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This study was financed by the Regional Economic Development Office of U.S. AID in Bangkok and includes a literature review of about 200 articles on kenaf for pulp and paper. The agro-economic sections of the report include a plan for supplying kenaf whole stalk and bast ribbon to a mill in the Mekong Basin. Also included are estimates of the costs of the fibrous raw materials. Future agro-economic studies of Kenaf (Hibiscus sabsariffa and Hibiscus cannabinus) for paper pulp are outlined.

Out of six primary sites in the four countries in the Lower Mekong Basin, two in Northeastern Thailand show commercial possibilities. An analysis of pulp markets, raw material costs, manufacturing costs, and capital investment requirements indicates that a kenaf bleached soda or sulfate market pulp mill would be economically viable and beneficial to the nation. A recommendation is made that full-scale experimental production of kenaf pulps be undertaken in existing bagasse mills to assure prior market acceptance before a mill is built. Also discussed are additional possibilities for using kenaf for production of newsprint and composition panel boards.

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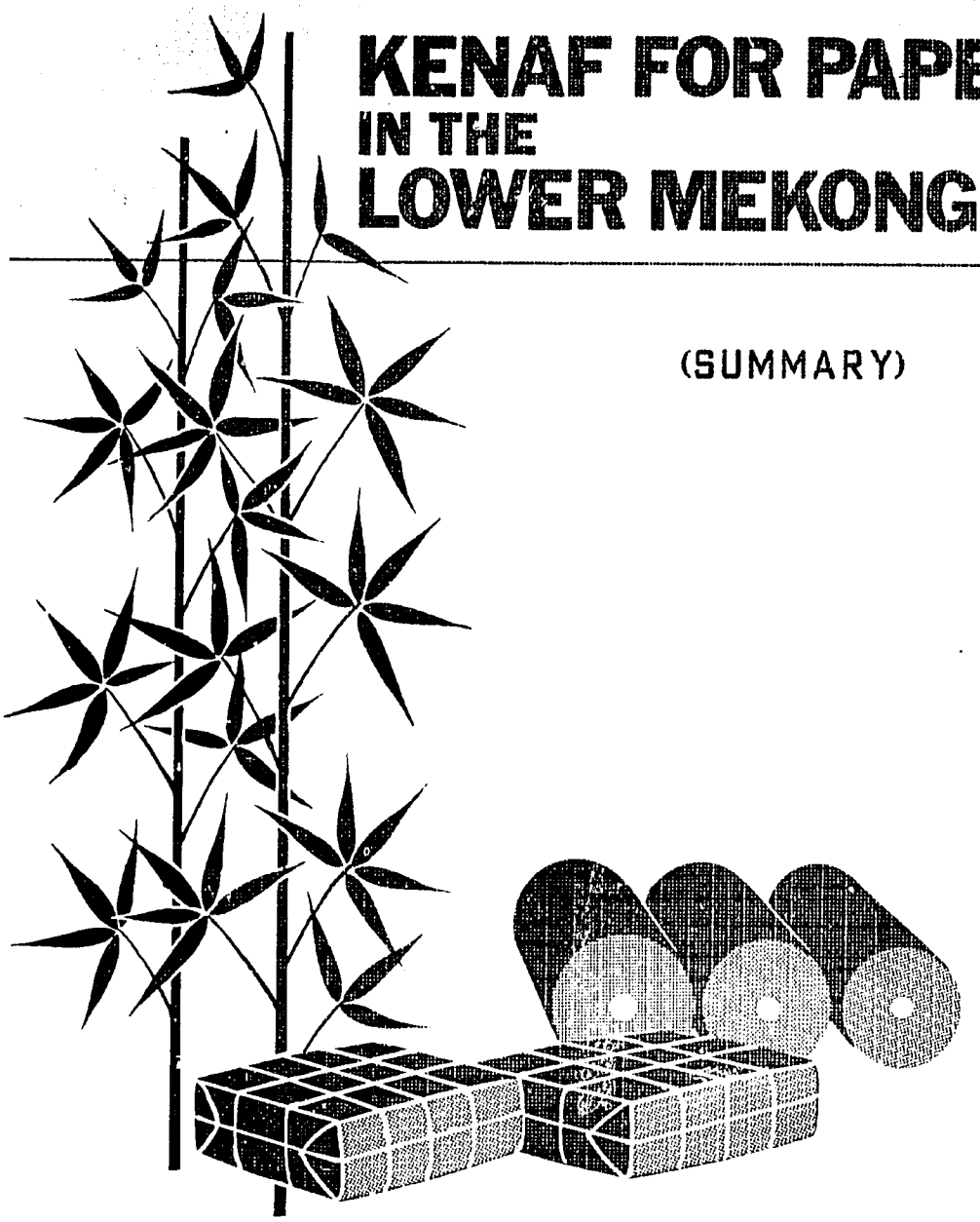

A Pre-Feasibility Study Prepared for

THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN

By

JOSEPH E. ATCHISON CONSULTANTS, INC.
In Association with
AGRI-BUSINESS CONSULTANTS

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KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN

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A pre-feasibility study on kenaf for pulp and paper prepared for The Committee for Coordination of Investigations of the Lower Mekong Basin and financed by the Regional Economic Development Office of U.S. A.I.D. in Bangkok, Thailand. The review covers about two hundred articles on kenaf for pulp and paper. The agro-economic sections include a plan for supplying kenaf whole stalk and bast ribbon, to a mill in the Mekong Basin area together with estimates of the costs for the fibrous raw materials. Future agro-economic studies on kenaf (Hibiscus sabdariffa and H. cannabinus) for paper pulp are outlined. Out of six primary sites in the four reparian countries, two in Northeastern Thailand show commercial possibilities. A study of pulp markets, the costs for raw materials and for manufacturing pulp, and capital investment required indicates that a kenaf bleached soda or sulfate market pulp mill would be economically viable and of great national benefits. Recommendations have been made that full scale experimental production of kenaf pulps be undertaken in existing bagasse mills to assure prior market acceptance before a mill is built. Additional possibilities for utilization of kenaf for production of newsprint and composition panel boards are also discussed.

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in the

LOWER MEKONG BASIN

A Pre-Feasibility Study
Prepared for
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of the Lower Mekong Basin
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by

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KENAF FOR PAPER PULP

in the

LOWER MEKONG BASIN

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LIST OF ABBREVIATIONS

AD	Air Dry (10% Moisture Content)
ADMT	Air Dry Metric Ton
ASRCT	Applied Scientific Research Corporation of Thailand
฿	Baht
CdE	A Bleaching Sequence of Chlorination & Chlorine Dioxide - Alkaline Extraction
CED	A Bleaching Sequence of Chlorination - Alkaline Extraction - Chlorine Dioxide
CEDED	A Bleaching Sequence of Chlorination - Alkaline Extraction - Chlorine Dioxide - Alkaline Extraction - Chlorine Dioxide
CdEHD	A Bleaching Sequence of Chlorination & Chlorine Dioxide - Alkaline Extraction - Hypochlorite - Chlorine Dioxide
CEH	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite
CEHD	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite - Chlorine Dioxide
CEHEH	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite - Alkaline Extraction - Hypochlorite
CEHH	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite - Hypochlorite
CSF	Canadian Standard Freeness Tester
CSIRO	Commonwealth Scientific and Industrial Research Organization
FAO	Food & Agriculture Organization of the United Nations
FD	Field Dry (12½% Moisture Content)

FDMT	Field Dry Metric Ton
GE	General Electric Brightness Tester (TAPPI Standard T 217 m 48)
H. cannabinus	Hibicus cannabinus L. (Western Hemisphere Kenaf)
H. sabdariffa	Hibiscus sabdariffa var. altissima (South Asian Kenaf)
M-C (Process)	Mechano-Chemical (Process)
NRRL	Northern Regional Research Laboratory of the U.S. Department of Agriculture
OD	Oven Dry
ODMT	Oven Dry Metric Ton
PFI	(Papir Industriens Forskninsinstitut) Mill - A Laboratory Refiner for Pulp
$	United States Dollar
S.-R.	Schopper-Riegler
TAPPI	Technical Association of the Pulp and Paper Industry
tpd.	Tons per Day
tpy.	Tons per Year
USDA	United States Department of Agriculture

UNITS OF MEASURE:

mm.	Millimeter
cm.	Centimeter
cc.	Cubic Centimeter
m.	Meter

km.	Kilometer
in.	Inch
ft.	Foot
sq.m.	Square Meter
sq.ft.	Square Foot
ha.	Hectare (1 ha. = 2.5 Acres = 6.25 Rai Approx.)
cu.m.	Cubic Meter
cu.ft.	Cubic Foot
g.	Gram
kg.	Kilogram
ml.	Milliliter
^{o}C	Degree Centigrade
^{o}F	Degree Fahrenheit

- Objectives and Scope of the Kenaf for Paper Pulp Pre-Feasibility Study

There are five major objectives of this Pre-Feasibility Study of the techno-economic aspects for manufacturing paper pulp from kenaf. The first is to make a practical and realistic appraisal of the extensive technical work on kenaf fiber preparation and pulping that has been carried on in all parts of the world. The development work on the pulping of this particular fibrous raw material also has to be related to the conventional manufacturing processes currently used to produce pulp from all types of fibrous raw materials. Particular consideration has to be given to employing processes which are already in widespread use by mills pulping other nonwood plant fibers.

The scope of a Pre-Feasibility Study does not allow a detailed technical investigation and financial analysis of all the possibilities for manufacturing the entire spectrum of grades of pulps and papers which could be made from kenaf. Therefore, the Consultants have had to prejudge, based on their experience and the overall picture the situation presents, which of the several technical alternatives would be the most logical to study and would have the best potential for planning a model mill that would be economically viable and would fulfill the needs of the Mekong Basin countries for the foreseeable future.

The agro-economic portion of this Study will summarize the history of kenaf and allied fibers in the riparian countries, examine the actual and potential kenaf production areas, and discuss the production, availability, procurement, and costs of the whole stalk and bast ribbon of kenaf for pulping. In parallel with that, another short range objective will be to develop the technical parameters of a model project to manufacture unbleached and bleached kenaf chemical pulps of types that could replace the hardwood and softwood chemical pulps that are presently imported by the existing paper industry in the Mekong Basin countries.

Manufacturing a range of pulps is made possible by the fact that kenaf bast ribbon chemical pulp has strength properties for papermaking comparable to world market sulfate pulps from major softwood species and whole stalk pulp is quite similar to hardwood sulfate and softwood sulfite pulps. This maximum versatility of pulp product types from a single fibrous raw material is one of the most favorable attributes possessed by kenaf as compared to other fibrous raw materials used for papermaking.

A third and long range objective of this Study is to show the need and potential for eventually manufacturing several grades of paper in the project mill with kenaf as the major fibrous raw material. This would be done when the market could absorb the paper grades without an abrupt and disruptive shutdown of existing small paper mills. Proper planning of the model for the initial project takes into consideration this very important requirement for eventual and gradual transition into paper manufacture. This objective can be met in later years at a minimum additional investment by the initial choice of a pulp machine of the fourdrinier, can-dryer type that can subsequently be modified to run several major grades of paper as well as market pulp for the other mills in the Mekong riparian countries.

A fourth major objective of this Study is to estimate the investment required, the operating cost, and the economic viability of a mill initially designed to meet the prior objectives. This requires consideration of potential sites with adequate fibrous raw material supplies of both kenaf whole stalk and bast ribbon and recommendation of the most advantageous locations with existing infrastructure for a pulp mill to serve the future paper requirements and the national interests of the Mekong Basin countries.

The fifth major objective of the pulp/paper part of this Study is to develop a course of action for detailed technical studies on kenaf fiber preparation and pulping that could be recommended as being worthy of future financial support by the Mekong Committee and/or other Governmental or international or private agencies. Such a program would take into consideration all the work that has already been carried on in various laboratories and mills in the world and would attempt to coordinate, influence, and direct future investigations by all scientists working on kenaf for paper pulp. The use of substantial pilot plant and laboratory facilities and a pulp/paper mill already in Thailand would be one central item in this planning and Study. An important advantage of utilizing these existing facilities for commercial trials would be to speed by several years the finalization of present technical investigations and the establishment of the major parameters necessary for the development of a successful commercial process for utilizing kenaf for paper pulp as outlined on a theoretical basis for the model mill in this Study.

- Acknowledgements

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Economic and Social Studies Division
Mekong Committee

Mr. Phot Inganinanda, Director
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Ministry of Commerce

Mr. Vichit Piyarom, Deputy Director
Division of Land Settlements
Public Welfare Department

Dr. Thomas L. Irving, Director
Mr. Louis A. Cohen, Deputy Director
Mr. James F. Hanks, Mekong Project Officer
Regional Economic Development Office
American Embassy

To the above and the officials listed in Annex IV the Consultants tender their sincere appreciation.

1. SYNOPSIS

This Pre-Feasibility Study discusses the establishment of a paper pulp industry in the Lower Mekong Basin using kenaf as raw material and aimed at providing a steady source of income to a substantial number of small farmers - some 20,000 families for each pulp mill unit - and at contributing towards the substitution of the paper pulp presently imported into the four riparian countries with domestically produced pulp.

Six primary potential project pulp mill sites have been located in the Basin area and, for Study purposes, a project mill unit capacity of 70,000 ADMT/year is assumed, requiring some 25,000 ha. and 80,000 ha. of South Asian Kenaf (Hibiscus sabdariffa)planting area annually for a whole stalk kenaf and kenaf bast ribbon pulp mill respectively, and about one-half that planting area for Western Hemisphere Kenaf (Hibiscus cannabinus)which, however, needs somewhat better soils.

Kenaf and allied fibers have, historically, been successfully produced in the Lower Mekong Basin countries, with Northeast Thailand being the world's largest kenaf production area with annual small holder plantings fluctuating between some 300,000 and 500,000 ha., and Study investigations show that ample kenaf for paper pulp supplies would readily become available, within economic transportation distance, for potential project mills at any one of the six primary sites, where mills at Site II near Ubon Ratchathani in Northeast Thailand and at Site III near Stung Treng in Cambodia would assume a regional character in that each could call upon raw material supplies from a three-country area.

Based upon a detailed Study evaluation of standard small holder kenaf textile fiber production methods in the Basin area (which involves stalk and bast ribbon water retting not required for kenaf for paper pulp production) and of the results of experimental and, so far, only limited kenaf for paper pulp pilot work carried out in the U.S.A , Europe and South Asia, it is concluded that, from the production and supply point of view, adequate quantities of kenaf whole stalk, chopped stalk and bast ribbon could readily be made available to the kenaf project pulp mills discussed herein. The raw material procurement areas within economic transportation distance and the procurement methods are discussed in depth for kenaf whole stalks for Mill Site I north of Khon Kaen and for kenaf bast ribbon for Mill Site II east of Ubon Rathchathani respectively, with the conclusions reached obviously applicable interchangeably for both sites and preference being given to procurement through the established kenaf fiber

baling and trading channels rather than through a mill operated organization and with strong encouragement being extended to the rapidly expanding participation of farmers organizations in the raw material supply.

The Study further recommends the establishment of one or more pulp mill operated kenaf Demonstration Farms to serve as extension services, demonstration and, possibly, input supply centers to the small holder kenaf producers in their respective areas of coverage.

The estimated prices payable by the project pulp mill(s) for kenaf pulping raw materials are calculated on the basis of farm revenues from traditional kenaf textile fiber production in Northeast Thailand and of such revenues realized from other crops that can be grown on land suitable for kenaf for paper pulp production. These prices, delivered local collection center, are then established at US$24.90/FDMT for kenaf whole stalks or chopped stalks and at US$96.75/FDMT for kenaf bast ribbon. After the addition of the estimated purchasing and handling costs, the delivered mill yard gate cost is then calculated at US$30.00/FDMT for kenaf whole stalks, at US$29.50/FDMT for kenaf chopped stalks, and at US$104.00/FDMT for kenaf bast ribbons.

Technical studies on kenaf for paper pulp started about 1950 with only four significant research investigations published by 1960. Since that time, however, and particularly in the last five years, there has been a quantum jump to a total of almost two hundred publications on kenaf pulping research from laboratories in many parts of the world. The information also includes a number of studies on the harvesting, transporting, and storing of kenaf for paper pulp and the effects of the storage conditions on the resultant pulp qualities and yields.

Analysis of the pulp strength test data from these reports has shown that the bast ribbon soda or sulfate (kraft) pulps are very similar in papermaking properties to the highest quality softwood sulfate pulps on the market. The kenaf whole stalk pulp is quite similar to softwood sulfite pulp and the hardwood sulfate pulps that are widely used in printing and writing papers. The kenaf woody core material pulp has lower tearing strength than the wood pulps and also the nonwood plant fiber bagasse and straw pulps manufactured commercially. Because of the low strength properties and the adverse drainage characteristics of its chemical pulps, the woody core material pulp would not be considered a suitable product for the Mekong Basin mill. It would, however, possibly serve as a low cost fuel and a source of fibrous raw material for the manufacture of newsprint, particleboard, or chemical by-products.

In this Study, a review of this technical information on pulping has been made. From the data, the parameters have been developed for the design of a paper pulp mill for the manufacture of kenaf whole stalk or bast ribbon bleached chemical pulp. A mill for pulping kenaf would be identical in design to a bagasse or straw pulp mill, with the exception of the equipment for fiberizing the kenaf for the wet cleaning process.

Consideration has been given to the cost comparisons for fiber from kenaf whole stalk with bagasse and hardwoods and bast ribbon with softwoods. As most of the cost of bagasse for pulp is based on replacing it with other fuel at the sugar mill, the availability of lignite in Thailand at a very favorable low price makes bagasse a much lower cost fibrous raw material than kenaf whole stalk. The mixed tropical hardwood sulfate pulps that will eventually be produced in large pulp mills in the South Pacific-Asia area will also have the competitive advantages of low wood costs as well as "economy of size" as compared to the kenaf whole stalk pulp mill considered in this Study.

In comparison to softwood bleached sulfate market pulps, the kenaf bast ribbon pulp would have a much higher fibrous raw material cost. An economic analysis has been made of the possibilities for mechanical separation of the bast ribbon at the pulp mill so that the woody core material can be used as fuel, pulp for newsprint, or for particleboard and the cost of the bast ribbon fraction could thereby be reduced.

Potential markets for kenaf pulp have been estimated, based on information concerning the importation of paper and paperboard and the productive capacities and pulp usages by paper mills in the Mekong riparian countries. Even with an anticipated low growth rate of only 3.5 percent annually in paper and paperboard consumption, it appears that, by 1980, the kenaf pulp could be absorbed by the local market and exports would not be necessary. However, if a large integrated pulp/paper mill were to be built using bamboo and bagasse in Thailand, a serious competitive constraint for local sales could develop for the kenaf pulp mill and a delay of another 5 to 10 years in building it might be required, unless the kenaf pulp is for export.

The project model mill has been based on a design for producing 200 ADMT/day or 70,000 ADMT/year of kenaf bleached soda or sulfate whole stalk or bast ribbon pulp. This is considered a minimum size of market pulp mill that would be economically viable. The two locations in the Mekong Basin judged to be the most suited for the pulp mill are in Northeast Thailand at Ubon Ratchathani and the Ubolratana Resettlement Area north of Khon Kaen. There are adequate sites and much of the required infrastructure which favor these locations.

In this Study, plans for the entire mill process and its operating parameters have been established. This includes the handling, storage, reclaiming, fiberizing, and wet cleaning of field dried baled kenaf received at the pulp mill. The problems of environmental control are discussed and a program to minimize pollution has been developed.

Detailed estimates have been made of production costs, capital requirements, profitability, and economic values of the project mill. The total capital requirements, including the entire mill, housing community, working capital, and all other costs for establishing the enterprise have been estimated to be US$81,284,000 of which 33.87 percent would be local funds provided for all local expenditures and the rest would be foreign loans covering the foreign costs for the "turn key" mill.

The 15-year financial projection for the kenaf whole stalk bleached pulp mill shows that, if the product were sold delivered in Thailand for US$450.00/ADMT, the present competitive price for imported hardwood bleached sulfate pulp, the project would have very good economic viability. The payback period would be 7.55 years. The average annual return on the basis of total investment would be 14.1 percent and on the basis of owners' equity would be 35 percent or 16.9 percent by the discounted cash flow method.

Because of its higher fibrous raw material cost, the kenaf bast ribbon pulp mill product would have to sell for US$600.00/ADMT to achieve an equivalent economic viability with that of the whole stalk project. As this is about US$130.00/ADMT above the present price in Thailand for imported softwood bleached sulfate pulp with which the kenaf ribbon pulp would compete, tariff protection for the local mill's product would require imposition of a 28 percent duty on imported softwood pulp.

The economic values of the kenaf paper project to the Mekong Basin area would be considerable. Many new industrial jobs would be created and the increase in agricultural production of the kenaf would furnish a large amount of new income to that sector. The financial analysis shows that, over the projection period, there would be an average net saving of foreign exchange of US$23,153,000 annually.

The Study also details the required future developmental activities deemed necessary prior to large-scale kenaf based pulp and paper mill project implementation. From the raw material supply point of view, these will have to concentrate on yield improvement through variety selection and improved cultural practices, and on the establishment of optimum specific kenaf for paper pulp harvesting and field processing

methods, these aims to be achieved through the implementation of a combined research and pilot scale program, preferably organized along Demonstration Farm lines.

In the pulp/paper portion of this Study, it is pointed out that commercial production of kenaf pulps has not materialized as originally anticipated. It has been concluded that the production of commercial quantities of kenaf pulps for market and papermaking trials would be more meaningful than further laboratory research, because there is already sufficient technical information on the pulping of kenaf and other nonwood plant fibers to serve as the design basis for a mill.

However, in parallel with the commercial production investigations, useful research on kenaf could be carried on in certain areas that have not been thoroughly explored. This would cover comparative pulping evaluations of kenaf samples from the agro-economic research program, the comparative evaluation of bulk versus bale storage systems, the development of a system for separating bast ribbon from woody core material at the pulp mill, the separation of the two types of fibers by fractionation after pulping, and the manufacture of newsprint and particleboard from kenaf.

In a continuing investigation which might be made before a kenaf pulp mill is implemented, the agro-economic studies would be best carried out at or near one of the primary sites that have been located in this Study. Because of this, the logical choice for Executing Agency for further studies on kenaf paperpulp would be the Committee for Coordination of Investigations of the Lower Mekong Basin. Possible sources of supporting grants for further studies would be the United Nations Development Programme, the World Bank and Asian Development Bank, as well as Governments of the riparian countries.

The technical and management services of an independent consulting firm, experienced with nonwood plant fiber pulping, to conduct the commercial pulping and papermaking trials and marketing tests are recommended. Such investigations could possibly be carried out at the Siam Kraft Paper Co., Ltd. in Thailand and/or the United Pulp and Paper Co. in the Philippines. The laboratory facilities of these mills would be utilized for the production runs. In addition, laboratory investigations in conjunction with the future kenaf agro-economic studies could be carried on by the Research Division of the Department of Science of the Ministry of Industry in Thailand.

2. SUMMARY

CHAPTER I - THE USE OF KENAF FOR PULP AND PAPER

1. Early History of Kenaf as a Raw Material for Pulp and Paper (1950-1960)

Although used for food, animal forage, and fiber for many centuries, the history of kenaf for paper pulp begins about 1950. This is surprising when a similar fiber, jute in the form of bast fiber textile wastes, was used in earlier years for making high strength papers in the United States and elsewhere. Prior to 1960, there were only four or five technical reports relating to the pulping of kenaf. Most of these, published by the United States Department of Agriculture (USDA), were based on laboratory tests comparing kenaf with the pulping qualities of nonwood plant fibers already in extensive use. The interest in kenaf at that time was thus essentially that of a laboratory curiosity.

2. A Review of Worldwide Experience in Harvesting, Transporting, Storing and Pulping of Whole Kenaf and Kenaf Components for Paper Pulp

2.1. Introduction

Little has been published on harvesting, bulk transport, and storage of kenaf for paper pulp other than by the USDA. Investigations by most of the others have mainly been based on the assumption that field dried kenaf, either whole stalk or bast ribbons, would be baled or bundled and delivered to the pulp mill. Lack of information contributed some years ago to the failure to develop commercial production of kenaf in Florida by the USDA and also in several Latin American countries. The USDA, recognizing the pressing need for agro-economic studies on kenaf for paper pulp, has continued its research in this area.

2.2. Harvesting the Bast Fiber in Kenaf for Paper Pulp

The traditional procedure for the hand harvesting and retting of kenaf and similar bast fibers for textiles and cordage is well known. During the retting process, the bast fiber is freed of its incrusting organic materials which are to a great extent water soluble and degradable. At this point, the wet cleaned fiber would also make an ideal pulping material for the manufacture of papers with high physical strength characteristics. The laborious retting, however, is not only costly, but is not needed for pulp manufacture and can be eliminated entirely.

Wet cleaning of the bast ribbons separated by the farmer can be carried out much more easily and economically at the pulp mill than at the farm by retting. This would save about 40 to 45 percent of the total time the farmer now spends in growing the kenaf and preparing the bast fiber for the textile mill.

Even more of the farmer's time would be saved by also eliminating his ribboning operation which would then be carried out on whole stalk kenaf with suitable processes at the pulp mill. Efforts by the USDA to develop complicated combined harvesting and decorticating machines suitable for subsequent textile fiber production were not successful and their development was dropped when funds ran out. The basic hand-fed, mechanical ribboning machines that have been successfully used in commercial operations on kenaf can nevertheless be expected to suffice in moderate-cost labor areas for producing bast ribbon at the farm level for a pulp mill. Various companies and other organizations are continuing the development work on ribboning machines or processes.

Although mechanization of kenaf ribbon production at the farm level is necessary or advantageous in some locations, this will not be required under the present agricultural system in the Mekong Basin before a pulp mill can be planned.

2.3. Harvesting Whole Stalk Kenaf for Paper Pulp

For the Mekong Basin area, the traditional procedure for hand harvesting kenaf whole stalk before retting it can be used in preparing field dried material for collection, baling, and shipment to the projected pulp mill.

Field studies in the United States by the USDA and others for utilizing whole stalk kenaf for paper pulp have included mechanical harvesting, transportation, bulk storage, and handling because hand harvesting would be out of the question.

At the First Conference on Kenaf for Pulp at Gainesville, Florida, in 1967, some very significant studies were reported. One study covered mechanized forage harvesting and storage of green kenaf ensilage on a semi-commercial scale in connection with a full scale pulping trial at Hudson Pulp and Paper Company.

By a 1975 study by the USDA it was recognized that forage harvesting of field dried stalks requires a heavy expenditure for energy and that the systems for handling and storing green kenaf appear to be too expensive to be applicable at the present time. It was indicated that much continued research would be required to develop satisfactory and economical equipment for the mechanized harvesting and handling of kenaf for paper pulp.

2.4. Transporting Whole Stalk Kenaf for Paper Pulp

Field work done on transporting whole stalk kenaf in bulk form has not been very satisfactory. The methods used were expedients and can not be compared to the sophisticated and successful systems that have been developed for the mechanized harvesting and bulk transportation of sugar cane which can readily be applied to kenaf.

Economists and agronomists of the USDA have published studies on means and costs for bulk transportation of chopped kenaf that would be applicable where labor costs are high and large farms could be developed. However, such mechanized systems are not considered to be necessary for producing the kenaf for a pulp mill project in the Mekong Basin under existing conditions. Hand harvesting the field dried whole stalk or ribboning the green stalk and field drying the bast ribbon before baling and transporting the kenaf to the pulp mill are expected to be economical systems that will be satisfactory for the production of pulp.

2.5. The Storage of Kenaf for Paper Pulp

2.5.1. Introduction

Since kenaf is an annual crop, it would have an important advantage for pulp mills in developing nations lacking adequate supplies of standing pulpwood. The generation or more required to establish a forest plantation and the long term capital requirements of forestry can be avoided by using kenaf.

However, as compared to tress which can be "stored" standing and growing in the forest until needed, kenaf, which must be harvested annually, will have to be stored for as much as eight months or longer between harvests. It is very important that storage conditions preserve the physical strength properties of the pulps and prevent an excessive loss of fiber suitable for papermaking. Fortunately, the storage of other nonwood plant fibers, such as bagasse for papermaking, has been successful for many years so that it is anticipated that kenaf can be handled similarly.

