FINAL REPORT

1999 Project Abstract
For the Period Ending June 30, 2001

TITLE: *Non-Wood Agricultural Fibers and Industrial Hemp for Pulp and Paper Manufacture (Subd. 7, (o)]*

PROJECT MANAGER: Ulrike Tschirner, Jim L. Bowyer
ORGANIZATION: University of Minnesota
Department of Wood and Paper Science
ADDRESS: Kaufert Laboratory
2004 Folwell Avenue
St. Paul, MN 55108

FUND: Future Resources Fund
LEGAL CITATION : ML 1999, [Chap. 231], Sec. [16], Subd. 7(o).
APPROPRIATED AMOUNT: $ 200,000

Overall Project Outcome and Results:
The technical and economical feasibility of a small-scale pulp mill utilizing agricultural residues for the production of papermaking fibers was determined. Two different processing sequences developed were investigated. Pulp fiber from wheat and barely straw showed excellent papermaking properties. It was possible to replace 10%-30% of a wood fiber furnish with non-wood pulps, while maintaining high paper quality. Pilot plant papermachine run using 20 % cereal straw fiber were performed successfully. An engineering company (Kellogg Brown & Root Inc.) was commissioned to conduct a feasibility study for the evaluation of both processes. Order-of-magnitude +/- 25% capital cost estimates, manufacturing cost estimates and a financial analysis were developed. Capital investment cost for both processes was determined to exceed $230 Million. Considering the presently suggested operation conditions internal rate of return was identified to be below 6% in all cases. Several modifications capable of reducing capital costs and/or production costs were identified.

In addition, a detailed report focused on the potential use of industrial hemp *(Cannabis sativa L.)* as paper making raw material was generated. Even though Hemp has a number of properties that favor its use as a papermaking raw material, there are several issues that must be addressed. Among these are problems related to economical bark/core separation, long-term storage and issues with the smaller core fibers. Although a given area of land will produce a greater quantity of hemp than wood fiber, the fact that hemp is an annual crop requiring relatively intensive inputs translates to substantial overall environmental impact from hemp production.

Project Results Use and Dissemination
Technical feasibility of potential use of cereal straw fiber for paper manufacture was demonstrated and was presented to Paper Industry on several occasions. There is a strong interest in this fiber material, nevertheless process modifications are required to improve economics. Several modifications capable of reducing capital costs and/or production costs were identified and will be considered.

Date of Report: July 1, 2001

Date of Next Status Report: Final report

Date of Workprogram Approval: June 16, 1999

Project Completion Date: June 30, 2001

LCMR Final Work Program Report

I. PROJECT TITLE: *Non-Wood Agricultural Fibers and Industrial Hemp for Pulp and Paper Manufacture (Subd. 7, (o)]*

Project Manager: Ulrike Tschirner, Jim L. Bowyer
Affiliation: University of Minnesota
Department of Wood and Paper Science
Mailing Address: Kaufert Laboratory
2004 Folwell Avenue
St. Paul, MN 55108

Telephone Number: (651) 624-8798 (Tschirner)
(651) 624-4292 (Bowyer)

E-mail: utschirn@forestry.umn.edu
Jbowyer@forestry.umn.edu

Fax: (651) 625-6286

Total Biennial project Budget:

$ LCMR:	$ 200,000	**$ Match:** (no match required)	$
-$LCMR Amount Spent:	$ 168,151	**-$ Match Amount Spent:**	$
= $ LCMR Balance:	$ 8,849	**=$Match Balance**	$

A. Legal Citation: ML 1999, [Chap. 231], Sec. [16], Subd. 7(o).

Appropriation Language: $200,000 is from the future resources fund to the University of Minnesota to investigate the feasibility of various agricultural pulp markets in the development of small scale pulp mills in the agricultural regions of the state.

B. **Status of Match Requirements:** no match required, but in-kind match was provided. In-kind match consisted of portion (10 %) of faculty scientist salary (Tschirner, Bowyer).

