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BNI COAL

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September 28, 1989

Mr. Tim Kingstad
State Land Commissioner
State Capitol
Bismarck, North Dakota
58505

Dear Mr. Kingstad:

RE: Lignite Research Council Grant Application

BNI Coal Ltd., and Minnesota Power are pleased to submit the attached application for an LRC grant. We are enthusiastic about the potential of North Dakota lignite that has been beneficiated with the "hot-water-drying" process: the subject of our application.

Please find attached five copies of the LRC grant application. If there are any questions or comments, feel free to contact the projcct's principle investigator, Mr. George Nehls, at tel: 218-722-2641. We look forward to discussing our project with you in the near future.

Sincerely,

Ronald Bertoch

Ronald Bertoch
Executive Vice-President

Attachment

CC: J. G. Miller
Coal Beneficiation

1136 WEST DIVIDE AVENUE • P.O. BOX 897 • BISMARCK, ND 58502

Hot Water Drying of North Dakota Lignite

Grant Application to the
North Dakota Lignite Research Council

for the amount of $100,000

submitted by,

BNI Coal, Ltd.
&
Minnesota Power

date of submission,
September 29, 1989

Principle Investigator,
George R. Nehls Jr.
tel: 218-722-2641

Project Summary

BNI Coal, Ltd. and Minnesota Power are developing the thermochemical process known as "hot-water-drying" to up-grade, or beneficiate, North Dakota lignite. The expected result of this project is the creation of a new industry which will market beneficiated North Dakota lignite for use in utility boilers both within and outside of North Dakota. Application for DOE Clean Coal Technology co-funding has been made under the project title: *ELFUEL Demonstration of Low-Rank Coals.* The DOE will make public its selections on December 26, 1989.

In anticipation of selection by the DOE, BNI Coal, Ltd. and Minnesota Power are undertaking activities which will provide for a smooth and effective transition into the demonstration program. LRC grant funding is being applied for to assist in completing several of theses tasks. A total grant of **$100,000** is being requested. The estimated gross cost of the activities is **$311,000.**

There are three primary tasks for which LRC co-funding is being requested:

- Continued characterization of waste streams based on North Dakota lignite, waste stream treatment options, and waste stream by-product applications. This work is being performed by North Dakota's Energy and Mineral Research Center (EMRC). This task is expected to be a continuous effort through the demonstration project.

- Market development. President Bush's proposed pollution control program is expected to have a significant impact on the market potential of beneficiated lignite. A study of the expected market impacts will be made. This task will be administered by BNI Coal, LTD.

- Reactor hydraulic study. Optimization of the hot-water-drying reactor design depends upon the fluid flows within the packed-bed reactor. A working model of the reactor's hydraulics will be developed. It is expected this task will be completed by the St. Anthony Falls Hydraulic Laboratory

The market study is expected to be completed during the first quarter 1990. The hydraulic study is expected to be completed during the second quarter 1990.

The major participants in the project (although not necessarily as project participants in the demonstration plant) are: BNI Coal, Ltd., Minnesota Power, North Dakota EMRC, the Electric Power Research Institute, St. Anthony Falls Hydraulic Laboratory, the Institute of Gas Technology, Combustion Engineering, and Bechtel National, Inc., which has been retained to assist in the engineering analysis.

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Objectives

The objectives of BNI Coal, Ltd. and Minnesota Power's lignite beneficiation project can be summarized as follows:

- The ultimate objective of the project is to economically up-grade, or beneficiate, North Dakota lignite to an export quality boiler fuel. An additional application may be found in blending the beneficiated lignite with raw lignite for use in sodium-limited boilers. This will require the construction and operation of at least one commercial-scale lignite processing plant following successful development of the beneficiation process under consideration.

- The intermediate objective of the project is the design, construction, and successful operation of a demonstration-scale lignite beneficiation plant. Co-funding has been applied for through the DOE's Clean Coal Technology Program (Phase III). The purpose of the demonstration plant would be to provide a means to complete process development at a scale large enough to permit full-scale boiler testing of the beneficiated lignite. The beneficiated lignite would be tested in applications by interested parties up to and including large utility boilers.

- The present objective at this time is to execute project research tasks which will provide continuing refinements of the market awareness, and the overall process development.

