MICROBEAM
TECHNOLOGIES, INC.

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February 5, 2021

Ms. Karlene Fine
Executive Director
ATTN: Lignite Research, Development and Marketing Program
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: North Dakota Rare Earth and Critical Element Resource Evaluation

Microbeam Technologies Incorporated is pleased to submit this proposal to develop information on coal and associated sediment rare earth element and critical element/mineral (REE-CM) content, project resource, and REE-CM extractability that can be used to determine potential economic production of 85% pure mixed REE-CM concentrate. The project team including the University of North Dakota and MLJ Consulting will work with project Co-Sponsor Great Northern Properties, along with Stantec, to perform the work outlined in the following detailed proposal.

The total cost of the project is $1,059,510. We are requesting funding from the North Dakota Industrial Commission for $529,529 and will have cost share from GNP for the remaining $529,981. Based on past work conducted on the abundance and form of REE-CM in lignite, North Dakota is in an exciting and unique position to play a significant role in the development of the infrastructure to provide REE-CM required by the US and the world.

We sincerely appreciate the ability to submit this proposal in a special grant round.

Please let me know if you have any questions or comments. We will send a check for $100 for the application fee.

Sincerely,

Steven A. Benson, PhD
President

c/enc. Mike Holmes, LEC

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North Dakota Rare Earth and Critical Element Resource Evaluation

Submitted to:

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
ATTN: Lignite Research, Development and Marketing Program
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Submitted by:

Microbeam Technologies Incorporated
4200 James Ray Drive, Ste 193
Grand Forks, ND 58203

Project Manager/Principal Investigator:

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2/5/2021

Total Project Costs: $1,059,510

NDIC Amount Requested: $529,529

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1.0 ABSTRACT

Microbeam Technologies Incorporated (MTI), project lead, the University of North Dakota (UND) Institute for Energy Studies, and MLJ Consulting will work with Great Northern Properties and Stantec to evaluate the resource rare earth elements (REE) and critical minerals (REE-CM) in selected ND coal seams and sediments (Note: mineral and element are used interchangeably).

GNP is interested in producing REE-CM concentrates that are derived from GNP coal and associated sediment resources. The goal of this project is to work with the GNP team to develop information on coal and associated sediment REE-CM content, projected resource, and REE-CM extractability that can be used to determine potential economic production of 85% pure mixed REE-CM concentrate.

The specific objectives of the project are to identify promising regions, characterize the coal in those regions, determine the extraction behavior of selected samples, collect a large sample to simulate full scale REE extraction at UND's pilot REE processing plant, and conduct a technical and economic assessment of recovery of REE-CM.

The team anticipates identifying multiple coal seams or sections of coal seams that will show an average of 300 ppm or greater total REE (TREE) content on a dry-coal basis which is the Department of Energy's threshold value for consideration for testing. It is also anticipated that the REEs in the given seams will be extractable with the current REE technology, which has been used to extract REE from lignite materials from various sources to date.

The duration of the project is projected to be 9 months. The total cost of the project is $1,059,510 with the cost share of $529,981 in the form in-kind contributions for drilling and other engineering performed in support of this project. The NDIC share of the proposed project is $529,529.

2.0 PROJECT SUMMARY

Selected coal seams in North Dakota are enriched in REEs and CM. The demand for these elements in electric cars, wind generators, catalysts, cell phones, and military applications is growing dramatically. A list of critical REEs and CM can be found in Table 1.

Table 1. List of Rare Earth Elements and Critical Mineral to be assessed.

Rare Earth Elements and Critical Mineral	
Element	Abbreviation
Cerium	Ce
Cobalt	Co
Copper	Cu
Dysprosium	Dy
Erbium	Er
Europium	Eu
Gadolinium	Gd
Gallium	Ga
Germanium	Ge
Holmium	Ho
Indium	In
Lanthanum	La
Lithium	Li
Lutetium	Lu
Manganese	Mn
Neodymium	Nd
Praseodymium	Pr
Samarium	Sm
Terbium	Tb
Thulium	Tm
Scandium	Sc
Ytterbium	Yb
Yttrium	Y
Zinc	Zn

The project aims to evaluate the technical and economic potential recovering the REE and selected critical mineral in GNP resources. The project will involve the following:

- Identification of promising regions: Stantec and GNP have identified two sites in western North Dakota for sampling and will select another site in northern Golden Valley County. This team will assist in the identification of the third site within the predetermined area.
- Selection of samples from cores for analysis: Survey analysis of each core sample will be performed using a portable x-ray fluorescence (pXRF) to identify potential high REE content. Based on pXRF and stratigraphic information, a total of up to 135 samples will be selected for detailed characterization.
- Characterization of coal samples: A total of 135 selected coal/sediment samples will be analyzed to determine the abundance of REE-CMs, to determine basic coal properties (proximate, ultimate, ash composition), and to identify forms of REE-CMs (organic/mineral forms).
- Extraction behavior of selected samples: The ability to recover REE-CM from the coals will be determined using laboratory and bench scale testing. This testing will require approximately 500 lbs of REE-rich coal.
- Large sample collection: A 100-ton sample will be collected for processing using UND's REE Processing Pilot Plant to determine the feasibility of a commercial-scale REE extraction facility using the determined coal resource. The 100-ton sample will be characterized, and the extracted material will be evaluated.
- Technical and Economic assessment of recovery of REE-CM: Any technical issues associated with the recovery of REE-CM will be identified. The economics of the overall process for the recovery of REE–CM will be determined.

The project team has a deep understanding of the abundance and forms of REE-CMs in lignite and associated sediments. This information will be used to assist in identifying the best seams to target for testing and as a potential resource for recovery. In addition, the team also has expertise in extracting and concentrating the REE-CM to a commercially viable ore that can be used for separation of REEs and CM into individual elements and oxides/carbonates.

Stantec Consulting Services, funded by GNP and used as cost share in this project, will conduct the sampling, modeling, and mine plan development. Stantec developed a proposal that consists of three phases, each phase broken into multiple tasks, with Go/No-Go decisions at the completion of each phase of work. Stantec's proposal can be found in the Appendix of this document. This proposal will follow the same structure with NDIC deciding whether or not to proceed to the subsequent phases consistent with the GNP-Stantec proposal.

The MTI Team (MTI, UND, and MLJ) will work closely with GNP and Stantec and will be responsible for assisting in sampling efforts, analyzing core and bulk samples, determining REE-CM extractability, performing an economic assessment, and providing guidance on sampling locations. This document summarizes the efforts outlined in that proposal and will focus on the responsibilities of MTI, UND, and MLJ Consulting.

The structure of the project consists of a project management and reporting task that is associated with communication and coordination of efforts to ensure the project is conducted on-time and within budget. The next task involves coring selected promising regions to obtain samples for analysis to determine the abundance of REE-CM as well as the properties of the coal. The following task is focused on the modes of occurrence of the REE-CM that are used to determine extractability. It will also provide information on the mineralogy that can be used as indicators of concentrations of REE-CMs and in future geochemical models of REE-CM distributions in seams. The extractability task will simulate a larger scale extractability and provide information used to determine capital and operating expenses associated with the production of the concentrates. The composition of the concentrates will be evaluated to determine the value of the products produced.

The project will provide information that will be vital to developing the framework for a future plant in ND to produce a concentrate with the potential to develop a separation and product development facility.

3.0 PROJECT DESCRIPTION

3.1 Overall Project Goal

The goal of this project is to work with the existing GNP team to develop information on coal and associated sediment REE-CM content, projected resource, and REE-CM extractability that can be used to determine potential economic production of 85% pure TREE-CM concentrate.

3.2 Project Objectives

To meet the goal, the following objectives have been identified:

- Identification of promising regions that have high levels of REEs and critical materials
- Perform survey analysis of each core sample to identify potential high REE content
- Characterize selected samples to determine the abundance and forms of REEs and CM
- Determine the ability to recover REE-CM from the coals using laboratory and bench scale testing
- Perform a Technical and Economic assessment on the recovery of REE-CM based on resource characteristics and extractability of REE-CM from the coal.

3.3 Scope of Work

Task 1. Management and Reporting

In order to achieve the goal of the project, the team will work together to ensure the project is conducted on-time and within budget. Progress meetings will be held on a monthly basis and the results of testing will be reported in the form of a power point presentation. Four reports will be prepared that include:

- Two Quarterly reports that will give an update on initial analysis, results, and interpretations
- Final report that includes final analysis, results, and interpretations; and
- Final technical and economic assessment for a commercial plant.

Task 2. Target Identification and Site Preparation

This task will be coordinated with Phase 1, Task 1, of the Stantec proposal. Two sites in western North Dakota have been identified for core sampling and one larger target area has been identified in northern Golden Valley County. The Harmon, Hansen, and H Bed seams or their stratigraphic equivalents are present in each location. The team will work with Stantec to determine the specific site in the northern part of Golden Valley County for core sampling. The drilling program is based partly on the results of the ND Geological Survey rare earth element project results reported in Kruger and others (8) and Murphy and others (10). The two proposed drill sites in Billings and Slope counties are within five miles of a site where the NDGS found high rare earth concentrations in the Harmon coal (555 ppm), the Hanson coal (402 ppm), and the H bed lignite (1,026 ppm). Figure 1 shows the site locations.