II. FINAL PROJECT SUMMARY

The technical and economical feasibility of a small-scale pulp mill utilizing agricultural residues for the production of papermaking fibers was determined. Two different processing sequences developed in our labs were investigated. The more traditional process uses Soda-Antraquinon followed by chlorine dioxide bleaching. The second process selected was a chlorine free, sulfur free sequence based on ethanol pulping and peroxide bleaching. Pulp fiber from wheat and barely straw showed excellent papermaking properties. It was possible to replace 10%-30% of a wood fiber furnish with non-wood pulps, while maintaining high paper quality. A pilot plant papermachine run using 20 % cereal straw fiber was performed successfully. .

An engineering company (Kellogg Brown & Root Inc.) was commissioned to conduct a feasibility study for the evaluation of both processes. Order-of-magnitude +/- 25% capital cost estimates, manufacturing cost estimates and a financial analysis were developed. Capital investment cost for both processes was determined to be above $ 230 Mill. Considering the presently suggested operation conditions internal rate of return was identified to be below 6% in all cases. Several modifications capable of reducing capital costs and/or production costs were identified.

In addition, a detailed report focuses on the potential use of industrial hemp *(Cannabis sativa L.)* as paper making raw material was generated. Even though Hemp has a number of properties that favor its use as a papermaking raw material, there are several issues that must be addressed. Among these are problems related to economical bark/core separation, long-term storage and issues with the smaller core fibers. Although a given area of land will produce a greater quantity of hemp than wood fiber, the fact that hemp is an annual crop requiring relatively intensive inputs translates to substantial overall environmental impact from hemp production.

IV.OUTLINE OF PROJECT RESULTS:

- **Result 1:**

Wheat and barley straw fiber was processes using two different pulping and bleaching technologies. The more traditional process employed Soda Anthraquinon as the pulping chemicals, followed by traditional chlorine dioxide bleaching sequences. The pulps generated with this process were extremely strong (stronger than some wood fiber) but had as expected a short fiber length which was reflected in a decrease in tear strength of paper. The second process used a more environmentally friendly process based on ethanol pulping followed by hydrogen peroxide bleaching. The fiber was slightly weaker but noticeable longer than the

Soda-Anthraquinon fiber. It responded well to a light mechanical treatment (beating) which improved strength properties.

Since there is little information available with regard of cereal straw fiber behavior in mixtures with wood fiber a detailed study examined response of paper properties to different addition levels of wheat straw fiber in a lab study. Four different experimental designs evaluated addition of ethanol pulps or Soda-Anthraquinon pulps to Printing and Writing grades and to Light-Weight-Coated grade. The non-wood pulps were mixed with wood fiber at different ratios and paper quality was assessed. Detailed statistical evaluation allowed generation of a model capable of predicting changes in paper properties based on cereal straw fiber addition. This is especially helpful since it could be seen that property changes are not always directly proportional to non-wood fiber concentration. It was concluded, that addition of Soda Anthraquinon wheat straw fiber increases bonding strength properties but slightly reduces tear strength. Reducing beating energy of the wood fiber, especially softwood fiber in the mixture can counteract this effect. It should be noted that this approach has the added advantage of saving mechanical energy. Ethanol pulps did not increase strength properties significantly. After beating however, the organosolv pulps too are capable of improving strength properties. In all instances smoothness and with that printability of the paper is improved by addition of non-wood fibers.

The results of this study are presented in detail in the master thesis of Ankur Goel (attached).

LCMR Budget: $ 48,000
Balance: $ 6,358*

* all tasks were performed. Since the research assistant hired for this project started only June 1999 some salary money remained unused. In addition $ 1,046 of the $5,000 budgeted for chemicals was not required.

Starting date: July 1999 Completion date: June 2001

- **Result 2:**

Pilot plant trials were carried out to validate results obtained from the initial laboratory experiments. The pilot scale pulping was carried out at the pilot plant facility of the Department of Wood and Paper Science at North Carolina State University, Raleigh, N.C. The pilot scale papermaking was done at the Department of Paper Science, University of Wisconsin, Stevens Point.