Utilization of lignite is currently limited due to its high moisture content, and other undesirable qualities, such as high sodium content, and tendencies to decrepitate, dustiness, and spontaneously ignite following exposure after mining. The hot-water-drying-based process under development appears to simultaneously reduce all of the above undesirable features. The end product is expected to be a high grade boiler fuel with stabilized physical characteristics. In order for the process to succeed at the commercial level, continued process refinement must be undertaken. The assistance of LRC funding will help provide the basis for expanded lignite marketability, to include the establishment of a new lignite export industry.

Details of the program activities are given in the section entitled: **Methods**.

Background

Minnesota Power has been investigating coal beneficiation processes for a number of years. The most recent efforts have been directed at up-grading raw lignite into a product suitable for utilization in utility sized boilers that were originally designed for burning a higher rank coal. Minnesota Power has been investigating the process known as "hot-water-drying" of low rank coals since early 1986. BNI Coal, Ltd. has provided valuable information regarding lignite characteristics and resource availability. Bechtel National, Inc. an Architect & Engineering firm, has considerable experience in coal beneficiating processes. Bechtel National Inc., has been retained by BNI Coal, Ltd. and Minnesota Power to assist in this project.

Hot-water-drying is a thermochemical means of improving, or beneficiating, low-rank coals such as lignite. The process has the potential to economically transform raw lignite into an exportable fuel product. The product may be marketable as a replacement fuel for utility boilers currently firing higher sulfur content coals.

The primary benefit derived from hot-water-drying a low-rank coal is improved heating value, which results from reducing the moisture and oxygen contents of the coal. For example, raw lignite characteristically has a heating value of 7000 Btu/lb, a moisture content of 35%, and an oxygen content of 12%. After hot-water-drying, the product lignite may be expected to have a heating value of 10,500 Btu/lb, a moisture content of 12%, and an oxygen content of 7%. The improvement in heating value results because water and oxygen content both contribute nothing to the heating value of the lignite: hence they are termed weighty impurities. Reducing the weighty impurities increases the heating value of the fuel, which improves the economics of transportation. In addition, reducing the moisture content of the fuel also helps improve combustion efficiency. During combustion, water present in the fuel must be evaporated, which requires a significant amount of energy. The energy required for evaporation then no longer available for use in performing work, and is usually lost as steam with the rest of the combustion gases.

Another significant benefit derived from hot-water-drying lignite is that the process has the potential to significantly reduce the lignite's sodium content. Sodium can have seriously detrimental effects on the ability to cleanly burn lignite in a combustion process. Many operators of lignite fueled boilers have become familiar with boiler fouling and forced outages due to high sodium content in the lignite. The fouling effect on boilers designed for higher rank coals can be even more serious. Hot-water-drying is almost unique among commercially attractive coal processes in its ability to reduce sodium content by as much as 85%, although 50% should be considered more the norm.

Other benefits resulting from the hot-water-drying process are improved fuel stability, resulting in reduced spontaneous combustion tendencies, and reduced tendency of the lignite to break down into dusty fine particles.

The hot-water-drying process makes use of a fundamental process which runs counter to intuition. A low rank coal, such as lignite, is immersed in water, pressurized, and heated for a short period of time. The temperatures used are usually in the range from 260° C to 320° C. The pressure must be maintained high enough to prohibit the water surrounding the coal from boiling: hence the term hot-water drying. Under these process conditions water is forced out of the coal particle, rather than into the coal particle. Keeping all water in the liquid phase during the process has another desirable side effect: since evaporating water (energy requirement about 1000 Btu/lb) is avoided, the process is inherently energy efficient. The fact that evaporation is avoided is particularly important when higher moisture content coals are the feedstock. For example, reducing the moisture content of a ton of lignite from 35% to 10% requires the removal of over 550 lbs of water. The energy required to evaporate this is substantial. As a result, hot-water-drying requires generally one-third to one-fourth of the energy of a conventional coal-drying process. In addition, liquid water is produced as a process byproduct, which may have value in arid regions.

Pilot plant testing has been completed and results indicate that the fuel product appears to be satisfactory for use in many industrial boilers. Several key questions remain, however. The marketability of the product, and details of the process design need additional refinement. Performing these studies at this time are timely regarding the overall schedule of the project.

Much of the fundamental development of hot-water-drying processes has taken place at the North Dakota Energy & Mineral Research Center in Grand Forks, ND.

Goals

- The general goal of the proposed work is to continue to improve the chances of success of the project as it proceeds toward the demonstration of the technology.

- The specific goals of the proposed work are to:

  1) Continue to develop the waste-water treatment methods to be used in the demonstration and commercial scale projects. Satisfactory progress will have been made when a working model of the waste-water treatment process is developed, along with suggested areas for further improvement and development.

