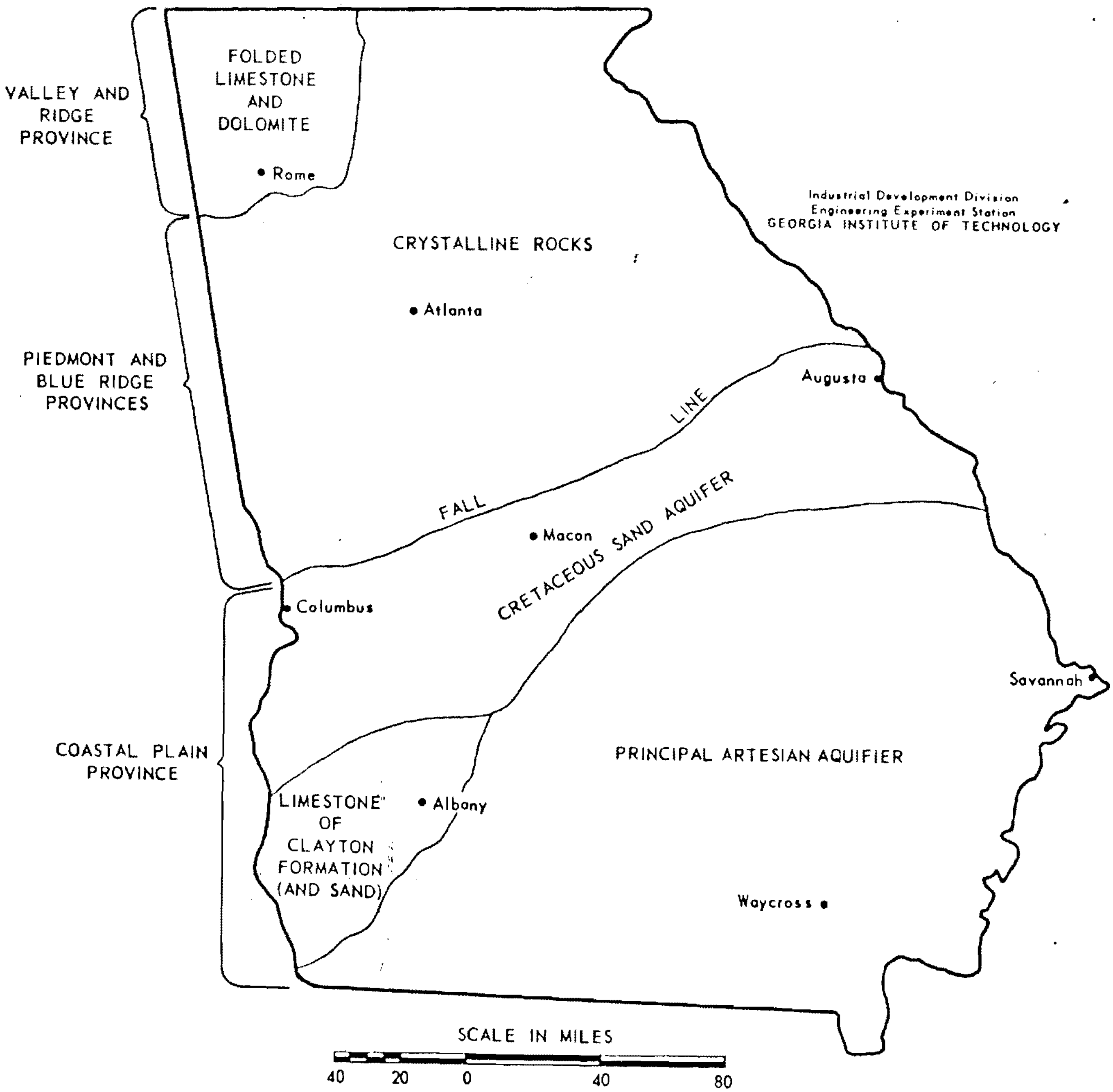

Figure 4A - The major aquifer areas of Georgia

Source - Reference 5.

which become sufficiently enlarged to form caverns. When these are penetrated by a well, large yields are obtained. The large springs of northwest Georgia flow from such solution channels and caverns in dolomite and limestone.[11] Sandstone and fractured quartzite also are favorable water producers. Drilled wells usually range from 5 to 10 inches in diameter and 30 to 500 feet in depth, with yields ranging from a few gallons per minute (gpm) to as much as 150 gpm and averaging about 17 gpm.[13]