Pulping of wheat and barley straw was done in a rotary globe digester. For these trials bales of wheat and barley straw were directly shipped from northern Minnesota to North Carolina State University. At a time 4 bales of wheat or barley straw were processed (each bale was 20 lbs.). The straw was washed in the digester,chemical were added and the material was cooked for a total of 95 minutes. (35 minutes heat-

up time and 60 minutes at temperature. A total of 6 cooks was required to obtain the desired amount of pulp. Bleaching of this material was done in closed tanks, employing a traditional chlorine dioxide – caustic extraction – chlorine dioxide stage. At this point it was observed that the pulp was significantly darker than pulp processed in the lab. Examination of the process water and the pulp revealed large quantities of Iron ions contamination, which caused the pulp to appear darker. Obviously this problem is specific for the set up in this particular pilot plant and will be easily avoided in a potential pulp mill. The generated pulp had slightly lower strength than the pulps generated in the lab, but otherwise showed approximately the same properties.

The papermaking trials were conducted on a Fourdrinier machine with 24 inches of wire width and a speed of up to 200 ft/min. Four runs were carried out, two control runs using the original wood fiber, one run with 20 % wheat straw fiber and one run with 20 % barley straw fiber. The original furnish was desigend to match the furnish used by Boise Cascade in International falls for their printing and writing grade paper.

During the runs with wheat and barley fiber the couch vaccum went up slightly. This was due to the fact that the sheet formation of the non-wood containing furnishes as actually better than for the control, so less air was being drawn through the web. This effect is most likely caused by the smaller fibers and the large amount of fines present in the cereal straw fiber furnishes. This also resulted in an increase in consistency of the web. The increased constancy did require some adjustments to the drying section (more energy). This problem could most likely be avoided by optimizing some of the chemicals added to the process (drainage help). No major problems were observed during the machine runs.

Paper test samples were taken from top, middle and bottom portions of the paper rolls and were analyzed. Tensile strength of sheets made with barley and wheat were around 50 % higher than the control sheets; the same is true for burst strength. Tear index on the other hand is reduced by 7-15 %. This difference is small enough that it will not cause significant issues in printing or other processing steps. It was concluded that 20 % cereal straw addition to a printing and writing grade paper is feasible.

LCMR Budget $ 44,900
Balance : $ 2,491*

* all planned tasks were performed. Remaining funds originate from unused travel funding and lower than expected cost for shipping and chemicals for the pilot plant runs.

Starting date: July 2000 Completion date: December 2000

- **Result 3 :**

The University of Minnesota commissioned Kellogg Brown & Root Inc. (KBR) to conduct a feasibility study for both processes for production of bleached market pulp from cereal straw, mainly wheat and barley straw.

The purpose of the study was to (a) evaluate technologies for pulping, chemical recovery and pulp drying, (b) define a process concept, (c) develop order-of-magnitude ±25% capital cost estimates, (d) develop manufacturing cost estimates and (e) conduct a financial analysis for these two processes. Bleach sequences for the process concept, and the process conditions for pulping and bleaching provided by the University were used for the estimates. No alternative sequences were evaluated.

The capital cost estimates are Total Installed Cost (TIC) estimates, and do not include Owners' Costs such as cost of training, risk insurance, cost for start-up inventories, storeroom spares etc. Estimates of the Owners' Costs have been included in the financial analysis. The capital cost estimates are based on the scope of facilities within the battery limits of the mill fence. The oxygen plant and utility sub-station are assumed to be across the fence, and owned and operated by the suppliers. The unit cost of oxygen and power in the manufacturing cost estimate are based on this assumption. Since a site has not yet been selected, water intake and effluent discharge structures and piping have not been included, and are considered outside the fence.

For purposes of establishing the capacity of the mill, and establishing the design criteria, the county comparison in the pre-feasibility study was briefly reviewed. Polk county was found to be the most attractive from the availability of straw. Other counties that were identified as potentially being able to support a straw pulp mill are Marshall, Pennington and Red Lake. A thorough site study needs to be carried out prior to proceeding with the next phase of the project.