In the case of whole stalk kenaf, as opposed to kenaf bast fiber material, there can actually be storage for some months by leaving the stalks standing in the field after being frost killed (in the temperate zone) or after maturity resulting from photoperiodism (in the tropics). Although the highest stem weight yield was found to result when the harvest was immediately before or after frost, studies by the USDA have shown that the decrease in yield of total stem weight for several months after that time resulted from a loss of water soluble and fermentable sugars, gums, and other nonfibrous materials. This is due to leaching by rain of the stalks standing in the field or other physical and chemical changes which take place in the kenaf. During this period, the cellulose, pentosan, and lignin percentages actually increase, and it was determined that the kenaf can be left standing in the field for at least two months after maturity before there is any loss of yield or quality of fiber for papermaking.

2.5.2. Bulk Storage of Kenaf

Studies on systems for bulk storage of green whole stalk kenaf and their effects upon pulp properties were started by the USDA in 1965. Storing the green kenaf as ensilage for several months and then wet cleaning the fiber before pulping were found to be satisfactory procedures. The commercial pulping trials on kenaf made at Hudson Pulp and Paper Company about that same time used whole stalk silage to which molasses had been added in an attempt to simulate the conditions for lacto-bacteria formation which exist in the Ritter storage system for hydraulically piled bagasse where anaerobic conditions prevail and complete papermaking fiber preservation results.

The USDA also determined that, when chopped green kenaf was stored in large piles at a moisture content above 35 percent, the temperature of the kenaf rose and deterioration resulted. A number of storage procedures were evaluated and found to be suitable for kenaf. Storage of green kenaf silage under anaerobic conditions such as in a silo or pit, submerged in water, or in a plastic cocoon was found to furnish adequate preservation. Artificial drying and storage under cover was successful but uneconomical. Daily immersion of samples in water followed by exposure to aerobic conditions resulted in deterioration of the kenaf, whereas storage submerged in water preserved it and improved the pulping characteristics by removing much of the pith and parenchyma cells and the soluble sugars and gums.

USDA studies also showed that dejuicing the green kenaf and also removing the foliage before storage improved the resultant whole stalk pulp quality. Wet cleaning of the stored fiber before pulping was

advantageous in all cases; it lowered the chemicals required for cooking and bleaching and produced a stronger pulp with better drainage rates than in tests where wet cleaning was not done.

The test data by the USDA indicated, however, that bale storage of field dried kenaf, as would be used in the Mekong project pulp mill, would be just as suitable as the best of the bulk storage systems evaluated on green kenaf. Therefore, it is emphasized that bulk storage systems are not being considered for the Mekong project pulp mill which will be based primarily on kenaf which has been field dried before baling and storing in covered ricks.

2.5.3. Storage of Baled or Bundled Kenaf

Bale storage of nonwood plant fibers, such as bagasse and straw, has been used commercially for many years. USDA investigations have shown that, when baled at a moisture content below 25 percent and stored in covered ricks, satisfactory preservation of kenaf fiber quality and maintenance of pulp yield result. Exposure of piles of bales to the elements was found to have a deleterious effect on the top bales. Although the research comparisons in the reports were not technically valid, cost data comparisons for pulps produced from protected baled kenaf with pulps from green kenaf from bulk storage showed the former cost less to produce and consumed less fibrous raw material than the latter pulps.

2.6. Review of Studies on Kenaf for Paper Pulp (1950-1975)

2.6.1. Introduction

There were only four or five significant technical articles on the pulping of kenaf prior to 1960, but by the latter half of the 1960's the literature on this subject began to expand rapidly. Attendees at the First World Conference on Kenaf in Havana in 1958 indicated a developing intere t in this crop for paper pulp. At the Second International Kenaf Conference at Palm Beach in 1964, there were three papers on pulping. By 1967, the interest in kenaf was such that a committee of the Technical Association of the Pulp and Paper Industry (TAPPI - U.S.A.) presented the First Conference on Kenaf for Pulp in Gainesville, Florida. By 1970, the interest in pulping nonwood plant fibers, including kenaf, had continued to increase so that TAPPI established a committee - the Nonwood Plant Fibers Committee - to conduct annual programs on all aspects of pulping these fibers. Since the beginning of these meetings, this committee has published 53 technical papers, 15 of which have been on kenaf.

These TAPPI papers are only an indication of the large number of published studies on paper pulp from kenaf. Annex III listing the Bibliography for this review gives about 200 such references. This listing does not cover the hundreds of technical reports on the growing of kenaf and its processing for textile uses.

The research information reviewed in the main text of this Study has been used as a basis for establishing the agronomic, economic, and technical parameters for the proposed pulp mill. The review of these investigations is found in Sections 2.6.3. through 2.6.9. of Chapter I.

2.6.2. Interpretation of Technical Data Reviewed

Caution has been found necessary in correlating the data on kenaf pulping from so many different laboratories. In addition to the normal differences in testing procedures, equipment, and methods of reporting results in publications, it has only recently been recognized that the variations in pulps, resulting from the systems of raw fiber preparation, are in many cases not clearly explained or related to the techniques of the investigations. This review has shown that it is most important to know conditions or treatments the kenaf may have been subjected to from the time it reached maturity, or was harvested, until if was fed into the digester for the pulping test. In many of these investigations, the history of the treatment of the kenaf samples and the raw fiber preparation steps have not been clearly stated, if at all, and this is responsible for some of the confusion and differences with regard to pulping yields and other data.

Therefore, future investigations of kenaf pulping should include the complete background of the harvesting, storage, and raw fiber preparation of the sample up until it enters the digester.

2.6.3. Studies on Kenaf for Paper Pulp by the United States Department of Agriculture

Much technical information has been published by the USDA on the growing, harvesting, storage, and pulping of kenaf. This work, over the last 10 years or more, has been an outgrowth of studies beginning in 1943/1944, and terminating about 1965, to assess the production of kenaf bast fiber for textile and cordage purposes in the United States.

As early as 1956, the Agricultural Research Service and the Northern Regional Research Laboratory of the USDA undertook a screening program for the major species of fibers in the world. Its purpose was to identify those plants which could be grown as an annual crop

and whose fibers would be the most promising for paper pulp. The earliest report covered approximately 1,200 samples of which about 850 were evaluated from the almost 500 species of plants received. The results showed the best nonwood plant fibers for paper making to be kenaf, bamboo, crotalaria, hemp, sesbania, and sorghum. Of these, kenaf received a high rating in all categories for paper pulp production.

Investigations of additional species and samples were then carried out in comparison with the most promising fibers already screened by the USDA. Although kenaf whole stalk chemical pulp was not rated the highest for physical strength properties, it was concluded that kenaf would be the prime potential nonwood plant crop for pulp because of its high growth productivity and other favorable agronomic characteristics in addition to its pulping qualities.

The agronomic and pulping investigations published by the USDA have been greater in scope than those of all others. The USDA has studied not only the agronomic and economic aspects of growing kenaf for pulp but also its mechanized harvesting, storage in all types of crop ensilage and bale systems at the full range of moisture and preservation conditions, the effects of precleaning the fiber before pulping, and pulping and bleaching of the kenaf components under all the conditions and chemical treatments known in the pulping industry. Practically every type of chemical and mechanical pulp has been produced from kenaf. Both experimental and semi-commercial papermaking runs have been made with kenaf pulps, with most of the trials oriented to produce kenaf whole stalk bleached chemical pulp that would substitute for bleached hardwood sulfate pulp

This work is so comprehensive that it can serve as a sound basis for the next required step in the development of kenaf for paper pulp. This is the production of kenaf pulps of both types for market and papermaking trials on a commercial scale preparatory to the final feasibility study for a kenaf paper mill in the Mekong Basin.

2.6.4. Other Investigations and Reports on Kenaf for Paper Pulp in the United States

A number of companies, technical associations, and others have worked on kenaf pulping in the United States. These investigations are reviewed in Subsections 2.6.4.1. through 2.6.4.13. of Chapter I. The most important work has been done by the A.B. Dick Company, the Bauer Brothers Company, the TAPPI ad hoc Committee on Kenaf and Related Raw Materials (and its successor, the TAPPI Nonwood Plant Fibers Committee), J.E. Atchison, the Black Clawson Company, Eastex, Inc.,

Kimberly Clark Corporation, the University of Florida Pulp Laboratory, Hudson Pulp and Paper Corporation, Herty Foundation, Champion Papers, Inc., and Eastman Kodak Company.

2.6.5. Work on Kenaf Paper Pulp in Nations Bordering on the Western Pacific Ocean

This research has been reviewed in Subsections 2.6.5.1. through 2.6.5.3. of Chapter I.

In Australia the Commonwealth Scientific and Industrial Research Organization (CSIRO) has been growing kenaf and other crop fibers for pulping studies. Also finding that kenaf has the greatest potential of the nonwood plant fibers for making paper, they have investigated the economics of supplying kenaf in bulk to Japan. Their reports have covered the pulping by several chemical processes of the whole stalk and its components separately, kenaf newsprint, improving the raw fiber for pulping by cleaning and dejuicing it, mechanical processes for separation of core material and bast ribbon, and removal of slow draining fines from the pulp by screening.

In Japan, the Oji Paper Company has made experimental paper machine trials with kenaf chemical and mechanical pulps, and the Toyo Pulp Company claims to have developed an automatic-feed kenaf ribboning machine.

2.6.6. Studies on Kenaf for Paper Pulp in Europe and West Asia

Kenaf pulping research in these areas has been reviewed in Subsections 2.6.6.1. through 2.6.6.6. of Chapter I.

Kenaf has been grown for pulping trials in Italy by the large paper manufacturer, FaBoCart, S.A. Whole stalk as well as kenaf stem components have been pulped for use in cultural paper grades ranging from newsprint to coated printing grades.

In the Tashkent region of the U.S.S.R., where kenaf for textile purposes is grown, the woody core material has been pulped to obtain chemical cellulose pulp for use in lacquers.

At Tvornica Papira Rijeka in Yugoslavia - the world's only full scale pulp and paper mill using kenaf - the bast ribbon is used, together with some core material, to manufacture cigarette paper of high quality. This paper was formerly made from hemp and flax waste fibers at this mill.

Organizations in France have investigated the possibilities of kenaf for paper pulp over the past 15 years. The Ecole Francaise de Papeterie has made studies for private clients. Le Centre Technique de l'Industrie Papetiere compared kenaf for pulp with pulps from sorghum, hemp, and Provence reeds. Kenaf was found to be unsuited for agricultural exploitation in France because the plant would not ripen and produce seeds under the climatic conditions found there. The pulping investigations showed that the physical strength properties and the drainage characteristics of the whole stalk pulp could be improved by fractionating it to remove the fines. In comparison with Provence reeds, however, the resultant low yields in both the field and pulp mill and the high cost of production of the raw kenaf fiber ruled out its use in that area.

Cellulose d'Acquitaine studied the pulping of kenaf in France and, in agreement with the other investigators there, judged that there are too many problems associated with kenaf for pulp for it to become a commercial crop in that country.

2.6.7. Investigations on Kenaf for Paper Pulp in Latin America

Countries in Latin America have been interested in or have used kenaf for textile fibers, so interest has followed in its use for paper pulp. The review of these investigations is given in Subsections 2.6.7.1. through 2.6.7.3. of Chapter I.

The Cuban Sugar Cane Derivatives Research Institute (ICIDCA) has prepared kenaf chemical cellulose pulp for acetylation.

The Laboratorios Nacionales de Fomento Industrial in Mexico studied kenaf bast fiber pulps and found them to be higher in strength characteristics than pulps from yucca, henequen decorticating waste, bamboo, bagasse, hardwoods, and softwoods.

The Department of Forestry in Argentina has made agronomic studies of kenaf from various parts of the nation for pulping. Because of the high strength properties of the pulp from the bast component of the whole stalk, these investigations employed procedures to separate the stalk components both before and after the cooking, whereby two very different pulp fractions were produced.

2.6.8. Development of Kenaf Paper Pulps in Nations Bordering on the Indian Ocean

Several studies on kenaf pulp have also been reported for these countries where jute is grown and has been considered for many years as being a high quality fibrous raw material for papermaking. These studies are reviewed in Subsection 2.6.8.1. through 2.6.8.9. of Chapter I.

In Bangladesh, the former Eastern Regional Laboratories (P.C.S.I.R.) studied the manufacture of printing and writing papers using both jute stick and kenaf woody core material pulps together with bamboo pulp for the high strength fiber in the furnish.

Rumors of production of paper from kenaf in India could not be traced to any commercial operation. However, studies on kenaf whole stalk pulps at J.K. Paper Mills resulted in an estimate that kenaf bleached whole stalk pulp would cost more to produce than would bamboo pulp. At Sirpur Paper Mills, Ltd., extensive laboratory trials have been made to produce pulps from kenaf and its stem components. As compared to bamboo and tropical hardwoods, the data indicated the kenaf whole stalk and woody core material would not be a primary choice for fibrous raw material to make chemical pulp.

Pulping tests to produce chemimechanical pulp for corrugating material and chemical pulps for wrapping paper and bleached papers were made at the Forest Research Institute in India. Studies at the Indian Technological Research Laboratories determined that kenaf core material pulp was not as satisfactory as that from jute sticks. However, the Indian Jute Technical research Laboratory found that kenaf core material left from the retting process could be used to prepare chemical cellulose pulp for nitrating.

The Eastern Paper Mills Corporation in Sri Lanka seems to have come nearest to practical commercial use of kenaf whole stalk bleached pulp as a result of test runs made in each of the past three years. In this company's pulp mill, which produces straw pulp, several large scale runs have been made in which kenaf pulp was used to substitute for imported softwood bleached sulfate pulp usually mixed with straw pulp to produce printing and writing papers. Reports have been issued by the researchers from this mill on the agronomic and pulping aspects of kenaf. They found that, while the bleached kenaf pulp was superior to straw pulp and could replace the softwood pulp in the furnish, the field yields of kenaf whole stalk so far achieved were much lower than would be required to compete in cost with plantation softwoods. This mill has also produced linerboard experimentally from unbleached kenaf chemical pulp and chemimechanical pulp that could be considered for use in newsprint.

2.6.9. Developmental Work on Kenaf Paper Pulps in Countries within the Mekong Basin Area

The field survey in Thailand for the present project found that considerable work has been done there on kenaf for paper pulp. The review of available information is given in Subsections 2.6.9.1. through 2.6.9.5. of Chapter I.

There are apparently four well equipped pulp/paper laboratories in Thailand, including the one at the Siam Kraft Paper Co., Ltd. Studies on kenaf pulping have been carried out in the Department of Science of the Ministry of Industry in Bangkok and at the laboratory of the Royal Department of Forestry. It is also reported that Kasetsart University's School of Forestry has a pulp/paper laboratory.

In addition to the kenaf pulping activities at these institutions, there have been three pulp mill projects promoted in Thailand in the last six years which were based wholly or partially on using kenaf whole stalk or wastes from bast fiber production.

The earliest of these projects was that of the United Pulp and Paper Company, Ltd. (UPPC) which was discontinued when the Thailand Board of Investment certificate for promotion expired in 1974. Feasibility studies for this project were made by Associated Consultants, Ltd. of Bangkok and kenaf pulping trials were made in the laboratories of several pulp and paper machinery manufacturers in Europe as well as in conjunction with the Applied Scientific Research Corporation of Thailand (ASRCT) at the Bang Pa-In mill. On the basis of these tests, it was proposed that both bleached and unbleached grades of kenaf whole stalk pulp be manufactured in Thailand.

A second project to manufacture kenaf whole stalk bleached pulp is now being developed by the Phoenix Pulp and Paper Co., Ltd. This is to be located near Khon Kaen in the Northeast of Thailand within the Mekong Basin. It has been reported that full scale pulping, bleaching, and papermaking runs using Thai whole stalk kenaf have been made for this project at the Ballarpur Paper & Straw Board Mills, Ltd. in India.

The third promoted project, that of the Sri Ayudhya Pulp Co., Ltd., is listed by the Board of Investment as using kenaf waste along with other nonwood plant fibers for pulping. Detailed information on this project was not available for review.

Apart from its work on the original UPPC project in the laboratory of the Royal Forestry Department and at the Bang Pa-In mill, the ASRCT has carried out numerous investigations in which various types of pulps have been prepared. Studies include 100 percent kenaf pulps or those from admixtures with woods or other nonwood plant fibers available in Thailand. Unfortunately, the technical reports on the work of the ASRCT on kenaf pulps were not made available for this review. However, the information in them would not change the general conclusions or affect the parameters of this Study.

In the field survey for this Study, the pulping facilities of the Fiber and Paper Laboratory, Research Division, Department of Science, of the Ministry of Industry (Thailand) were discussed. Excellent testing equipment was furnished for this laboratory in 1964 by the United Nations Development Programme (UNDP) and the buildings, services, and personnel were supplied by the Government of Thailand. The extensive pulping studies made by this laboratory have included such raw materials as woods, kenaf, fibrous agricultural wastes, and other nonwood plant fibers found in Thailand. The experience of the technical staff of this organization in pulping kenaf would be very valuable in carrying out some phases of the research work on kenaf pulping which has been recommended for the Mekong Basin project.

3. The Physical Strength Properties of Kenaf Pulps Compared to Other Major Papermaking Fiber Pulps of the World

3.1. Introduction

Most of the studies on kenaf pulping and bleaching have been at the laboratory level. Particularly in the case of the whole stalk kenaf chemical pulp, there is a lack of commercial-scale operating data that would serve as the basis for building the mill and selling the products considered in this Study. There is a need for commercial quantities of pulps for market studies and trials so that the physical strength properties and papermaking characteristics of the kenaf pulps, used for up to 100 percent of the fibrous furnish, can be established for all major grades of paper using full chemical pulps. It is most important that such pulps be produced with the optimum strength properties and best drainage characteristics that would result from the use of a wet cleaning system for the fibrous raw material and the pulping and bleaching of the pulps in the continuous systems used for other nonwood plant fibers in commercial practice.

3.2. Comparison of Laboratory Pulp Strength Test Data for Kenaf Paper Pulps with Other Nonwood Plant Fiber and Wood Chemical Pulps

In consideration of kenaf paper pulp for its papermaking qualities, an analysis has been made for this review of the data published or furnished by laboratories from several countries. The test results were averaged for the kenaf whole stalk, bast ribbon, and woody core material pulps and compared with the average data on strength tests for full chemical pulps made from hardwoods, softwoods, and other nonwood plant fibers used for papermaking.

The comparison of pulp test data uses a simplistic expression of the laboratory refining-strength curves as shown in Figure I.1. of the main text of this report. (A copy of this is included as an annex to this summary.) This method for comparing the strength of pulps from the various fibrous raw materials is based on the relationship between the two physical tests for tearing strength and bursting strength at various levels of freeness on the laboratory beater curves.

The interpretation of the respective locations of the curves in Figure I.1. is that the stronger pulps used in conventional papermaking, such as the softwood sulfate pulps, have both high tear and burst factor values. Pulps of medium strength properties with lower tearing strength are the esparto soda pulp, hardwood sulfate pulps, bamboo sulfate pulp, and softwood sulfite pulp. The pulps of low tearing strength are those of the major nonwood plant fibers in commercial use, such as bagasse and straw soda pulps, which are useful and perfectly acceptable for many grades of paper where stronger softwood sulfate pulps can be added to give the required tearing strength properties to the finished product.

It can be seen from these data that the pulped bast ribbon yields a product comparable in strength properties to the best of the softwood sulfate pulps on the market.

The refining-strength test curve for the whole stalk kenaf pulp shows it to be somewhat higher in the relationship of strength properties than the market hardwood sulfate pulp which is widely used in the major grades of printing and writing papers, sanitary papers, etc. However, the kenaf whole stalk soda pulp, because of its content of fines, has the detrimental property of a much lower initial freeness test than the other pulps except that for straw. The fines affect the sheet properties as well as the speed of the paper machine. This pulp is also very sensitive to refining which also slows the drainage characteristic further. However, this may not be a drawback for all grades of paper when compared to the other paper pulps with higher initial freeness values.

The kenaf woody core material soda pulp has very low tearing strength properties and very poor drainage characteristics for use in conventional papermaking furnishes. Its use in any appreciable percentage in the fibrous furnish for most grades of paper would be ruled out where high speed production is required. The papers that would be suitable products when containing very much of this pulp would be limited in number. For this reason, the woody core material from kenaf should only be considered for use as a fuel, for the manufacture of mechanical-type pulps for newsprint and low grade printing papers, for semichemical pulps for corrugating medium, for particleboard, or for chemical by-products.

Therefore, the conclusion that can be drawn from these data for the strength properties of kenaf pulps in comparison with other pulps is that the bast ribbon soda or sulfate pulps would be excellent substitutes for the high strength softwood sulfate pulps for most grades of paper in which they are used.

The strength properties of the kenaf whole stalk soda or sulfate pulps are as good or better than the short fibered wood pulps and nonwood plant fiber pulps now in production. An improvement in drainage characteristics of the whole stalk chemical pulps, however, may be required before they become interchangeable with other market pulps.

The woody core material of kenaf is not suitable for use in producing the chemical grade of paper pulp because of its detrimental drainage properties. It should, however, receive proper consideration for its value as fuel or for the manufacture of newsprint and particleboard in any further studies for a Mekong Basin project pulp mill involving kenaf.

4. The Value of Kenaf as a Raw Material for Paper Pulp Compared to Sugar Cane Bagasse and Wood on a Worldwide Basis

4.1. Introduction

It is important to recognize that a comparison of the costs of the various fibrous raw materials used in papermaking is not valid unless consideration is given to final pulp product yields and delivered fibrous raw material cost on an equivalent oven dry basis for each material. In addition, there are differences in processing costs, equipment investment, pollution control costs, fuel and power consumption, economy of size for the mill, and other factors that enter into the final product cost. These can be quite variable, depending upon the fiber pulped. The true costs of using kenaf for paper pulp would include these considerations when the competitive costs of other

fibrous raw materials are discussed. For that reason, a full feasibility study for the pulp mill together with an exact determination of the price the product will bring in the market is required to determine the economic viability of the project. Although the cost of the kenaf fibrous raw material, in comparison to the fiber that would be available to other pulp mills, is important, it is only one of several factors that have been found necessary for investigation in this Study.

4.2. The Cost of Kenaf Whole Stalk in Comparison with Bagasse and Hardwoods as Fibrous Raw Materials for Paper Pulp

The major nonwood plant fiber raw materials competitive, on a technical basis, with whole stalk kenaf for pulp in Thailand are bamboo and sugar cane bagasse. Bamboo is outside the scope of this Study but bagasse has a great potential for future increased usage in this market area for the proposed Mekong Basin pulp mill's products. It is considered to be a strongly competitive raw material to kenaf whole stalk for paper pulp.

Bagasse is a unique fibrous raw material for papermaking in that it is an agricultural residue of cane sugar production. Therefore, it carries no fixed cost for land to grow it or the labor to harvest and get it through the sugar mill. Its value, therefore, bears no relationship to a cost of "producing" the bagasse but is related directly to the cost of replacing it with other fuels at the sugar mill, where the bagasse is now used for fuel. There must also be added the cost of moist depithing and transporting the bagasse to the pulp mill together with some small premium payment for profit to the sugar mill.

In this Study it has been considered that oil is available as replacement fuel to the sugar mill at ฿1,800/MT (US$90.00/MT) and lignite is also available at ฿310/MT (US$15.50/MT) delivered. On this basis, when furnace efficiencies for burning the different fuels and the bleached pulp product yields and other pertinent factors of cost are considered, the following comparison results:

Case	Fibrous Raw Material	Replacement Fuel	Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product (฿/ADMT)	(US$/ADMT)
1	Bagasse	Oil	1,554	(77.70)
2	Bagasse	Lignite	910	(45.50)
3	Whole Stalk Kenaf*	-	1,865	(93.25)

* Note: Includes cost of fiberizing kenaf.

In order to equal the cost of bagasse based on its replacement with oil, the field dried kenaf whole stalk bales would have to be delivered to the pulp mill for ฿494/MT (US$24.70). If lignite is the fuel, in comparison with bagasse the pulp mill could pay only ฿275/MT (US$13.75/MT) for the field dried kenaf whole stalk instead of the price estimated in this Study as being ฿600/MT (US$30.00/MT) delivered.

These estimated fibrous raw material costs for kenaf and bagasse for paper pulp in Thailand should be considered in relation to recent costs for hardwood for pulping in various parts of the world.

Item	Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product (US$/ADMT)
Mixed tropical hardwood chips (South Pacific-Asian mill)	55.00
Mixed tropical hardwood chips (at Dock in Japan)	120.00
Eucalyptus chips (from Australia delivered to Japan)	160.00
Hardwood chips (delivered to pulp mill)	
U.S.A.	100.00
Sweden	110.00
Finland	130.00

It must be emphasized that, although the bagasse and kenaf pulps in Thailand have a basis for comparison with regard to fibrous raw material cost, they can not be compared with these wood costs for a ton of product for the reasons explained previously. For example, the South Pacific-Asian mill that would pulp mixed tropical hardwood chips, and probably market some of the pulp in the Mekong riparian countries, would have a great advantage of "economy of size" because it could be expected to produce three or four times as much pulp as the mill considered for this Study. It would also utilize low cost wood waste to produce the lower amount of power and steam required per unit of product by the hardwood pulp mill. In the case of the wood chips for Japan, their industry has been willing to pay the higher costs, which include freight on about four times the wet weight of raw material for that of the pulp produced, to provide employment within the country and to reduce imports of hardwood pulp from other high cost producing countries.

Considering the economies and high land and labor costs of the developed countries that are producing hardwood market pulps, the fibrous raw material costs are actually relatively low because of the high degree of mechanization and the efficiencies that have been achieved in pulpwood production, transportation, and processing. In the case of Thailand and some of the other developing countries, the agronomic system for providing kenaf whole stalk to the pulp mill as envisioned for this project is fully dependent upon plentiful and low cost agricultural labor. The use of marginal land unsuited for mechanized farming and the production of more valuable crops also favors a low cost for kenaf. If these economic and other conditions where kenaf is now grown at low cost do not continue, kenaf could become a relatively much higher cost fibrous raw material than bagasse in Thailand. Eventually, even hardwood pulpwood plantations might become a lower cost source of raw material than whole stalk kenaf for the Mekong Basin mill. These possibilities will have to be considered in the full scale feasibility study and long range planning for any kenaf pulp mill.

4.3. Comparative Costs of Kenaf Bast Ribbon and Softwoods as Fibrous Raw Materials for Paper Pulp

Kenaf bast ribbon soda or sulfate pulps are technically interchangeable in papermaking with the softwood sulfate (kraft) pulps because of the comparable physical strength properties. In the Mekong riparian countries' papermills, the bast ribbon pulp would not be required as a substitute for the lower strength full chemical pulps from kenaf whole stalk, bagasse, or hardwoods, but would be used only in those grades of paper requiring the high tearing strength pulps for all or part of the furnish.

The mills in the developed countries of North America and Scandinavia, where most of the high strength market softwood pulps are produced, have the advantages of "economy of size" in comparison to that of the mill projected in this Study. There are many adverse factors such as high labor, sales, transportation, and handling costs for the softwood sulfate pulps from the developed pulp producing countries supplying the riparian countries' paper mills. These aspects, together with steadily increasing costs for fuel and wood for these mills, make it worth considering the use of kenaf bast ribbon for pulp in the Mekong Basin.

In comparing the cost of manufacturing pulp from kenaf bast ribbon with the cost of producing softwood sulfate pulp, the following values for fibrous raw material costs were determined in 1975 during this Study:

Item	Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product (US$/ADMT)
Softwood delivered to mill in interior of B.C., Canada	
Sawmill chips	60.00
Pulpwood	90.00
Softwood chips from West Coast USA (delivered to Japan)	180.00
Softwood from Southern USA	
Pulpwood (delivered to mill)	88.00
Chips (delivered to Sweden)	190.00
Domestic softwoods (as chips)	
Sweden	145.00
Finland	170.00
Kenaf bast ribbon (delivered to Mekong Basin mill)	237.70

The data show that, to be competitive on the pulp market with bleached softwood sulfate pulp in the South Pacific-Asia area, the kenaf bast ribbon for bleached pulp would have to cost about ฿3,000/ADMT (US$150.00/ADMT) of product. This would be equivalent to paying ฿1,313/MT (US$65.65/MT) for field dried bast ribbon delivered to the mill rather than the ฿2,080/MT (US$104.00/MT) estimated as the cost in the agro-economic sections of this Study.

Three theoretical possibilities for lowering the cost of kenaf bast ribbon for pulp production have been examined in this Study. Cases 1 and 2 are based on the development of dry or wet process systems for separation of the bast ribbon from the woody core material when field dried kenaf whole stalks would be delivered to the pulp mill at the price of ฿600/MT (US$30.00/MT), as determined in the agro-economic sections of this Study. Case 3 is based on the separation of the two stalk components by the farmer and their delivery to the mill in baled, field dried condition.