Since most of this province is underlain by limestone and dolomite, much of the available ground water is hard. Total hardness ranges between 100 and 160 parts per million (ppm) in dolomite of the Knox group, between 132 and 188 ppm in the Newala limestone (essentially a dolomite) of the Knox group, and between 165 and 229 ppm in the Conasauga formation, Lowville and Moccasin limestones, and the Floyd shale.[2]

Dissolved solids ordinarily range from 100 to 400 ppm. A content of 300 ppm is considered high although, where circulation is poor, it may go to 1,200 ppm. Iron content may be objectionably high in some shale-derived waters.

Rome and Floyd County typify well the ground-water conditions of the Valley and Ridge province. In this county are numerous places where over a million gallons of water per day (mgd) could be developed either from springs or drilled wells, while in other areas, quantity supplies of water would be difficult to develop. The best potential source rocks in the county are limestone, dolomite, sandstone, fractured quartzite, and chert; the limestones and dolomites are the best producers, while shales are the poorest. Of wells dug into the "saprolite" (weathered rock), that from shale yield less than 1 to 3 gpm, while that from dolomite, sandstone and quartzitic rocks may yield 5 gpm up to 10 gpm from depths of 15 to 100 feet in wells of 3- to 4-foot diameters.[12]

The most important unweathered water-bearing rocks in Floyd County are dolomites of the Knox group and limestone beds in the Conasauga formation. Of lesser importance are the sandstones of the Rome formation and the limestone beds of the Floyd shale. The eastern third of the county is underlain by the Knox group, beginning in the southwest corner and extending northeast through Rome, then along the east side of the Oostanaula River to the county line; smaller masses of the Conasauga are in-folded with the Knox and are much faulted. The northern half of the remainder of the county is underlain by the Floyd shale and other rocks, and the southern half by the Conasauga.

Faults are another important structural control of ground water. In Floyd County, the greatest number of faults are found in the Rome area and southward to the county line and in the vicinity of Cave Spring, making this what is believed to be the area of greatest water potential, since these shattered and broken rocks in the fault zones are good storage reservoirs. Many Floyd County springs also issue along such zones. Wells drilled in fault zones usually yield much more water than those drilled in other parts of the county; yields range up to 1,500 gpm.[11]

Ground water is used in the county principally for municipal, industrial, and rural domestic supplies. Lindale Mills, Plant Hammond (steam power generating unit of Georgia Power Company), and the town of Cave Spring are the largest users of ground water.

This county, like the rest of the province, contains many large springs that yield from a few gallons per minute to over 1,000 gpm; elsewhere in the province flows range up to 20 mgd. The largest flows are from carbonate rocks (limestones and dolomites). Both artesian and non-artesian springs occur in the county.

Piedmont and Blue Ridge Provinces

Ground water occurs in the Piedmont and Blue Ridge provinces of Georgia in comparatively small quantities because the only open spaces in the rocks are either the fractures in the crystallines or the pores in the overlying unconsolidated mantle rock derived through the weathering and disintegration of the underlying crystalline bedrock. Thus, the ground water generally occurs under water-table conditions.

Most dug wells obtain water from the surface residuum and from cracks in the deeper unweathered bedrock. The largest yielding wells, therefore, are those that penetrate the more highly fractured rocks or the greater thickness of residuum in the lowland areas. Successful wells are more likely to be obtained along the valley bottoms than on ridgetops, and occasionally artesian flows occur, especially when the well is located near the bottom of a valley. Many dug wells yield less than 5 gpm, while drilled wells generally range from 10 to 20 gpm. In fairness to the region, however, it should be pointed out that wells yielding as much as 400 gpm have been drilled. Dug wells range from 30 to 90 feet in depth and 3 to 4 feet in diameter. Drilled wells, used mainly to supply cities and towns and small industrial plants, range from 4 to 12 inches in diameter and from 100 to 1,000 feet in depth, with the average being 200 feet.