Based on the fiberline yields and losses established in the design criteria, it was found that these counties have a sufficient supply of straw to support a pulp mill with a bleached production capacity of 250 oven-dry short tons per day (average rate). This was established as the capacity of the mill for the study.

The process concept selected for the soda-AQ process consists of technology selections for the various mill areas that have been proven on a commercial scale for the most part, though not all of them at a single facility. The process concept for the ethanol process has a greater degree of risk at present. There are no commercial ethanol pulping operations currently running, not only on straw but even on wood. The process concept chosen for the soda-AQ process is based on continuous Pandia digesters, and the Enders fluidized bed chemical recovery system. Both flash drying and air-float drying options were evaluated. A 15 tons/day capacity R8 chlorine dioxide plant is included in the mill scope of facility. The capital cost estimates for the two options are as follows:

Air-float Dryer Option: $ 325,620,452
Flash Dryer Option: $ 280,585,527

The manufacturing cost estimates for the two options are:

Air-float Dryer Option: $ 338.15/ton
Flash Dryer Option: $ 349.43/ton

The best case manufacturing costs, based on lower screening losses and lower straw cost, are:

Air-float Dryer Option: $ 321.65/ton
Flash Dryer Option: $ 332.93/ton

The process concept chosen for the ethanol pulping process is based on batch digesters, and a distillation system for recovery of ethanol. The process concept also includes separation and recovery of byproducts, primarily lignin and furfural. Both flash drying and air-float drying options were evaluated for this process as well. This process does not require a chlorine dioxide plant, since the bleach plant is based on peroxide.

The capital cost estimate for the two options are as follows:

Air-float Dryer Option: $ 265,799,155
Flash Dryer Option: $ 233,482,947

The manufacturing cost estimates for the two options are:

Air-float Dryer Option: $ 472.92/ton
Flash Dryer Option: $ 484.21/ton

The best case manufacturing costs, based on lower screening losses and lower straw cost, as well as no ethanol feed required during normal operation due to near-100% recovery, are:

Air-float Dryer Option: $ 406.33/ton
Flash Dryer Option: $ 417.62/ton

The financial analysis was carried out using the above cost estimates, and using KBR estimates of straw costs and selling price for straw pulp. Historical data and projections for hardwood market pulp were used as indicators for determining the selling price of straw market pulp. Hardwood market pulp prices have varied in the past from $400/ton to as high as $900/ton. A best-case price of $600/ton was picked for this analysis.The financial analysis was carried out for the air-float dryer and flash dryer option for both the soda-AQ and ethanol processes. All of them had

an internal rate of return (IRR) of less than 6%. This is extremely poor, and will not be able to attain commercial financing. Typical domestic project finance projects require an IRR greater than 15% (pre-tax) at a minimum, with a Debt Service Coverage Ratio (DSCR) nearing 1.25 – 1.3 to successfully attain financing.

Keeping the manufacturing cost at the best case levels described above, a what-if analysis was carried out to determine what the TIC cost needs to be to attain an IRR of at least 15%. It was determined that the TIC cost needs to come down to around $150 million. KBR recommends that the following steps be considered to reduce both the capital and operating costs:

(a) Eliminate some of the mill areas from the scope of facilities. Some opportunities for this include:
- Siting the pulp mill on an existing pulp and paper mill site to take advantage of existing facilities. One could potentially eliminate chemical recovery, recausticizing/lime kiln, raw water and effluent treatment, and steam generation based on available capacity at the existing site. The pulp dryer could be eliminated if the site had papermaking facilities, and pulp could be supplied in slush form.
- Eliminate effluent treatment, by discharging effluent to a publicly owned treatment works (POTW). This may require upgrading of the POTW.

(b) Determine real costs for baling, transportation and storage of straw. The straw cost used in the manufacturing cost estimate and financial analysis is based on KBR's best guess based on previous similar project data. However, there is a definite opportunity to reduce this cost, and favorably impact the economics, through negotiations with the farming community on the purchase price of straw.