2) Investigate the market potential of the up-graded lignite, particularly in light of President Bush's proposed emissions program. Satisfactory progress will have been made upon submittal of a completed market study which clearly shows the potential for commercially marketing the up-graded lignite product, along with key indicators for additional market study.

3) Develop a working model for the hydraulic flows within the hot-water-drying reactor. Satisfactory progress will have been made upon the development of an analytical model which predicts the flows within the hot-water-drying-reactor vessel along with recommendations for future development work.

Methods

A detailed description of the three primary tasks is given below.

Waste-Water Treatment Program

The hot-water-drying process under development produces large amounts of water containing organic and inorganic detritus. A commercial scale facility could be expected to produce about a million gallons of water per day. The source of this water is the raw lignite, from which it is extracted. Although this water in the raw state could not be returned to the environment, with appropriate treatment it can become a valuable by-product.

BNI Coal Ltd., and Minnesota Power initiated wastewater treatment studies with North Dakota's Energy and Mineral Research Center (EMRC) in February 1989 with a characterization of the waste-water produced in autoclave experiments. This primary goal of this program is to determine the most effective means of converting the process waste-water into a useable by-product. The EMRC is currently performing activated sludge experiments on waste-water produced in the pilot plant test experiments. This work has been undertaken by BNI Coal Ltd., and Minnesota Power at a cost of approximately $65,000 and is expected to be completed within the next sixty days. The purpose of the current test program is to determine the effectiveness of current state-of-the art technology in chemical and biological oxygen treatment of the process waste-water.

Following completion of the current work, the next stage of waste-water treatment development will be to evaluate the remaining "salty-water", and to determine which technologies can be used to produce a water by-product which can either be used in further industrial processes or returned to the environment. The current plan is to investigate advanced membrane separation technology and compare this to existing technology such as distillation, and evaporation concentration methods. This work will be undertaken by the EMRC. This type of work is also of current interest to the Electric Power Research Institute (EPRI), and discussions are underway to investigate the possibility of expanding the work and co-funding by EPRI.

The possible use of membrane separation technology is of particular interest in that the briny concentrate produced by the process may have value as a sulfur sorbent in combustion flue gas applications. It is the intent of the currently proposed work to begin investigating this potential.

It is expected that this new round of study will begin upon completion of the current work. It is not expected that a final solution to the waste-water treatment process will be completed during the next six-months; instead, the waste-water treatment process development will likely continue up to and through the demonstration project.

Market Research

President Bush's clean air proposal may provide the impetus for significant increases in the marketability of up-graded lignite products. BNI Coal Ltd., and Minnesota Power recognize that this new situation requires immediate and continuing investigation. It is the intent of the proposed market study to evaluate these potential markets. Although data will be collected from a wide range of sources and many different products may be marketable, it will be the intent of this market study to concentrate primarily on the marketability of a product which will have the general specifications resulting from the process under development. In order to further specify this product, future references will be to ELFUEL™, which stands for **E**nhanced **L**ignite **FUEL**.

ELFUEL™ products, which will be produced from North Dakota lignite, will have Btu and moisture characteristics similar to bituminous coal. Therefore, the potential market for lignite will be expanded beyond the traditional market for lignite as ELFUEL™ products will be able to be used in boilers not designed for lignite. In addition, ELFUEL™ products will be considered as a potential design fuel for new boilers located in areas that have historically been uneconomic because of transportation costs. This study will evaluate the potential market in new and existing utility and industrial boilers. The market study will be administered by BNI Coal, Ltd., and will be performed by a highly qualified analyst firm. Efforts are currently underway to select the appropriate analyst. Several are being considered. The North Dakota EMRC will be consulted prior to the final decision and will also participate in the analysis, where appropriate.

An additional market which may be investigated is the taconite industry in Northern Minnesota. This industry currently uses large amounts of natural gas to operate induration furnaces which produce taconite pellets. Efforts are currently underway between the taconite producers and the Minnesota Department of Natural Resources to research the possibility of switching over to coal combustion. Due to the proximity of North Dakota lignite resources to Northern Minnesota, a new and important market for ELFUEL™ may emerge within the next five years. This topic needs further definition and may only be addressed in a cursory manner in the proposed study. The remainder of the task description concentrates on the market as it relates to the Clean Coal Technology Program and President Bush's proposal.