Case 1. A dry fiberizing process would be used at the pulp mill to separate the bast ribbon from the woody core of the field dried kenaf whole stalk. The core would be used for fuel at the pulp mill.

Case 2. A wet fiberizing process would be used at the pulp mill to separate the bast ribbon from the woody core material. The core material would be pressed to a 50 percent moisture content and used for fuel at the pulp mill.

Case 3. In this situation, it is assumed that the income to the farmer from the bast ribbon at the price of ฿2,080/MT (US$104.00/MT) delivered to the mill would make it advantageous for him to supply the proportional amount of the woody core material that he separates so that it can be delivered as field dried material to the pulp mill for ฿400/MT (US$20.00/MT) for use as fuel.

The detailed calculations for the hypothetical Cases 1, 2, and 3 have been summarized as follows:

Case	Situation	Fuel Replaced	Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product (฿/ADMT)	(US$/ADMT)
1	Dry Separation Process, Core Used for Fuel	Oil	1,833	(91.65)
		Lignite	3,084	(154.20)
2	Wet Separation Process, Core Used for Fuel	Oil	3,249	(162.45)
		Lignite	4,384	(219.20)
3	Separation by Farmer, Core Used for Fuel	Oil	3,386	(169.30)
		Lignite	5,077	(253.85)
-	Kenaf Bast Ribbon Cost in this Study (at ฿2,080/MT)	-	4,754	(237.70)
-	Kenaf Bast Ribbon Cost Considered Competitive with Softwood for Pulp (at ฿1,313/MT)	-	3,000	(150.00)

With regard to Case 3 above, rather than the ฿400/MT (US$20.00/MT) used here for the delivered cost of kenaf woody core material, the cost would have to be ฿340/MT (US$17.00/MT) to compete with lignite on a straight fuel-into-steam value basis.

These data from the calculations for these hypothetical cases show the importance of considering the waste woody core material for fuel, particularly if oil would be the only fossil fuel available to the project mill. In Case 1, where the two components would be separated by a dry process at the pulp mill, the cost of the kenaf bast ribbon could be lowered by 35 percent if the proportional amount of the core material were used as fuel to replace the low cost lignite available and expected to be used for the pulp mill in Thailand. This is based on the assumption that the 195 percent excess woody core material, which would theoretically be available above that needed for the fuel requirements of the pulp mill, would be used instead of lignite to generate steam and/or power for other industries nearby or power for the national grid.

As an alternative to its use for fuel, part or all of the woody core material could be considered for manufacturing particleboard or mechanical pulp for newsprint at the same mill. The woody core material separated by the hypothetical dry process, if not used for fuel to replace lignite, could be used to produce the equivalent of about 653 ODMT/day of mechanical pulp costing only ฿554/ODMT (US$27.70/ODMT) of pulp for fibrous raw material. Assuming that the mechanical pulp were 85 percent of the fibrous furnish for newsprint and that 128 ADMT/day of kenaf bast ribbon slush semi-bleached soda pulp (64 percent of the project pulp mill's productive capacity) could be used for the high strength chemical pulp furnish component, there could be a newsprint production of 810 tpd. or 283,500 tpy. from the woody core material theoretically available from the manufacture of 200 tpd. or 70,000 tpy. of kenaf bast ribbon bleached pulp.

In Case 2, the use of a wet fiberizing process, as compared to a dry or hand separation of the two kenaf stalk components, results in a loss to the effluent system of some of the solids which have fuel value. In addition, the pressed kenaf woody core material at 50 percent moisture content has a dry basis fuel-into-steam efficiency of 65 percent as compared to 75 percent efficiency at the field dried moisture content of 12.5 percent. For these reasons the economics of the wet separation process are not as favorable for lowering the cost of bast ribbon as the dry process. However, the economics of producing mechanical pulp from the core material for newsprint would remain the same as for the dry separation process.

In Case 3, when the farmer collects the proportional quantity of core material from the bast ribbon production for the mill and it is delivered to the mill baled and in field dried form, its cost for fuel only at ฿400/MT (US$20.00/MT) is higher than the cost of lignite it would replace. For this purpose, the woody core material furnished by the farmer could not carry a delivered price of more than ฿340/MT (US$17.00/MT) although, at the higher price, it could be considered as possibly economical for the manufacture of particleboard and/or newsprint at the project pulp mill.

5. The Potential Market for Kenaf Paper Pulp from a Mekong Basin Project Mill

5.1. Introduction

In making this Study, it was found that complete up-to-date statistical information was lacking on the production, importation, and consumption of the various grades of paper within the Mekong riparian countries. Based upon the data available, an estimate has been made of the possible market within this area for the products of a kenaf paper pulp mill that might be built by 1980.

5.2. Capabilities of the Existing Pulp and Paper Industry of the Riparian Countries

An analysis of the information available shows that there has been no existing paper manufacturing industry in Laos and that the small mill at Chhlong in Cambodia was shut down in 1971.

The paper mills in South Viet-Nam were reported as having a capacity of 50,000 tpy. and it was expected that pulp production would reach 15,000 tpy. by 1974.

Thailand has a very active paper manufacturing industry of about 32 mills, based mostly upon imported pulps and waste paper from various sources. The data available indicate existing mills have a maximum total productive capacity of about 40,000 tpy. of pulp (bamboo, bagasse, grasses, and straw). With about 91,000 tpy. of imported pulp and approximately 200,000 tpy. of waste paper, this furnish has been estimated as the requirements for the paper and paperboard that could be produced in Thailand in existing mills under optimum operating and favorable market conditions.

Therefore, it appears that the Mekong riparian countries have a pulp supply of only 55,000 tpy. for a total paper and paperboard manufacturing capacity of about 380,000 tpy. at the present time. It would appear that the local market for pulp in the riparian countries would approximate 100,000 tpy. at full operating rates of the existing mills.

5.3. Importation, Production and Consumption of Pulp, Paper, and Paperboard by the Mekong Basin Countries

A number of reports giving statistical data on these aspects of pulp and paper have been reviewed. In general, it can be said that total per capita paper and paperboard consumption and its growth in the entire area of the Mekong Basin countries has been quite low, as shown by data reported for the period of 1960-1974 as follows:

Area and Country	Consumption of Paper and Paperboard (Kg./Year/Capita) 1960	1970	1974	
North America				
Canada	127	169	196	(Least)
United States	196	252	279	(Highest)
Europe				
Albania	8	5	5	(Least)
Sweden	120	191	220	(Highest)
Latin America				
Haiti	1.4	0.5	0.6	(Least)
Costa Rica	7	67	63	(Highest)
Africa				
Burundi	-	0.2	0.03	(Least)
South Africa	27	42	50	(Highest)
Asia and Oceania				
Afghanistan	0.2	0.1	0.1	(Least)
New Zealand	80	114	146	(Highest)
Cambodia	1.3	0.8	0.3	
Laos	1.8	0.9	0.9	
Thailand	2.3	7.3	6	
South Viet-Nam	2.3	3.6	5	

These data indicate that any improvement in the industrial production level and the standard of living and increases in population would apply an upward pressure on these low levels of consumption of paper and paperboard within the Mekong Basin countries.

5.4. Estimates of Future Markets for Kenaf Paper Pulp in the Mekong Basin Countries

The survey does not indicate that Laos or Cambodia would be markets for kenaf paper pulp in the near future, although this Study shows both these countries have potential sites and raw material supplies for the project mill.

In the case of South Viet-Nam, data indicate that, by 1980, that country might have a requirement of 15,000 to 20,000 tpy. of kenaf pulp.

Thailand would have a much higher requirement for pulp than the other countries. In addition, there will eventually be a need to replace the small pulp mills in Thailand lacking recovery systems with a large modern pulp mill with chemical recovery, generation of bleaching chemicals, and effluent treatment facilities. Later on, as consumption increases, this pulp mill would shift over to the manufacture of paper from its own pulp, and the mills to which it formerly sold pulp would obtain their supplies elsewhere or would convert to grades requiring only waste paper.

In this Study, the potential market in 1975 for the Mekong Basin countries for the pulp and paper and paperboard products that could have been made out of kenaf has been estimated to be equivalent to 96,500 tpy. of kenaf pulp of all types. The soda or sulfate pulp equivalents were found to be 57,000 tpy. of bleached whole stalk pulp, 23,000 tpy. of bleached bast ribbon pulp, and 16,500 tpy. of unbleached bast ribbon pulp.

The growth rate of apparent consumption of basic paper and paperboard grades in Thailand was 4.5 percent compounded annually for the period from 1969 through 1974. Based upon a lower and more conservative estimate of growth rate of consumption of 3.5 percent annually for the riparian countries, it was estimated that total pulp equivalent requirements would reach 114,600 tpy. by 1980 and 136,100 tpy. by 1985. This would enable planning for expansion or new pulp capacity beyond the present project mill by the early 1980's and even sooner if newsprint from kenaf is shown to be feasible.

Under the present situation, it is estimated that the 70,000 tpy. of kenaf pulp manufactured by the project pulp mill would all find a market by 1980, which is the soonest such a project could begin production even if final planning and building started now. However, if a large integrated pulp/paper mill based on bagasse and bamboo, as has been planned, were to be implemented before or shortly after the kenaf pulp mill, a strong competitive constraint for the kenaf pulp mill would develop. Without export markets for the kenaf pulp, present viability based only on potential local markets would be greatly diminished and planning and building of the kenaf pulp project might be delayed another 5 to 10 years until a level of consumption requiring the additional productive capacity for pulp is reached.

For this reason, in this Study it has been concluded that the project pulp mill must be equipped with a pulp drying machine of the fourdrinier type with can-type driers, so that production can be shifted from pulp to paper as soon as markets develop for the latter.

This reasoning on the adverse competitive possibilities in Thailand for the kenaf pulp mill is also based on the Consultants' judgement that the high growth rate in consumption of paper and paper board of 7 to 10 percent compounded annually, as estimated in earlier reports, will not be attained in the Mekong Basin countries for the period 1975-1985. These high estimates of consumption given in various studies were based on a period of rapid expansion of the paper industry in Thailand in the 1960-1970 period. Actually, the total consumption of paper and paperboard in Thailand increased only 4.5 percent in the period from 1969 to 1974 and, therefore, a growth in consumption of such products of more than 3.5 percent compounded annually for all of the riparian countries can not be expected for the foreseeable future.

5.5. The Possibilities of Export Markets for Kenaf Paper Pulps as Related to Technical Qualities and Future World Demand for Paper and Paperboard

From the technical standpoint, there are no reasons why kenaf bast ribbon pulp could not be sold on the export market to mills in East Asia as a substitute for softwood sulfate pulp. From the economic standpoint at the present time, however, kenaf bast ribbon pulp would have quite a cost disadvantage. The cost of fibrous raw material in the form of bast ribbon in Thailand is much higher for a ton of pulp than the cost of softwood chips in the developed pulp producing countries. Therefore, at present pulp prices, for kenaf bast ribbon pulp to be competitive, it would be necessary to develop a dry process to separate the bast ribbon from the woody core material of field dried whole stalk kenaf at

the pulp mill, or both the core and bast ribbon material would have to be delivered to the mill. This would make the woody core material available for fuel at the pulp mill or for the manufacture of mechanical pulp for newsprint and thereby reduce the cost of the bast ribbon below that projected in this Study's agro-economic sections.

A long range shortage of softwood pulp on the world export market is also expected to develop as consumption increases in the presently producing countries; finished paper products, rather than pulp, will then be manufactured and consumed locally or exported. The cost of softwood pulpwood in developed countries will also probably increase at a greater rate than the cost of kenaf bast ribbon in the Mekong Basin area. It also will be more than 20 years before sufficient softwood plantations producing relatively low cost fibrous raw material for pulp can be developed in the tropical areas. It is believed that the premium price for softwood sulfate pulp over hardwood pulp will increase greatly. These factors tending to raise the cost of softwood for pulp are seen as favorable for reducing the existing gap between the cost of kenaf bast ribbon for pulp and softwood chips. Some of the major pulp sales companies serving the Asian market agree with this analysis of the situation.

A somewhat different situation is anticipated for hardwood market sulfate pulp. Pulp mills planned for the South Pacific-Asia area to use mixed tropical hardwoods and, later on, low cost plantation hardwoods, will have the advantage of "economy of size" as well as very low wood costs. Kenaf whole stalk pulp would not only have to compete with the hardwood pulp but with the bagasse pulp that could be manufactured for export by a number of countries where this lower cost raw material is available.

From this Study, it does not appear that export markets for the projected mill would be necessary as long as competition does not arise in the beginning years from a new bagasse and bamboo pulp mill in Thailand. Consideration of the predicted increase in consumption of pulp and paper products in Far East Asia, however, leads to the conclusion that the products of this mill could be sold outside the Mekong riparian countries when necessary. One of the major studies reviewed has projected a growth rate of 5.2 percent and an increase in paper and paperboard demand in Asia of 11.3 million tpy. by 1980 and 56 million tpy. by the year 2000. To produce this amount of pulp would require the building of 162 mills the size of the Mekong project mill by 1980 and 800 such units by the year 2000.

The Consultants do not believe that the projected consumption levels will be reached due to a shortage of productive facilities. The expected demand in that area of the world, however, will most likely provide markets for all the kenaf whole stalk or bast ribbon pulps that would be produced in the Mekong Basin, assuming costs for fibrous raw materials would make these pulps competitive with wood pulps.

6. Choice of Products, Capacity and Location for a Kenaf Paper Pulp Mill in the Mekong Basin

6.1. Grades and Types of Kenaf Pulps to be Produced in the Model Mill

The various grades and types of pulps that could be produced commercially from kenaf bast ribbon, whole stalk, or woody core material have been discussed. The best quality pulps that could be made from kenaf with conventional pulping, bleaching, and spent liquor recovery systems would be the unbleached and bleached bast ribbon and whole stalk soda or sulfate grades. These would be comparable in paper making properties to softwood sulfate and hardwood sulfate pulps respectively. The kenaf woody core material alone is not considered suitable for production of full chemical pulps.

Kenaf has great versatility as a fibrous raw material for paper-making because pulps the equivalent of softwood long fibered pulp or hardwood short fibered pulp can be produced from it as required for the market using the same mill equipment and processes for both types. This is a very favorable characteristic of the nonwood plants which have a high bast fiber content.

6.2. Model Pulp Mill Capacity

The "economy of scale or of size" is a very important investment and cost factor in the manufacturing of pulp. The most recent single-line - equipment mills have been built to produce 700 to 1000 tpd. of hardwood and/or softwood pulps. Nonwood plant fiber pulp mills using bagasse have been planned for up to 500 tpd. output.

Such mills of maximum capabilities have lower operating costs, are more efficient, and have lower capital investment per ton of capacity than smaller mills.

In designing this project, it has been considered that a Mekong Basin bleached market pulp mill producing less than 200 ADMT/day would not be economically viable when using kenaf. The correctness of this estimate is indicated by the financial projections for this size mill as discussed in Chapter IX.

The following data on estimated investment requirements for complete kenaf bleached pulp mills built today on a "turn key" basis clearly show the effect of "economy of size."

Rated Daily Productive Capacity of Pulp Mill (ADMT/Day)	Turn-Key Kenaf Pulp Mill Project Total Investment Requirements (US$/ADMT/Day)
100	550,000
200	425,000
400	350,000
700	310,000

It is quite obvious from these data that the smaller the mill, the greater the burden of debt repayment and interest that must be covered by the sales price of each unit of product. As brought out elsewhere in this report, it is actually only under especially favorable circumstances of fuel, fibrous raw material, and labor costs that a pulp mill project of 200 ADMT/day size for the Mekong Basin shows economic viability when producing kenaf whole stalk bleached pulp and selling it at the present prices paid for imported hardwood bleached sulfate pulp in Thailand.

6.3. Locating Pulp Mill Sites in the Mekong Basin

Based on information on potential kenaf supplies and available infrastructure, the most logical choice for the proposed pulp mill would be in the Mekong Basin within Northeast Thailand.

6.3.1. Potential Mill Locations Based on Water Availability

Although the mill designed for this project would include facilities for air and stream pollution control to meet the standards set by the Thai Government regulatory authorities, one of the primary requisites for a pulp mill site is that it be located near a large river with appreciable flow even in the dry season. This river not only furnishes water to the mill when water from wells can not be produced at low cost and in sufficient quantity, but is necessary for disposal of the mill's effluent. This is after the effluent has been treated to remove most of the fiber and oxygen-consuming materials in it, which represent only a small percentage of the fibrous materials processed, and the spent pulping liquor recycled to the recovery system.

Based on stream flow data from the Lower Mekong Hydrologic Yearbook, consideration was given to 22 possible sites on the Mekong, Stung Sanke, Nam Pong, Nam Chi, Nam Takong, Nam Mun, Se Bang Fai, Se Bang Hieng, Dak Bla, Ka Krong, Se Kong, Se San, and Sre Pok rivers in the Mekong Basin.

Although having sufficient water flow in the rivers, most of these locations were discarded because they lacked too many of the other major requirements of infrastructure for a pulp mill site.

6.3.2. Potential Mill Locations Based on Technical, Sociological, Economic, and Ecological Requirements

Location of a pulp mill requires a nearby or, at least, readily available supply of fibrous raw material, a basic area established infrastructure, communication and transportation facilities, adequate water supply and effluent disposal means, accessibility to chemicals and fuel, a nearby electric grid for start-up and standby power, a pool of skilled and unskilled labor, and the schools, hospitals, and business facilities provided by a nearby city. These are in addition to the normal requirements for suitable land for the plant and mill community nearby.

Based upon these criteria, it has been determined that there are six potential areas for kenaf pulp mill locations in the Mekong Basin that would possibly serve the purposes of this Study. Only two of these areas, in Northeast Thailand, have been considered to be of primary importance and they were investigated during the field survey. However, all of the primary and secondary locations are discussed in the main text of this report for their possible advantages and disadvantages in relation to this project, based on the limited information available to the Consultants on the secondary site areas.

Site I of the two primary potential areas of approximately equal suitability is located at the Ubolratana Resettlement Area of the Province of Khon Kaen. At least two potential sites are about 35 to 40 km. north of the town of Khon Kaen on the Nam Pong River between the Ubolratana Dam and the Friendship Highway running parallel to the railroad.

The other primary location (Site II) found to be suitable is near Ubon Ratchathani in the Province of Ubon Ratchathani. Several excellent sites are along the Nam Mun River below the city. This location not only benefits from the large flow of water in the river but also appears to be within economic transportation distance of potential kenaf production areas in neighboring Laos and Combodia.

The secondary potential mill sites that have been considered, based on the limited information available, are:

Site III - Stung Treng, Province Stung Treng, Cambodia, on the Mekong River.

Site IV - Phnom Penh in the Province of Kandal, Cambodia, on the Bassac or Mekong Rivers.

Site V - Battambang in the Province of Battambang, Cambodia, on the Stung Sanke River.

Site VI - Drayling in Darlac Province, Viet-Nam, on the Ka Krong River.

These locations for possible mill sites appear to be less favorable than the two primary sites.

7. Kenaf Raw Material Requirements and Supplies

The bleached pulp yield from whole stalk kenaf raw material being estimated at 35 percent, a 70,000 ADMT/year whole stalk kenaf pulp mill will require 206,000 FDMT/year of whole stalks or, assuming a 12½ percent moisture content of the FD stalks, 180,000 ODMT/year. At an estimated FD whole stalk yield range of 7,500 to 9,375 kg./ha. (1,200 to 1,500 kg./rai) for H. sabdariffa, this is equivalent to a planting area requirement of from 22,000 to 27,500 ha. (137,500 to 172,000 rai). At an estimated FD whole stalk yield range of 15,000 to 20,000 kg./ha. (2,400 to 3,200 kg./rai) for H. cannabinus, it would require a planting area of from 10,300 to 13,750 ha. (64,500 to 86,000 rai).

The bleached pulp yield from kenaf bast ribbon raw material being estimated at 45 percent, a 70,000 ADMT/year long fiber pulp mill will require 160,000 FDMT/year of ribbon or, assuming a 12½ percent moisture content of the FD ribbon, 140,000 ODMT/year. At an estimated ribbon yield of 24 percent of the whole stalk, equivalent to an estimated FD ribbon yield range of 1,800 to 2,250 kg./ha. (290 to 360 kg./rai) for H. sabdariffa, this is equivalent to a planting area requirement of from 71,000 to 89,000 ha. (444,000 to 555,500 rai). At an estimated FD ribbon yield range of 3,600 to 4,800 kg./ha. (580 to 770 kg./rai) for H. cannabinus, it would require a planting area of from 33,500 to 44,500 ha. (209,500 to 278,000 rai).

Under Lower Mekong Basin conditions, it is anticipated that kenaf will continue to be produced by small holders, as presently in Northeast Thailand, preferably supported by pulp mill or cooperative organized central (nucleus) farms servicing neighboring production areas. This Study assumes that, in Northeast Thailand, the pulp mill(s) will purchase only up to 25 percent of the kenaf crop in any one season in order not to disrupt the traditional retted fiber sales to the local bag factories and the exporters; no such kenaf raw material purchase limitations are assumed to apply to Laos, Cambodia and Viet-Nam.

CHAPTER II - HISTORY OF THE KENAF AND ALLIED FIBER INDUSTRY IN THE RIPARIAN COUNTRIES

1. Introduction

Kenaf is the common popular name of two closely related jute substitute fiber plant species, namely Hibiscus cannabinus (or Western Hemisphere kenaf) and Hibiscus sabdariffa (or South Asian kenaf, also known as Thai kenaf, mesta and rosella), where H. cannabinus is grown mostly in Africa and Latin America and is the faster maturing and higher yielding species but requires somewhat better soil and climatic conditions, and H. sabdariffa is cultivated principally in India, Bangladesh, Thailand and Indonesia and matures more slowly and produces lower yields but is more drought and disease resistant. Both species are photo-sensitive but a number of varieties with different photoperiod response have been selected for H. cannabinus.

2. Cambodia

Kenaf was introduced into Cambodia in the mid-1950's and, by 1971, was grown by small holders in seven central and western provinces of the country where it has largely replaced jute. No overall fiber production statistics are available but it is estimated that it never exceeded 4,000 tons annually all of which was consumed by the bag factory at Battambang. Preliminary research trials showed that two kenaf crops can be grown per year and that, with proper management, retted fiber yields of 2.5 tons per hectare and more can be obtained.

3. Laos

Due to the lack of a local market, no attempts at the development of a kenaf industry have been made in Laos in the past. An effort to organize the production of polompom, a native bast fiber plant, met with little success and was soon abandoned.

4. Viet-Nam

Both kenaf and jute have long been grown in Viet-Nam for village and domestic cottage industry consumption.

Intensive kenaf research and fiber production efforts were started in 1958 and, by 1961, the crop had been introduced into 15 provinces. Output reached its maximum with 9,000 tons in that year but then declined due to war related causes, but small scale production continues to this day, particularly in Tay Ninh, Darlac and Kontum Provinces. There is no question that both H. sabdariffa and H. cannabinus can readily be grown in Viet-Nam and that retted fiber yields in the 2.5 tons per hectare range can be realized.

Similar jute research and fiber production promotion resulted in a maximum output of some 2,500 tons in 1960 in four provinces in the Delta and demonstrated that retted fiber yields of 2,000 to 2,350 kg. per hectare could be achieved.

5. Thailand

Commercial kenaf fiber production in Northeast Thailand, one of the lowest income areas of the country, rapidly increased after its initial introduction in 1950. For the last ten years, retted fiber production has fluctuated generally between 350,000 and 500,000 tons annually, with an average of 440,000 tons but with peak outputs of more than 620,000 tons in 1966 and 1973. During that same period, the crop was planted on between 320,000 ha. and 480,000 ha. (2 and 3 million rai) per year, with an average of 384,000 ha. (2.4 million rai) annually but maxima of 528,000 ha. and 544,000 ha. (3.3 and 3.4 million rai) in 1966 and 1973 respectively. For 1975, the planting area is estimated at just short of 320,000 ha. (2 million rai) and retted fiber yield is projected in the 300,000 tons range. The statistics show wide fluctuations in annual outputs (e.g. 184,000 tons in 1968 and 625,000 tons in 1973) and that as a result of wide fluctuations in the farm level price of the fiber which, in turn, is largely determined by the size and price level of the jute crops in India and Bangladesh. More recently, tapioca has replaced kenaf to a substantial degree in the Northeast in view of its ease of production and the very attractive prices offered for the crop combined with a decline in kenaf fiber yields from 1,250 to 1,150 kg./ha. (200 to 184 kg./rai) and less as a result of lack of research and of improved seed, and a general decline in soil fertility in the absence of conservation measures.

Domestic kenaf fiber demand by the twelve local bag mills and for village consumption is estimated at about 230,000 tons per year. Exports have varied from 220,000 to 320,000 tons annually between 1965 and 1974 but are forecast at an average of only 175,000 tons yearly over the next ten-year period in view of the general decline in the international jute and kenaf market due to competition from the man-made fibers. The combined local and export demand for retted kenaf fiber would then amount to, say, 400,000 tons per year which, at an average yield of 1,150 kg./ha. (184 kg./rai), could be produced on some 350,000 ha. (2.2 million rai).

A limited amount of jute fiber is also produced in Northeast Thailand and outputs of as much as 20,000 tons annually have been achieved in recent years. Although its soil and climatic requirements restrict successful jute production principally to the northern and eastern sectors of the Northeast, i.e. to a band adjacent to the Mekong River, it is estimated that, with intensive promotion and an assured and attractive market, a 100,000 tons per year jute fiber output could well be achieved.

CHAPTER III - KENAF AGRONOMY AND FIBER PRODUCTION

This chapter provides an overview of the general agronomy of kenaf for textile fiber production upon which any future kenaf for paper pulp production will have to be based.

For H. sabdariffa, the standard practices in Thailand are cited where kenaf is generally grown on low fertility sandy upland soils and with a minimum of mechanization. The land is plowed and raked with animal drawn wooden implements and the seed is planted by hand after the start of the rainy season in May and June, still largely by broadcasting rather than in rows as recommended for higher yields and lower costs. After 30 days, the crop is weeded and the seedlings thinned to a distance of 7 to 10 cm. between plants; a second weeding should be done 30 days later. Fertilizer is used only rarely. The species is highly disease resistant although some inroads have been made by collar rot and the development of immune varieties is essential. Preferably, the stalks should be harvested when they start flowering - about mid-October in Northeast Thailand - but in practice harvesting is done from as early as the end of August to as late as March, with an interval for rice harvesting in December and January. The stalks are either cut at ground level with a bushknife or pulled out of the ground and then shocked in upright bundles for field drying prior to transport to the retting facility.

H. cannabinus, with its shorter growing cycle and higher yield, is somewhat less drought resistant than its South Asian cousin, requires somewhat better quality soils, and is susceptible to rootknot nematodes so that it should not be grown on light sandy soils. Land preparation in the riparian countries would probably duplicate that for H. sabdariffa, although some mechanization would be desirable on the heavier soils suitable for the crop. It should also be planted in rows and adequately fertilized. Seed varieties with different photoperiod response are available to permit extensive staggering of the planting (and harvesting) dates. Due to rapid seedling growth and the mostly palmate leaves of the species, H. cannabinus plantings need not be weeded or thinned since their leaf "carpet" shades out both the weeds and the less vigorous slower growing seedlings. Again, harvesting should be done at the flowering stage and, as with South Asian kenaf, the plants are mostly cut by bushknife; however, almost all Western Hemisphere kenaf is ribboned, i.e. the bast is stripped off the stalk by hand or by machine, and this must be done while the stalk is still fresh.

In Northeast Thailand and in Southeast Asia in general, the whole kenaf stalks are submerged in water for retting; after the decomposition of the vegetable matter in the bast, the fiber is stripped from the stalk by hand, washed, dried and field baled, and then sold to the local merchant, a baling plant, or a bag mill. In the Western Hemisphere kenaf growing areas, on the other hand, the stalks are almost always ribboned before retting, principally because this reduces both labor and water requirements very substantially.

All kenaf and jute in Southeast Asia is produced by small holders. This Study suggests that the small holders could greatly benefit from the organization of central or nucleus farms which would assist the growers in their areas by providing improved seed, fertilizer, agricultural equipment and ribboning machine services, and centralized retting facilities, all on credit repayable at harvest time, as well as extension services and marketing assistance. Such nucleus farms could be either Government or cooperative or, eventually, pulp mill administered and could, in the latter case, form part of a commercial plantation type operation designed to produce a minimum raw material supply for the mill and, simultanously, to serve as demonstration and extension center.