(c) Initiate discussions with paper companies to get first-hand information on the acceptability of flash-dried pulp. Determine paper company perspectives on the value of straw pulp. The price used in the financial analysis is based on historical data on northern bleached hardwood kraft (NBHK) pulp prices, and KBR's estimate of a realistic value for straw pulp.

A copy of the final summary from KBR is submitted with this report.

LCMR Budget: $ 84,100
Balance : 0

Starting date: September 2000 Completion date June 2001

- **Result 4:**
  Hemp has a number of properties that favor its use as a papermaking as a papermaking raw material. About one-third of the fiber of the hemp stalk, that from the outer layers or "bark", is quite long, a desirable quality for developing

high –strength paper. Also, the proportion of lignin throughout the stalk is lower that in wood, a property that favors high pulp yields. Fiber from hemp bark has also been found by a number of researchers to be acceptable raw material for use in contemporary papermaking, and it appears that hemp paper could be manufactured at a competitive price to paper made from wood pulp.

Despite the seemingly promising outlook for industrial hemp as a papermaking raw material, there are several issues that must be addressed if hemp is to become a viable fiber source in Minnesota. Among these are persistent problems related to economical bark/core separation, long term fiber storage following harvest, and potential issues related to ongoing large-scale agricultural production of hemp. Other issues arise from the fact that hemp core fiber, which comprises 65 to 70 percent of stalk volume, has markedly different properties than hemp bark fiber, and generally less desirable properties than even the juvenile fiber of wood.

From an environmental perspective it makes little sense to promote the use of hemp over fiber produced in intensively managed forests or forest plantation. Although a given area of land will generally produce a greater quantity of hemp than wood fiber, the fact that hemp is an annual crop requiring relatively intensive inputs, as compared to trees that are managed less intensively over longer harvest cycles, translates to substantial overall environmental impact from hemp production.

LCMR Budget: $ 23,000
Balance : $ 0

V. DISSEMINATION:

- Presentation to members of FFP (Future Fiber Partners), including paper industry (Potlatch, UPM Kymmene).
- Presentation at the 2000 TAPPI Pulping conference November 5-8, 2000
- Master Thesis Ankur Goel, University of Minnesota
- "Industrial Hemp as a Papermaking Raw Material in Minnesota: Technical, Economical and Environmental Considerations" report by Jim Bowyer, May 2001
- Additional publications to be submitted

VI. CONTEXT:

A. Significance:

National and world demand for paper continues to rise at the same time policy constrains are reducing timber harvest. The proximity of Minnesota's pulp and paper industry to the Red River valley and the Great Planes suggests that there may be huge quantities of alternative fiber available for the state's paper making industry. There are approximately 60 mills worldwide using straw as raw material for

papermaking. Straw is used in these regions due to lack of forest resources from which to draw their fiber. However, the current pulping and bleaching technologies used for straw processing are faced with environmental and quality constrains. This project will attempt to demonstrate, using novel pulping and bleaching technologies, that there is room for an agricultural based fiber pulp within the grades currently produced in the state's paper manufacturing sector.

The second part of this project will focus on the use of industrial hemp as papermaking raw material. Presently Industrial hemp is being widely promoted in the United States as a potential alternative source of papermaking fiber, and initiatives in the public policy arena to legalize and encourage hemp production are underway in several northern states. However, notably lacking at this point is scientifically based information regarding technical, economical, and environmental aspects of large-scale production of hemp and use of this material as a papermaking fiber. This study will provide the basis for rational discussion and systematic evaluation of any future proposal regarding industrial hemp production in Minnesota.

B.Time: This project will be completed within two years.

C. Budget Context:

No LCMR funding requested or received in past

Non-LCMR funding : A total of $ 89, 239 has been assembled from the "Future Fiber Partners" to conduct preliminary research addressing pulping characteristics of various agricultural fibers, evaluate different pulping and bleaching technologies and outline the environmental issues associated with pulping/bleaching alternatives. This research will be completed June 30, 1999.