Springs are common throughout the Piedmont-Blue Ridge area, and most are of the seepage type. Topographic location of springs is important here, since their seasonal flow is more affected by location than geologic conditions. For example, hillside springs tend to go dry in periods of drought, while those in valley bottom locations continue to flow throughout the year, often with little reduction in amount of total flow. While many springs of the Piedmont are small, some have substantial flows and constitute dependable sources of supply for domestic uses and for commercial and individual private water systems. This is also true for wells, particularly in the metropolitan Atlanta area, which is situated mainly on high ridges of the Piedmont Plateau. Here, well waters are used rather extensively by industries, especially for cooling purposes, despite the adequacy and nearness of rivers. In the aggregate, these spring and well usages are quite substantial; it is estimated that between 5 and 10 mgd are used by metropolitan Atlanta residents from springs and wells and about another 5 mgd by industries from wells. In the Atlanta area, most ground water is obtained within 400 feet of the land surface, although the Atlanta city well drilled downtown at Five Points in 1885 went 2,175 feet into the crystallines. Well yields here have ranged from less than 1 gpm to as much as 100 gpm, with the highest yields obtained in the valleys. Chemical quality is good, with most waters containing less than 200 ppm of dissolved solids. A few wells in Cobb County, however, are too saline for human use.[5]

The chemical quality of ground water varies more in the Piedmont-Blue Ridge area than in any other area of the state, due to the variation in rock types. Each type of rock produces a water that reflects the chemical composition of the host rock. Granite, quartzite, and other light-colored or "acid" rocks usually yield good quality water, low in dissolved solids. The dark-colored or "basic" rocks, such as hornblende gneiss, periodotite, and basaltic rocks, produce more highly mineralized water with objectionable amounts of iron. The iron content may be 2 ppm or more, while calcium and magnesium contents may run high, resulting in hard water.

Hardness may range from 18 to 1,000 ppm. Near Austell, in southern Cobb County, several wells and springs produce a highly mineralized water (high in sodium chloride), and one well produced water with 6,000 ppm of dissolved solids.

In a study of seven counties of central-east Georgia,[7] [3/] it is shown that dug wells in the residuum of the igneous and metamorphic rocks of the Piedmont part of the area generally extend to an average depth of about 30 feet and yield only a few gallons a minute. Drilled wells which go into the fractured bedrock below the zone of weathering have an average yield of about 20 gpm. At Warrenton, for example, three wells drilled to depths of 500, 632, and 1,200 feet in granite on upland areas (the least favorable water situation) had respective yields of 15, 30, and 38 gpm. At Camak, a 650-foot well ending in granite gneiss pumped only 9 gpm in the summer of 1946.[4]

Coastal Plain Province

The Coastal Plain province, which includes all of Georgia south of the Fall Line, not only is the largest single region in the state, but also contains the most productive aquifers. In this region, nearly all of the towns and cities, as well as many industries, derive their water supplies from ground-water sources. The sediments here consist of alternating beds of unconsolidated gravel, sand, clay marl, and silt and consolidated limestones and dolomites that dip generally southeastward. The region may be subdivided into three smaller areas, on the basis of the water-bearing character of the aquifers. These are (1) the Cretaceous sand aquifer area just south of the Fall Line

(Figure 5A); (2) the limestone-sand aquifer are in southwestern Georgia; and (3) the principal artesian (limestone) aquifer area in the southern and southeastern parts of the state, where limestones ranging in age from middle Eocene to early Miocene constitute one of the most productive aquifers in the United States. Drilled wells in the Coastal Plain range from 3 to 24 inches in diameter and in depth from 90 to 1,000 feet. Yields range from 5 to 2,000 gpm.[13]

Cretaceous Sand Aquifer. The Cretaceous sand aquifer, whose sands and gravels crop out in a belt 30 to 60 miles south of the Fall Line, yields 20 to 1,000 gpm, depending on the thickness of the water-bearing sands and method of well development. Since the sands range in thickness from 50 feet to 600 feet, thickening southward away from the Fall Line, wells drilled close to the Fall Line penetrate the least thickness of sand before hitting the underlying crystalline basement rocks. Consequently, these wells yield the least amount of water -- sometimes none at all. Where the maximum thickness of sand is penetrated, yields of 1,000 gpm may be obtained.