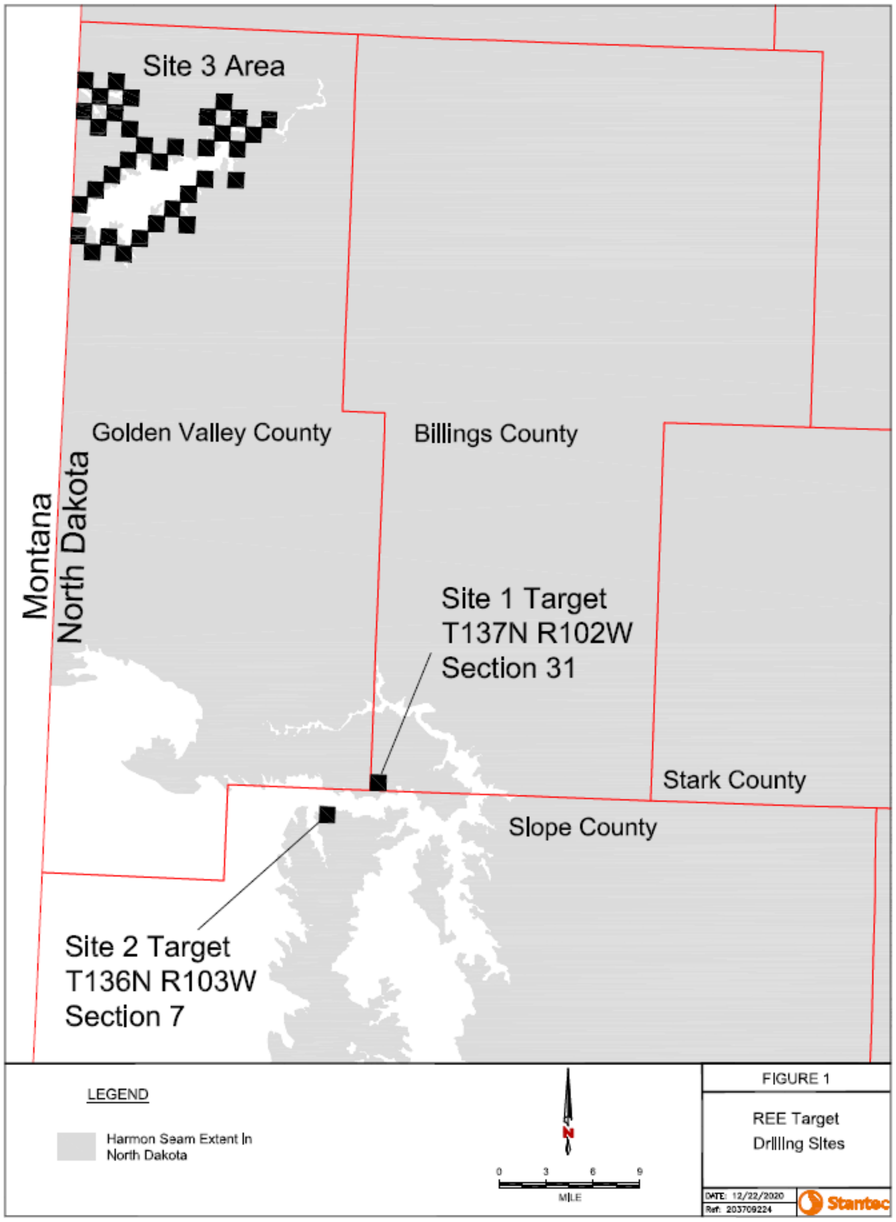


Figure 1. Site locations for core sampling efforts.

The project team will confer/consult with the N.D. Geological Survey regarding the local coal stratigraphy, the proposed sampling horizons, and the results of the sampling program.

Task 3. Target Area Drilling and Analysis

This task will be coordinated with Phase 1, Task 2, of the Stantec proposal. A core hole will be drilled at each of the three (3) locations (resulting in a total of three core samples). Each core will be drilled to a depth of 200ft below the surface in order to sample each coal seam of interest (Harmon, Hansen, and H Bed). Refer to Appendix A for details on the coring efforts.

MTI and UND will accompany Stantec on the drilling efforts to provide assistance on location and geographical background of each site. MTI will conduct pXRF analysis on site of each core sample. MTI plans to analyze about 10 samples from each core using pXRF to provide initial REE content results throughout each seam.

The cores will be delivered to MTI and UND labs to undergo further sample analysis. The full analysis includes:

- Process/grinding/storage
- Determine basic coal properties (proximate, ultimate, ash composition) using ASTM methods
- Determine abundance of REE–CM using ICP-OES/ICP-MS
- Measure the modes of occurrence (extractability) and mineralogy (SEM/XRD) on selected promising samples
- Examine relationships between elemental composition, REE-CM abundance, and mineralogy
- Calculate the value of REE-CM present in the samples based on projected values.

Based on the analysis completed for the cores, the team will evaluate geological factors that impact accumulation of REE-CM in ND. These include describing the stratigraphic sequence for each sample and reviewing the geochemical characterization (XRD) and SEM analysis to determine regions of concentration.

A Go/No-Go decision will be made based on the information collected in Tasks 2 and 3. There is no guarantee that the results will provide the information necessary to support further development of the project. The Go/No-Go decision will be made by GNP and NDIC based on the data presented by the team. The decision should be made on the following criteria:

- Economic evaluation of the resource at the 3 drill sites, and
- Extractability of the resource from the 3 drill sites, and
- REE extraction technology evaluation using the laboratory extractability testing.

Task 4. Exploratory Drilling and Analysis

This task will be coordinated with Phase 2, Task 1, of the Stantec proposal. Upon a Go decision made after Task 3, the team will complete ten (10) large diameter core drilling holes at one of the three sites identified to further evaluate that resource. Drilling details can be found in Phase 2, Task 1, of the Stantec proposal in Appendix A.

Similar to Task 3, a member of the MTI team will accompany Stantec for the core drilling. MTI will conduct pXRF analysis on the core samples to provide initial analysis for each seam.

Stantec will also provide UND with 1,000 pounds of coal to be processed using UND's bench-scale REE extraction process.

The cores will be delivered to MTI and UND labs to undergo further sample analysis. The full analysis includes:

- Process/grinding/storage
- Determine basic coal properties (proximate, ultimate, ash composition) using ASTM methods

- Determine abundance of REE-CM using ICP-OES/ICP-MS at UND and commercial laboratories
- Measure the modes of occurrence (extractability) and mineralogy (SEM/XRD) on selected promising samples
- Examine relationships between elemental composition, REE-CM abundance, and mineralogy
- Calculate the value of REE-CM present in the samples based on projected values.

Task 5. Geological Modeling and Conceptual Mine Plan

This task will be coordinated with Phase 2, Task 2, of the Stantec proposal. This task will be led by Stantec as their team will develop the geological model and conceptual mine plan. Details of Stantec's plans for this task can be found in Phase 2, Task 2, of their proposal in Appendix A.

MTI, UND, and MLJ Consulting will aid Stantec by interpreting data from tasks 3 and 4, providing geographical knowledge of the area of interest, and providing information on the construction of an REE processing plant and transportation to that plant.

A Go/No-Go decision will be made based on the information collected in Tasks 4 and 5. There is no guarantee that the results will provide the information necessary to support further development of the project. The Go/No-Go decision will be made by GNP and NDIC based on the data presented by the team. The decision should be made on the following criteria:

- Estimated resource of the site based on the geological model, and
- Economic feasibility of the conceptual mine plan, and
- Estimated concentration of REE is equal to or greater than 300 ppm.

Task 6. Bulk Sample Collection and Extraction Simulation

This task will be coordinated with Phase 3 of the Stantec proposal. Upon a Go decision made after Task 5, Stantec will excavate a 100-ton bulk sample at the site determined in Phase 2. Details of the extraction effort can be found in Phase 3 of the Stantec proposal in Appendix A. The objective of this effort is to simulate practical REE and byproduct recoveries at the REE processing pilot plant at UND. MTI and UND will sample the bulk sample to characterize it and then will conduct analysis of the byproduct. If greater than 300 ppm, the coal may be utilized in another ongoing effort by DOE/NDIC, and costs would be utilized from that effort for the pilot utilization.

This effort will help the team further evaluate the feasibility of the identified resource.

Task 7. Technical and Economic Assessment of Recovery of REE-CM

After the core sampling, analysis, and extraction simulation, the team will conduct a technical and economic assessment (TEA) of the recovery of the REE-CM from the identified resource. This effort will evaluate the process from the mining plan to the REE-CM processing plant. Other byproducts, other than REE-CM, will be included in the evaluation. The work in this task will overlap with Tasks 3-6 as ongoing evaluation of the technology and economics will be required for the Go/No-Go decisions in this project.

A final TEA report will be submitted to GNP and NDIC upon completion of this task.

3.4 Anticipated Results

MTI, and UND have conducted initial sampling efforts in many coal seams in ND to determine the potential REE resource. Results from these efforts have shown that the REE content can range from <10 ppm to >1000 ppm in certain seams. The REE content varies from seam to seam as well as stratigraphically within one seam. Lateral concentrations of the REE within the host material have been more consistent, with some variability still present.

The distribution of specific REEs and concentration of each REE will provide for a better understanding of the feasibility of mining and processing the given coal seam. Efforts will be aimed at identifying seams with high concentration of REEs throughout the seam and a high abundance of valuable REEs.

In addition to the distribution and concentration of the REEs in the coal seam, the REEs must show to be extractable using current REE extraction technologies. UND and MTI have collected samples from the seams being considered and have processed them with success using the extraction process at UND. As a result, it is anticipated that the REEs in the given seams will be extractable with the current technology.

3.5 Facilities

Microbeam Technologies Incorporated

Algorithms for REE Assessments (Patent pending)

Microbeam has developed an algorithm that predicts REE content of a coal sample based on the trace element readings from a pXRF. This algorithm provides an estimate of total REEs, heavy REEs, light REEs, and individual REE content. This method was developed using ND lignite coal from seams across the state. This technology will be used to assist in the down-selection of core samples for additional analysis. Using a pXRF to provide an initial REE measurement is an inexpensive and time-effective way to make decisions of what samples should be sent for further analysis, reducing overall costs for expensive analysis methods on samples that may not need to be further assessed.