Contributions are broken down as follows:
$11,500 Blandin Paper Company
$11,000 AURI
$10,000 Barley Council
$ 5,000 Red Lake Cooperative
$ 30,000 Northwest Initiative
$ 21,739 University of Minnesota

An additional $ 14,000 was provided by AURI to cover the higher than expected costs for the engineering study by KBR

A total of $ 18,000 was provided by the Forest Product Management Development Institute to support a study evaluating the potential use of kenaf for papermaking fiber. This study was completed November 1997 and will be used as model for the study focusing on Industrial Hemp.

1. Budget:

Personnel	$ 69,500
Equipment	$ 0
Acquisition	$ 0
Development	$ 0
Other	$ 130,500
Total:	**$ 200,000**

2. Detailed budget, attachment A

VII.COOPERATION

Dr. Shri Ramaswamy (faculty member in the Department of Wood and Paper Science) will work as co-Pi in this project along with the Project Managers Dr. Tschirner and Dr. Bowyer. Besides overall participation in the project, Dr. Ramaswamy will be responsible for the pilot plant evaluations and part of the economic feasibility analysis.

Other cooperators include the members of the Future Fiber partners (John Chell and Marlene Mixa form Blandin Paper company; Brenda Finkenbinder from Minnesota Wheat Growers; Gary Fulcher from University of Minnesota Dept. of Food Science and Nutrition; Scott Josiah from CINRAM; Brent Sorenson from AURI; Marvin Zutz from the Minnesota Barley research and promotion Council; No funding will be received by the above mentioned cooperators.

Pilot plant facilities were rented to perform larger scale pulping, bleaching and papermaking experiments. Pulping experiments were performed in North Carolina State University and Paper machine runs was performed at the University of Wisconsin, Stevens Point. Economic feasibility study was conducted by Kellog, Brown & Root Houston, TX

VIII: LOCATION:

Approximately 75 % of the activities were conducted at the University of Minnesota, Department of Wood and Paper Science in St. Paul, MN. Pilot plant runs ere performed in Wisconsin and North Carolina. In addition part of the economic feasibility study was performed at the home office of the selected Engineering consulting company in Houston TX.

X. Research Projects

I. *Abstract*
The project proposes evaluation of the use of agricultural residues and industrial hemp as possible fiber sources for paper manufacturing. We will attempt to demonstrate that novel pulping and bleaching technologies make it possible to produce a high quality fiber raw material from agricultural fiber and residues in an environmentally sound and economically feasible manner.

I.Background
National and world demand for paper continues to rise at the same time policy constraints are reducing timber harvest. The proximity of Minnesota's pulp and paper industry to the Red River Valley and the Great Plains suggest that there may be huge quantities of alternative fibers available for the papermaking industry. In addition, current pulping and bleaching technologies used for wood processing are facing environmental constraints. Lab experiments presently underway at the University of Minnesota using ethanol pulping and oxygen based bleaching chemicals to process agricultural fibers have shown encouraging results. In the lab, it was possible to produce strong, bright pulp fibers from straw without using either chlorine or sulfur containing chemicals (both chemicals commonly used in wood pulping and bleaching).

This project will attempt to demonstrate, using these novel pulping and bleaching technologies, that there is room for utilization of ag fiber based raw material for pulp and papermaking.

In addition, industrial hemp is being widely promoted in the United States as a potential source of papermaking fiber, and initiatives in the public policy arena to legalize and encourage hemp production are underway in several northern states. However, notably lacking at this point is scientifically based information regarding technical, economical and environmental aspects of large-scale production of hemp and use of this material as papermaking fiber. This study will provide the basis for rational discussion and systematic evaluation of any future proposal regarding industrial hemp production in Minnesota.

III. Methodology:
Several pulping and bleaching process are presently being optimized in lab studies. This work will be completed June 1999 and will be used as basis for the proposed project.

Pulps using various agricultural raw materials, namely wheat straw, barley straw, oat straw, flax, corn stalks, alfalfa stems will be prepared in larger quantities. Handsheets (small test sheets prepared in lab) from above pulps will then be evaluated for various standard physical and optical properties. Physical (strength) properties to be evaluated include tensile, tear, burst and folding endurance; optical properties include brightness, opacity and smoothness. Systematic comparison of

properties of agricultural pulp and traditional commercially available market pulps will be conducted. This systematic comparison will enable us to identify the exact position of agricultural pulps within the realm of market pulps in comparison to traditional pulps.