CHAPTER IV - POTENTIAL KENAF PRODUCTION AREAS IN THE LOWER MEKONG BASIN

From the point of view of soil quality, ample areas suitable for kenaf for paper pulp production exist within the Mekong watershed in all four riparian countries, including the traditional kenaf growing area in Northeast Thailand; the Vientiane Plain and the Provinces of Khammouane, Savannakhet, Sedone, Champassac and Sithandone in Laos; most of Cambodia with the exception of the mountainous area facing the Gulf of Thailand, the Tonle Sap flood plain, and part of the hill country in the east; and substantial portions of the Provinces of Darlac, Pleiku and Kontum in Viet-Nam.

CHAPTER V - KENAF PRODUCTION FOR PAPER PULP

1. Kenaf Stalk Composition

Extensive tests on the composition of H. cannabinus in the United States showed an average stalk fraction ratio of 60 percent core and 40 percent bast ribbon material. No similar tests having been carried out for H. sabdariffa, this Study assumes that its stalk composition is the same. Detailed stalk composition tests on both species of kenaf grown specifically for paper pulp manufacture under Lower Mekong Basin conditions are essential.

2. Kenaf Production Agronomics

2.1. to 2.7. Land Preparation, Planting, Cultural Operations, and Seed Production

Good land preparation is essential to assure uniform kenaf seed germination. For H. sabdariffa, additional development work on improved seed varieties is required; for H. cannabinus, the standard Cuban, Guatemalan and Everglades varieties should be used.

The start of planting should coincide with the start of the rainy season and planting of the photo-sensitive varieties should be completed not later than the second half of June; however, the late maturing varieties (e.g. Guatemala 4 and 45) permit planting on a much more extended schedule. Row-planting should be strongly encouraged, since it results in higher yields and lower labor requirements, and it should preferably be done either with the help of a multi-row seed rake or by tractor drawn seed drills on larger operations. Since H. sabdariffa has to be weeded and thinned, it should be planted at an inter-row distance of 30 cm; the row spacing for H. cannabinus, on the other hand, will be 17 to 20 cm.. The seeding rates should be 12.5 kg. and 25 kg /ha. (2 and 4 kg./rai) respectively.

H. sabdariffa is fertilized only rarely in Northeast Thailand and, in view of the maximum 25 percent yield increase resulting from fertilizer application and of its present cost, such application apparently produces a positive financial return to the grower only if the farm gate price of Mixed Grade retted kenaf fiber exceeds ฿3.30/kg. ($0.165/kg.) which has seldom been the case. On the other hand, much greater yield increases have been achieved through fertilization in the H. sabdariffa research program in Viet-Nam. H. cannabinus always responds strongly to fertilizer application, particularly nitrogen, and this applies also under Lower Mekong Basin conditions as already confirmed by the research programs in Cambodia and Viet-Nam. Further research is required into this aspect of the kenaf for paper pulp development program.

H sabdariffa should be weeded twice, 30 and 60 days after planting, and the seedlings thinned to 7 to 10 cm. between plants immediately after the first weeding. Due to the shading effect of its faster growing seedlings, these operations are not required for the H. cannabinus species.

Although both South Asian and Western Hemisphere kenaf are exceptionally pest and disease resistant, these do of course occur; standard control measures are itemized in this Study. Special attention is drawn to the rootknot nematode susceptibility of H. cannabinus on light sandy soils.

For a successful kenaf for paper pulp production program, the large scale production of improved seed is of much importance, a matter so far sadly neglected. It is estimated that an annual improved H. sabdariffa seed planting area of from 900 to 3,000 ha. (5,600 to 19,000 rai) and an H. cannabinus seed area of from 500 to 1,700 ha. (3,100 to 10,000 rai) would be required, to satisfy the raw material requirements of the whole stalk kenaf and the kenaf bast ribbon pulp mills respectively.

2.8. Harvesting

In order to obtain maximum yields, H. sabdariffa should not be harvested before mid-October in the Lower Mekong Basin area; the harvest of the faster maturing H. cannabinus species can start as early as mid-August.

For whole stalk production, the kenaf should be cut close to ground level by bushknife in the traditional manner; thereafter, some 30 cm. of the tip ends should be cut off and the plants shocked vertically for field drying. The operation can be mechanized in large scale operations through the use of a cutter bar or a high crop harvester.

For chopped stalk production, the small holder would then simply cut the dry stalks into chips of the desired length or he could deliver his stalks to a central chopping plant. The operation could again be mechanized through the use of standard forage harvesters or similar equipment, but much work remains to be done to properly adapt such equipment to kenaf for paper pulp production.

For bast ribbon production, the long fiber bearing bast is stripped from the stalk either by hand or by machine, as has been standard practice in retted kenaf fiber production for many years, particularly in Africa and Latin America. Various simple aids have been developed to facilitate manual bast stripping or ribboning and efficient ribboning machines are commercially available.

3. Whole Stalk Kenaf Raw Material

3.1. Whole Stalk Kenaf Raw Material Requirements

As discussed previously, a 70,000 ADMT/year whole stalk bleached kenaf pulp mill will require 206,000 FDMT/year of stalks and this Study arbitrarily assumes that such a mill will be established at the potential Site I at Nam Phong near Khon Kaen in Northeast Thailand and uses that mill as an example for other whole stalk kenaf pulp mills which could be established elsewhere in the Basin area.

3.2. Kenaf Stalk Yield Per Unit Area

The basic aspects of kenaf for paper pulp project development have, so far, been only fragmentarily researched anywhere outside the United States. Nevertheless, it is considered that the results obtained in limited tests in Northeast Thailand indicated that a yield of at least 7,500 kg./ha. (1,200 kg./rai) of field dry H. sabdariffa stalks can be obtained in that region and that it might increase to some 9,375 kg./ha. (1,500 kg./rai) under somewhat more favorable soil conditions. Similarly, using the U.S.A. research results on a basis, it is conservatively estimated that H. cannabinus field dry whole stalk yields in the Basin area will range from 15,000 to 20,000 kg./ha. (2,400 to 3,200 kg./rai).

3.3. Kenaf Production Areas and Whole Stalk Supplies Within Economic Distance of Mill Site I

It is assumed that whole kenaf stalks can be trucked economically to the mill site from a distance of up to 160 km. A listing of all kenaf producing districts within that distance from Mill Site I shows a total average annual kenaf planting area, during the 1970 to 1974 period, of some 198,000 ha. (1,240,000 rai). At a stalk yield of 7,500 kg./ha. (1,200 kg./rai) and a total stalk consumption of 206,000 tons, a kenaf planting area of about 27,500 ha. (172,000 rai) per year will be required; at the same time, only 25 percent of the available kenaf crop is to be purchased in the Northeast by the mill so as not to disrupt the established kenaf fiber trade. Hence, a total annual kenaf planting area of some 110,000 ha. (688,000 rai) is necessary to cover the mill's whole stalk raw material requirements. The listing and supporting tables and maps show that these requirements could be purchased within a maximum transportation lead distance of 120 km.

3.4. Kenaf Stalk Procurement

One system of stalk procurement could be through a pulp mill operated organization. On the assumption that the small holder can conveniently transport his stalks by bullock cart over a maximum distance of 15 km., this would require the establishment of 4 collection centers and 20 satellite purchasing depots within the supply area where the stalks brought in by the farmers would be weighed, paid for, and stacked pending dispatch to the nearest collection center or the pulp mill.

A second and preferable stalk procurement system would be to contract with the existing kenaf baling plants and traders. It is submitted that this approach would not only relieve the pulp mill of all organizational problems of raw material purchasing and would be more economical, but that it would also assure the cooperation of the established kenaf trade rather than arouse its opposition through competition for the available kenaf raw material. In addition, this procedure would open up the entire Northeast as a raw material supply area since the more distant kenaf balers and traders would be willing to absorb the greater stalk transportation costs.

Finally, it is anticipated that a portion of the mill's kenaf stalk requirements could be purchased through local cooperatives, as for example the Ubolratana Resettlement Area Cooperative which could potentially furnish up to one-third of the needs of a mill at Site I, and it is hoped that the participation of cooperatives in supplying the raw material requirements of the mill(s) will rapidly increase.

Loose stalks being too bulky to be transported economically by truck, they must at least be field bundled by the growers, much as they are used to doing with retted fiber. The stalks could then be further compressed in the regular kenaf fiber baling presses. It is reported that bulk densities of 100 to 120 kg./cu.m. and 300 to 400 kg./cu.m. respectively are achieved by these two methods without crushing the stalks.

The stalk field bundles would be transported by the growers to the nearest collection center, depot or road head with their own bullock carts. Stalk transport between the road head, the depots/collection centers and the mill would be by truck.

4. Chopped Stalk Kenaf Raw Material

4.1. Chopped Stalk Field Handling

As previously indicated, if chopped kenaf stalk material is to be supplied to the mill, the stalks could either be chopped by the farmers by hand or harvester-choppers could be employed. In either case, it is essential that, during subsequent storage, the moisture content of the chips does not exceed 35 percent at the most. When the kenaf is harvested after about mid-December in the Lower Mekong Basin, these moisture limitations would not be exceeded since the rainy season is then well past; if necessary, the stalks could be shocked before chopping or the chopped material spread on the ground to achieve further drying. However, harvesting prior to, say, mid-November definitely presents a chip drying problem; it could be overcome by harvesting and shocking the stalks prior to chipping, either by hand, by mobile field choppers or by stationary choppers, say at the baling plants, or by artificial drying.

4.2./4.3. Chopped Stalk Baling and Transport

Since loose stalk chips have a bulk density of only some 72 kg./cu.m., they must be baled for economic long distance transport and the standard kenaf fiber baling presses should prove adequate for the purpose and could produce bales with a bulk density of at least 427 kg./cu.m. Whereas the standard 30 cu.m. body of both the local 6-ton and 10-ton trucks would hold only a little more than 3 tons of stalk chips, close to 13 tons of stalk bales could then be loaded into that same body by volume.

5. Kenaf Bast Ribbon Raw Material

5.1. Kenaf Ribbon Raw Material Requirements

As already discussed, a 70,000 ADMT/year bast ribbon bleached kenaf pulp mill will require 160,000 FDMT/year of ribbon and this Study again arbitrarily assumes that such a mill will be established at the potential Site II near Ubon Ratchathani in Northeast Thailand and uses that mill as an example for other long fiber kenaf pulp mills which could be established elsewhere in the Basin area.

5.2. Kenaf Ribbon Yield Per Unit Area

Based upon the Consultants' long-term experience with H. cannabinus ribbon production for subsequent conversion into retted fiber, ribbon yield ranges for Western Hemisphere kenaf are set at 3,600 to 4,800 kg./ha. (580 to 770 kg./rai). They are estimated therefrom at 1,800 to 2,250 kg./ha. (290 to 360 kg./rai) for H. sabdariffa, an estimate which is confirmed by conversion into known retted South Asian kenaf fiber yields in Northeast Thailand.

5.3. Kenaf Ribbon Supply Area Parameters and Supplies

Based on the previous assumption that whole kenaf stalks could be trucked economically over a maximum distance of 160 km. and in view of the greater pulp yield and greater bulk density of kenaf ribbon, the maximum economic transportation distance for the latter is assumed to be 270 km. by road or 200 km. in a straight line. A circle with that radius drawn around Mill Site II covers some 50 percent of the traditional kenaf production area in the Northeast as well as most of the potentially suitable kenaf areas in Laos and the Northern tier of provinces in Cambodia.

If only H. sabdariffa ribbon supplies are assumed and since, in the Northeast, only 25 percent of the available kenaf crop is to be purchased by the mill, a total planting area of 355,500 ha. (2,222,000 rai) would be required to satisfy the raw material requirements of the mill or almost twice the average 1967 to 1974 annual planting area in the Northeast within the 200 km. straight line parameter from Mill Site II; the shortfall could be made up by yield increases as a result of supplies of improved seed, a planting area increase as a result of pulp mill offered incentives, a production increase in the seven Resettlement Areas within easy reach of the mill site, from kenaf production in the neighboring provinces of Laos and Cambodia, or from kenaf baler and trader supplies in the remainder of the Northeast.

For H. cannabinus ribbon, the actual required planting area, would be reduced to 44,500 ha. (278,000 rai) because of its higher yield. It is estimated that 27,200 ha. (170,000 rai) would become available within the 200 km. radius from Mill Site II in the Northeast alone and that the balance of 17,300 ha. (108,200 rai) could readily be secured from the neighboring provinces in Laos and Cambodia.

Obviously, any shortfall in H. cannabinus ribbon could also be made up by H. sabdariffa ribbon and vice versa.

5.4./5.5. Kenaf Ribbon Processing, Drying and Baling

The ribboning of the kenaf stalks would be done in the same manner and with the same equipment as used for many years for kenaf textile fiber production, either manually or by machine.

Since ribboning has to be done while the stalks are still green, the ribbon must be dried after stripping by spreading it on bamboo or other drying lines during the rainy season and on the ground during the dry season. It should then be field baled either by duplicating the standard Northeast Thailand retted fiber drum or in a wooden box in which the ribbon could be manually compressed to a bulk density of about 140 kg./cu.m. The ribbon should then be high density baled to about 576 kg./cu.m. in one of the standard Thai kenaf baling presses for long distance transport and subsequent storage.

5.6. Kenaf Ribbon Procurement

As for whole stalks, there are three basic ribbon procurement alternatives available to the pulp mill - by a mill organization, through the kenaf baling plants and traders, and through cooperatives. It is submitted that, in view of the much larger procurement area involved in ribbon purchases and the requirement for high density baling of the ribbon, it would be even more burdensome for the mill to set up ribbon collection centers and depots than for stalk purchases and that the use of the established kenaf trading channels offers the most practical and economic solution apart from assuring the trade's cooperation rather than its opposition; furthermore, it would open up the entire Northeast as a ribbon supply area rather than only a portion thereof. It is also estimated that the cooperatives operating in the Resettlement Areas of the Department of Public Welfare located in the Southern sector of Northeast Thailand could contribute up to 54,000 FDMT of bast ribbon annually to the overall 160,000 FDMT per year ribbon requirements of a kenaf bast ribbon pulp mill established at Site II.

5.7. Kenaf Ribbon Transport

A 30 cu.m. standard truck body could carry only 4 tons of field baled ribbon but up to 17 tons, by volume, of high density baled ribbon. In practice, 10-ton trucks would probably be used and loaded with 12 to 14 tons of the latter type of ribbon bales.

6. Kenaf Raw Material Availability Projection

6.1. Northeast Thailand

The area planted to kenaf each year in the Northeast largely depends on the fiber price the farmer received the previous year and, over the last decade, has fluctuated from as little as 1.1 million rai to as much as 3.4 million rai (171,000 to 535,000 ha.) annually, but has averaged about 2.4 million rai (384,000 ha.). In the past, a steady farm gate price of at least ฿2.50/kg. ($0.125/kg.) of Mixed Grade retted fiber encouraged the Northeast kenaf farmers to increase their plantings. Reasonable Northeast Thailand kenaf demand projections indicate that the above average 2.4 million rai (384,000 ha.) annual planting area would just about meet the requirements of the local mills, the fiber export trade and a 70,000 ADMT/year whole stalk kenaf pulp mill, but that it would fall some 350,000 rai (56,000 ha.) short if a kenaf bast ribbon pulp mill using 100 percent bast ribbon raw material was installed.

Until recently, kenaf was the only major upland crop in the Northeast, although it competed for the available upland planting areas with a variety of other crops, where the kenaf was - and is - normally grown on the poorer soils. Such general upland crop plantings are estimated to have reached some 3,250,000 rai (520,000 ha.) in 1975 but did not, in themselves, adversely affect kenaf production. However, a more serious competitor is tapioca which has made some inroads into kenaf production during the last year or two since it can be grown on the same poor soils as kenaf, is easy to produce and, at prevailing and projected market prices, offers the farmer a greater revenue estimated at some ฿600/rai ($187.50/ha.) under Northeast conditions which would be equivalent to the gross revenue generated by a Mixed Grade retted fiber farm gate price of ฿3.25/kg. ($0.1625/kg.)

Since this Study assumes that the kenaf pulp mill(s) would offer the farmer a gross revenue of ฿600/rai ($187.50/ha.) for his whole stalks (without further processing and thus as easy or easier to produce than tapioca) and a 10 percent higher revenue for his kenaf ribbon (requiring about the same amount of work as tapioca production), it is then concluded that (i) the availability of upland crop areas in the Northeast is not a limiting factor of the kenaf stalk or ribbon supply potential; (ii) an adequate price incentive can assure an adequate supply; and (iii) the farm price for field dry kenaf stalks and/or ribbon to be offered by the kenaf pulp mill constitutes such an adequate price incentive.

6.2. Laos

Since the small local market could not support a pulp mill, any kenaf for paper pulp produced in Laos would have to be supplied to mills either in Northeast Thailand or in Northern Cambodia. In view of the absence of Government authorization for the Consultants to visit the potential production areas, it can only be assumed that the competitive position between kenaf and other upland crops in Laos would be similar to that in Northeast Thailand and that the prices to be offered for kenaf stalks and/or ribbon by the projected pulp mills would provide an adequate incentive to the Lao farmers to produce the crop.

6.3. Cambodia

The past positive results of kenaf promotion programs in Cambodia seem to indicate that adequate supplies would become readily available once an assured market exists. This combined with the fact that, from the point of view of soil and climatic conditions, the crop can be grown in large areas of the country, would make it appear that prospects for kenaf for paper pulp production in Cambodia do indeed look favorable.

6.4. Viet-Nam

In Viet-Nam, only the Central Highlands Provinces of Darlac, Pleiku and Kontum are both located within the Mekong watershed and offer suitable soil conditions for kenaf production; the Delta, the only other sector of the country in the Mekong watershed area, consists mostly of poorly drained soils and, in any case, is largely reserved for food crop production. Kenaf has been grown successfully in the Central Highlands in the past and extensive areas suitable for its production do indeed exist in the three Mekong Basin provinces. The same applies to 12 other provinces in Viet-Nam and there is no doubt that ample kenaf raw material supplies would become available once a reliable market in the form of a kenaf pulp mill exists.

7. Pulp Mill Demonstration Farm

It is proposed that the pulp mill should establish one or more nucleus farms to serve as extension services, demonstration and, possibly, credit supply centers to the small holder kenaf producers in their respective areas of coverage. Such Demonstration Farm(s) should be organized along commercial plantation lines and one 240 ha. Farm "Unit" is described in detail, where it is assumed that they would be planted to the higher yielding H. cannabinus species of kenaf.

7.1./7.2. Cultural Operations, Seed Planting and Fertilization

The Demonstration Farm area would be thoroughly cleared and stumped to permit extensive mechanization of all farming operations, including plowing, disking, seeding and fertilizer application. No weeding and thinning should be required for H. cannabinus.

7.3. Harvesting and Processing

Whole Stalk Production: Harvesting should start about the middle of December, after the crop has started to dry out, and should be completed by the end of March. The whole stalks should be cut by a high-crop harvester and then topped and field bundled.

Chopped Stalk Production: The same harvesting period applies as for whole stalks. The stalks should be cut and chopped by a forage harvester and the chips blown into a follow-up trailer.

Bast Ribbon Production: Harvesting and ribboning should be scheduled for the August to December period when the stalks are still green and the ribbon can readily be separated from the woody core. The stalks should be cut and bundled by a high-crop harvester and then passed through ribboning machines for bast stripping. After the ribbon has been dried, it should be field baled.

7.4./7.5. Operating Schedules and Equipment, Facility and Personnel Requirements

Detailed operating schedules for all three types of kenaf raw material have been worked out for the 240 ha. Demonstration Farm Unit and it has been established that each Unit will require three 70 to 80 HP. wheel tractors complete with a full range of tractor implements; a fourth stand-by tractor should be provided for general transportation purposes and as a reserve unit. With regard to stalk harvesting and processing equipment, whole stalk production would require two high-crop harvesters; for chopped stalk production, these two units would be replaced by one pull-type forage harvester (or a sugar cane harvester/chopper); and for bast ribbon production, two high-crop harvesters and six ribboning machines would be required.

Including allowances for farm roads and buildings, each Unit would require some 250 ha. and a prefabricated storage shed should be provided.

Each Unit would be administered by a Farm Manager assisted by two Field Supervisors. Except for tractor operators and helpers, all labor would be employed on a temporary basis as and when needed.

CHAPTER VI - THE HANDLING, STORAGE, RECLAIMING, FIBERIZING, AND WET CLEANING OF KENAF AT THE PULP MILL

1. Introduction

Research on kenaf storage, together with the knowledge of the storage of other nonwood plant fibers for commercial pulp/paper operations, are sufficient for the design of systems for storage of green or field dried kenaf at the pulp mill.

2. The Handling of Green and Field Dried Whole Stalk and Bast Ribbon Kenaf Brought to the Mill in Bulk or Bundled Form

Some green and field dried whole stalk and bast ribbon kenaf in either chopped or bundled form would be hauled directly to the mill from nearby farming areas when transportation of the bulky material would be economical. The flow of this kenaf during the harvest season would be scheduled to be less than the daily requirements of the pulp mill so it would be processed directly into the fiber preparation system.

3. The Handling and Storage of Field Dried Whole Stalk and Bast Ribbon Kenaf Bales at the Pulp Mill

Bales of field dried kenaf from the collecting and baling stations and their satellite storage yards would be hauled to the mill by trucks and either used directly in the fiber preparation system or put into storage.

There are a number of bale storage and handling systems which have been used successfully for bagasse and straw pulp mills. They are described in the main text of this report and are listed as the Celotex Method, the Mechanical System, the Taiwan Method, and the Thessalian Method.

It appears that the heating and fermentation problems which have arisen in the storage of bagasse baled at 50 percent moisture content will not be present for the field dried kenaf which would be stored in bales at approximately 12.5 percent moisture. The handling and storage of baled field dried whole stalk and bast ribbon is judged to be a suitable procedure for maintaining at the pulp mill an inventory of about 25 percent of the annual kenaf requirements.

4. Alternative Systems Considered for Bulk Storage and Handling of Kenaf at the Pulp Mill

It has been determined in the agro-economic sections of this Study that transportation of field dried kenaf in high density bales is the most economical way to get it to the mill. It has also been estimated that, because of the low labor cost in the Mekong project mill kenaf storage yard, bulk handling and storage of the kenaf in either wet or dry form would be more costly than bale storage and would not be required to preserve the papermaking qualities of the raw fiber to a satisfactory degree.

The bulk handling and storage systems which are used for wood chips and agricultural residues such as bagasse could be considered for use on kenaf only in an area of labor shortage and high costs or where the kenaf would be grown on large farms with mechanized harvesting and transporting of the crop to the mill in bulk form.

The bulk storage and handling systems that have been used successfully by the bagasse pulp mills and would be suitable for a kenaf pulp mill are the Ritter Biological Process System, the wet bulk storage system developed at Technica Cubana in Cuba and also used by International Paper Company in Puerto Rico, the Valentine Method, and the Celotex Wet Bulk Storage System. These are described in the main text of this Study.

5. The Handling, Fiberizing and Wet Cleaning of Kenaf in Preparation for the Digester

Kenaf, after fiberizing at the pulp mill, would be handled, wet cleaned, and pulped with the same type of equipment used for bagasse and straw. The baled or loose kenaf, in either whole stalk or bast ribbon form, would be shredded or fiberized with the type of machine which is used to prepare sugar cane for the sugar extraction process.

After mechanical preparation of the kenaf fiber, it would be conveyed to a Hydrapulper where a slurry would be made with recycled water whereby the fiber would be washed to remove soluble sugars, waxes, etc. and dirt, sand and fine parenchyma cells and pith would be loosened from the fiber desired for pulping.

The kenaf slurry would then be pumped through a low gravity centrifugal cleaner to separate and remove heavy and abrasive particles, such as sand and dirt, and then onto a rotating dewatering drum, a drainer conveyer, a vibratory screen, or a fourdrinier type wire drainer.

The dewatered kenaf would then be dropped into a centrifugal hammermill-type apparatus similar to a bagasse depither for removal of fiber fines and pith from the longer fiber and for final separation of residual excess water and loose dirt to prepare the kenaf fiber for feeding to the digester.

Photographs of the equipment and flowsheets of processes that would be used for converting the kenaf raw fiber into finished baled pulp for shipment are found in the main text of this Study.

CHAPTER VII - THE UTILIZATION OF KENAF FOR THE MANUFACTURE OF PAPER PULP IN THE MEKONG BASIN PROJECT MILL

1. Introduction

The techniques of producing paper pulp from other nonwood plant fibers have been judged to be suitable for the manufacture of kenaf pulp. In this chapter, the practical aspects of the manufacture of kenaf pulp in the Mekong project mill are outlined.

2. The Harvesting, Transporting and Storing of Kenaf for the Mekong Basin Project Paper Pulp Mill

The large scale mechanized harvesting and bulk transporting systems used in the sugar cane industry would be expected to be used in countries with high labor costs. The wet or dry bulk storage systems that are used for bagasse would also be used for kenaf under the same situation.

Such systems are not considered to be economical or necessary for the fibrous raw material supply for the kenaf paper pulp mill planned in this Study. In the Mekong Basin, where the kenaf would be field dried and produced as whole stalk or hand stripped bast ribbon by the farmers, it would be hauled by cart to the nearest collection station or baling plant. The kenaf would be pressed into high density bales and stored at the satellite storage yards at the baling stations or hauled by truck directly to the pulp mill for processing or storage in the mill yard.

The woody core material from which the bast ribbon would be stripped could be used for fuel, particleboard, or for certain types of pulp such as mechanical pulp for newsprint or semichemical pulp for corrugating medium. However, for the project as planned, such items are not considered for the mill.

3. The Expected Effects of Storage Conditions on Yield and Quality of Kenaf Paper Pulps in the Mekong Basin Project Mill

The technical reports reviewed have stated yields of pulp ranging from 30 to more than 40 percent for kenaf whole stalk pulp. Bleached pulp yields from as low as 35 percent to as high as 55 percent have been reported for the bast ribbon. In most cases, the higher yield values have been found to be based on the moisture-free weight of the fiber fed to the digester and the moisture-free weight of the bleached pulp produced. While correct as digester yield values in most cases, the high values can be very misleading if considered in predicting the overall yield between the field yield of the green kenaf stalk at

maturity or time of frost kill and the yield of bleached pulp off of the pulp dryer. In the case of some of the reported high yield values, it was obvious that something not mentioned had happened to the kenaf sample before it was cooked and which removed material that would have been removed from the fiber in pulping, thus resulting in a correspondingly lower yield value.

Considering that the USDA has found that about 25 percent of the kenaf stalk dry solids at maturity is water soluble organic matter consisting of gums, sugars, etc., it becomes obvious that the confusion and inconsistencies in yield data reported result from the removal of some of these materials prior to the cooking trials. These losses in solids can result from leaching by the rains during the field drying, during storage when bulk storage systems are used, and as a result of wet cleaning the raw fiber in preparing it for the digester. Such losses are in addition to the mechanical losses of kenaf in harvesting, handling, and storage and the losses of fine fibers in the processing through the pulping and bleaching and papermaking operations before finished pulp in bales is produced for sale.

Taking all these factors into consideration, it appears that, in the projected pulp mill, the average overall yield of kenaf bleached whole stalk pulp will be 35 percent on an oven dry equivalent (moisture-free) basis of the raw material as purchased from the farmer. On the same basis, the finished pulp yield for kenaf bast ribbon has been estimated to be 45 percent.

As for the possibility of detrimental effects of storage and handling the raw fibrous materials on the yield and physical strength properties of the pulps,the system using covered bale storage of the field dried kenaf for the project mill will minimize such effects. Although alternative systems for mechanized harvesting, and bulk handling and storage of kenaf would not be used for this particular project due to their higher cost, they would be equally satisfactory for use on kenaf.

4. The Effect of Wet Cleaning the Kenaf on Pulp Yield and Quality and Mill Operation

Some studies have shown the improvements in pulp physical strength properties and drainage rates which result from wet cleaning the fibrrized raw material to remove the sand, dirt, organic acids and other soluble materials and some of the pith, parenchyma cells, and other fibrous debris before cooking the kenaf. In addition, as is the case for commercial operations pulping straw and bagasse, such a wet cleaning step will have many beneficial effects in the subsequent pulp

washing and bleaching steps and the recovery of the spent liquor from the pulp. These benefits accrue with little or no additional loss of papermaking fiber than would occur at other points further on in the process if the wet cleaning had not been done.

5. Pulping and Bleaching Processes and Conditions Suitable for the Manufacture of Paper Pulp from Kenaf in the Mekong Project Mill

Although almost every possible grade and type of pulp has been produced experimentally from kenaf whole stalk, woody core material and bast ribbon, most of them could not be considered to be suitable products for the project mill. Based upon the market for pulp in the Mekong riparian countries, the logical choices for mill products are the unbleached and bleached grades of fully cooked chemical pulps made from kenaf whole stalk or bast ribbon by the soda or sulfate (kraft) processes.