Market opportunities for ELFUEL™ products will be determined by examining the fuel supply requirements and obligations of utility and industrial coal customers within an economic range of the production that can use the quality of the ELFUEL™ products. The economic range of the production will depend upon ELFUEL™ production costs relative to production costs of the alternatives to ELFUEL™ (e.g., Colstrip or Illinois Basin production costs) and relative transportation rates. The lower Great Lakes area is currently believed to be the primary market area for ELFUEL™ products.

The utility and industrial coal requirements in this market area that could use the quality available through ELFUEL™ products will be identified on a plant by plant basis. Market opportunities will be quantified based upon contract expirations, spot requirements, timing of new plants, and load growth. In addition, potential opportunities as a result of acid rain legislation will also be identified.

The competitiveness of ELFUEL™ will be determined by evaluating the delivered cost of ELFUEL™ to a given plant compared to the delivered cost of its alternatives. The delivered cost of the alternatives will reflect their cost of production and the demand/supply balance in that supply region. The market clearing price for ELFUEL™ can also be determined by evaluating at what price ELFUEL™ could compete in the target market area.

An outline of the tasks as currently identified follows:

1. Identify those steam electric plants and industrial users of steam coal in the lower Great Lakes that will be faced with meeting newly proposed clean air standards:

    a. 1.2 lbs. SO_2/million Btu's by the year 2000
    b. 2.5 lbs. SO_2/billion Btu's by the year 1995

2. Current suppliers to identified steam electric stations.

3. Mode of transportation and associated cost.

4. Coal quality, quantity, and price per million Btu's.

5. Determine a reasonable estimate of marketable quantities of enhanced lignite fuel in the lower Great Lakes.

6. Estimate cost of enhanced lignite fuel to be competitive in the market under potential acid rain legislation.

7. Identify other markets which ELFUEL™ products may penetrate. These markets may include, but are not limited to the taconite industry, the iron and steel industry, and steam coal users outside of the lower Great Lakes. Other potential steam coal locations may be the eastern seaboard, foreign sales and Canada.

Hydraulic Study

The hydraulic study task is currently outlined as a four sub-task program with the St. Anthony Falls Hydraulic Laboratory as the subcontractor. The purpose of the study will be to develop a working, analytical model of the flows within the reactor vessel.

The basic concept of the vertical shaft, descending coal, ascending liquid hot-water-drying reactor is simple heat exchange between the two counterflowing media (lignite and water). Cold coal (or lignite) is introduced at the top of the reactor and slowly flows downward in a packed bed. The downward motion is imparted by removing coal product from the bottom of the reactor. The cold coal is heated by direct contact with warmer process water flowing countercurrent to the coal. The highest temperatures are achieved by injecting steam or other forms of energy into the middle section of the reactor.When the descending coal has reached the proper temperature, it begins to be cooled by cold water flowing countercurrent which has been injected at the reactor's bottom. The concept, analysis, and design become more complicated however, when key variables such as viscosity, density, temperature, porosity, rate of heat transfer, and convective currents are considered. In order to design a reactor for the most effective throughput, a model must be created which can account for the interrelation of the most important variables. The result of such a study would be a model of sufficient sophistication to adequately predict the best design configurations. The initial modelling will be conducted under this study. The task is currently planned to achieve this goal by proceeding as follows:

1. Develop a computational math model of the mass flows and energy transfer in the hot-water-drying reactor.

2. Identify parameters in the model that need to be better defined, i.e. those that will significantly affect the outcome within the uncertainty of the parameter's expected value.

3. If required, develop small scale experiments to improve the estimation of certain parameters identified under item number two.