Chemical Fractionation

Chemical fractionation methods are used to selectively extract elements based on their solubility in water, ammonium acetate, and hydrochloric acid. The methods quantitatively determine the modes of occurrence of the inorganic elements. Subsequent analysis of the fractions for REE content will determine the mineral associations of the REE-CMs. Chemical fractionation analysis provides an indication of the association of selected important inorganic components in lower rank coals. The water-soluble fraction consists of elements that are present in ground water and pore water in the lignite coal. The ammonium acetate-soluble fraction contains more organically-associated elements. These elements are bonded to oxygen functional groups such as carboxylic acids. A third step (acid-soluble) is used to identify carbonates or coordination complexes. Residual material typically consists of insoluble minerals that consist mainly of quartz, clays, and sulfides. The residues after extraction will be digested and analyzed using ICP-MS.

Automated Scanning Electron Microscope and X-ray Microanalysis

Microbeam's scanning electron microscopes (SEM) are a central component of our testing and analysis of fuels and flux as well as ash and slag-related materials produced in gasification and combustion systems. The system includes advanced imaging, stage automation, x-ray microanalysis, and image analysis capabilities. The SEMs are completely automated and can size and analyze thousands of particles and perform phase identification and classification. The datasets from the SEM are utilized in a suite of post processing tools that allows for interpretation of ash and slag behavior processes and provides key data for predicting ash/slag formation and behavior.

Computer controlled scanning electron microscopy (CCSEM) - CCSEM is used to determine the size, composition, abundance, and association of mineral grains in prepared coal, biomass, and petroleum coke samples. The information derived from this analysis is used to assess the behavior of the mineral grains during combustion or gasification. Examples where CCSEM is used to determine the impacts of fuel properties include system component wear, slag flow, slagging deposit, fouling of heat exchangers, fine particle collection, and ash handling.

SEM morphological analysis – Morphological analysis is used to obtain high-magnification images and chemical compositions of selected features of deposits and slags. Backscattered electron and secondary electron imaging are used to provide images of the deposits. Backscattered electron imaging provides discrimination of features based on atomic number.

Advanced Materials Characterization Lab (UND)

The AMCL was established to support UND research and educational activities, industry research and sample analysis needs, and as a regional satellite lab. It is supported by experienced technicians and analytical chemists and has a vast array of analytical equipment and capabilities, including SEM-EDS, XRF, XRD, ICP-OES and thermal gravimetric analysis. Sample preparation equipment include a microwave digestor for ash samples and for production of lithium meta-borate fusion beads for ICP and XRF analysis.

Bench-Scale REE Extraction Unit (UND)

UND has procured and has access to unique bench-scale equipment for the processing of lignite coal for REE extraction in a semi-continuous mode for up to 25 kg/hr lignite feed and is capable of producing >50% concentrates as currently installed. The processing equipment also utilizes continuous monitoring equipment for temperature, pH, pressure, and flow rates of all inputs, allowing accurate mass balances and data collection throughout the process pathways.

Pilot-Scale REE Extraction Facility (UND)

UND is in the process of constructing a pilot facility capable of processing 500 kg/hr of cleaned coal through the aforementioned REE extraction and recovery process with low rank coals. The facility operates in a continuous mode in producing a pre-concentrate at a rate of roughly 8-10 kg (pure REE basis, despite a concentration near 60-70%) per week of a 300 ppm feedstock. The facility, when completed in July 2021, will utilize a vast array of continuous sensing, process control methods, and other automation strategies to determine the steady-state conditions for bulk processing.

4.0 STANDARDS OF SUCCESS

The primary standard for success will be the identification of REE-CM rich seams that can provide adequate coal for production of REE concentrates that are technically and economically feasible.

This is the first effort in North Dakota to complete a full evaluation of distribution of REE-CM coal seams, extractability, bench/pilot testing, and technical economic feasibility of developing a mine. As a result, there is no guarantee that the results will show that it is economically viable to mine and process ND coal seams for REE. The team has completed initial sampling efforts that show that there is promise but full characterization is needed to determine the feasibility of a processing plant in ND.

5.0 BACKGROUND

5.1 Introduction

North Dakota is in an exciting and unique position to play a significant role in development of the infrastructure to provide REE-CM (REE) required by the US and the world. Rare earth elements (REEs) include a group of elements with atomic numbers from 57-71. This includes the elements lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Yttrium (Y) and Scandium (Sc) are often included in the group because of their similar properties. The rare earth elements are classified as light (LREE) and heavy (HREE). The LREEs include La to Eu. The HREEs include Gd to Lu, and Y. Another grouping of critical REEs, classified based on the combination of their supply scarcity and end use importance, are typically considered to include Nd, Eu, Tb, Dy, Er and Y.

In addition to the REEs, the critical materials (CM) include aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium.

Today the US consumes 16,000 tons/year and is 100% dependent on imports for the REE that are crucial materials in an incredible array of consumer goods, energy system components and military defense applications. ND lignite from Southwest ND contains high levels REE that are easy to recover with environmentally benign methods. <u>For a single seam of lignite, the resource of recoverable REE is estimated to be between 1.8 to 3.7 million tons. Multiple REE-rich seams exist.</u>

The REE content in ND lignites has been found to be as high as any other coal reported in the literature for U.S. coals (1-3). Several locations in ND and multiple coal seams have been identified with REE content exceeding 300 ppm on a dry whole coal basis, with concentrations over 800 ppm on a dry coal basis (4). In addition to the exceptionally high total REE content, the distribution of REEs in lignites is more enriched in the valuable heavy rare earth elements (HREE) as compared to higher rank coals. the REEs can be associated with the organic fraction of the coal. The current work on ND lignite (5, 6) takes advantage of these weak bonding forms by extracting the REEs and other metals/elements via a mild solvent while preserving the organic content of the coal. The products resulting from this process are an REE-containing aqueous solution and a beneficiated coal. These samples have high levels of REEs ranging from 300 to over 1000 ppm on a dry basis.

5.2 Coal as a source of REEs

Figure 2 shows the enrichment distribution of REEs in the H-Bed and other Harmon-Hansen coals relative to the upper crustal levels. Some REE levels in the H-Bed have levels 10 times the upper continental crust levels. H-Bed coals also contain several valuable critical elements. For example, in one of the coals, the team found germanium (28 ppm), gallium (18 ppm), lithium (25ppm), and vanadium (616 ppm). A study by PacMag Metals found germanium levels averaging 106 ppm in selected lignite seams in the Harmon Hansen coal zone (7).

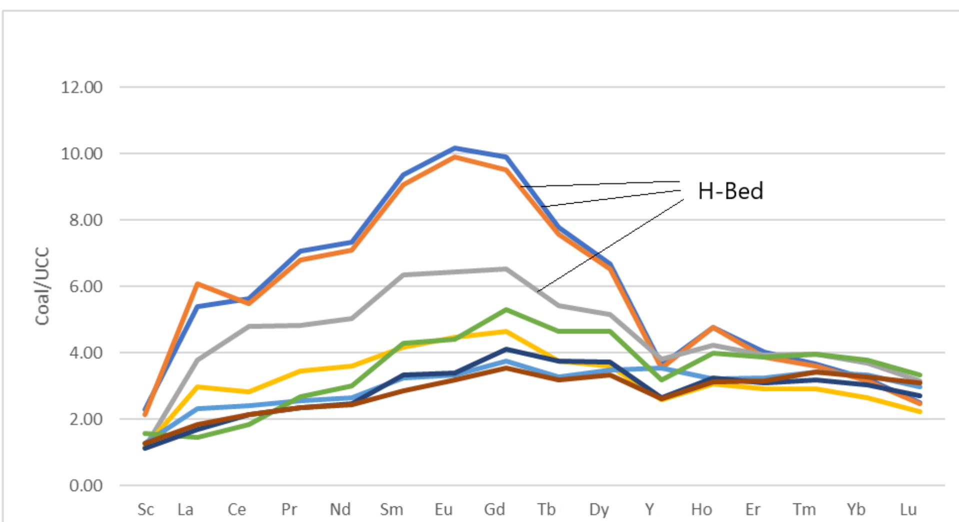


Figure 2. Normalized distribution of REEs in Harmon-Hansen lignite samples – dry whole coal basis divided by concentration in the upper continental crust (UCC).

Table 2 summarizes the abundance of REEs in samples collected from the Harmon-Hansen coal seams and associated sediments during several sampling trips led by the ND Geological Survey (8). The range of levels varied from 47 to over 600 ppm on a dry whole sample basis, and represent both coals (i.e. < 50% ash) and clay-rich sediments collected from the margins of the coal seams and in the associated roof/floor/partings materials. Overall, five of the sampling locations exceeded the program target of 300 ppm TREEs (dry whole sample basis), with three of these being coals and the other two being clay-rich sediments. Although the 6AA sample does not meet the 300 ppm target, it is very interesting from the standpoint of its extreme enrichment in the HREEs and its valuable distribution. Similarly, although 3A does not have the highest TREEs, it is significantly more enriched in the HREEs, having the highest content of Dy-Lu and Y of all samples collected in the project. Some of the very low ash coal samples (7E, 9H and 5E), also have attractive ratios of HREE/LREEs. The samples were collected from exposed outcroppings, with coal thicknesses ranging from about 12 to 18 inches, with the 6A, 3A and 6AA samples representing the entire thickness of the coal portion of the seams, while the 6A-2 and 3C samples were collected near the margin of the coal and the roof or floor, and the 6A-1 was taken from the roof.

The UND IES identified optimum methods to recover rare earth elements that have resulted in a patent (9). The work initially involved the use of sequential extraction methods (5). Figure 3 illustrates the results of initial testing that have led to a pilot scale demonstration project that is currently on-going ("Rare Earth Element Extraction and Concentration at Pilot-Scale from North Dakota Coal-Related Feedstocks," DE-FE0031835). It was found that most of the REEs were in the form of an organic coordination complex in the coal and were extractable with a dilute acid.