In the project mill as planned, the wet cleaned kenaf would be cooked in a continuous, horizontal tube-type digester, as is used for other nonwood plant fibers, where only a short cooking cycle at high pressure is required for the fiberized material.

Following this, the spent liquor washed out of the kenaf after it is cooked would be returned to the liquor recovery system. The steps in this process are evaporation of the spent liquor followed by burning it in the recovery furnace to remove the organic materials cooked out of the kenaf from the sodium salts that are the basis for the cooking liquor. The solution of sodium salts is then treated (causticized) with reburned lime to convert them into alkali for cooking more kenaf and the lime sludge is recycled and reburned to convert it back to lime for use again in the causticizing process.

For bleaching, any one of the several standard sequences of chemical treatments used on pulps from wood, straw, or bagasse would be satisfactory. For the project mill, the bleaching sequence CEHD (chlorination, alkaline extraction, calcium hypochlorite, and chlorine dioxide) with a final wash with sulfur dioxide as an anti-chlor has been chosen.

For maximum economy and efficiency of operation, the project mill as planned would include electrolytic facilities for producing part of the cooking chemicals and all of the bleaching chemicals required. Lime makeup would be produced from burning limestone in the sludge reburning kiln.

6. The Anticipated Characteristics of Kenaf Pulps in Washing and Screening

The major criticism of kenaf pulp, particularly for pulp from whole stalk and even more so for that from the woody core material, has been because of its slow drainage characteristics as shown by low initial freeness values. In this respect, these kenaf pulps are similar to pulp from rice straw that has not been thoroughly wet cleaned or bagasse which has not been depithed before cooking.

In the processing of the fibrous raw material in the project mill, it would be wet cleaned to improve the drainage characteristics of the whole stalk pulp. The pulp washing equipment surface area in the brown-stock washing system and the bleach plant would be designed to handle the more slowly draining kenaf whole stalk pulp so that the more rapidly draining bast ribbon pulp could easily be produced at a higher rate.

The screening and fiber cleaning systems for the kenaf pulp mill would be based on certrifugal principals which would serve adequately for producing either type of pulp.

7. Pulp Drying and Papermaking with Kenaf Pulps

The papermaking properties of kenaf pulps of both types have not been clearly demonstrated for manufacturing the major tonnage grades of paper and paperboard from a 100 percent furnish of these fibers on a commercial scale. The laboratory and pilot plant papermaking runs have not been made with kenaf pulps produced with modern optimum continuous pulping and bleaching processes. In addition, in most of the trials the kenaf pulp, usually that from whole stalk, has merely been used to replace some other pulp in a mixed furnish so that the specific papermaking characteristics of the kenaf pulp were somewhat obscured.

Despite the scarcity of knowledge on the commercial operation of pulp driers or papermachines using kenaf pulps, the project mill would be planned to anticipate the possible problems that could arise in running the whole stalk pulp over the dryer. The equipment would consist of a fourdrinier wet end followed by a press section with means to convey the weak wet web through to the dryer section. The dryer section would consist of can-type dryers with any necessary dryer fabrics to minimize breaks in the web.

In addition, and in anticipation of the importance for plans to convert the pulp mill into an integrated paper mill, the pulp drying equipment would be designed for minimum expense and modification requirements for conversion into a paper machine.

8. Environmental Control for the Kenaf Paper Pulp Mill

8.1. Introduction

The project mill would be designed for air and stream pollution control capabilities matching those of a modern pulp mill in developed countries.

8.2. Stream Pollution Control Facilities for the Mekong Basin Paper Pulp Mill

The project mill would be designed for maximum recycling of waste water and condensates within the process. The effluent from the mill would be treated in a primary system to remove by settling most of the dirt, fiber fines, and other solids separated from kenaf in the processing. The settled sludge would be further dewatered and used for land fill or burned in a boiler in which kenaf core material might be used as fuel.

The clarified primary effluent would then undergo a secondary treatment step in suitable aeration and impounding basins, resulting in a breakdown of the soluble organic materials which would consume oxygen if not eliminated before dumping the effluent in the receiving stream.

The effluent from the mill to the river would meet the working standards for industrial effluents discharging to inland streams as established by the Government of Thailand. It would contain no sanitary sewage or harmful or poisonous chemicals.

For the project mill, the effluent from the part of the process wherein the kenaf would be wet cleaned would not be treated. Because of its great load of oxygen consuming organic materials and fibrous debris this effluent would carry to the treating system, it would instead be used for irrigation as is done at one of the bagasse pulp mills. This would be beneficial in that organic matter, nutrients, and trace minerals washed out of the kenaf would be returned to the soil.

8.3. Air Pollution Control Facilities for the Mekong Basin Paper Pulp Mill

Although it is not planned to locate the pulp mill in an urban area where there might be public objections to traces of odors and dust, noise, and a misunderstanding that steam plumes from condensed harmless water vapor from the process are smoke, the project mill has been designed for a high degree of air pollution control in normal operation.

As the pulp mill will be designed to operate within the chemical range of a full soda process (sodium hydroxide make-up) to a full sulfate or kraft process (sodium sulfate make-up), the air pollution control system would include equipment for abating unpleasant odors which can arise when using the sulfate process. The units for odor control would be those widely used for this purpose in the pulp industry, such as a black liquor oxidation system, facilities for burning noncondensible reduced sulfur gases from the evaporators and digester blow system, an oversized black liquor recovery furnace equipped with a high efficiency electrostatic precipitator, a high efficiency Venturi-Scrubber on the lime kiln, and means for absorbing waste bleach plant gases in water going to the effluent system for further treatment.

The use of these pollution control systems would leave the area adjacent to the mill suitable for other industrial or agricultural enterprises.

CHAPTER VIII - FINANCIAL ASPECTS OF KENAF PRODUCTION FOR PAPER PULP MANUFACTURE

1. Farm Revenue from Kenaf Textile Fiber Production in Northeast Thailand

Farm level prices for Mixed Grade retted fiber averaged ฿2.30/kg. ($0.115/kg.) during the most recent 5-year period and stood at ฿2.46/kg. ($0.123/kg.) for the 1974/1975 season. In an attempt to reverse the recent decline in kenaf production, the Thai bag and hessian mills established guaranteed minimum

fiber prices equivalent to a farm gate price of ฿2.75/kg. (US$0.138/kg.) for Mixed Grade in April 1975 and increased this to a farm gate price equivalent to ฿3.25/kg. (US$0.1625/kg.) in July 1975. At the latter price level and on the assumption of an average retted fiber yield of 184 kg./rai (1,150 kg./ha.), the farmers' gross revenue would amount to ฿598 or, say, ฿600/rai (US$187.50/ha.).

2. Estimated Farm Prices of Kenaf Pulping Raw Materials

Although the grower will expend from 40 to 45 percent less costs and labor on the production of kenaf stalks (whole or chopped) for sale to the pulp mill compared to retted kenaf production for sale as textile fiber, this Study assumes that his gross revenue must remain at the same level to provide him with the necessary production incentive, particularly in competition with tapioca. On the basis of a 1,200 kg./rai (7,500 kg./ha.) field dry whole stalk yield, the price payable for one metric ton of such stalks would then have to be ฿498 (US$24.90), delivered local collection center. It is noted that, at a stalk yield of 1,500 kg./rai (9,375 kg./ha.), this cost would be reduced by one-fifth to ฿400 (US$20.00) per metric ton.

For kenaf bast ribbon, a 10 percent increase in gross revenue is assumed to provide the required incentive to induce the farmer to carry out the additional stripping operation. At a bast ribbon yield of 340 kg./rai (2,100 kg./ha.), the price payable for one metric ton of field dry ribbon would then have to be ฿1,935 (US$96.75) delivered local collection center.

2.2. Western Hemisphere Kenaf

H. cannabinus is expected to produce about twice as large yields as *H. sabdariffa* but it will require some increased expenditures, particularly on selected seed and on fertilizer, so that its adjusted gross revenue will not be twice as much but only some two-thirds greater. In addition, since *H. cannabinus* must be planted on more fertile soils on which the farmer would have the alternative to grow a higher value crop, this Study assumes (most conservatively) that the pulp mill will pay the same stalk and ribbon prices, per field dry metric ton delivered local collection center, for both kenaf species as follows:

Whole Kenaf Stalks = ฿ 498 (US$24.90)/FDMT;

Kenaf Bast Ribbon = ฿1,935 (US$96.75)/FDMT.

3. Kenaf Raw Material Purchasing and Handling Cost Estimates

3.1. Pulp Mill Procurement Organization

For whole kenaf stalks, the average collection center costs of purchasing, weighing, stacking, waterproof cover protection, and destacking, rebundling and loading into trucks for transport to the pulp mill are estimated at $45.00 (US$2.25)/FDMT.

To establish a pulp mill operated chopped whole stalk purchasing and baling organization would require an estimated capital investment in baling plant and allied facilities of some ฿45 million (US$2.25 million) and, at an estimated baling cost of ฿48 (US$2.40) per chopped stalk material bale, an annual operating expenditure of some ฿54.4 million (US$2,720,000).

For bast ribbon purchasing and baling, a somewhat smaller capital investment of about ฿35 million (US$1.75 million) and annual operating costs of some ฿42.2 million (US$2,110,000) would be required, if the ribbon is to be procured by the mill itself.

3.2. Procurement Through Kenaf Baling Plants and Traders

This procurement system would eliminate all capital investment requirements by the pulp mill, since the established kenaf baling plant facilities would then by utilized. Furthermore, it is anticipated that the balers would be willing to bale stalk chips or bast ribbon on contract at a rate of about ฿20 (US$1.00) per bale. Allowing for reasonable storage charges at the baling plants, it is suggested that the same ฿45 (US$2.25)/FDMT of handling costs estimated for the mill operated collection centers be set aside for the balers but that including the baling charges.

3.3. Procurement Through Cooperative

If the cooperatives were to establish their own baling plants, the capital and operating costs would be the same as those estimated for a mill operated procurement organization and it is suggested that it would be to their advantage to contract for baling with the established baling plants.

4. Kenaf Raw Material Transportation Cost Estimates

Based upon the bulk densities and average lead distances established for the various types of kenaf pulping raw material in this Study and upon a brief survey of Government and private firm trucking rates, the following transportation costs per field dry metric ton from the collection centers to the mill yard have been calculated:

	₱	$
A. Whole Stalks:		
Field Bundled	136.00	6.80
Press Baled	52.00	2.60
B. Chopped Stalks:		
In Bulk	208.00	10.40
Press Baled	45.00	2.25
C. Bast Ribbon (Press Baled)	90.00	4.50

5. Kenaf Raw Material Cost, Delivered Mill Yard Gate

The total costs, rounded off, of the various types of kenaf raw material, delivered to the pulp mill yard gate, are then summarized as follows:

	Cost/FDMT	
	₱	$
A. Whole Kenaf Stalks:		
Field Bundled	680.00	34.00
Press Baled	600.00	30.00
B. Chopped Kenaf Stalks:		
In Bulk	750.00	37.50
Press Baled	590.00	29.50
C. Kenaf Bast Ribbon(Press Baled)	2,080.00	104.00

6. Pulp Mill Demonstration Farm

Detailed capital cost, operating cost, profit & loss and cash flow estimates are presented for a 240 ha. Demonstration Farm Unit and for the whole stalk, chopped stalk and bast ribbon production alternatives respectively and these may be summarized as follows:

	Whole Stalks	Chopped Stalks	Bast Ribbon
Capital Costs:			
1st. Year	$189,135	$179,015	$363,360
2nd Year	12,780	12,550	27,380
Operating Costs (Per Year)	73,345	70,405	96,150
Production Costs/FDMT	24.00	22.90	146.10
Suggested Sales Price/FDMT	28.80	27.50	175.30
Investment Repayment Period	10 years	11 years	15 years

CHAPTER IX - ESTIMATED PRODUCTION COSTS, CAPITAL REQUIREMENTS, PROFITABILITY, AND ECONOMIC VALUES OF A KENAF PAPER PULP MILL IN THE MEKONG BASIN AREA

1. Introduction

In a pre-feasibility study for an undertaking of the magnitude of the kenaf paper project in a developing country, it is essential that there be not only a realistic appraisal of all the technical factors but of the financial and economic aspects as well. There have been far too many projects in both developed and developing countries where faulty engineering planning and underestimation of capital investment requirements and manufacturing costs have resulted in great and continuing difficulties for a new enterprise. For this reason, a very detailed financial analysis has been made for the kenaf project mill.

2. Development of the Estimated Production Costs of the Mekong Basin Project Kenaf Pulp Mill

It has been estimated that approximately 781 local workers, including 320 of them in the kenaf storage and handling area of the

mill, would be employed. In addition, the services of a foreign technical assistance team for a period of the first four years of mill operation have been included in the costs for labor. Including all perquisites, salaries, and wages, it has been estimated that the labor cost for the project mill would be ฿303/ADMT (US$15.15/ADMT) of bleached pulp product after the departure of the foreign technical assistance team.

Estimates of direct production costs at full operating rate have been developed for both kenaf whole stalk and bast ribbon bleached pulps. These estimates have been based on the kenaf fibrous raw material costs developed in the agro-economic sections of this Study, the cost of chemicals and fuel at the mill site in Northeast Thailand, labor costs, maintenance and operating materials and supplies, contingencies, and fire insurance on kenaf in the mill storage yard.

The direct production costs have been estimated to be US$181.74/ADMT for whole stalk pulp and US$331.91/ADMT of pulp for the bast ribbon type.

The cost of products sold, based on the direct production costs, selling expense, prepaid freight on pulp, insurance of fixed assets, and the business tax, have been estimated to be US$239.03/ADMT for whole stalk pulp and US$403.33/ADMT for the bast ribbon pulp.

These costs have been based on the plan that the pulp mill would use lignite mined in Thailand as the most available and lowest cost fuel. If imported oil were used as the fuel, US$34.44/ADMT would have to be added on to the cost figures. It has been planned that the project mill would generate all the necessary steam and power, including that required by the townsite.

3. Estimated Total Capital Requirements to Establish a Kenaf Paper Pulp Mill

For estimating the total capital requirements of the project mill, budget quotations at 1975 price levels were obtained on the major pieces of equipment that the mill would use. From this information, it was estimated that total machinery and equipment, delivered to the mill site, would cost US$32,300,000 in foreign currency and US$6,400,000 in local currency for a total of US$38,700,000.

For land, site development, and plant buildings and structures there would be required US$550,000 in foreign currency and US$6,250,000 in local money.

All other items to be capitalized for the plant, such as spare parts and consumables, erection labor, materials, and supervision, engineering and technical services, personnel training abroad, prestart-up and start-up expenses, contingencies, and interest during construction were estimated to require a capital of US$20,900,000 in foreign currency and US$8,300,000 in local money for a total of US$29,200,000.

The total of the foregoing capital requirements for implementing the pulp mill was US$53,750,000 in foreign currency and US$20,950,000 in local money for a total of US$74,700,000. When the local capital for the housing community of US$3,357,000 is added, the total cost of the fixed assets becomes US$78,057,000.

Inclusion of working capital of US$3,227,000 results in an estimated total capital required to establish the "turn key" project for whole stalk pulp at start-up of US$53,750,000 from foreign funds and US$27,534,000 from local sources for a total of US$81,284,000. If the mill would pulp only kenaf bast ribbon, the additional working capital required for the inventory of kenaf at the mill would be US$2,617,000. However, in the financial projections it was assumed this would be borrowed at 10 percent interest from local sources and would be repaid as soon as possible from funds generated by the mill.

Based upon these estimates that the local funds would be 33.87 percent of total capital requirements, this was chosen as the amount of equity to be put up by the owners of the mill during the period before the start of commercial operations. This 2:1 debt to equity ratio was judged to be more than adequate to obtain favorable terms for financing from foreign or international agencies for the balance of the total capital requitements.

It is interesting to note that the total capital requirement of US$406,000/ADMT/day of pulp that has been estimated is only slightly less than the US$425,000 for this size of "turn key" kenaf pulp mill when read from the general curve for total investment requirements discussed in Section 6.2. of Chapter I and attached hereto.

4. <u>The Estimates of Profitability for Kenaf Paper Pulp Mills</u>

In developing profit and loss statements for this project, it was assumed that interest of 10 percent would be paid on the foreign loan, with the first interest payment due on the theoretical start-up date of the mill. Thereafter, at 6 months intervals, interest would be paid and the principal would be paid off in 20 installments over a 10 year period.

This interest rate and period for debt repayment were used because it was judged that foreign lenders would require this in view of the inflationary forces at work in the economy of the world.

Depreciation on the "straight line" basis of 20 years for buildings and structures and 15 years for machinery and other capitalized items have been used in view of the favorable income tax holiday granted by the Thai Board of Investment for Promoted Enterprises in the Special Investment Zones. Two other important items in the financial analyses are the following:

Pulp Price

For the financial projection for the kenaf whole stalk pulp mill, it was assumed that this product would be priced at US$450.00/ADMT delivered to a paper mill in Bangkok. This was estimated to be competitive with the total price, duties and handling costs for bleached hardwood market pulp in Thailand at the end of 1975.

In the financial projection for the kenaf bast ribbon pulp project, consideration had to be given to the fact that the fibrous raw material cost for the bast ribbon would be US$160.65/ADMT of pulp higher than for whole stalk pulp. Therefore, to show a mill of approximately the same financial viability as for whole stalk pulp, the delivered sales price of the bast ribbon pulp was increased to US$600.00/ADMT. This is approximated US$130.00/ADMT higher than the bleached softwood market pulp was costing, delivered in Thailand, at the end of 1975.

The use of this price for the bast ribbon pulp was also based on the fact that the national and regional benefits of such a project as planned for Northeast Thailand would justify the imposition in its favor of an import duty of about 28 percent of the C.I.F. value against imported softwood pulp.

Inflation Factor

Additional estimated profit and loss statements for the kenaf pulp mill have also been made in which an average inflation factor of 3 percent per annum was used. This type of "indexation" estimate, which is coming into use more in the business world, shows the effect of long term escalation of prices and costs in relation to the initial fixed debt of the project and the interest paid on it.

It is not only important to show the effects of inflation in a financial projection but the time value of the money invested in the project as equity by the owners must be considered in the profitability analysis covering a projection period of 15 years of operation of the mill. In this Study, the profitability of the projects has been determined on the Discounted Cash Flow (DCF) basis in which return on equity put into the project before start-up of commercial operations is also given equal consideration along with value of working capital and of the mill at the end of the projection period. This is believed to be the most realistic way to appraise the financial aspects of this project. However, for comparison purposes, the different calculations used in this Study and estimates of project profitability were as follows:

Kenaf Pulp Type	Inflation Factor (%)	Payback Period (Years)	Average Annual Return on Basis of Total Investment (%)	Average Annual Return on Basis of Owners' Equity (%)	Average Annual Return on Basis of Owners' Equity (DCF) (%)
Whole Stalk	0	7.55	14.1	35.0	16.9
	3	6.76	20.3	53.1	20.4
'Bast Ribbon	0	7.75	13.5	34.6	16.4
	3	6.90	19.3	52.3	19.9

The Payback Period measures the rapidity of return of the capital investment. It is not considered a proper expression of profitability because it ignores earnings beyond the period, the time value of money, and the residual value of the mill and working capital.

The return on Total Capital Investment does not take into acccunt the timing of money flows and is considered to be suited only as a secondary expression of profitability.

Simple expression of the Return on Equity is considered misleading for this profitability analysis because it ignores the time value of money and the years prior to start-up when most of the equity investment would be made. However, when Return on Equity is expressed on the Discounted Net Cash Flow basis which removes payment of the foreign debt from the Gross Cash Flow, a realistic financial appraisal of the project's value to the owners is obtained.

In the case of the kenaf whole stalk pulp mill selling its product at the competitive market price for imported hardwood pulp in Thailand, the Rate of Return on Equity (DCF basis) of 16.9 percent per annum is very favorable.

However, the kenaf bast ribbon pulp has such a high fibrous raw material cost in comparison with the kenaf whole stalk pulp that to achieve the same approximate profitability it would have to sell for US$600.00/ADMT or US$150.00/ADMT more than the latter product. This sale price for the bast ribbon pulp is about US$130.00/ADMT higher than for the technically competitive bleached softwood sulfate pulp imported into Thailand at the present time.

5. The Economic Values of the Various Kenaf Pulp Project Options

The financial projections of this Study show the important long range economic benefits which would result from establishing the kenaf pulp mill in the Mekong Basin. As an example, the kenaf whole stalk bleached pulp mill project, without any consideration given to the factor of inflation, would produce in the following benefits:

Employment

At least 780 people directly employed in the mill.

At least 2,400 supportive and service jobs in nearby communities.

Full or part time employment of an estimated 20,000 families in the agriculture sector to grow, harvest, and transport kenaf.

Creation of new jobs for producing and transporting chemicals and fuel to the mill and transporting the pulp products.

Jobs of several years duration to build the mill and equipment from local sources.

Local Expenditures

A total expenditure of ฿486,140,000 (US$24,307,000) for local goods and services during the construction of the mill.

An average annual expenditure of ฿288,280,000 (US$14,414,000) for local goods and services out of a sales revenue of ฿611,100,000 (US$30,555,000) per year.

Taxes

A considerable amount of taxes resulting from new business activity and on income to those supplying goods and services to the mill and on dividends to stock-holders would be paid.

A business tax averaging ฿30,280,000 (US$1,514,000) per year on sale of products would be paid.

Corporate income tax averaging only ฿7,920,000 (US$396,000) per year would be paid due to favorable tax incentives for Promoted Enterprises in Northeast Thailand.

A loss of duties and other taxes on imported pulp amounting to ฿16,840,000 (US$842,000) per year would result.

Foreign Exchange Savings

During the financial projection period, the annual average payout of foreign exchange would be US$6,384,000 for repayment of foreign debt and the interest on it, for the services of the Technical Assistance Foreign Team, and for imported spare parts and supplies.

Foreign exchange for the purchase of hardwood pulp amounting to US$29,537,000 per year on the average would be saved. Therefore the net saving of foreign exchange would be US$23,153,000 annually.

6. The Financial Viability of the Kenaf Pulp Project Options

The results of this Study indicate that the kenaf whole stalk bleached pulp mill would be economically viable at the present prices paid for hardwood bleached sulfate pulp imported into Thailand.

However, a serious local competitive situation could result if proposed bagasse/bamboo pulp/paper mills are implemented. It has been estimated that bagasse bleached pulp could be sold in Thailand for as much as ฿852/ADMT (US$42.60/ADMT) less than the kenaf whole stalk pulp due to its lower cost for fibrous raw material. This would be the case where lignite is the replacement fuel for bagasse at the sugar mill and is used for fuel at the pulp mill.

Despite this specific situation, it should be considered that the kenaf pulp mill would furnish additional employment in the agricultural sector of the Mekong Basin which the bagasse pulp mill would not do. It would also stabilize the market for kenaf in that area.

In the case of kenaf bast ribbon pulp, it would have to sell for about 33 percent more than the whole stalk pulp for the mill to have equivalent financial viability. This higher price for kenaf bast ribbon pulp would require that a duty of about 29 percent of the C.I.F. value would have to be imposed on softwood bleached sulfate pulp imported into Thailand to make the two pulps competitive in price.

Although the mill as designed would produce either type of kenaf pulp, it appears that kenaf whole stalk pulp would be the better product option, if the entire production of the mill could be marketed at the sales price used for the financial projections of this Study.

CHAPTER X - DEVELOPMENTAL ACTIVITY REQUIREMENTS

1. Introduction

The further investigative, research and pilot program activities deemed necessary prior to large-scale kenaf based pulp and paper mill project implementation are discussed and the Draft Terms of Reference for a follow-up development program are established.

2. Agro-Economic Aspects

2.1. Agronomic Considerations

Variety testing and selection will have to be one of the basic development program concerns and should include both the local and newly introduced kenaf varieties. These activities should be complemented by investigations into land preparation methods; time-of-planting and planting method trials, the latter with particular emphasis on planting implements and planting distances; fertilizer trials under different soil conditions; weeding and seedling thinning for the *H. sabdariffa* species; pest and disease control investigations, prominently including rootknot nematode problems with respect to *H. cannabinus* planting areas; production and processing of improved seed; rotation crop trials and soil conservation measures; and a detailed survey of potential kenaf for paper pulp production areas in the Lower Mekong Basin area.

2.2. Crop Harvesting, Processing and Handling

Investigative activities under this heading must include the establishment of optimum harvesting periods and feasible harvesting period ranges for whole stalk, chopped stalk and bast ribbon production respectively; harvesting method and procedure tests, both manual and mechanized, again for the three types of kenaf pulping raw material and including stalk chopping and bast ribbon stripping; detailed and exhaustive analyses of stalk and bast ribbon yields and of stalk composition; field drying and field and production area storage alternatives; field and high-density whole stalk, chopped stalk and bast ribbon baling; and investigations into kenaf raw material transport from the production areas to the pulp mill yard gate.

2.3. Agri-Economic Development Program Implementation and Evaluation

The proposed agro-economic development activities should be implemented through a combined research and pilot scale program which, in turn, must be closely coordinated with the ongoing local kenaf research efforts. In view of the large potential savings to the pulp mill by even minor kenaf yield improvements, development program financing might be assigned to the mill project. The research program should follow the already well established investigative procedures, and the pilot program - possibly organized along Demonstration Farm lines - should aim at duplicating commercial methods, although obviously on a limited scale of the order of 80 ha. (200 acres - 500 rai). Subsidiary small-scale research and pilot programs would have to be carried out in each major kenaf for paper pulp production area, again in close cooperation with the local agricultural research authorities.

Thorough evaluation of the research and pilot programs would be undertaken upon completion of the first season.

2.4. Draft Terms of Reference, Additional Development Program

Detailed proposed Terms of Reference for further investigative activities of the agro-economic project aspects as required to complement and confirm the conclusions and recommendations of this present Pre-Feasibility Study are listed.

3. Pulp and Paper Manufacturing Aspects of Near Term Developmental Activity Requirements

3.1. The Value of Further Laboratory Studies on the Pulping of Kenaf

In the 25 years since the extensive laboratory and the limited pilot plant investigations of kenaf for paper pulp began, there have been many independent studies published. For lack of facilities and funds to conduct full scale mill trials under proper conditions, or the judgement based on research that they would not be warranted, the commercial development of kenaf pulps has not taken place as originally expected when the unusual qualities of this fibrous raw material for papermaking were first recognized. No mills with recovery systems have been built for kenaf pulp production during this period when there has been a very significant expansion in the commercial exploitation of other nonwood plant fibers such as bagasse and straw for pulp and paper.

Although a number of mills and research organizations have produced some kenaf pulp and paper in limited test runs, there is only one plant, the cigarette paper mill of Tvornica Papira in Yugoslavia, that is using kenaf pulp and it is the bast ribbon type.

3.2. The Need for Production of Commercial Quantities of Kenaf Pulps for Market Trials

Therefore, it has been concluded by the Consultants that it has not been a shortage of research investigations and knowledge on pulping this fiber but the lack of production of kenaf pulp on a large enough scale for market trials that has impeded its development in the industry. Sufficient kenaf chemical pulp produced with the proper fiber wet cleaning and continuous digesting, bleaching and drying systems from both whole stalk and bast ribbon would be required for substitution trials in nonintegrated paper mills using softwood and hardwood sulfate pulps in mixed furnishes. In addition, papermaking trials should also be made with 100 percent kenaf slush pulp to produce the major grades of paper and paperboard now manufactured from wood pulp.

These are the major investigations needed to be undertaken in preparation for further development of a kenaf paper pulp mill.

3.3. The Problems Relating to Pulp/Paper Manufacturing Remaining to be Solved Before Building a Pulp Mill Using Kenaf

The only problem of major significance that needs to be solved for equipment for kenaf fiber processing is that of bale breaking, chopping and fiberizing the large quantities of kenaf needed for the pulp mill. It is believed that equipment already in use by the cane sugar industry can be used in this step in pulp production. If such equipment were to be installed at one of the modern mills pulping bagasse, it would complete the entire series of equipment and process stages needed to pulp kenaf whole stalk and bast ribbon fiber.

The other major problem remaining to be solved is that of market trials of the pulps and the production of as wide a grade range as possible of paper and paperboard. Favorable results in solving this problem should accelerate the commercial acceptance of kenaf pulp and furnish a much sounder basis for building a kenaf pulp mill than presently exists.

3.4. Draft Terms of Reference, Additional Development Program for Pulp and Paper from Kenaf

In parallel with the commercial production and market trials which are needed for further commercial development of kenaf pulp production, there are several areas for research and pilot plant investigation that have not been thoroughly explored. However, these studies would not necessarily be required before a kenaf pulp mill could be implemented.