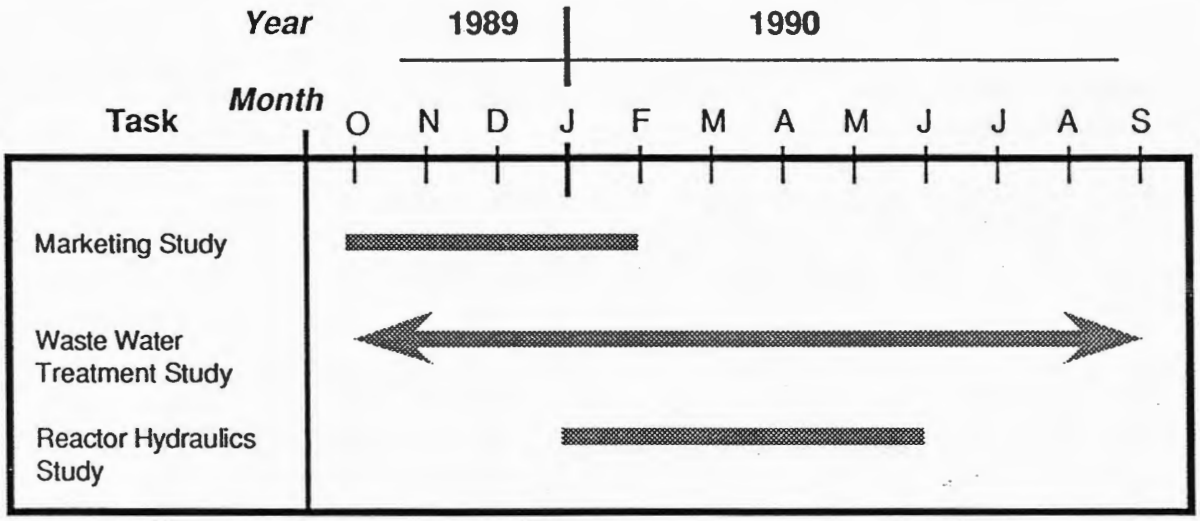
4. Design a pilot plant reactor and develop a test program in association with Minnesota Power personnel.

Accomplishment of the above, and the successful execution of the pilot program to prove out the model will allow predictive design at the larger demonstration and commercial reactor sizes. The pilot program is not considered to be part of the current program: it will be proposed and budgeted at a later date.

Timetable

A timetable of the major activities by task is presented below. Following the timetable, brief descriptions of the tasks with date and deliverable summaries are given.

Lignite Beneficiation Project Timetable



Description of Tasks

Marketing Study Evaluate the potential market penetration of ELFUEL™ products as a result of President Bush's clean air proposal. In addition, estimate potential new markets such as the taconite, and steel industries. This work is expected to begin immediately, and the report will be expected to be completed during the first quarter 1990.

Waste Water Treatment Study Continuing investigation of the most effective way of dealing with the processes water effluent. This task was initiated in February 1989 and is expected to continue through the demonstration program.

Reactor Hydraulics Study Development of an analytical model which can predict the hydraulic flows within the reactor vessel. Work is expected to begin early in 1990 and continue for the next two quarters.

Personnel

Brief narrative summaries of the experience and qualifications of the principal investigator and other major participants in the project are provided as required. The major project participants for the pilot plant test program are Minnesota Power, North Dakota EMRC, and Combustion Engineering.

Minnesota Power

George R. Nehls Jr. -- Principle Investigator
Research Engineer

Mr. Nehls is responsible for research activities in the area of fuels technology and minerals development. His primary duties include the investigation and evaluation of advanced coal technologies and advanced extractive metallurgical processes.

Mr. Nehls has an extensive background in industrial processes and thermochemical systems. He has participated in numerous studies determining the technical and economic feasibility of alternative energy supply systems, coal beneficiation, and advanced steelmaking.

John E. Pelerine
Supervisor Plant Engineering

Mr. Pelerine is responsible for administration and technical management of Minnesota Power Plant Engineering's Mechanical, Civil, and Chemical Engineering Group. Plant Engineering performs project and support engineering for Minnesota Power's generating facilities.

Mr. Pelerine has an extensive background in plant operations, environmental/regulatory, and construction engineering. His experience includes participation in start-up and operation of pulverized-coal utility boilers, lignite-fired cyclone boilers, and the conversion of Minnesota Power's Hibbard Steam Station to a multiple-fuel-capable co-generation facility.

North Dakota Energy and Mineral Research Center

Todd A. Potas
Research Supervisor
Low-Rank Coal Beneficiation

Mr. Potas has been the Research Supervisor of the Low-Rank coal Beneficiation Group since 1987. His primary duties currently involve

supervising and performing research programs involving low-rank coal cleaning and drying technologies and coal/water fuel preparation. Mr. Potas has extensive experience with the EMRC's continuous hot-water-drying pilot plant, and coal gasification analysis.

Mr. Potas' principle areas of expertise include thermal upgrading and drying of low-rank coals, physical and chemical cleaning of low-rank coals, and the preparation and rheology of coal/water fuel.

Gale G. Mayer
Research Supervisor
Waste Water Treatment

Mr. Mayer has been the Research Supervisor of the Waste-Water Treatment program since 1982. He has an M.Sc in geology and a B.Sc. in biology and chemistry, both from the University of North Dakota. He has planned and directed numerous research and development projects to address the characterization and treatment of effluents from coal beneficiation and conversion processes.