Table 2. Abundance of REEs from samples collected from the Harmon-Hansen coal zone. Highlighted samples indicated those that exceed 300 ppm TREEs and one unique high-value sample (6AA).

Sample ID	Ash (wt%)	Sc	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	TREE (dry whole, ppm)	LREE/ HREE	TCREE (dry whole, ppm)	$/MT	TREE (ash, ppm)
6A	25.2	38.4	45.6	63.4	180.2	26.1	119.3	29.0	6.4	22.0	2.9	14.7	2.5	6.3	0.8	5.3	0.7	563.7	2.9	188.9	598.5	2234.6
6AA	47.3	38.0	67.0	16.5	29.5	3.8	15.7	3.9	1.4	5.3	1.1	8.5	2.2	7.9	1.3	8.8	1.6	212.4	0.5	93.6	579.5	448.8
6A-2	36.7	27.6	54.1	104.4	231.5	28.7	114.3	24.4	5.3	20.5	2.8	14.1	2.4	6.0	0.8	4.6	0.6	642.2	3.6	190.6	436.9	1752.0
3A	40.7	25.6	87.0	39.9	87.6	10.7	43.8	10.2	2.7	12.8	2.3	14.9	3.3	10.0	1.4	9.3	1.5	363.2	1.1	150.7	400.5	891.6
3C	61.3	21.9	42.1	49.3	103.1	12.3	49.5	10.3	2.5	9.7	1.4	8.0	1.6	4.6	0.6	4.1	0.6	321.7	2.3	103.5	340.6	524.8
6A-1	76.5	19.5	38.9	81.3	161.4	19.0	75.1	15.5	3.4	13.6	1.9	9.6	1.7	4.2	0.6	3.5	0.5	449.5	3.6	128.8	307.2	587.3
15G	32.7	15.7	22.4	26.2	57.7	6.9	25.9	4.9	1.0	4.2	0.7	4.1	0.9	2.7	0.4	2.7	0.4	176.8	2.2	54.0	241.9	540.7
1Q	63.1	15.1	28.1	27.2	53.0	6.4	24.0	4.7	1.0	4.4	0.7	4.7	1.0	3.2	0.5	3.3	0.5	177.9	1.8	58.5	233.4	281.8
17B	37.9	12.6	22.3	13.7	28.7	3.6	14.4	3.2	0.8	3.8	0.6	3.9	0.8	2.5	0.4	2.4	0.4	114.0	1.3	42.0	193.7	301.0
BE	92.3	12.6	18.9	26.0	49.8	5.7	21.2	3.9	0.7	3.4	0.5	3.4	0.7	2.2	0.3	2.2	0.4	151.8	2.4	44.7	193.3	164.5
10G	43.9	11.3	22.3	16.0	31.6	4.0	15.5	3.3	0.8	3.4	0.5	3.6	0.8	2.5	0.4	2.6	0.4	119.0	1.4	42.8	173.6	271.1
7F	21.0	9.2	45.9	20.0	50.3	6.7	27.1	6.1	1.4	7.3	1.2	7.6	1.6	4.4	0.6	3.7	0.6	193.7	1.3	83.2	146.7	924.3
5F	16.0	8.8	25.8	14.5	25.8	2.9	11.4	2.5	0.7	3.3	0.5	3.5	0.7	2.2	0.3	1.9	0.3	105.2	1.2	42.0	136.8	659.1
5E	10.3	5.6	13.5	4.3	9.0	1.2	4.9	1.3	0.4	1.7	0.3	2.0	0.4	1.3	0.2	1.2	0.2	47.5	0.8	21.1	85.8	462.1
7E	11.2	5.4	31.7	5.7	9.9	1.2	5.4	1.6	0.5	2.7	0.5	4.0	1.0	2.9	0.4	2.7	0.4	76.2	0.5	42.1	85.4	680.5
9H	15.8	5.3	20.3	7.7	16.4	2.2	9.2	2.4	0.6	3.0	0.5	3.3	0.7	2.0	0.3	1.7	0.3	75.9	1.0	33.9	83.3	479.6
10	26.3	3.3	37.7	21.3	40.7	4.5	16.7	3.2	0.8	4.5	0.7	4.7	1.1	3.1	0.4	2.5	0.4	145.7	1.5	60.7	55.4	554.5

NOTE: $/MT is value of REEs per metric ton of sample using data available in Appendix C (Phase 2 Renewal Package Instruction document) – uses metal prices with the exception of Eu (oxide); no pricing available for Ho, Tm, Yb or Lu.

HREE/LREE: Σ (Sc, Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) / Σ (La, Ce, Pr, Nd, Sm)

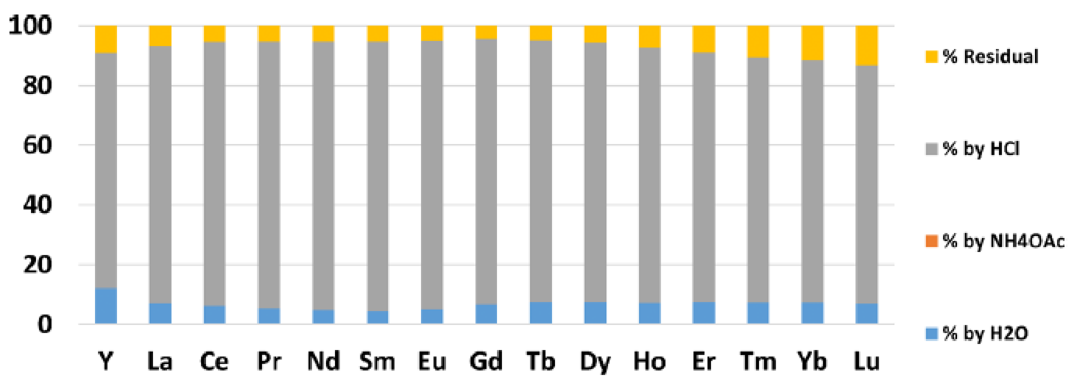


Figure 3. REE extractability testing results for a lignite coal (9).

5.4 H Bed Bench-Scale Parametric Testing

The overall UND process is summarized by the process schematic provided in Figure 4. With the completion of physical preparation and separation of the H Bed lignite feedstock utilized as the feedstock for this project, batch-wise parametric testing was conducted on the bench-scale equipment.

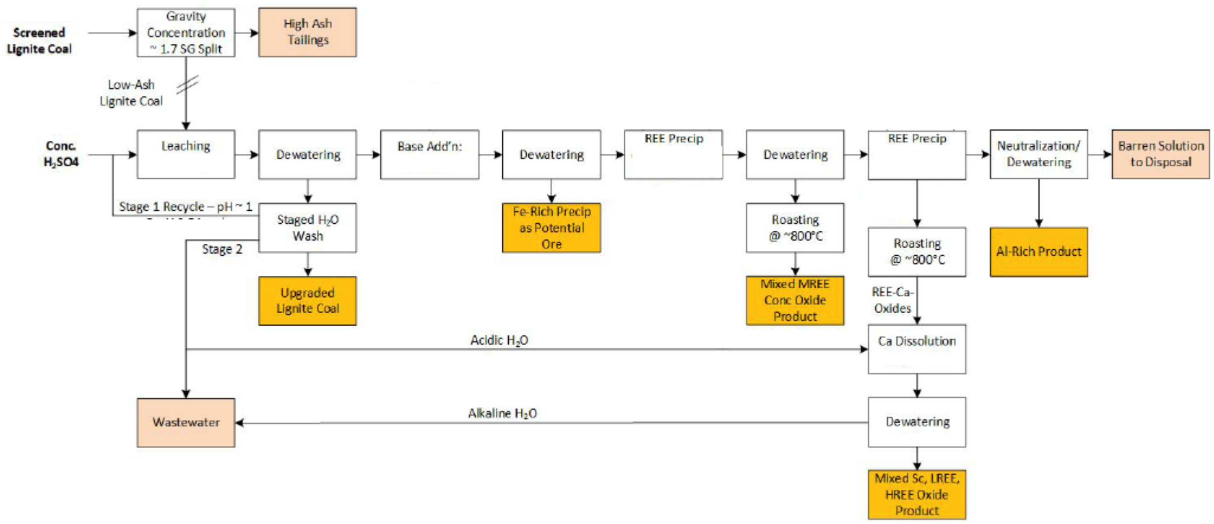


Figure 4. Process flow diagram for the UND REE extraction and purification process.

The production testing using the H Bed lignite was completed using the optimized process conditions selected in parametric testing. The REEs extracted from the coal during leaching were lower than expected, with the highest recovery at 43% in Week 3 (Figure 5). This was theorized to be a result of poor dewatering efficiency, a challenge associated with the significant pore volume and structures within lignite. However, acid consumption was shown to be decreasing with bench-scale testing week-to-week, due to recycling of the coal washing liquids and potential reincorporation of heavy ions (actinides) into the coal.