Water occurs in the Cretaceous sand aquifer under both water-table and artesian conditions. The former conditions prevail in the outcrop area of the sands, but as ground water moves down deep it becomes confined between clay beds above and the bedrock or clay beds below, thus creating artesian conditions. The principal water-bearing formations of the Cretaceous in this belt are, in ascending order, the Tuscaloosa formation, Cusseta sand, and the Providence sand. The residuum developed on the outcrop belt of the Cretaceous rocks yields water to both dug and drilled wells at relatively shallow depths. Springs commonly emerge along hillsides because the downward percolating waters are forced to move laterally by interlayered beds of clay or fine sandy clay. Few large springs are known; one that supplies the swimming pool at Fort Benning flows at a rate of 237 gpm.[2] Artesian conditions occur everywhere except in the vicinity of the Fall Line, where there are no impervious beds above the sands. Most flowing wells are in the valleys of tha larger streams, such as the Chattahoochee, Flint, Savannah, and other rivers. Flows from the Cretaceous sands occur from city wells at Perry, Montezuma, Dublin, and Toomsboro. In the more southerly parts of the state, the Cretaceous sands are so deep that their development is not economical. Wells ending in the Cretaceous range in depth from about 100 feet to over 1,500 feet, depending on which water-bearing sand is tapped, the Tuscaloosa being the deepest. A total of 1.5 mgd from two mills is withdrawn form this aquifer for pulp and paper needs.

In central-east Georgia, a study over a seven-county area indicates that wells in the Coastal Plain sediments draw water from the unconsolidated sand deposits and, in some places, from limestone. Water-bearing sands of the Tuscaloosa formation (Cretaceous) yield as much as 1,000 gallons a minute to individual wells in Jefferson and Burke counties. Another important aquifer in that area is the Barnwell formation (Eocene). Besides supplying many shallow wells, the Barnwell yields flowing wells in the lowland areas of Jefferson and Burke counties. Flowing wells at Bartow, Wadley, and Midville produce from the Barnwell horizon at 100- to 250-foot depths.[7]

Water from the Cretaceous sands is generally soft and low in dissolved solids. Hardness ranges from 5 to around 160 ppm, with both hardness and dissolved solids increasing with distance southeast of the Fall Line and with depth. The deeper sands in south Georgia reportedly yield salty water. Objectionable amounts of iron are locally present in waters of the Cretaceous aquifer.

Analyses of water from the Tuscaloosa formation collected from 13 points in central-each Georgia confirm that the dissolved mineral content is low.[7]

Ground water from the Barnwell formation varies in chemical character according to the geologic horizon from which it comes. Although thin limestone beds make up only a small part of the formation, many of the drilled wells tap solution channels in the limestone and, as a consequence, the water commonly has a hardness in excess of 140 ppm and a bicarbonate content of over 175 ppm. The sands in the formation yield water low in mineral content.

Limestone-Sand Aquifer. The Clayton limestone (Paleocene-Midway group) and the overlying Tuscahoma sand of the

Wilcox group (Eocene) form the limestone-sand aquifer and furnish most of the water. This aquifer underlies all of Calhoun and Early counties and parts of Clay, Randolph, Terrell, Seminole, Baker, Miller, and Dougherty counties.[2] The Clayton formation is 100 to 200 feet thick and some wells in it have yielded nearly 2,000 gpm. A few flowing wells have been developed in Calhoun County and in limited areas of Clay County. Several wells at Albany, Morgan, and Leary are reported to have flowed when first drilled. Water-table conditions occur throughout the area in the residuum developed in the land surface and in the limestone and sand aquifers, where they are unconfined. Shallow bored or dug wells, commonly 3 to 4 feet in diameter, go 50 to 70 feet into the residuum and obtain yields up to 10 gpm. Most domestic and drilled wells range from 3 to 6 inches in diameter, go to depths of 100 to 150 feet, and are capable of yielding 50 to 900 gpm.[2] In the area of the Clayton formation, many wells are drilled through the limestone and additional water is developed from underlying Cretaceous sands, thus giving water from two aquifers with considerably increased yield. Wells in the Albany area produce mainly from formation of Upper Cretaceous, Midway (Clayton), and Claiborne (Tallahatta) groups. The Ocala limestone, east of the Flint River in the Albany area, appears to be cavernous, with channel connections to the river that can cause pollution of wells in this formation when the river reaches flood stage.