Comparative Pulping Evaluations

These tests would determine significant differences in pulps from the samples of kenaf grown under the agro-economic research program.

Evaluation of Various Storage Conditions for Kenaf

Systems used for bulk storage and handling of other nonwood plant fibers and wood chips would be evaluated for relationship to yield and preservation of physical strength properties of kenaf pulps.

Development of Equipment and Processes for Separating Kenaf Stalk Fiber Components Before Pulping

Systems for wet or dry separation of the woody core marerial and the bast ribbon from the whole stalk would be very much worthwhile and should be developed.

Study of Equipment and Processes for Fractionating Kenaf Stalk Components After Pulping

An investigation should be made of partial or complete fractionation of the long and short fibers in whole stalk kenaf pulp, preferably before bleaching. If a use could be found for the short fiber pulp, the cost of the bast ribbon type might be lowered significantly.

Development of Newsprint from Kenaf

There is a possibility that kenaf whole stalk mechanical, thermomechanical, or chemimechanical pulp or mixtures of these could be used for 100 percent of the fiber content. This would eliminate the need for chemical pulp as about 10 percent of the furnish with groundwood in newsprint. The use of woody core material for these grades of pulp in newsprint, low cost printing and writing papers, and tissue and towelling grades should be explored. A pre-feasibility study for newsprint based on kenaf should also be made.

Investigation of Kenaf for Particleboard

The woody core material should also be investigated by the laboratories of the international firms which build particleboard machinery and a pre-feasibility study should be made for production of this product when the full feasibility study is made for the kenaf paper pulp mill.

CHAPTER XI - PROJECT ORGANIZATION AND MANAGEMENT

1./2. The Kenaf Raw Material Supply

This Study has concluded that, for the Mekong Basin project mill, the kenaf raw material will continue to be produced by small holders and that it will be supplied to the mill through farmers cooperatives as well as through the established kenaf dealers and traders, and that in the form of whole stalks or separate bast ribbon and core material. This production and supply method limits the required intervention by the mill to that of a Procurement Office.

In addition, this Study envisages the establishment, by the mill, of one or more Demonstration Farms which will be staffed by mill employed supervisory personnel and labor and which will serve as research and seed production centers in addition to their function of demonstrating improved kenaf production practices to the small holders and of serving as bases for mill organized extension services. It is estimated that the cost of organizing and operating such demonstration farms and services will be recovered many times over through raw material cost savings resulting from increases in kenaf yields.

3. Paper Pulp Production

3.1. Introduction

It has been recognized that full scale commercial runs of kenaf pulps for papermaking trials are required before there can be assurance that kenaf pulps could replace pulps from wood, bamboo, and bagasse for market. There would be a better possibility for bringing this about if there could be a worldwide coordination of the work on kenaf for paper pulp.

If such actions are taken as the preliminary step in the development of the Mekong project mill, then the proposed agro-economic studies should be made at or near one of the suitable primary pulp mill sites located in this investigation. This would assure the possibilities of fibrous raw material supplies for the pulp mill project.

3.2. The Executing Agency

Due to its cooperative and efficient handling of the contract for the present pre-feasibility study and its long term and continuing responsibilities for planning and guidance for projects in the Mekong Basin, the logical choice for Executing Agency for further studies on kenaf paper pulp would be the Committee for Coordination of Investigations of the Lower Mekong Basin. The worldwide significance of these studies on kenaf pulp is such that supporting grants might be obtained from the United Nations Development Programme, the World Bank and the Asian Development Bank, as well as the Governments of Thailand and other riparian countries. This would be a particularly good opportunity for agencies of the U.S. Government to help bring to commercial application the great amount of research and pilot plant work on kenaf growing and pulping by the U.S. Department of Agriculture.

3. Consulting Services for the Pulp and Paper Development Studies

In contrast with the agro-economic studies for a future project, the pulp and paper development studies will have to be carried on outside the Mekong Basin proper because there are no suitable facilities available for such investigations in that area. Kenaf grown in some other locations would be comparably suitable for the commercial production tests or baled kenaf could be shipped from the Mekong Basin. Therefore, the choice of an existing pulp mill for the tests should be made on the basis of the one which would be the best equipped to process such nonwood plant fibers.

The technical consulting and management services for the pulping trials and marketing tests should, preferably, be supplied by an independent consulting firm that would not be directly involved later on in owning part of the mill or promoting it, as a contractor in building it, or in furnishing equipment and detailed engineering services for the project. This would allow complete objectivity on the part of the consultant in choosing the best combination of equipment and processes for the mill when the final feasibility study is made in continuation of the next investigation. The consultant to carry on these studies would be chosen on the basis of experience in the processing and pulping of nonwood plant fibers.

4. Pulp and Paper Mills for Commercial Trials with Kenaf

There are at least two nonwood plant fiber pulp mills in the Southeast Asia Area which have facilities for producing kenaf pulps under commercial conditions. These are the Siam Kraft Paper Co., Ltd. in Thailand and the United Pulp and Paper Co. (UPPC) in the Philippines, both pulping bagasse. Kenaf chopping and fiberizing equipment would have to be installed at these mills before they would be in a position to produce unbleached kenaf pulps.

The Siam Kraft paper mill could produce linerboard and bag papers and the UPPC mill could produce extensible multiwall bag papers using the Clupak unit. Wet lap or wet pressed pulp could also be produced and transported to other mills where bleaching equipment and facilities for making printing and writing and tissue grades of paper would be available.

In addition to the excellent laboratory facilities at these two companies that would be used for the commercial pulp and papermaking studies, the pulp and paper laboratory of the Research Division of the Department of Science of the Ministry of Industry in Thailand could serve adequately for the physical and chemical analyses and laboratory pulping trials needed for screening the kenaf samples produced in the agro-economic development trials of future studies.

Fig. I.1.

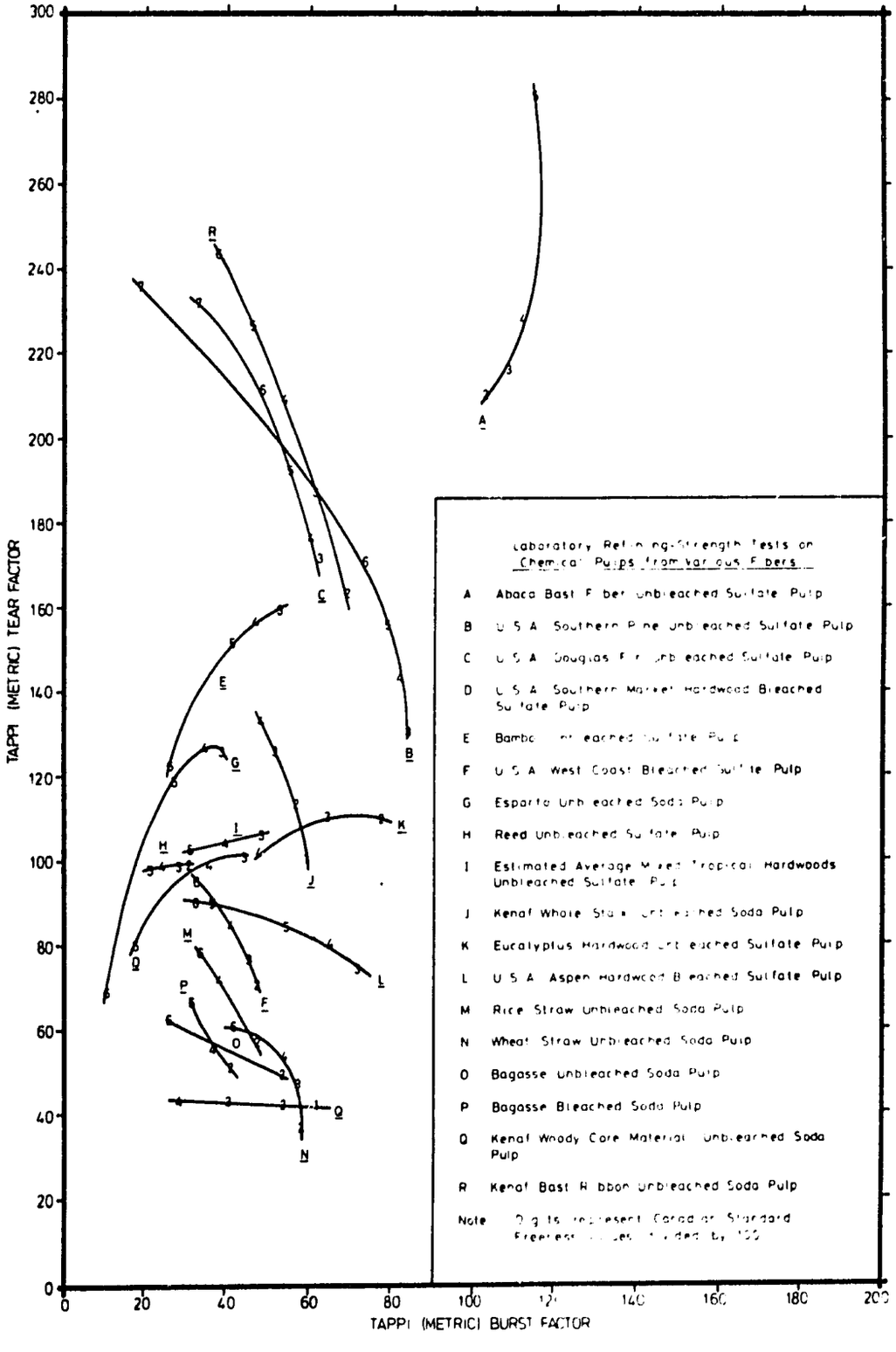

TAPPI (METRIC) TEAR FACTOR
TAPPI (METRIC) BURST FACTOR
Laboratory Refining-Strength Tests on Chemical Pulps from Various Fibers
A Abaca Bast Fiber Unbleached Sulfate Pulp
B U S A Southern Pine Unbleached Sulfate Pulp
C U S A Douglas Fir Unbleached Sulfate Pulp
D U S A Southern Mixed Hardwood Bleached Sulfate Pulp
E Bamboo Unbleached Sulfate Pulp
F U S A West Coast Bleached Sulfate Pulp
G Esparto Unbleached Soda Pulp
H Reed Unbleached Sulfate Pulp
I Estimated Average Mixed Tropical Hardwoods Unbleached Sulfate Pulp
J Kenaf Whole Stalk Unbleached Soda Pulp
K Eucalyptus Hardwood Unbleached Sulfate Pulp
L U S A Aspen Hardwood Bleached Sulfate Pulp
M Rice Straw Unbleached Soda Pulp
N Wheat Straw Unbleached Soda Pulp
O Bagasse Unbleached Soda Pulp
P Bagasse Bleached Soda Pulp
Q Kenaf Woody Core Material Unbleached Soda Pulp
R Kenaf Bast Ribbon Unbleached Soda Pulp

Fig. I.2.

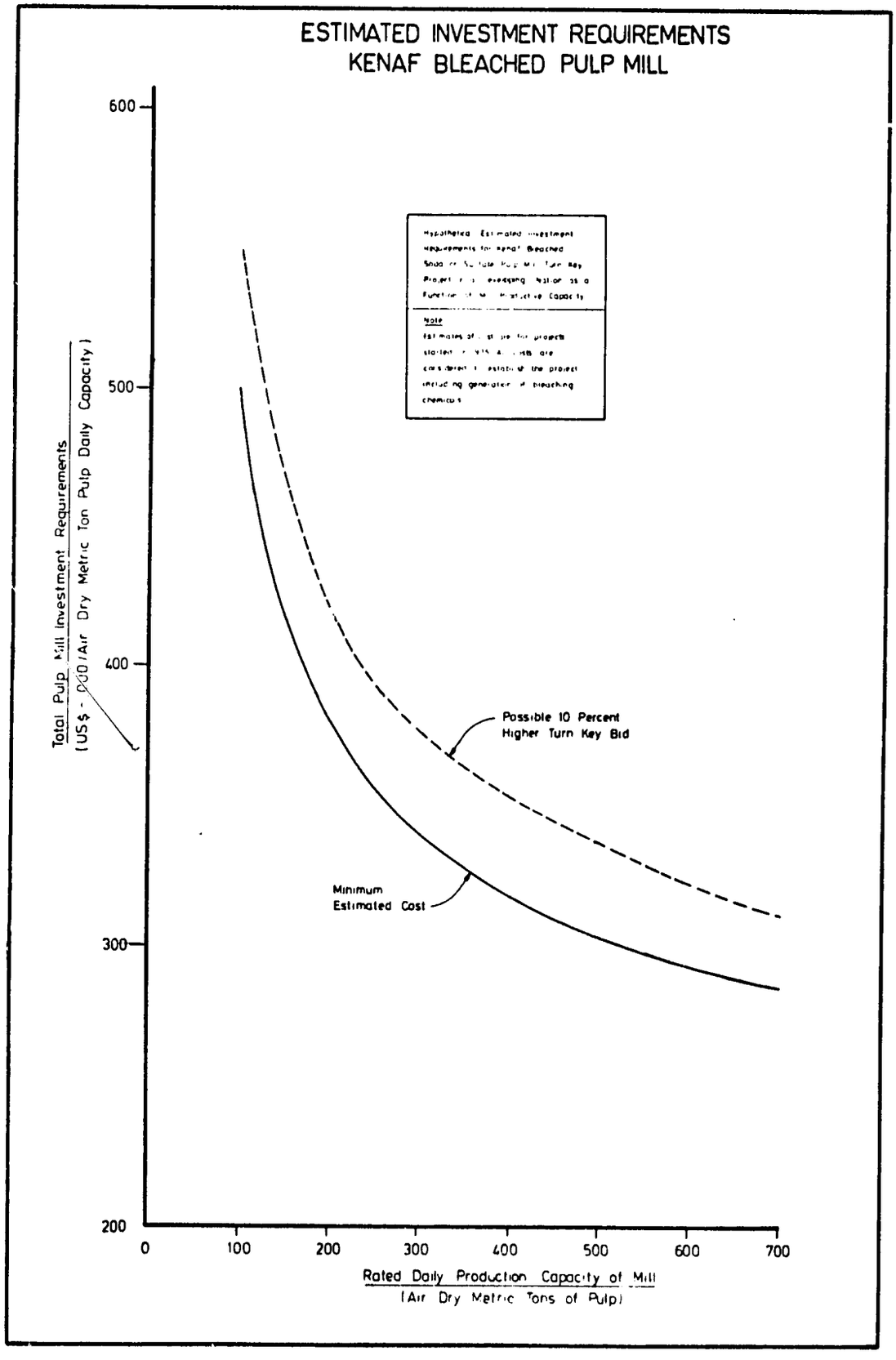

ESTIMATED INVESTMENT REQUIREMENTS
KENAF BLEACHED PULP MILL
Total Pulp Mill Investment Requirements
(US$ - 000/Air Dry Metric Ton Pulp Daily Capacity)
600
500
400
300
200
0
100
200
300
400
500
600
700
Rated Daily Production Capacity of Mill
(Air Dry Metric Tons of Pulp)
Possible 10 Percent
Higher Turn Key Bid
Minimum
Estimated Cost

Photo 1 - Plowing with Animal-Drawn Wooden Plow, Thailand

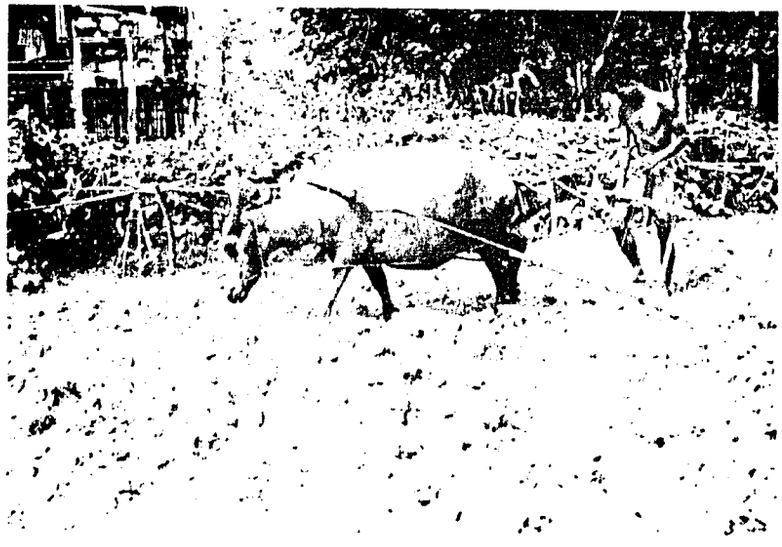


Photo 2 - Raking with Animal-Drawn Wooden Rake, Thailand

Photo 3 - Row-Planting with Marking String - Furrow Opening and Kenaf Seed Dibbling, Thailand

Photo 4 - Animal-Drawn Kenaf Planting Rake, Thailand

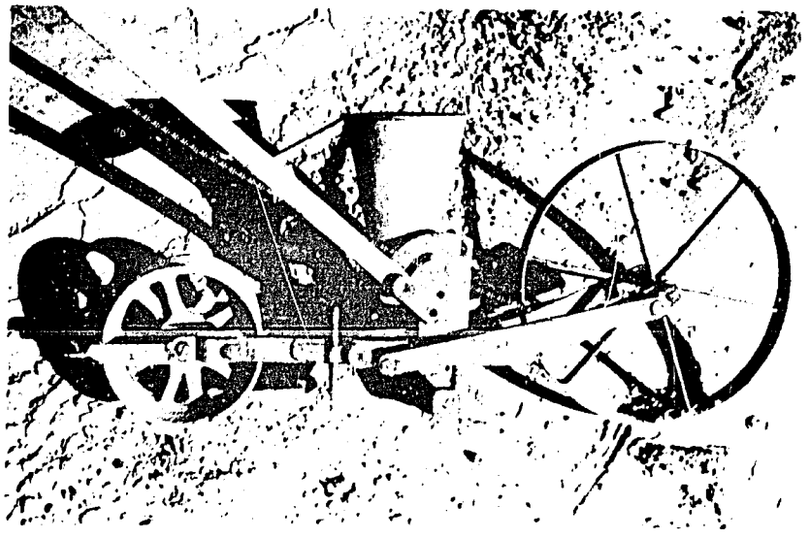


Photo 5 - Hand-Pushed Jute and Kenaf Seed Drill, Bangladesh

Photo 6 - H. sabdariffa Seedling, 20 Days Old, Thailand

Photo 7 - Line-Sown H. sabdariffa, 60 Days Old, Thailand

Photo 8 - Line-Sown H. sabdariffa, 150 Days Old, Thailand

Photo 9 - Thinning of Row-Planted H. sabdariffa, Thailand

Photo 10 - Thinned Row-Planted H. sabdariffa, Thailand

Photo 11 - Flowering Stage of H. sabdariffa, Thailand

Photo 12 - H. sabdariffa Flower and Seed Capsules, Thailand

Photo 13 - Bushknife Harvesting of H. sabdariffa, Thailand

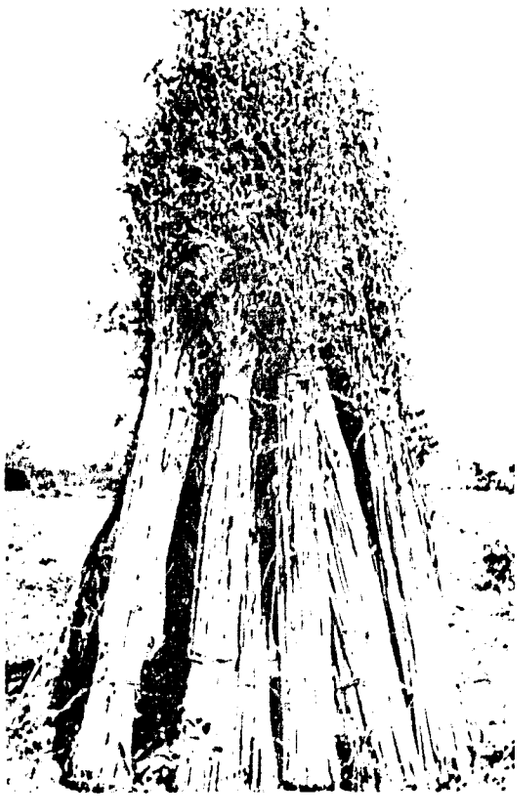


Photo 14 - H. sabdariffa Stalks Shocked after Harvest, Thailand

Photo 15 - H. sabdariffa Stalks Shocked for Field Storage, Thailand

Photo 16 - Bullock Cart Transport of Kenaf Stalks, Thailand

Photo 17 - Hand Ribboning of Kenaf

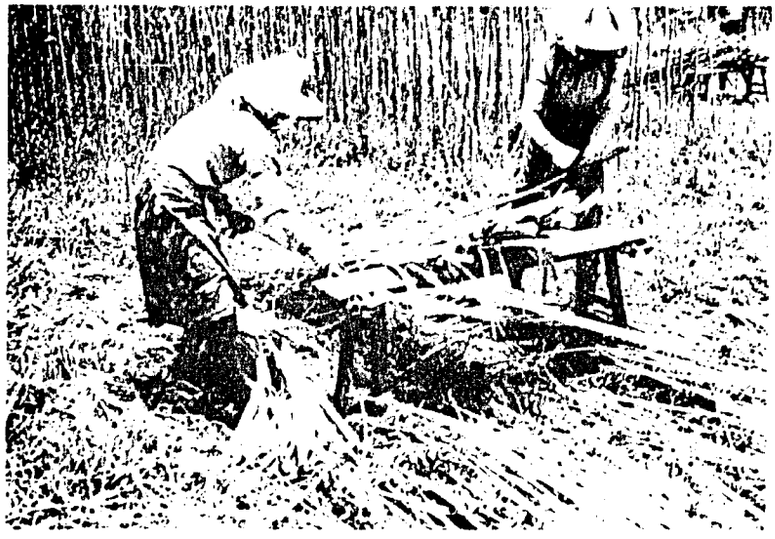


Photo 18 - Hand Ribboning of Kenaf with Stripping Table

Photo 19 - Bullock Cart Transport of Kenaf Bast Ribbon Bundles

Photo 20 - Tractor Plowing, Kenaf Demonstration Farm, Zambia

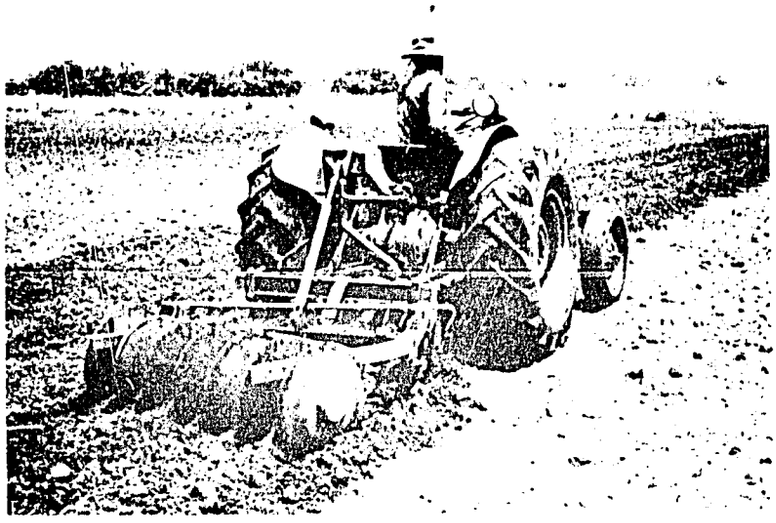


Photo 21 - Tractor Disking, Kenaf Demonstration Farm, Zambia

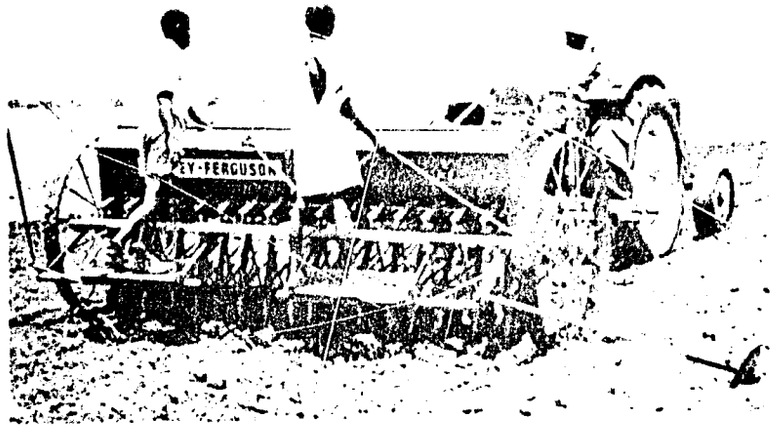


Photo 22 - Seed Planting with 21-Row Tractor-Drawn Seed Drill with Fertilizer Box, Zambia

Photo 23 - Line-Sown H. cannabinus, 8 Days after Seeding, Zambia

Photo 24 - H. cannabinus, 35 Days Old, Stalk Height = 78 cm., Zambia

Photo 25 - H. cannabinus, 120 Days Old, Stalk Height - 3.50 m., Zambia

Photo 26 - Stalk Harvest, Kenaf Demonstration Farm, Zambia

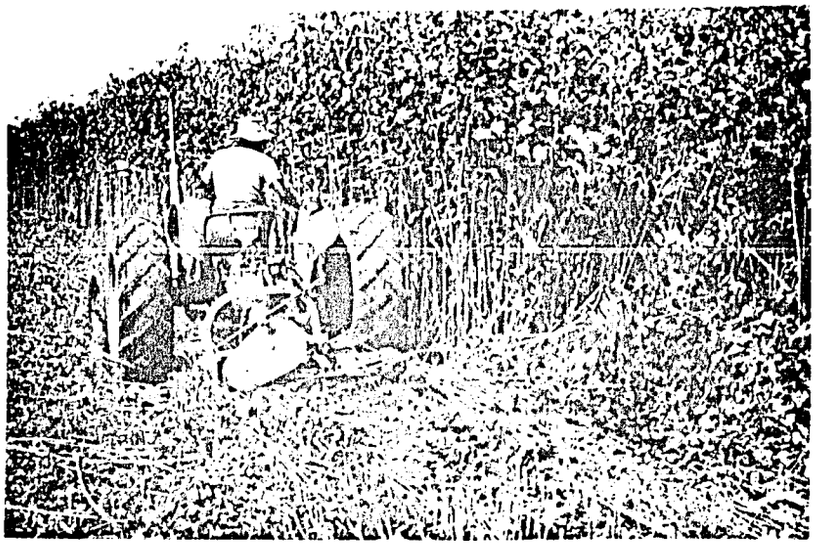


Photo 27 - H. cannabinus Stalk Harvest with Tractor Side-Mounted Cutter Bar, Zambia

Photo 28 - Machine Ribboning of Kenaf, Stalk Feeding, Zambia

Photo 29 - Machine Ribboring of Fence, Bast Ribbon Delivery, [illegible]

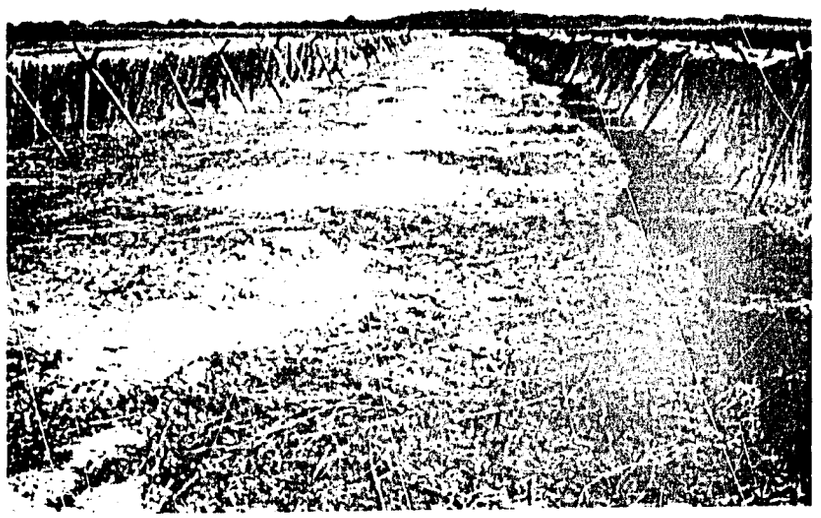


Photo 30 - Bast Ribbon Spread on Drying Lines, [illegible]