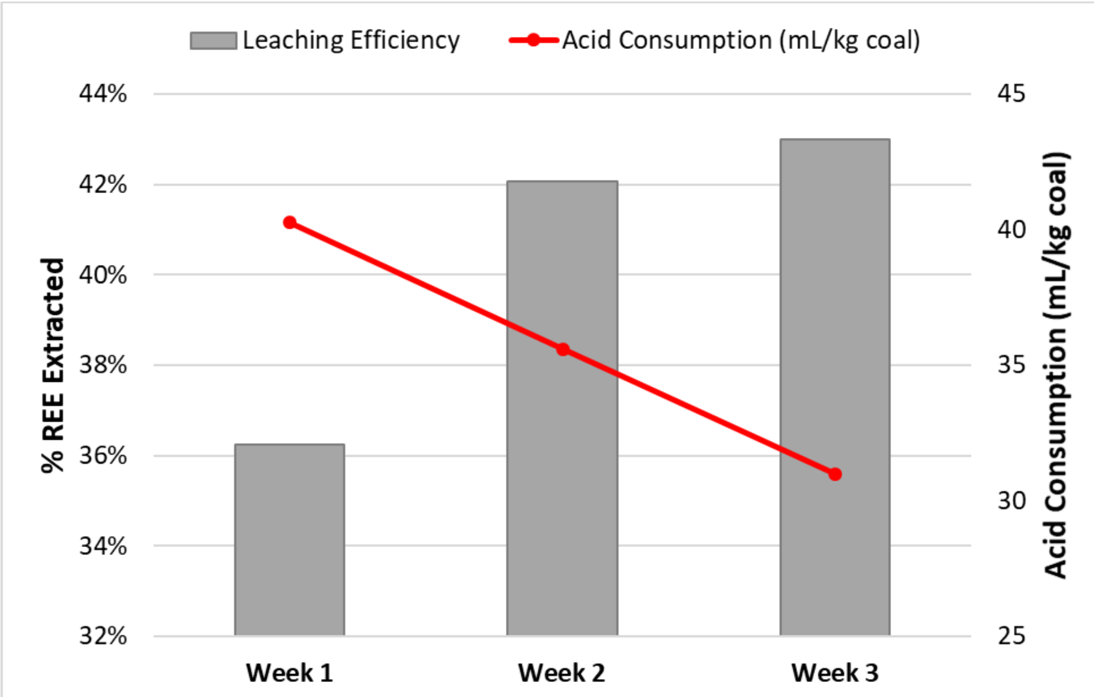


Figure 5. Overall REE extraction from the coal and acid consumption during leaching tests.

The primary focus of the impurity removal step in the process is the removal of iron. During production testing, over 70% removal of iron was observed for Weeks 1, 2, and 4, with less than 5% loss in total REEs. Equipment issues in Week 3 of testing resulted in a shorter than desired residence time in this processing step, resulting in lower removal of iron and high loss of REEs. This proved that a longer residence time is required for this step, and that at the longer residence time, high extraction of iron with minimal REE loss is achievable.

The concentration of REE in the products generated during testing are presented in Table 3. In Week 4, a concentration of 54.4 wt% REE was achieved in the primary product (on an oxide basis), and the Week 3 secondary product had a concentration of 8.6%.

Table 3. REE concentration for all REE products produced during continuous testing.

Test	Primary Product REE Concentration (wt%, oxide basis)	Secondary Product REE Concentration (wt%, oxide basis)
Week 1	40.3%	3.5%
Week 2	32.3%	4.1%
Week 3	27.0%	8.6%
Week 4	54.4%	7.5%

6.0 QUALIFICATIONS

Resumes for the key participants are included in the appendix.

Mr. Alex Benson, Project Manager, will be responsible for managing the project. Mr. Benson has focused his attention on REE-CM recovery from coal. He has extensive experience with the High REE-CM-containing coals in the Williston Basin and has worked with the ND Geological survey to obtain larger quantities of samples for testing. Mr. Benson also brings experience in moving technologies from R&D to production as well as in the management and supervision of large teams.

Dr. Steve Benson, Microbeam President, is a world class expert on the forms and occurrence of major, minor, and trace elements including REE and CM in coal and associated materials. He has worked extensively with coal beneficiation, combustion, gasification, and air pollution control technologies. Dr. Benson was the PI for a DOE funded project entitled "Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks" (DE-FOA-0001202). He manages the Microbeam team that consists of highly talented and trained engineers (chemical, mechanical, and electrical) and scientists (data, chemical, materials, and physical) who have conducted over 1600 projects worldwide on the association and behavior of major, minor and trace elements in coal, biomass, petroleum, and wastes and their fate in and impact on energy conversion systems. This information, combined with Microbeam's expertise associated with the ability to determine the abundance and forms of REE-CM in coal and ash-related materials, make Microbeam uniquely qualified to lead this effort and to successfully achieve the objectives of the project.

Mr. Nolan Theaker has led the technical efforts on the DOE-funded REE extraction projects completed and ongoing at UND IES (DE-FE0027006 and DE-FE0031835) as a Co-PI, and has experience with coal beneficiation and high-value materials projects. His experience with solution chemistry modeling, mass balances on coal utilization projects, and his unique experience with REE extraction technologies from low rank coals will be leveraged in the project.

Dr. Mike Jones, President of MLJ Consulting, has been involved in research and development on technologies applicable to lignite coals for over 40 years. The focus of his work has been understanding the unique properties of lignite coals and using that information to optimize the opportunities for using that carbon source in the most effective way in existing systems or developing new opportunities for value added products from this resource.

7.0 VALUE TO NORTH DAKOTA

The value to North Dakota of the proposed work is the implementation of a new technology that utilizes ND resources to provide a domestic source of REE–CM. Currently, the United States is nearly 100% reliant on imports of REEs. The market is dominated by China (both industrially and politically). China has over 80% of the total mining and concentrating market, restricting new entities from joining the market. REEs provide significant value to our national security, energy independence, environmental future, and economic growth. REEs are utilized in a suite of high importance end-uses, such as cell phones, hybrid vehicles, magnets, computer components, catalysts and many others. Developing a domestic source will provide an increase in jobs in the recovery, separation, and utilization of REE-CM in advanced products, such as magnets.

8.0 MANAGEMENT

MTI will oversee the project as illustrated in Figure 6 and will manage the project schedule. Mr. Alex Benson is the PI on the project and will coordinate the efforts with the assistance of other team members. MTI uses the management software Smartsheet to manage projects. Using this software, the team will be able to oversee project action items, owners, and due dates. The team will meet on a biweekly basis to review action items. In these meetings, the team will discuss what is needed to keep the project on track and how to work through any issues that arise that may affect the overall project timeline.

The following milestones will be used to evaluate the project's progression throughout the duration of the project. These milestones align with the project deliverables.

- End of Task 1: Selection of three sites
- Go/No-Go Decision after Task 3: Evaluation of core samples from each of the three sites
- Go/No-Go Decision after Task 5: Geological model, conceptual mine plan, and evaluation of the core samples from the one identified site
- End of Task 6: Bulk sample collection and extraction simulation at pilot plant
- End of Task 7: Technical and economic analysis of developing an REE-CM mine and commercial plant for producing a concentrate

9.0 TIMETABLE

The project is expected to take 9 months to complete. The timeline is shown in Table 4.

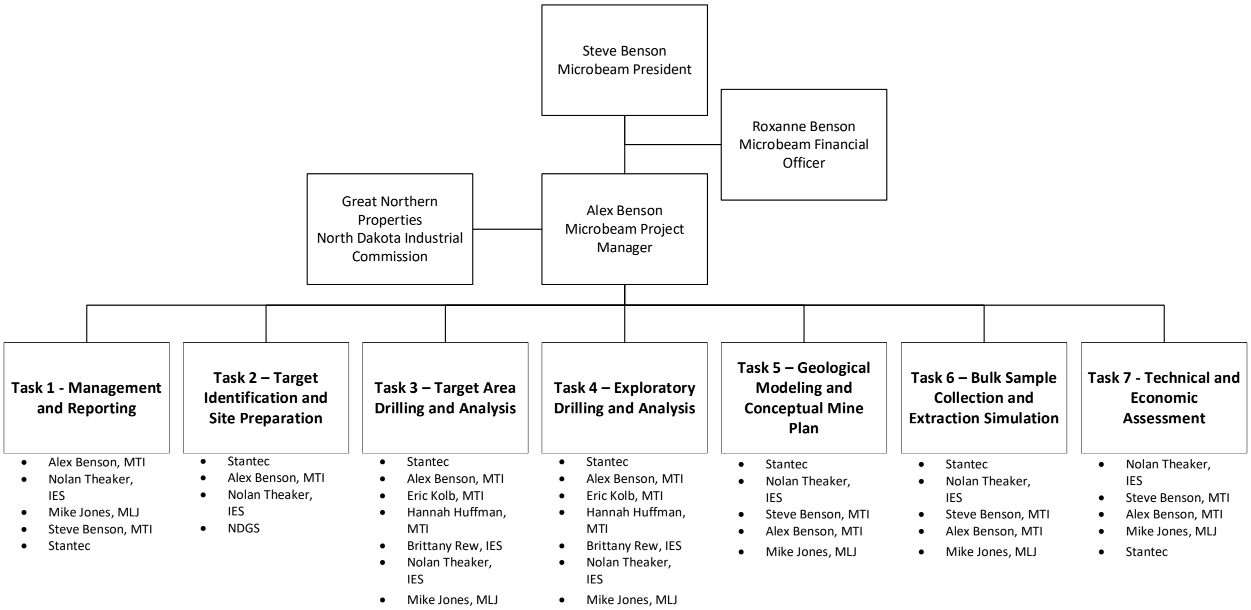
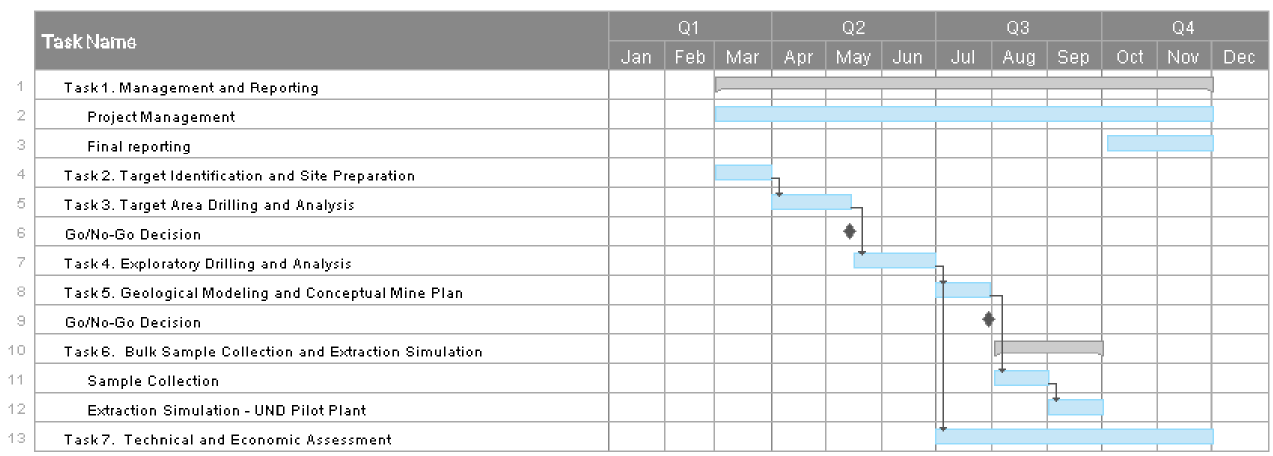


Figure 6. Management structure.