Calhoun County, in the Dougherty Plain (Figure 5A), is representative of the conditions in the area of the sand-limestone

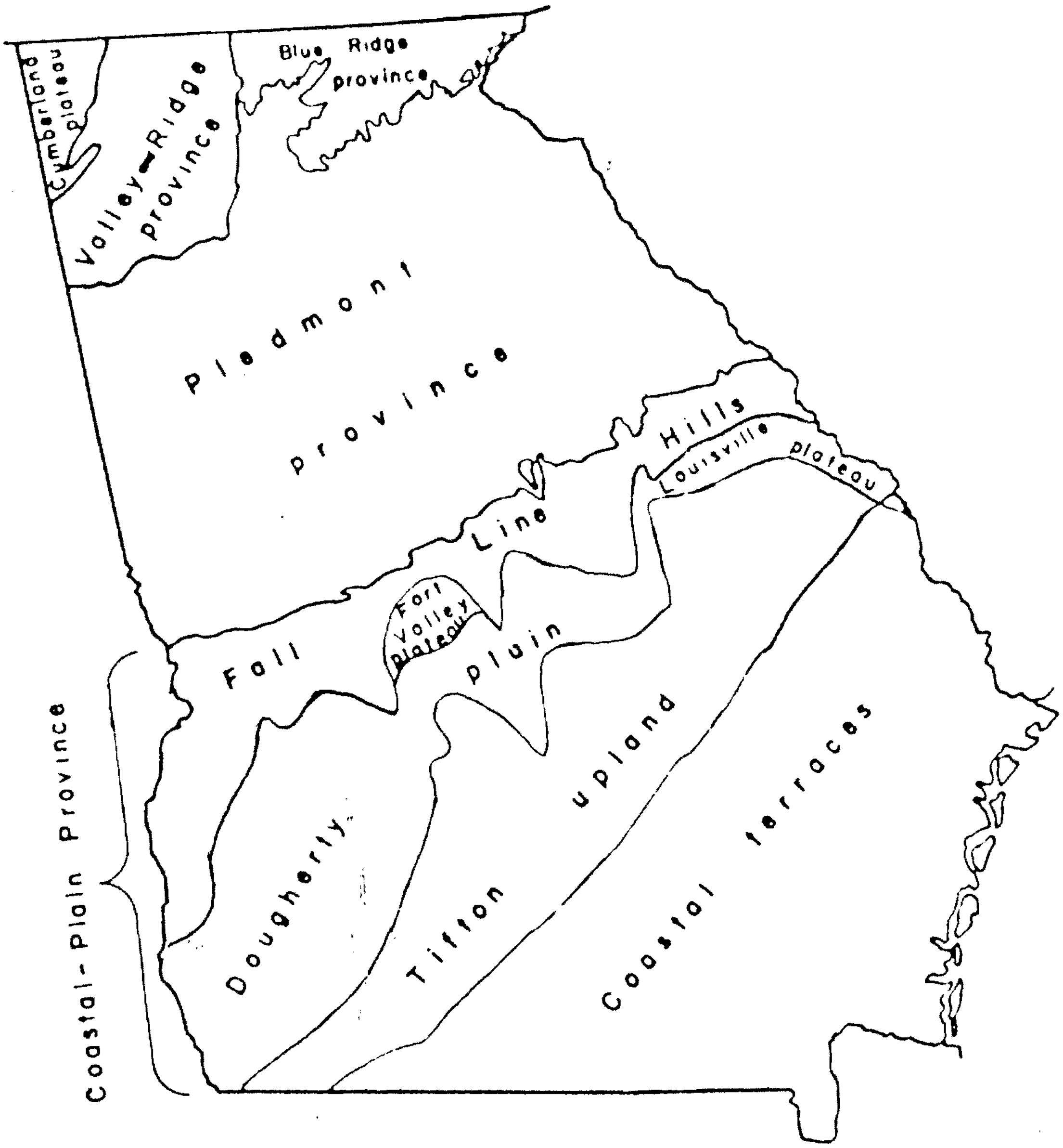

Figure 5A - Physiographic provinces of Georgia

Source - Reference 5

aquifer. Here the Ocala limestone (late Eocene) is the principal outcropping formation over more than two-thirds of the county, while the Claiborne group (middle Eocene) crops out only along major streams.[14] The Ocala, being at or near the surface, has developed many sinkholes which serve to recharge the limestone. Dug and drilled wells in the Ocala obtain water yields throughout the county that are believed to range up to several hundred gallons per minute; springs from the Ocala horizon supply much water to creeks in the county. Elsewhere in the Dougherty Plain, as in Mitchell County, 6- to 12-inch wells at only 200- to 300-foot depths obtain yields of at least 1,000 gpm from the Ocala limestone, and properly constructed wells might obtain up to 4,000 gpm.