Next, properties of agricultural pulps in conjunction with commonly used wood fibers will be evaluated. A systematic comparison of paper produced with and without ag fiber will be performed, determining an optimum addition rate for several paper grades (such as newsprint, xerographic paper, magazine paper etc.).

Concurrent with the above investigations the effect of variation in raw material quality and effect of storage time on fiber properties will be investigated.

A detailed economic feasibility study for one or several small scale pulp mills in Minnesota will be compiled. Data collection to be used for this study is presently underway. The information to be taken in consideration includes factors such as raw material cost, transportation costs, water and energy cost and availability, storage cost, environmental considerations, pulp market.

Information on hemp production will be gathered from literature sources worldwide and from agricultural research institutions in countries currently experimenting with industrial hemp production. Data will be converted to a common standard, and used in conjunction with manufacturing data from a variety of sources in evaluating technical and economic feasibility of pulp and paper production from hemp. Similarly data as to agricultural processes and input will be used to assess likely environmental impact of large scale hemp production.

IV. Results and Products

This study will provide a detailed understanding of the properties of papermaking fiber produced from agricultural residues. We will be able to estimate the maximum amount of agricultural fiber that can be used in the manufacture of variety of paper grades. Pulping and Papermachine pilot plant runs will also provide key information on the "scale-up" and "runability" issues.

The economic feasibility study will provide insight as to whether one or more small scale pulp mills in Minnesota might be economically viable. This study will be conducted in collaboration with an engineering consulting company. If feasibility is demonstrated, this study will be an important tool for attracting potential investors for building an actual mill in rural Minnesota.

This study will also result in a comprehensive report that details and summarizes research findings from around the world, provides a technical and economic assessment of the potential for industrial hemp production and use in Minnesota and outlines the environmental implications of a hemp oriented fiber production system.

V. Timetable

Lab evaluation/development of pulping and bleaching methods for ag fiber: ongoing, to be completed July 1999

Lab paper testing	July 1999 – June 2001
Pilot plant trials and evaluation of test paper	July 2000-December 2000
Economic feasibility study	Sept. 2000-June 2001
Hemp as alternative fiber	July 1999-December 2000

VII. Budget

Total LCMR budget requested $ 200,000

Lab scale papermaking trials using ag fibers:	$ 48,000
Pulping and papermachine pilot plant runs:	$ 44,900
Economic feasibility of an ag fiber mill in rural Minnesota:	$ 84,100
Industrial Hemp as potential alternative fiber	$ 23,000

Attachment A deliverable Products and related Budget					
LCMR Project Biennial Budget	Objective/Results				
	Result 1	Result 2	Result 3	Result 4	ROW TOTAL
Budget Item	Lab scale papermaking	Pilot plant runs	Economic feasibility study	Industrial hemp study	
Wages, salaries & benefits	$ 43,000 Research Assistant	$ 4,500 Research Assistant		$ 22,000 Research Assistant	$ 69,000
Space rental, maintenance & utilities		$ 31,900 pilot plant			$ 31,900
Printing and Advertising					
Communications, telephone, mail etc.					
Contracts					
Professional/technical			$ 84,100 Engineering Consulting Company		$ 84,100
Other contracts					
Local automobile mileage paid					
Other travel expenses in Minnesota					
Travel outside Minnesota		$ 4,000			$ 4,000
Office Supply					
Other supplies	$ 5,000 Chemicals	$ 0 fiber raw material		$ 1,000 copying, purchase of research reports etc.	$ 6,000
Tools and equipment					
Office equipment & computers					
Other capital equipment					
Other direct operation costs		$ 4,500			$ 4.500
Land acquisition					
Building or other land improvements					
Legal fees					
COLUMN TOTAL	$48,000	$ 44,900	$ 84,100	$ 23,000	$200,000