Table 4. Project timeline.



10.0 BUDGET

The overall project is summarized in Table 5. Table 6 lists the planned number of samples to be analyzed. The budget includes the purchase of a handheld XRF for $14,595 to be used during the project to expedite the analysis of samples in the field.

Table 5. Overall project budget including cost share.

Budget Category	Task 1 - Management and Reporting	Task 2 - Target Identification and Site Preparation	Task 3 - Target Area Drilling and Analysis (Stantec PI Task 2)	Task 4 - Exploratory Drilling and Analysis (Stantec P 2 Task 1)	Task 5 - Geological Modeling and Conceptual Mine Plan (Stantec P2 Task 2)	Task 6 - Bulk Sample Collection and Extraction Simulation (Stantec P3)	Task 7 - Technical and Economic Assessment	Total
A. Total Personnel	$ 11,178.44	$ 2,906.41	$ 16,149.64	$ 15,593.24	$ 6,202.82	$ 11,984.83	$ 5,422.82	$ 69,438.20
B. Total Fringe Benefits	$ 2,332.94	$ 606.57	$ 3,370.43	$ 3,254.31	$ 1,294.53	$ 2,501.23	$ 1,131.74	$ 14,491.75
Total Salaries & Fringe Benfits	$ 13,511.38	$ 3,512.98	$ 19,520.07	$ 18,847.55	$ 7,497.35	$ 14,486.06	$ 6,554.56	$ 83,929.95
C. Travel	$ -	$ 3,864.32	$ 3,864.32	$ 3,864.32	$ -	$ -	$ -	$ 11,592.96
D. Equipment	$ -	$ 15,355.37	$ -	$ -	$ -	$ -	$ -	$ 15,355.37
E. Supplies	$ -	$ 1,715.82	$ 1,715.82	$ -	$ -	$ -	$ -	$ 3,431.64
F. Contractual (MLJ Consulting and UND)	$ 21,846.00	$ 21,846.00	$ 21,846.00	$ 21,846.00	$ 21,846.00	$ 21,846.00	$ 21,846.00	$ 152,922.00
G. Construction								$ -
H. Other - Analysis (Includes ICP-OES at UND)	$ -	$ 10,889.49	$ 62,390.00	$ 87,807.10	$ -	$ 11,640.05	$ -	$ 172,726.64
Total Direct Costs	$ 35,357.38	$ 57,183.97	$ 109,336.21	$ 132,364.97	$ 29,343.35	$ 47,972.11	$ 28,400.56	$ 439,958.56
I. Indirect costs								
Labor Overhead of Direct Cost (A+B Only)	$ 3,918.30	$ 1,018.76	$ 5,660.82	$ 5,465.79	$ 2,174.23	$ 4,200.96	$ 1,900.82	$ 24,339.69
General & Administrative (A+B+C+E+H)	$ 3,244.08	$ 4,797.82	$ 21,006.40	$ 26,535.60	$ 1,800.11	$ 6,272.88	$ 1,573.75	$ 65,230.65
Total Indirect Costs	$ 7,162.38	$ 5,816.59	$ 26,667.22	$ 32,001.39	$ 3,974.34	$ 10,473.84	$ 3,474.57	$ 89,570.34
Total Direct and Indirect Costs	$ 42,519.76	$ 63,000.56	$ 136,003.43	$ 164,366.36	$ 33,317.69	$ 58,445.95	$ 31,875.14	**$ 529,528.90**
Cost Share: GNP/Santec	$ -	$ 42,465.00	$ 82,605.00	$ 197,900.00	$ 34,730.00	$ 172,281.00	$ -	$ 529,981.00
Total Project Costs	$ 42,519.76	$ 105,465.56	$ 218,608.43	$ 362,266.36	$ 68,047.69	$ 230,726.95	$ 31,875.14	$ 1,059,509.90

Table 6. List of analysis and number of samples[1].

	Task 1 - Management and Reporting	Task 2 - Target Identification and Site	Task 3 - Target Area Drilling and Analysis	Task 4 - Exploratory Drilling and Analysis	Task 5 - Geological Modeling and	Task 6 - Bulk Sample Collection	Task 7 - Technical and Economic	Totals
Period 1:	**# of samples**	**# of samples**	**# of samples**	**# of samples**	**# of samples**	**# of samples**	**# of samples**	**# of samples**
Sample Prep	0	10	60	60	0	5	0	135
CCSEM I/E	0	0	20	25	0	0	0	45
CCSEM	0	0	0	0	0	0	0	0
Morphology	0	0	30	40	0	0	0	70
X-ray Diffraction	0	0	0	0	0	0	0	0
Prox/Ult	0	0	30	40	0	5	0	75
ICP-OES - REE	0	0	0	0	0	0	0	0
ICP-MS - Standard lab	0	19	30	60	0	15	0	124
Partial Chem Fractionation	0	3	10	10	0	5	0	28
Ash Comp	0	0	30	50	0	0	0	80
Total Analysis BP1	0	32	210	285	0	30	0	557

[1] ICP OES is included in the UND Budget.

11.0 MATCHING FUNDS

The matching funds are provided by GNP in the form of inkind of $529,981. The inkind cost will include engineering and testing conducted by Stantec supported by GNP.

12.0 TAX LIABILITY

None

13.0 CONFIDENTIAL INFORMATION

None

14.0 APPENDICES

14.1 References

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5. Laudal, D. A., Benson, S.A., Addleman, R.S., and Palo, D., Leaching behavior of rare earth elements in Fort Union lignite coals of North America, International Journal of Coal Geology, Volume 191, 15 April 2018, Pages 112-12
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7. PacMag Metals, Investor Presentation, Sept 2008, www.pacmag.com.au.
8. Kruger, N. W.; Moxness, L.D.; Murphy, E. C. 2017. "Rare Earth Element Concentrations in Fort Union and Hell Creek Strata in Western North Dakota." Report of Investigation No. 117. North Dakota Geological Survey.
9. Laudal, D., & Benson, S. (2020). Rare Earth Extraction from Coal (US Patent No. 10,669,620 B2).

10. Murphy, E., L., Moxness, N., Kruger, C., Maike, Rare Earth Element Concentrations in Harmon, Hanson, and H Lignites in Slope County, North Dakota, Report of Investigation No. 119, North Dakota Geological Survey, 2018.

14.2 Resumes

ALEX BENSON
Project Manager
Microbeam Technologies Incorporated
Grand Forks, ND 58203

Areas of Expertise

Alex Benson's principal areas of interest and expertise is in project management and technology commercialization. Alex manages and conducts projects for government and industry clients on rare earth and critical mineral and on energy conversion system p erformance.

Education and Training

University of St. Thomas Mechanical Engineering B.S. 2011

Professional Experience

2019 – Present Project Manager, Microbeam Technologies Incorporated. Alex Benson is responsible for the management of multiple projects at Microbeam. He develops project plans and manages resources to meet project deadlines and financial commitments. He has created a commercialization plan for a DOE sponsored Rare Earth Element (REE) extraction from coal project. He develops and tests methods for rapid and on-line analysis for rare earth element and critical materials. He has also participated in sampling coal and coal related materials rich in REE and critical materials.

2017 – 2019 Sr. Research Engineer (part-time), Microbeam Technologies Incorporated. Alex Benson analyzed datasets using statistical methods to determine potential relationships and correlations between fuel properties and plant parameters. Worked with computer scientists to develop neural networks based on observed correlations.

2017 – 2019 Manufacturing Manager, Medtronic – Minimally Invasive Technology Group. Alex Benson managed manufacturing operations of a medical device manufacturing plant with an annual budgeted Cost of Production of $360M. He was responsible for managing a three-shift manufacturing team of 7 production supervisors and 350+ production personnel. He also managed manufacturing build plans to meet financial commitments and demand requirements for 134 SKUs, including developing production capacity, growth, and expansion plans to meet customer demand.

2016 – 2017 Sr. Product Engineer, Medtronic – Minimally Invasive Technology Group. Alex Benson lead commercialization activities for new product launches related to manufacturing build plans, engineering line design and validation, and production personnel training of new processes. He implemented process improvement activities of new manufacturing lines to improve output, yield, and efficiency, using statistical analysis and six sigma tools. He also led a team of engineers and production personnel in duplication of manufacturing lines to meet increased demand.

2015 – 2016 Sr. Manufacturing Engineer, Medtronic Energy and Component Center. Alex Benson was responsible for providing 24-hour engineering support of lithium ion battery manufacturing lines. He managed a cross-functional team through the commercialization process of new lithium ion battery manufacturing lines, leading yield and efficiency improvements through product design and equipment improvement projects.