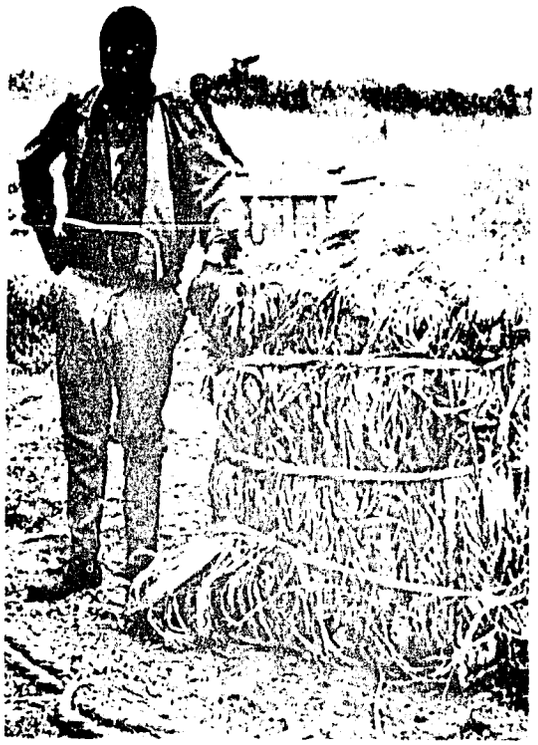


Photo 31 - Bast Ribbon Field Bale, Zambia

Photo 32 - Bullock Cart Transport of Retted Kenaf Fiber "Field Drums", Thailand

Photo 33 - High-Density Baling of Retted Kenaf Fiber, Thailand

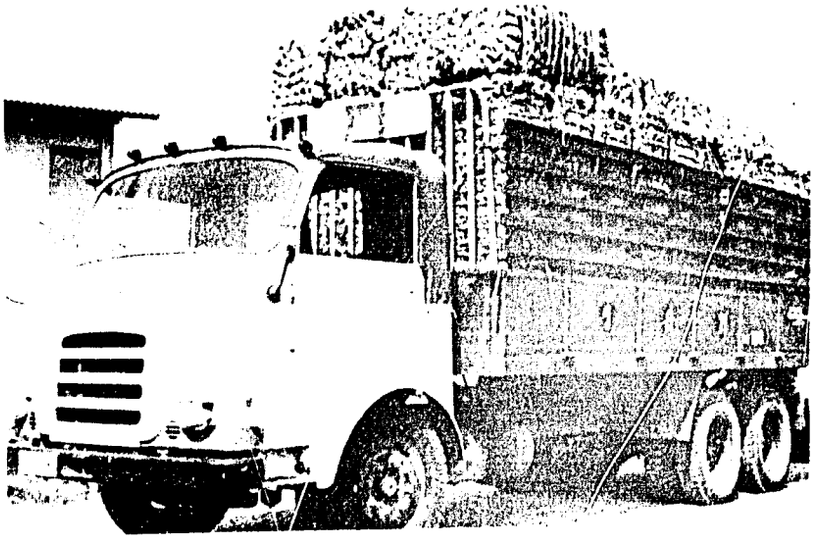


Photo 34 - Truck Transport of High-Density Kenaf Fiber Bales, Thailand

Photo 35 - Research Trial Planting with 6-Row Planting Rake and Seed Dibbling, Zambia

Photo 36 - N.P.K. Factorial Trial, H. cannabinus, Zambia

Photo 37 - Kenaf Variety and Time-of-Planting Trial, 100 Days Old, Zambia

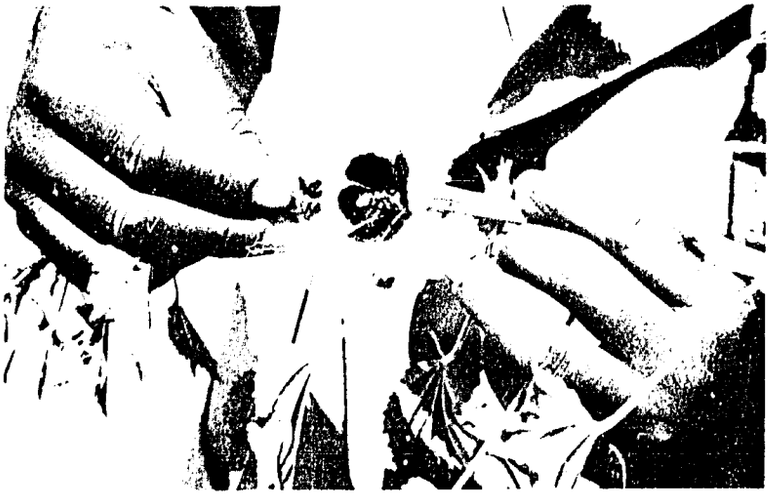


Photo 38 - Cross-Pollination, H. cannabinus, Zambia

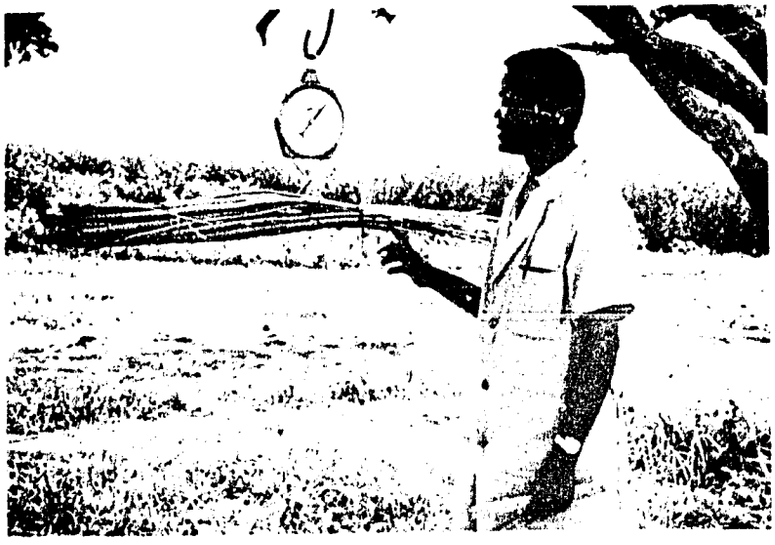


Photo 39 - Usable Stalk Weight Research, H. cannabinus, Zambia

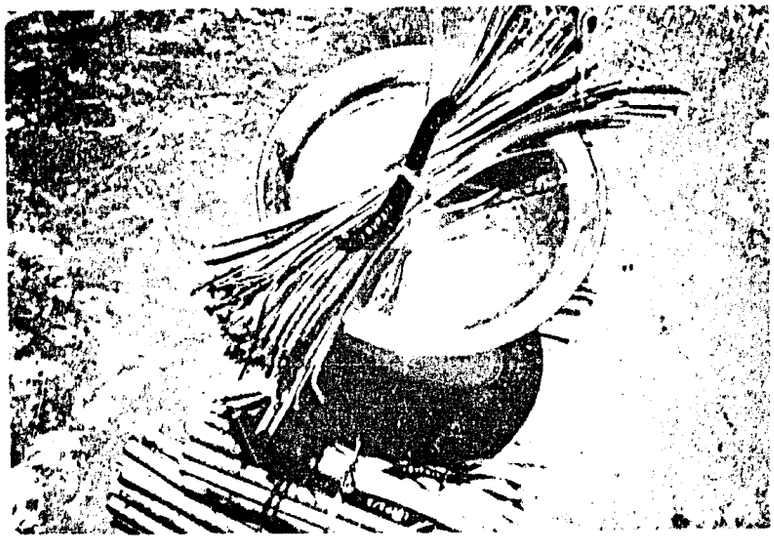


Photo 40 - Ribbon Yield Research, H. cannabinus, Zambia

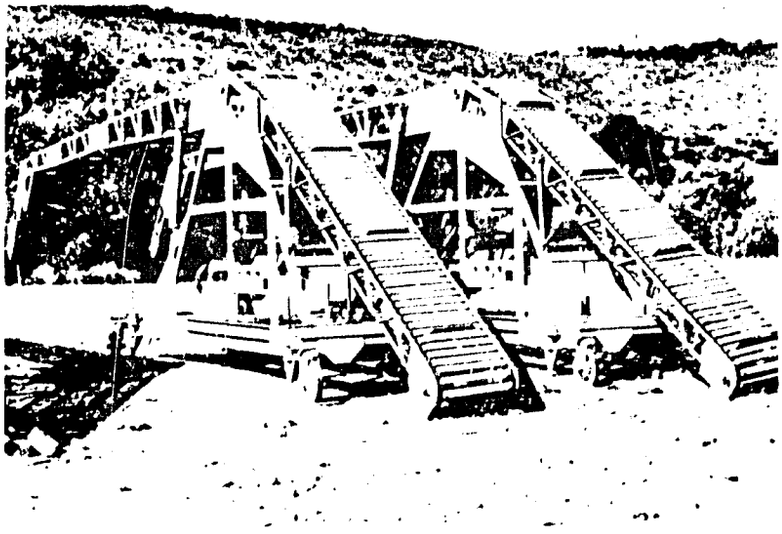


Photo 41 - Inclined Mobile Stackers for Baled Nonwood Plant Fiber

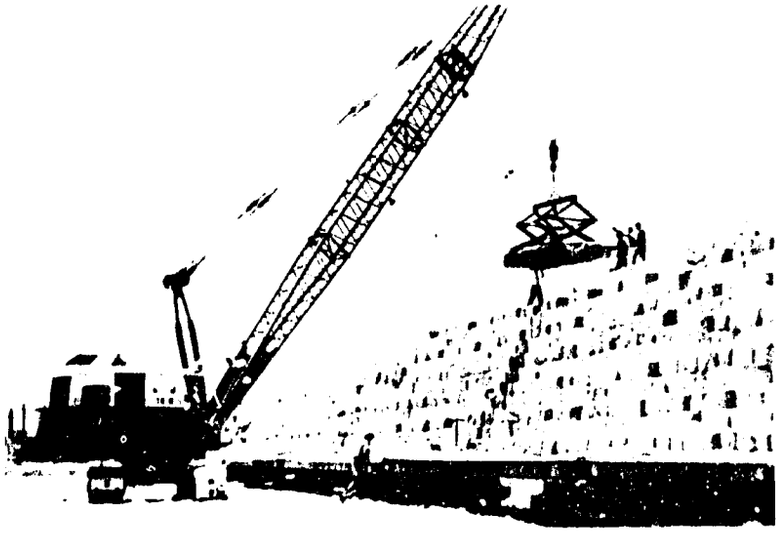


Photo 42 - Heavy Duty Crane Stacking Nonwood Plant Fiber Bales in Mill Storage Yard

Photo 43 - Positioning Nonwood Plant Fiber Bales by Hand on Partially Completed Stack

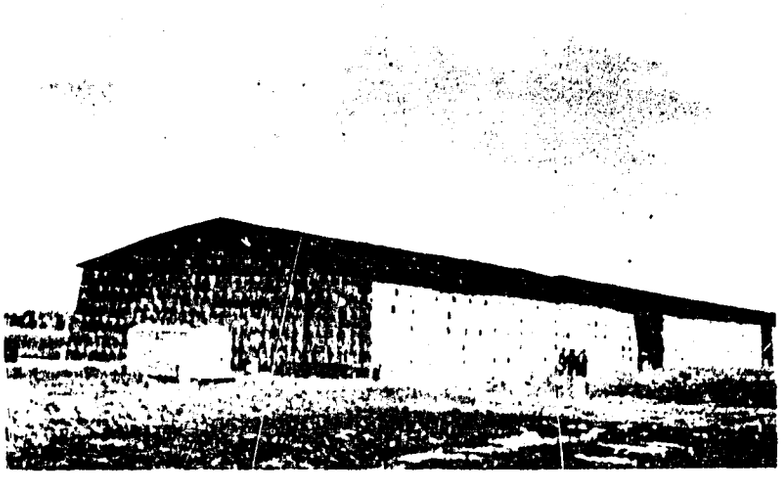


Photo 44 - Covered Bale Storage of Nonwood Plant Fiber

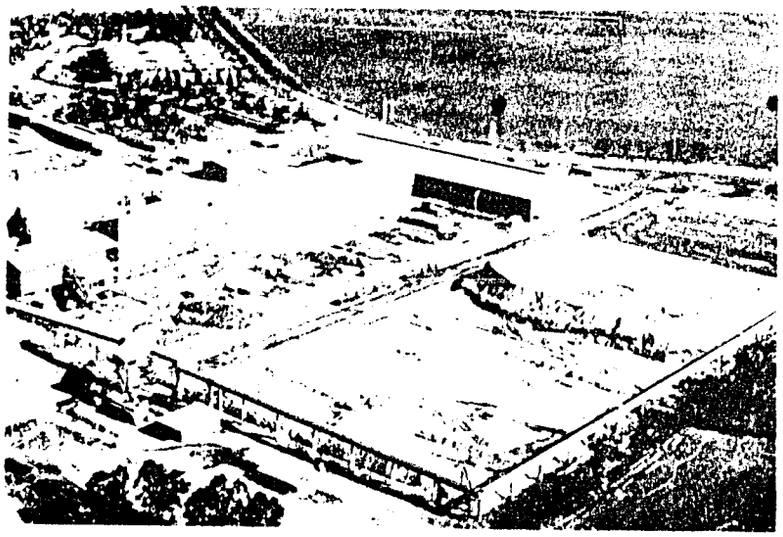


Photo 45 - Ritter Bulk Storage of Nonwood Plant Fibers with Pulp and Paper Mill in Background

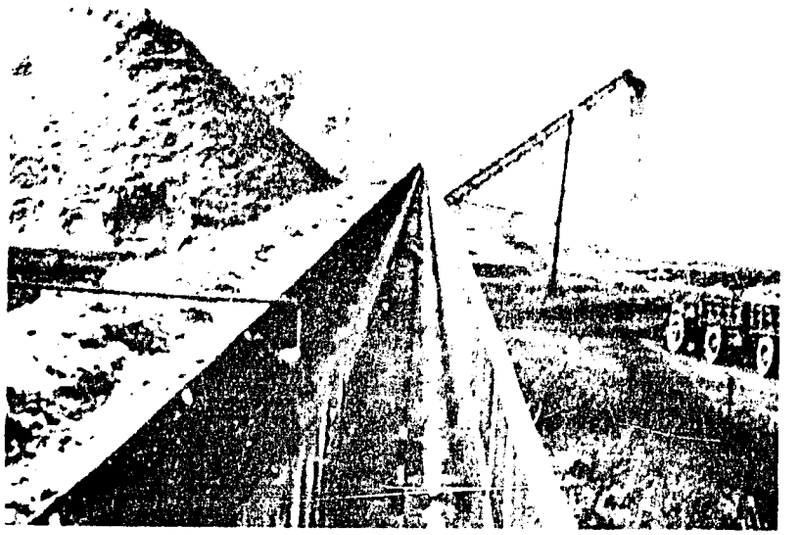


Photo 46 - Moist or Wet Bulk Storage of Nonwood Plant Fibers Using Circular Stacker

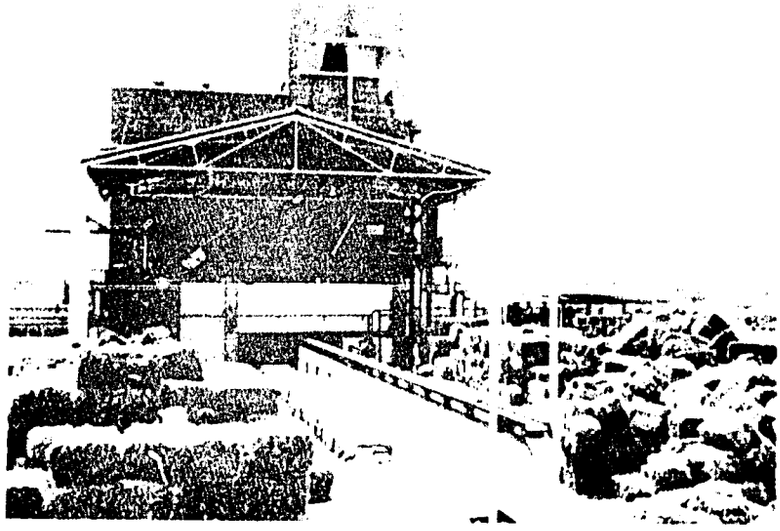


Photo 47 - Bale Feed to Shredder and Wet Cleaning System

Photo 48 - Feed of Loose Whole Stalks to Shredder

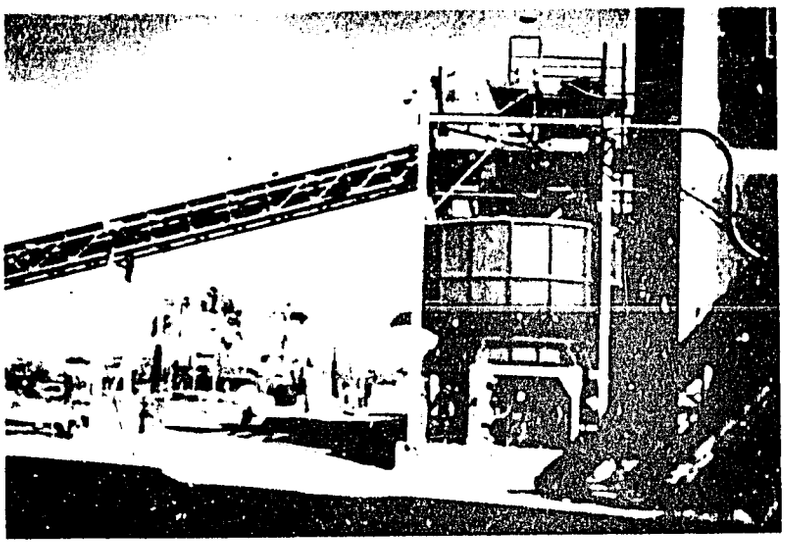


Photo 49 - Hydrapulper for Wet Cleaning
Shredded Fiber

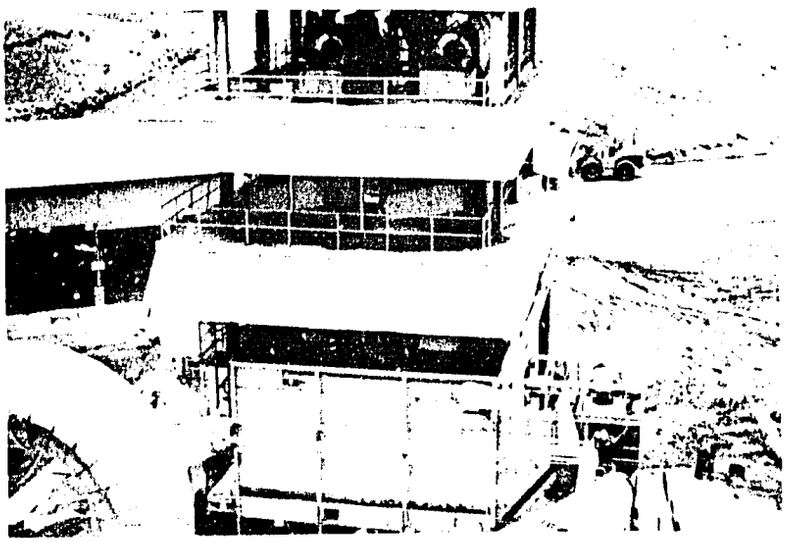


Photo 50 - Wet Cleaning Plant for Nonwood Plant
Fibers with Live Bottom Bin

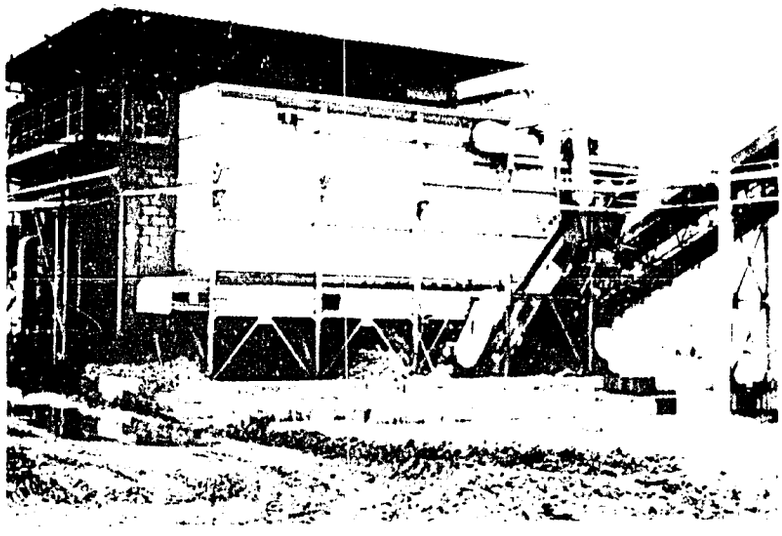


Photo 51 - Live Bottom Bin Feeding Belt Conveyor to Digester

Photo 52 - Belt Conveyor for Cleaned Fiber to Digester with Blowtank in Foreground