Mr. Mayer's principal areas of expertise are in the areas of physical, chemical, and biological treatment of process waters generated from the hot water-drying of coal and from various gasification processes. Pilot- and bench-scale treatment processes studied have included both novel and conventional methods.

Qualifications

BNI Coal, Ltd. (BNI) was incorporated in the state of North Dakota in 1949. BNI is engaged in the business of surface mining and sale of North Dakota lignite coal. BNI operates the Center mine, which delivered 3.7 million tons of lignite to its customers in 1987. Historically, BNI has been one of the lowest cost producers of lignite in the state of North Dakota. BNI is a wholly owned subsidiary of Minnesota Power.

Minnesota Power (MP) is an investor owned electric utility operating generating facilities and providing electric service in northern Minnesota and northwestern Wisconsin. MP operates the coal fired Clay Boswell Steam Electric Station in Cohasset, Minnesota. Clay Boswell SES is rated at over 1,000 MW of generating capacity. In addition, MP operates the Syl Laskin SES near Aurora, MN, and the Hibbard steam station in Duluth, MN.

Budget

BNI Coal, Ltd. and Minnesota Power are requesting a grant of **$100,000** from the Lignite Research Council to help defray the cost of their lignite beneficiation project during 1989. The gross cost of all the tasks described in this application is estimated to be **$311,000**.

BNI Coal, Ltd. and Minnesota Power charge at a rate of $26 per person-hour ($4,500 per person-month), including overheads. Detailed information regarding subcontractors can be obtained from Minnesota Power and/or the specific sub-contractor.

The project budget is separated into three primary tasks: Waste-Water-Treatment Study, Marketing Study, Hydraulic Study. Descriptions of the costing of each are given below.

The Waste-Water-Treatment Study is expected to cost **$164,000** during the current study cycle. The specific sub-tasks included in this cycle include the present waste water treatment work at EMRC (activated sludge and packed bed surface water removal: authorized July 6, 1989), and the expected future work involving treatment and re-use of the final brines and pure water. Specifically excluded from this list is work undertaken and listed in the previous application to the Lignite Research Council. Work which fell in the excluded category was the initial characterization in autoclave studies and was identified in the LRC application of March 31, 1989 as Bench Scale Studies.

- The current work was subcontracted to the EMRC for $75,000.
- The planned work will be subcontracted to the EMRC for a currently estimated $80,000.

In addition to the fixed price contracts, BNI Coal, Ltd. and Minnesota Power expect that in-house labor to administer, manage, and engineer the Pilot Plant Testing will require two person-months of effort. This is equivalent to a cost of $9,000. Contingency costs are included in the Future EMRC Testing estimate. These costs are summarized below.

Waste-Water-Treatment	**Cost ($)**
BNI, MP labor	9,000
Current Testing	75,000
Future EMRC Testing	80,000
Total Gross Cost	**$164,000**

The Marketing Study is estimated to cost **$59,000**. This is split between a retained consultant expenditure of $50,000, and an assumed $9,000 in-house expenditure at BNI Coal, Ltd. and Minnesota Power (two person-months of

effort). Contingency is included in the consultant estimate. These costs are summarized below:

Marketing Study	**Cost ($)**
BNI, MP labor	9,000
Consultant	50,000
Total Gross Cost	**$59,000**

The Hydraulic Study is estimated to cost **$88,000**. The hydraulic study is expected to be sub-contracted to the St. Anthony Falls Hydraulic Laboratory. The subcontract is estimated to cost $70,000, which includes a $10,000 contingency. Minnesota Power's estimated cost of internal engineering, administration, and general is estimated at four person months. This is equivalent to a cost of $18,000. These costs are summarized below:

Hydraulic Study	**Cost ($)**
BNI, MP labor	18,000
Consultant	70,000
Total Gross Cost	**$88,000**

A summary of the total anticipated program cost is given below:

Three Task Program	**Cost ($)**
Waste-Water Treatment Study	164,000
Market Study	59,000
Hydraulic Study	88,000
Total Project Gross Cost	**$311,000**
Lignite Research Council Grant	**($100,000)**
BNI Coal, Ltd. & Minnesota Power Net Project Cost	**$211,000**

This concludes BNI Coal, Ltd. and Minnesota Power's research grant application to North Dakota's Lignite Research Council.