2012 – 2015 Manufacturing Engineer, American Medical Systems. Alex Benson oversaw multiple 2 shift medical device manufacturing lines, managing yield, efficiency, and other process improvement projects. He was a member of a team to develop a novel antimicrobial coating process for implantable medical devices. He oversaw the commercialization of this new technology. He also led the qualification of the manufacturing plant's first DI water system.

2007 – 2012 Lab Assistant (part-time), Microbeam Technologies Incorporated. Alex Benson prepared ash, coal, metal, and other samples for SEM analysis. He completed CCSEM analysis for these samples. Alex also developed sample porosity and stress test process including equipment design and manufacturing (stress tester) and developing standard procedures for completing these tests. He assembled high temperature furnaces at Microbeam and installed associated software.

Publications and Presentations

Benson, S.A, Patwardhan, S., Stadem, D., Langfeld, J., Benson, A., Desell, T., Application of Condition Based Monitoring and Neural Networks to Predict the Impact of Ash Deposition on Plant Performance, Impacts Fuel Quality Conference, Sweden, September, 2020 (Accepted – conference delayed because of Covid-19).

Synergistic Activities

Continued Education (CE)/Professional Development Hour (PDH) Classes Completed:

- Combined Cycle Power Plant Fundamentals (EUCI)
- Heat Recovery Steam Generator (HRSG) Fundamentals (EUCI)
- A Comparison of the New SEC Regulation S-K 1300 on Modernization of Property Disclosures for Mining Registrants to Canadian National Instrument 43-101 (SME)

STEVEN A. BENSON, PH.D.
President
Microbeam Technologies Incorporated
Grand Forks, ND 58203

Areas of Expertise

Dr. Benson's principal areas of interest and expertise include development and management of complex multidisciplinary programs that are focused on solving environmental and energy problems.

Education and Training

Minnesota State University	Chemistry	B.S. 1977
Pennsylvania State University	Fuel Science	Ph.D. 1987

Research and Professional Experience

1991 – Present President, Microbeam Technologies Incorporated. Dr. Benson founded Microbeam Technologies Incorporated (MTI), a spin-off company from the University of North Dakota to conduct service analysis of materials using automated methods aimed at assessing efficiency and reliability problems in renewable and fossil energy conversion systems. MTI began operations in 1992 and has conducted over 1600 projects for industry, government, and research organizations worldwide. Since 2017, Dr. Benson has been working exclusively at Microbeam and is responsible for technical direction, data interpretation and proposal preparation.

2015 – 2017 Associate Vice President for Research, Energy & Environmental Research Center, University of North Dakota -- Dr. Benson was responsible for assisting EERC in developing and managing projects on the clean and efficient use of fossil and renewable fuels.

2008 – 2017 Chair/Professor/Director - Petroleum Engineering, Chemical Engineering and Institute for Energy Studies at the University of North Dakota -- Dr. Benson was responsible for teaching courses on energy production and associated environmental issues. In addition, Dr. Benson developed managed projects and conducted research, development, and demonstration projects on carbon dioxide separation and capture technologies, advanced analytical techniques, and computer-based models.

1999 – 2008 Senior Research Manager/Advisor, Energy & Environmental Research Center, University of North Dakota (EERC, UND) -- Dr. Benson is responsible for leading a group of about 30 highly specialized group of chemical, mechanical and civil engineers along with scientists whose aim is to develop and conduct projects and programs on combustion and gasification system performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide.

1994 – 1999 Associate Director for Research, EERC, UND -- Dr. Benson was responsible for the direction and management of programs related to integrated energy and environmental systems development. Dr. Benson led a team of over 45 scientists, engineers, and technicians.

1986 – 1994 Senior Research Manager, Fuels and Materials Science, EERC, UND -- Dr. Benson was responsible for management and supervision of research on the behavior of inorganic constituents in fuels in combustion and gasification.

1984 – 1986 Graduate Research Assistant, Fuel Science Program, Department of Materials Science and Engineering, The Pennsylvania State University, Mr. Benson took course work in fuel science, chemical engineering (at UND), and ceramic science and performed independent research leading to a Ph.D. in Fuel Science.

1983 – 1984 Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center -- He was responsible for management and supervision of research on coal geochemistry.

1977 – 1983 Research Chemist, Energy Resources Development Administration (ERDA) and U.S. Department of Energy Grand Forks Energy Technology Center, Grand Forks, North Dakota

Selected Publications and Presentations – Dr. Benson is author and co-author of over 220 publications

1. Desell, T., ElSaid, A., Lyu, Z., Stadem, D., Patwardhan, S., Benson, S., Long term predictions of coal fired power plant data using evolved recurrent neural networks. at -Automatisierungstechnik, 68(2), 130-139, 2020.
2. Laudal, D. A., Benson, S.A., Palo, D., and Addleman, R.S., Rare Earth Elements in North Dakota Lignite Coal and Lignite-Related Materials, ASME, J. Energy Resour. Technol 140(6), 062205 (Apr 09, 2018) (9 pages).
3. Laudal, D. A., Benson, S.A., Addleman, R.S., and Palo, D., Leaching behavior of rare earth elements in Fort Union lignite coals of North America, International Journal of Coal Geology, Volume 191, 15 April 2018, Pages 112-124.
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9. Trace Element Transformations in Coal Fired Power Systems, Special Issue of Fuel Process. Technol.; Benson, S.A.; Steadman, E.N.; Mehta, A.K.; Schmidt, C.E., Eds.; Elsevier Science Publishers: Amsterdam, 1994; Vol. 39, Nos. 1–3, 492 p.
10. Inorganic Transformations and Ash Deposition During Combustion; Benson, S.A., Ed.; American Society of Mechanical Engineers: New York, 1992.

Patents – 5 patents

- 7,574,968 **-** Method and apparatus for capturing gas phase pollutants such as sulfur trioxide.
- 7,628,969 - Multifunctional abatement of air pollutants in flue gas.
- 7,981,835 -System and method for coproduction of activated carbon and steam/electricity.
- 8,277,542- Method for capturing mercury from flue gas
- 10,669,610 – Rare earth element extraction from coal

Awards

- Lignite Energy Council, Distinguished Service Award, Research & Development, 1997
- GEMS Award, College of Earth and Mineral Sciences, Pennsylvania State University, 2002

- Lignite Energy Council, Distinguished Service Award, Research & Development, 2003
- Lignite Energy Council, Distinguished Service Award, Government Action Program (Regulatory), 2005
- Lignite Energy Council, Distinguished Service Award, Research & Development, 2008
- UND Spirit Award for Teaching and Research, 2013
- Science and Technology Award, Impacts of Fuel Impurities Conference, 2014.

NOLAN L. THEAKER
Research Engineer, Institute for Energy Studies
University of North Dakota, Grand Forks, ND 58202

Education and Training

University of Louisville	Chemical Engineering	B.S. 2016
University of Louisville	Chemical Engineering	M.Eng. 2017
University of North Dakota	Chemical Engineering	Pursuing PhD

Research and Professional Experience

2017-Present Research Engineer, UND Institute for Energy Studies.

Responsibilities include high-level innovative research and development of novel concepts for submission of funding proposals. Coordinated and led efforts associated with downstream rare earth element concentration operations that have resulted in the development of final process flow diagrams. Key contributor to multiple proposals involving REE extraction and/or concentration from multiple feedstocks. Proposed efforts associated with coal conversion and value improvement using chemical/thermal methods. Key contributor on proposals and projects for CO2 capture and/or utilization from coal combustion flue gases. Currently co-PI on pilot-scale REE work (DE-FE31835), and leading day-to-day research activities on the project.

2016-2017 Research Assistant, University of Louisville Conn Center.

Research involved design and operation of multi-stage electrochemical reactor scheme for efficient production of fuels from CO2. Developed nano-functionalized electrocatalysts for improvements in activity and selectivity for targeted reactions in two phase reaction systems.

2014-2015 Co-op Engineer, University of Kentucky CAER.

Research involved improvement and operation of a DOE bench-scale CO2 capture unit in multiple reaction conditions. Evaluation and comparison of catalyst performance in a holistic view for CO2 capture was conducted, including novel organic and enzymatic catalysts.

Publications/Presentations

1. Theaker, N., Strain, J. M., Kumar, B., Brian, J. P., Kumari, S., & Spurgeon, J. M. (2018). Heterogeneously Catalyzed Two-Ctep Cascade Electrochemical Reduction of CO2 to Ethanol. Electrochimica Acta, 274, 1-8. doi:10.1016/j.electacta.
2. Park, D., Middleton, A., Smith, R., Laudal, D., Theaker, N., Hsu-Kim, H., Jiao, Y. A Biosorption-based approach for the selective extraction of REEs from coal byproducts. Separation and Purification Technology. 2020.

3. Mann, M; Theaker, N; Benson, S; Palo, D. "Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks – Final Report". Submitted March 31, 2020.
4. Theaker, N., Rew, B., Laudal, D., Mann, M. Investigation of rare earth element extraction from North Dakota Coal-Related Feed Stocks. 2019 NETL Annual Crosscutting Projects Review Meeting. April 9th, 2019. Pittsburgh, PA.
5. Zygarlicke, C; Folkedahl, B; Feole, I; Kurz, B; Theaker, N; Benson, S; Hower, J; Eble, C. "Rare-Earth Elements (REEs) in U.S. Coal-Based Resources: Sampling, Characterization, and Round-Robin Interlaboratory Study – Final Report". Submitted September 30th, 2019.

Patents/Applications:

1. Theaker, Nolan; Laudal, Dan. 2020. Method for Leaching Rare Earth Elements and Critical Minerals from Organically Associated Materials. USA. 63/112,846A, filed Nov. 12, 2020.