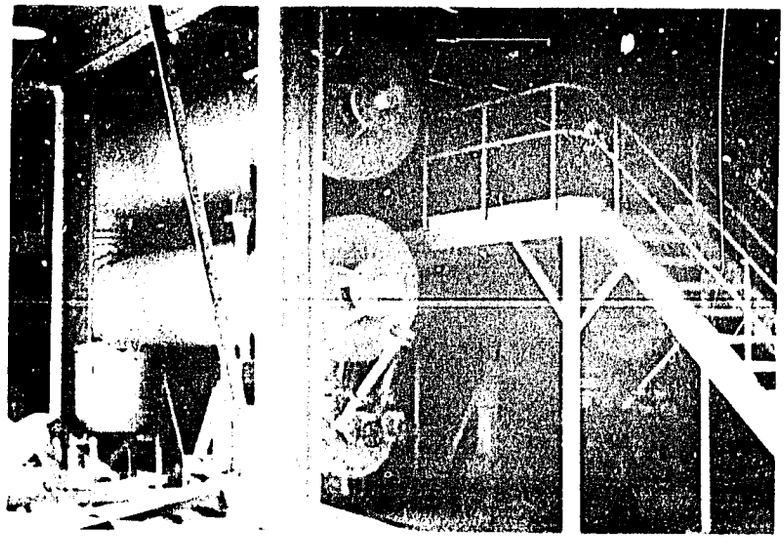


Photo 53 - Horizontal Tube Continuous Digester

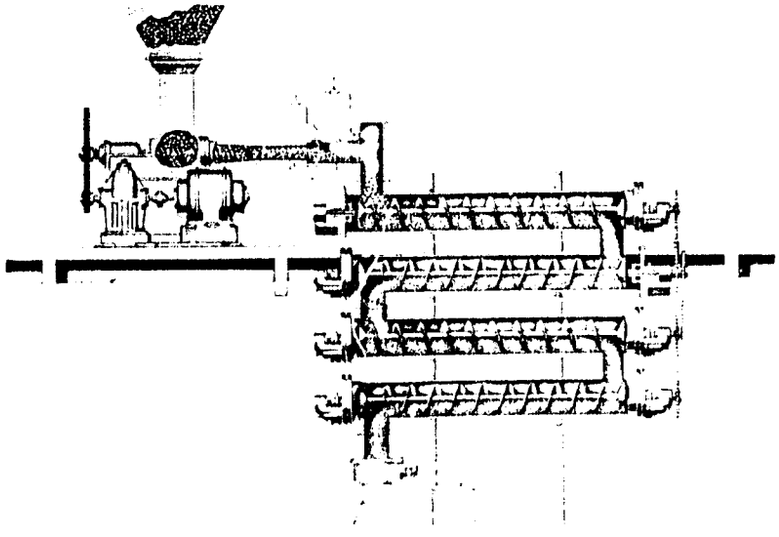


Photo 54 - Horizontal Continuous Digester
Showing Screw Feeder and Discharger

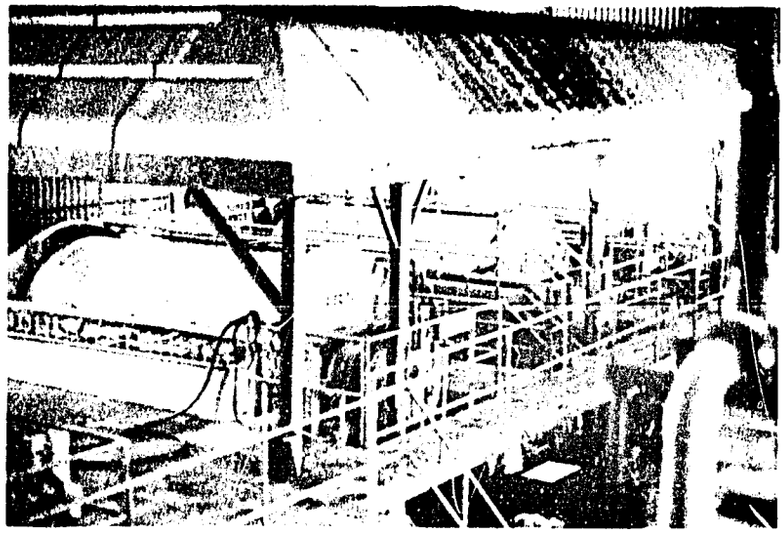


Photo 55 - Unbleached Pulp Washers

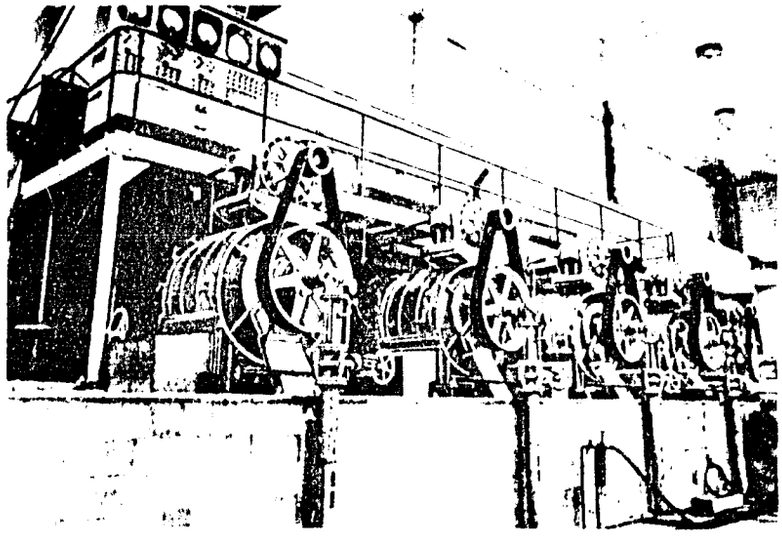


Photo 56 - Bank of Centrifugal
Pulp Screens

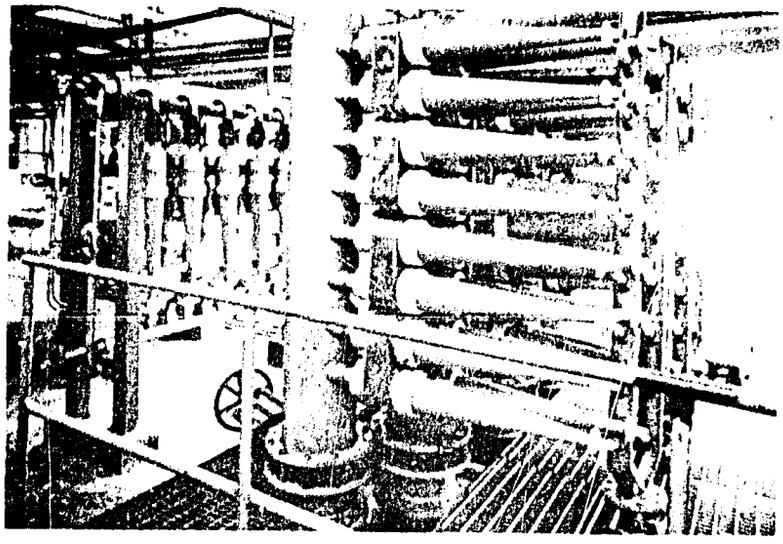


Photo 57 - Centrifugal Pulp Cleaning Installation

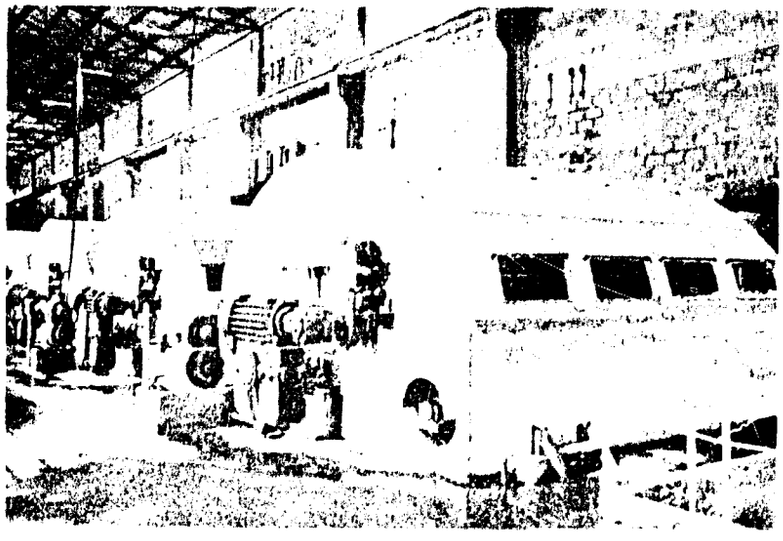


Photo 58 - Bleach Floor Washers

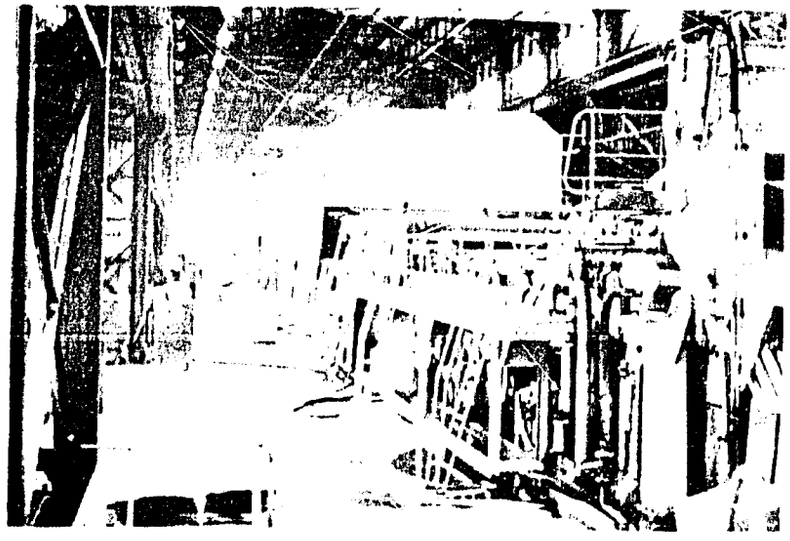


Photo 59 - Pulp Forming and Drying Machine

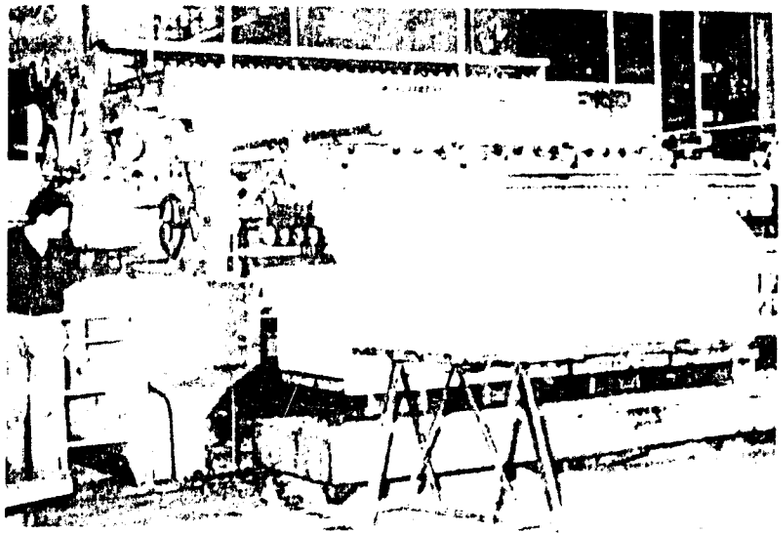


Photo 60 - Pulp Sheeter

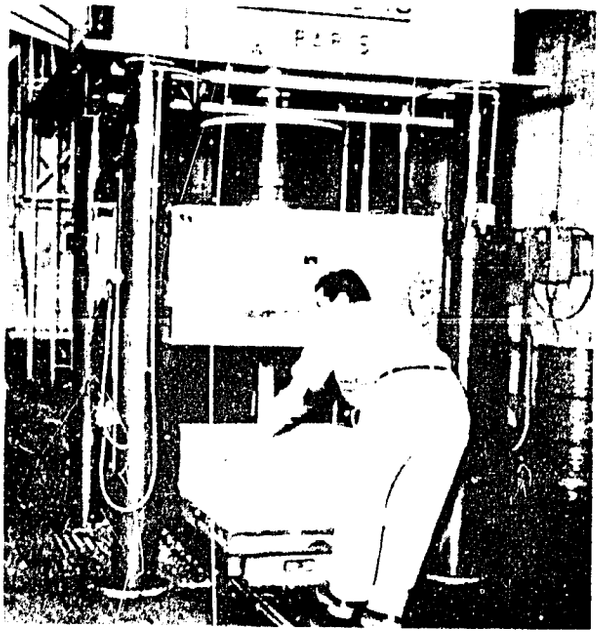


Photo 61 - Pulp Bale Press

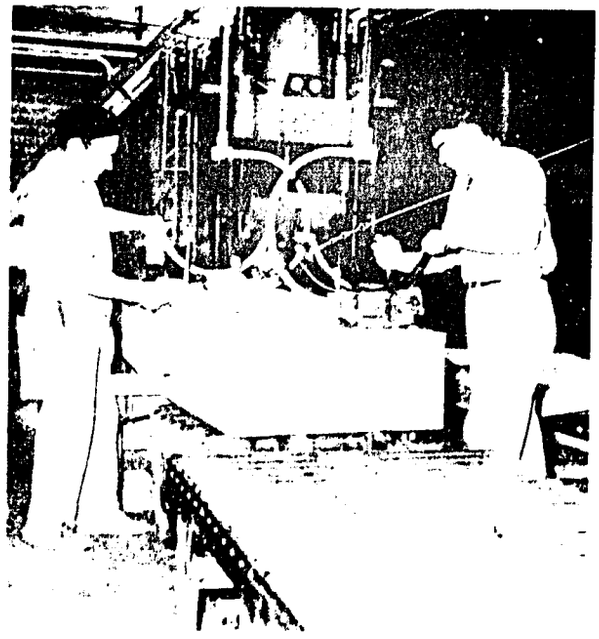


Photo 62 - Wrapping and Tying Pulp Bales

Photo 63 - Handling and Loading Pulp Bales for Shipment

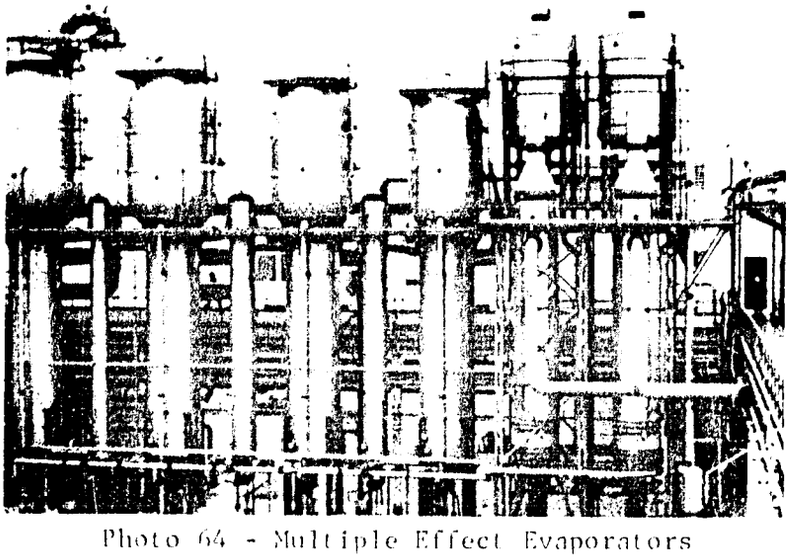


Photo 64 - Multiple Effect Evaporators for Black Liquor

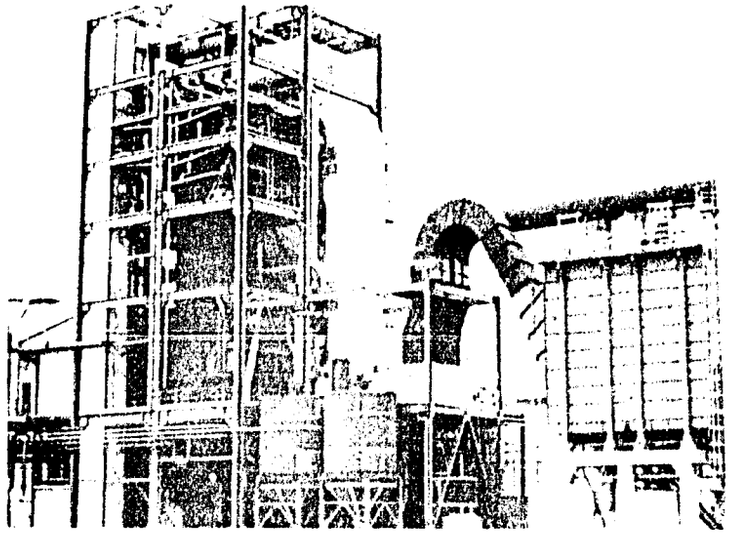


Photo [illegible] - Recovery Boiler, Cascade
Economizer, Precipitator and Stack

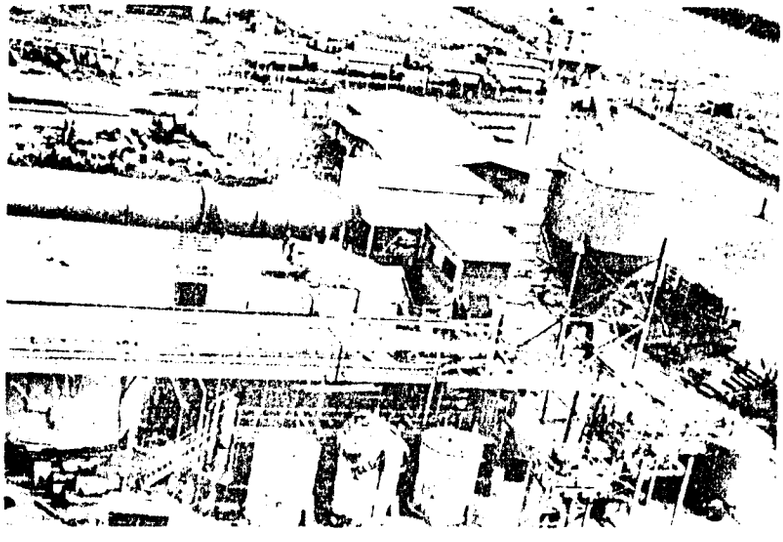


Photo [illegible] - Lime Kiln and Recausticizing
Scene

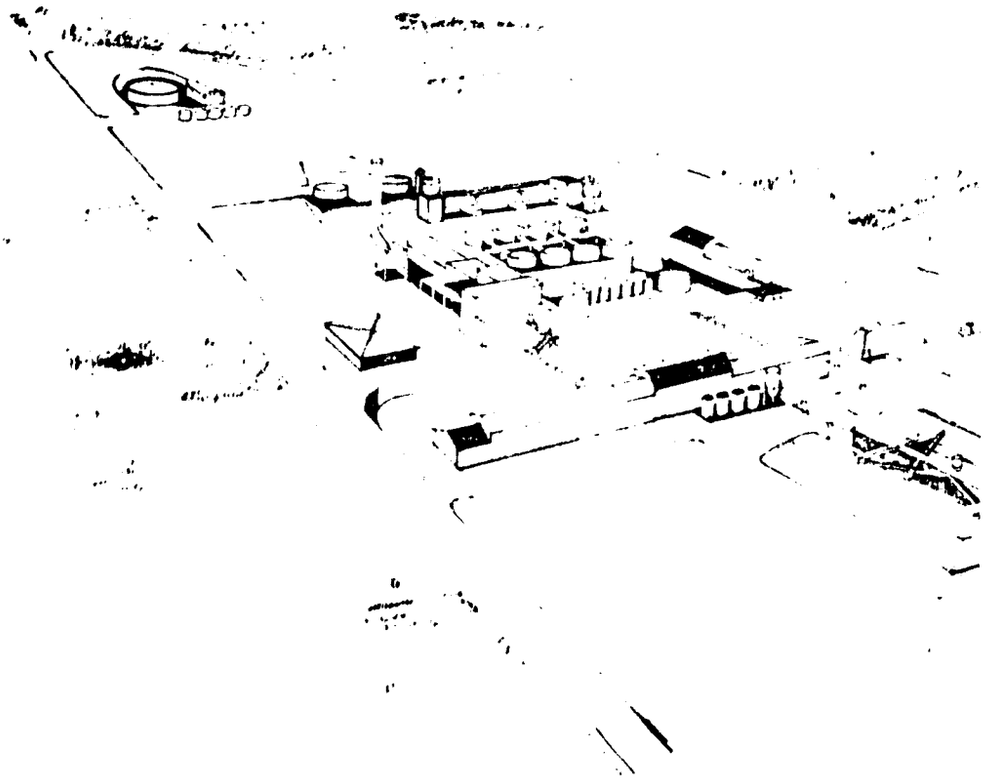
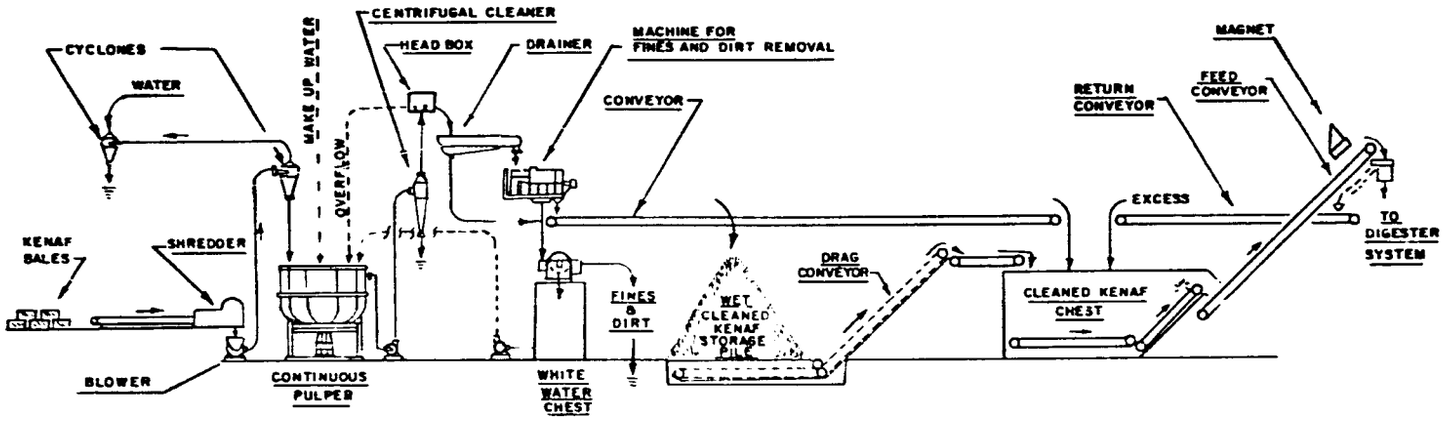


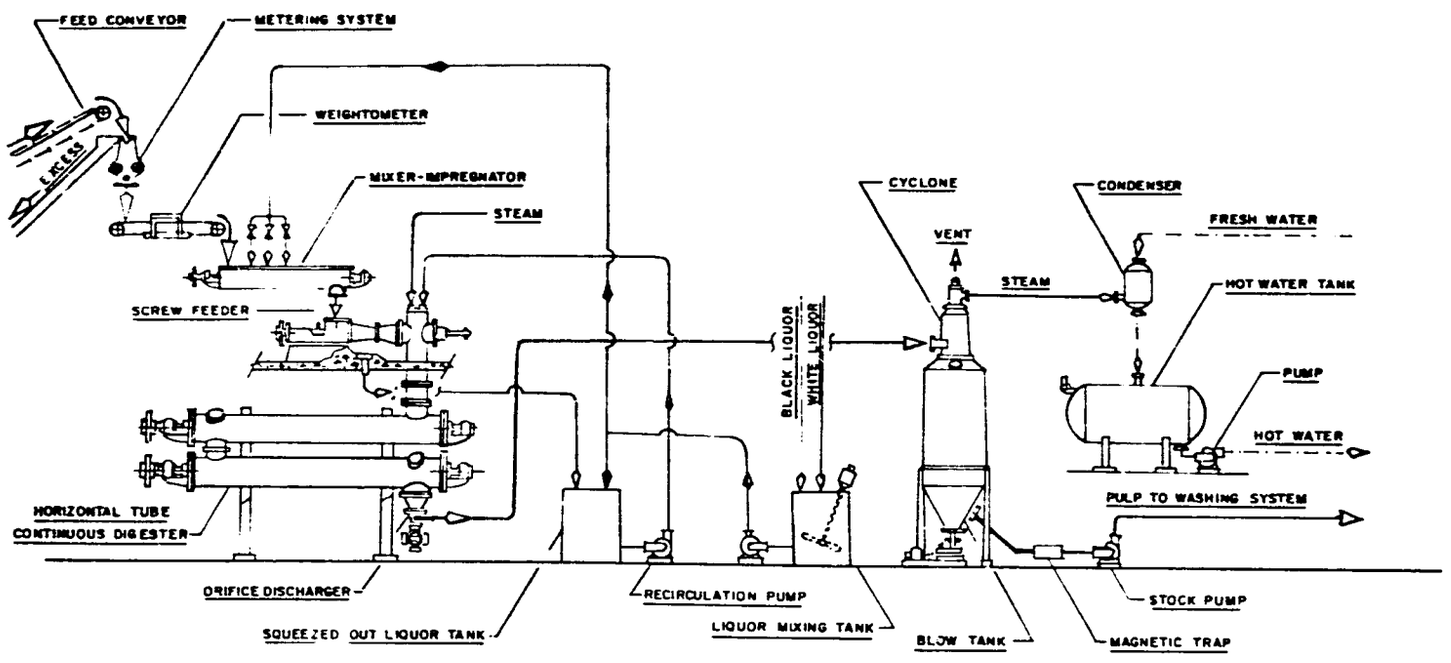
Photo 67 - Panoramic View of Proposed Kenaf
Paper Pulp Mill for Mekong Basin Area



THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN

PRE-FEASIBILITY STUDY
KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN

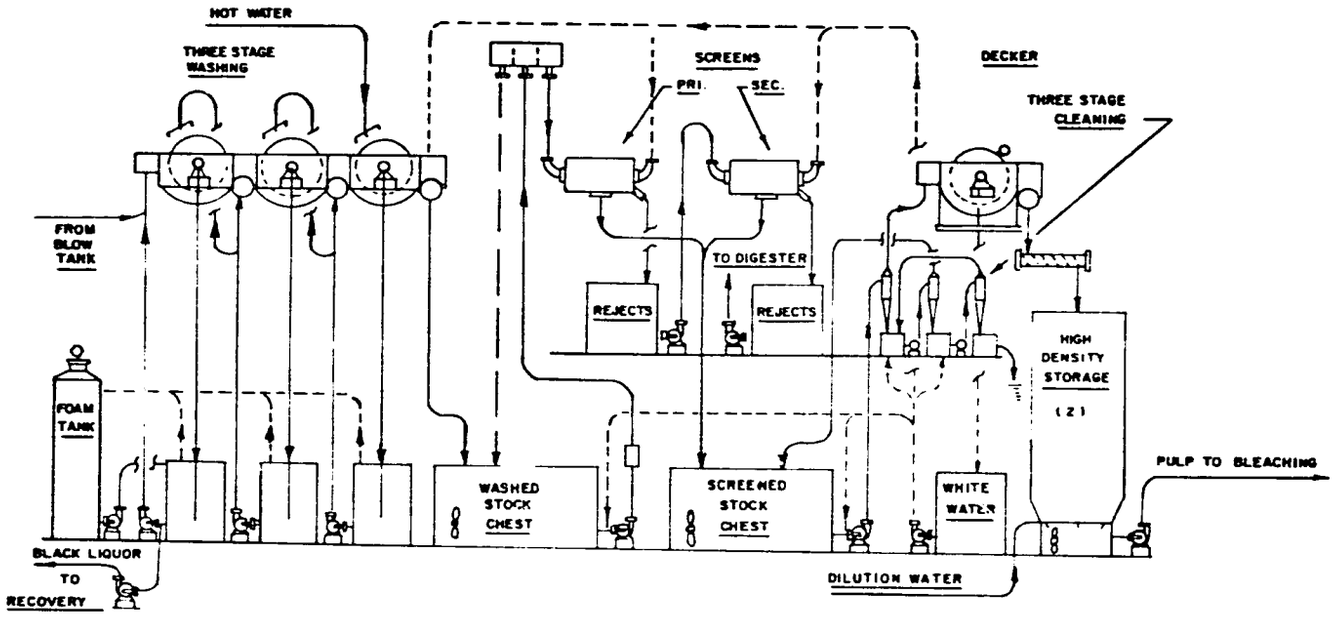
PREPARATION AND WET CLEANING OF KENAF



THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN

PRE-FEASIBILITY STUDY
KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN

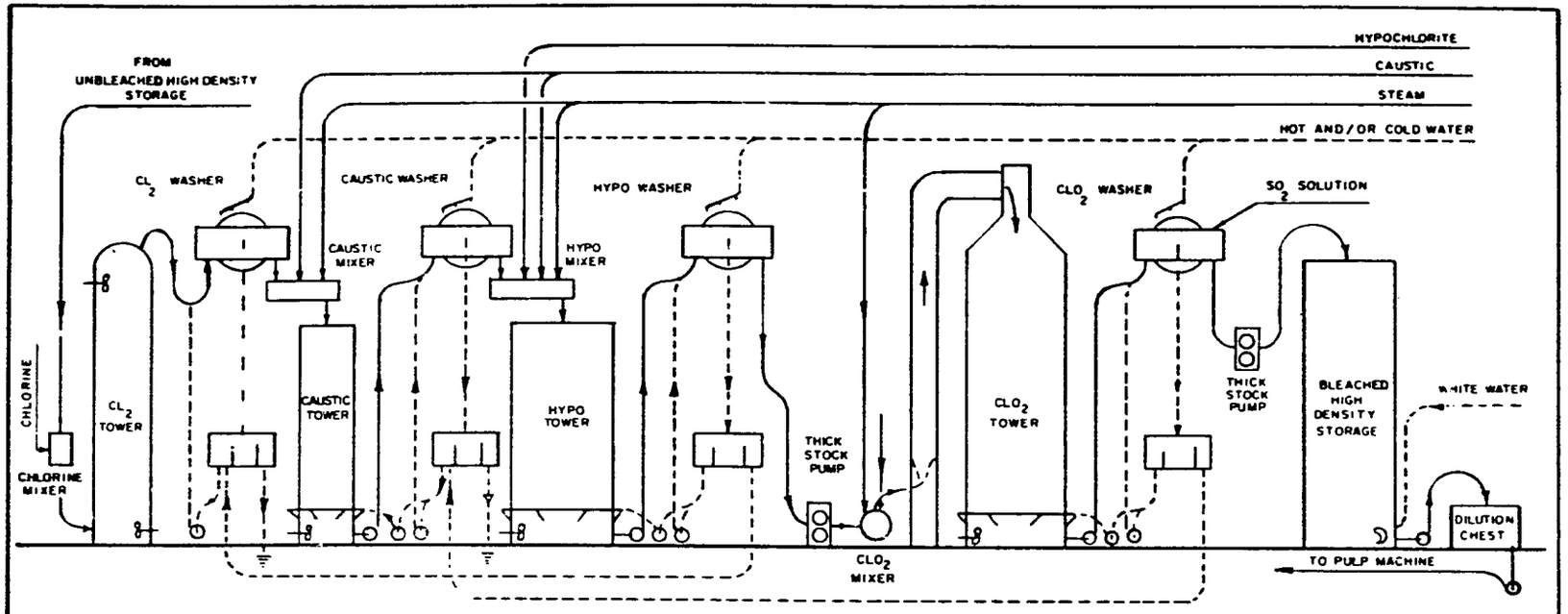
CONTINOUS DIGESTION SYSTEM



THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN

PRE-FEASIBILITY STUDY
KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN

WASHING AND SCREENING SYSTEM



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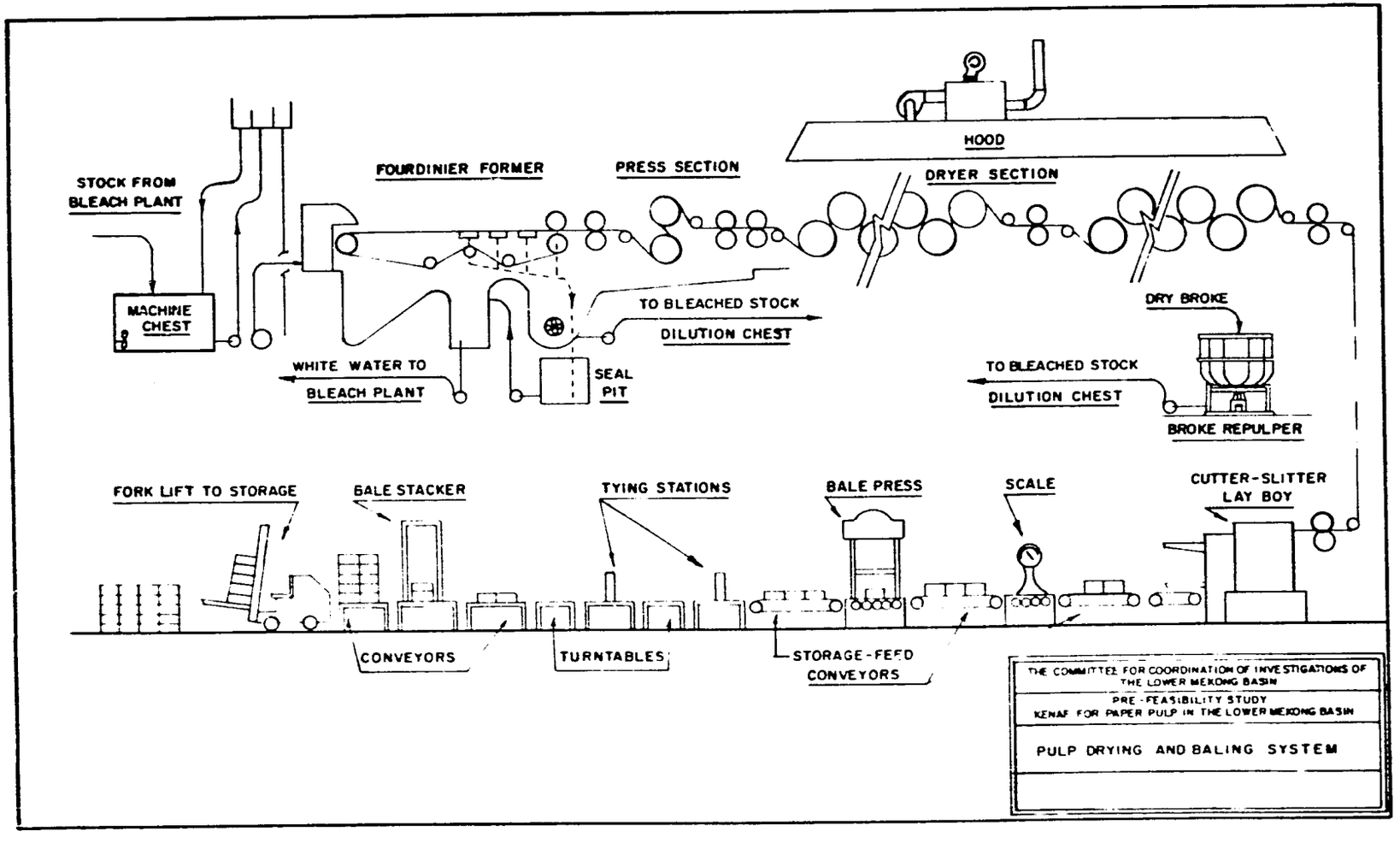
PRE-FEASIBILITY STUDY
KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN

BLEACHING SYSTEM


STOCK FROM BLEACH PLANT
MACHINE CHEST
FOURDINIER FORMER
PRESS SECTION
HOOD
DRYER SECTION
TO BLEACHED STOCK
DILUTION CHEST
WHITE WATER TO BLEACH PLANT
SEAL PIT
DRY BROKE
TO BLEACHED STOCK
DILUTION CHEST
BROKE REPULPER
FORK LIFT TO STORAGE
BALE STACKER
TYING STATIONS
BALE PRESS
SCALE
CUTTER-SLITTER LAY BOY
CONVEYORS
TURNTABLES
STORAGE-FEED CONVEYORS
THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN
PRE-FEASIBILITY STUDY
KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN
PULP DRYING AND BALING SYSTEM