The rocks of the Clairborne group, a major aquifer in this southwestern Georgia area, consist of a coquina limestone and a massive sand in the lower part of the group, both of which yield up to 1,200 gpm to wells in Crisp and Dougherty counties. In Calhoun County, however, the yields range only to about 500 gpm; yields of 300 gpm can be obtained at depths not exceeding 300 feet. The Wilcox, below the Clairborne, is not an important aquifer in this county.

The underlying Clayton formation (Paleocene-Midway) consists of a coarsegrained sand at the top, a thick bed of porous limestone in the middle, and a basal coarse-grained sand. The total formation ranges between 200 and 300 feet in thickness.

This is the main source of ground water for municipal use in Calhoun County, and wells drilled between the 515- and 556-foot depths yield from 200 to 340 gpm, with some wells being artesian.[5]

Flowing wells of up to 300 gpm also are obtainable from the deeper rocks of the Upper Cretaceous series, reached at depths between 650 and 800 feet. Such fresh-water bearing rocks extend to depths of at least 1,000 feet and possibly close to 2,000 feet. If the several aquifers that are encountered in a single well are drilled to the greater depths, the combined yield of water may reach 1,000 gpm.[5]

Water from these Tertiary rocks (Ocala of the Jackson group, the Claiborne group, and Clayton of the Midway group) in Calhoun County is of the calcium-bicarbonate type and is moderately hard to hard, containing 200 ppm or less of idssolved solids. Waters from the lower part of the Clayton and from the Upper Cretaceous are usually of the sodium carbonate type. Deep oil-test wells, drilled in this county to depths of 1,200 to 2,800 feet, have encountered salt water -- some as saline as sea water.[15]

Waters from the limestone-sand aquifer are usually of good quality, ranging from soft to hard; iron contents are low, and dissolved solids range from 108 to 218 ppm.

Principal Artesian Aquifer. About two-thirds of Georgia's Coastal Plain is underlain by the principal artesian aquifer, as are parts of South Carolina and Florida. Limestones ranging in age from middle Eocene to early Miocene constitute this aquifer. In ascending order, these limestones are the Ocala (late Eocene), the Suwannee (Oligocene), and the Tampa (Miocene). They generally act as a single hydrologic unit, and together they constitute the most important single aquifer in the state. This aquifer provided the water needs of 50% of the mills visited during this project. They withdrew a total of over 214 mgd.

This aquifer furnishes nearly 70% of the ground water used in Georgia, including the municipal and industrial demands at Savannah, Jesup, Brunswick, St. Marys, Waycross, Valdosta, and many other cities and towns.[2] In 1979, Brunswick was using over 100 mgd, largest ground-water withdrawal of cities in the Coastal Plain. Ninety percent of the Brunswick water was used by three industrial plants. Of these, Brunswick Pulp and Paper Company, with six wells averaging 44.7 mgd, was the largest single user in Glynn County, as well as in the Coastal Plain area. The second largest user, Hercules Powder Company, averaged 60.3 mgd, and the third largest, Solvay Process Division of Allied Chemical Corporation, used 10.2 mgd. In this same period, other ground-water withdrawals were 60 mgd at Savannah, 42 to 45 mgd at Jesup, and 26.6 mgd at St. Marys.[2,5]

In 1979, it was estimated that over 500 mgd of ground water was being discharged in the 10 coastal counties of Brantley, Camden, Charlton, Glynn, Liberty, Long, McIntosh, Wayne, Bryan, and Chatham.

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FOOTNOTES

1/ Six of these are Georgia Power Company's Langdale, Riverview, Barlett's Ferry, Goat Rock, Oliver, and North Highland dams, downstream in that order from West Point to near Columbus. City Mills and Eagle & Phenix are the other two dams, operated at Columbus by textile companies.

2/ On the basis of legal interpretation, minimum flow below Buford Dam is maintained at 650 cfs.

3/ Includes Burke, Columbia, Glascock, Jefferson, McDuffie, Richmond, and Warren counties.

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