2. Theaker, Nolan; Laudal, Dan; Lucky, Christine. 2020. Generation of Rare Earth Elements from Organically-Associated Leach Solutions. USA. 63/112,842A, filed Nov. 12, 2020.

Synergistic Activities:

Mr. Theaker's principal area of research interest includes energy, fuels, and alternative critical material research. These include developing alternative uses and sources of fuels and valuable materials, both carbon and mineral based.

DR. MICHAEL L. JONES
President
MLJ Consulting, LLC
Grand Forks ND
Phone: (701) 739-1419, E-Mail: jones_ml2003@yahoo.com

Principal Areas of Expertise

Dr. Jones' principal areas of interest and expertise include management of and technical direction for multidisciplinary science and engineering research teams focused on a wide range of integrated energy and environmental technologies. Specific program areas of interest include clean and efficient combustion of low-rank fuels, matching of fuel characteristics to system design and operating parameters, development of advanced power systems based on low-rank fuels, fundamentals of combustion and gasification, ash deposition in combustion and gasification systems, and analysis of inorganic materials. Current focus includes minimizing the carbon footprint of energy systems based on lignite coal, including CO_2 separation and sequestration. Minimization of emissions from lignite based energy conversion systems and development of niche opportunities for use of lignite coal including extraction of rare earth elements.

Qualifications

Ph.D., Physics, University of North Dakota, 1978.

M.S., Physics, University of North Dakota, 1973.

B.S., Physics, Bemidji State University (Minnesota), 1971.

Professional Experience

2017- Present; President, MLJ Consulting LLC. After retiring from the Lignite Energy Council, Dr. Jones formed MLJ Consulting to provide consulting services based on his over 39 years working on research and development of energy and environmental technologies with special emphasis on lignite coal.

2009-2016; Vice President R&D, Lignite Energy Council. Dr Jones responsibilities include identification of critical issues to facilitate the enhanced use of lignite coal. Technologies of interest include combustion, gasification chemical from coal and hydrogen from coal. Provides recommendation to the Lignite Research Council and the North Dakota Industrial Commission on funding of R&D activities to ensure completion of critical project in support of enhanced use of North Dakota lignite. Develops strategies to increase working relationships with research groups around the world including US DOE, EPRI, Canadian lignite coal users and others.

2004–2009: Senior Research Advisor, Energy & Environmental Research Center (EERC), University of North Dakota (UND). Dr. Jones' responsibilities include management of and technical direction for multidisciplinary science and engineering research teams focused on a wide range of integrated energy and environmental technologies. Specific program areas of interest include clean and efficient use of low-grade fuels, matching of fuel characteristics to system design and operating parameters, development of advanced power systems based on low-grade fuels, fundamentals of low-grade fuel combustion, ash behavior in low-grade fuel conversion systems, and analysis of inorganic materials in low-grade fuels. Projects emphasize a cradle-to-grave approach from resource assessment, to optimum utilization systems, to minimization of emissions and waste management featuring by-product utilization.

2004–Present: Adjunct Professor, Physics, UND.

1994–2004: Adjunct Assistant Professor, Physics, UND.

1983–2004: Associate Director, Industrial Relations and Technology Commercialization, EERC, UND. Dr. Jones' responsibilities include planning, staffing, and technical direction of combustion and gasification research, including projects in combustion chemistry or gasification chemistry, behavior during coal utilization, fluidized-bed combustion, coal–water fuels, SO_x/NO_x removal, and particulate removal and characterization. Special emphasis was given to low-rank coal systems; activities ranged from field testing of full-scale power plants, to pilot-scale studies, to laboratory investigations that examine both fuel and system characteristics and their impacts on overall performance.

1990–1994: Adjunct Professor, Department of Chemical Engineering, The University of Utah, Salt Lake City, Utah.

1979–1983: Grand Forks Energy Technology Center, U.S. Department of Energy, Grand Forks, North Dakota. Dr. Jones' responsibilities included technical direction of research and development projects related to combustion technology for low-rank coals, with specific responsibility for fundamental research on pulverized coal combustion. Directed research on new, specialized analytical procedures for determination of inorganics and trace elements in coal and materials derived from coal combustion and conversion processes. Instrumentation included methods Auger/ESCA spectrometer, scanning electron microscope, x-ray diffraction, x-ray fluorescence, argon plasma spectrometer, and atomic absorption spectrometer.

Professional Activities

Dr. Jones has chaired or co-chaired numerous technical conferences.

Publications and Presentations

Dr. Jones has authored or co-authored over 100 publications and presentations.

14.3 Great Northern Properties and Stantec Proposal

Great Northern Properties, L. P.

1415 Louisiana Street, Suite 2400 • Houston, TX 77002
(713) 751-7500 • Fax (713) 751-7591

Rich Southwick
Manager-Projects
Direct Mail: 173 Cottonwood Rd.
Townsend, MT 59644

rsouthwick@gnplp.com
Direct: (406) 266-4360

February 5, 2021

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
ATTN: Lignite Research, Development and Marketing Program
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine,

I am writing to you on behalf of Great Northern Properties, L.P. (GNP) to communicate GNP's support for the ongoing research into the potential recovery of rare earth elements from North Dakota lignite reserves. Specifically, I write to communicate GNP's support for the instant proposal to continue exploration of ND's lignite reserves for the purpose of identifying prospects that hold lignite potentially suitable as feedstock for the economic, commercial-scale recovery of REE.

Toward that end, GNP is committed to funding next-step exploration activities. GNP asked Stantec to develop a proposal to conduct exploration activities in southwestern North Dakota that would produce lignite samples for evaluation by others for its potential to yield economically recoverable REE. As proposed, that work would be conducted in coordination with researchers at the University of North Dakota and Microbeam Technologies, Inc. in order to ensure that it efficiently builds upon previous exploration results and yields samples specifically targeted for subsequent analysis of REE potential.

GNP encourages the North Dakota Industrial Commission to help fund this important piece of the ongoing investigation into lignite's potential as a source for REE. Thank you for your consideration.

Sincerely,

Richard A. Southwick
Manager-Projects
Great Northern Properties, L.P.

cc: Kai Xia, President GNP

Stantec

Memo

To:	Kai Xai; Rich Southwick; George Luther Great Northern Properties (GNP)	From:	Derek Loveday Stantec Consulting Services
File:	203709224	Date:	January 19, 2021

Reference: North Dakota REE Study Work Plan for 2021 – revision 3

Great Northern Properties LP (GNP) asked Stantec to develop a scope of work, budget and schedule (proposal) for a field sampling program designed to further understanding of the potential for North Dakota lignite to serve as a feedstock for rare earth element (REE) recovery. The samples collected in each phase of the work would be delivered to UND/Microbeam team for analysis.

As requested by GNP, Stantec has broken down the scope of work into the following 3 phases:

Phase 1 – Initial Resource Assessment

Phase 2 – Site-Focused Resource Assessment

Phase 3 – Bulk Sample Collection for REE Extraction Process Testing

Also as requested by GNP, Stantec has designed the work to provide for a go/no-go decision at the completion of each phase of work. That is, at the completion of each (and based upon the findings) GNP will decide whether to proceed to the subsequent phase.

Finally, GNP has requested that Stantec describe potential next steps if the results of the work warrant resource development to support a commercial-scale REE production facility in North Dakota.

This memorandum describes Stantec's proposed approach to the work, its estimate of the cost to perform the work and its estimate of the work schedule. Following the proposal, Stantec has described next steps for resource development if further development is approved.

The target coal seams for the work plan are the Harmon, Hanson and H-bed seams that have been identified as having elevated REE concentrations in southwest North Dakota. The proposed phased work plan broadly includes site selection, permitting, drilling, geologic modeling and bulk sampling. Drilling and sampling are planned to start in early spring 2021.

Phase 1 Initial Resource Assessment

The initial resource assessment is split into two (2) tasks as described below.

Task 1 - Target Identification and Site Preparation

Task 1 will include the identification and preparation of three (3) target areas (sites) for REE exploration drilling and the application for associated exploration permits to drill on these targets. Rules established for each target identification include selecting a 640-acre section on private surface and GNP minerals that are also located in areas relatively well supported by coal and REE exploration data that could potentially support a low-cost, low-environmental impact coal mine to supply feedstock for REE recovery and other byproducts.

Two (2) of the three (3) potential sites have already been identified and are shown in attached Figure 1. The third site has not been selected but rather a target region has been selected in northern Golden Valley County as indicated in Figure 1. Additional work would be necessary in selecting a suitable site to drill in northern Golden Valley County. This would involve desktop study and reconnaissance mapping of the area and building a basic (high-level) geological model from the mapping data, overlain with surface and mineral ownership, to ultimately select a site for a single exploratory hole.

GNP will secure surface use agreements with the surface owners covering all planned and potential work described in this proposal through Phase 3 prior to any field work on the three (3) target areas. Surface owner communications will continue during and after field work. Pending access permissions, the reconnaissance mapping will be undertaken by Stantec to estimated depths to base of H-bed and estimate surface disturbance acreage for drilling and bulk sampling. The maximum target depth for this exercise is 200ft below ground surface. While in the same general region of North Dakota, the geologist will also use the opportunity to inspect road access and associated surface disturbance acreage at proposed drill site 1 (Billings County) and site 2 (Slope County) shown in Figure 1.

Once the final locations of the three sites are determined, GNP will begin work with the surface owner on a surface use agreement. Once surface access is secured, an application for permission to drill will be presented to the North Dakota Geologic Survey.

Task 2 - Target Area Drilling

Drilling of the targets will be undertaken in Task 2 and is limited to three (3) core holes comprising one core hole within each of the target areas. The proposed drilling is to determine which, if any, of the 3 sites has the desired REE concentrations at mineable intervals using conventional coal mining methods. The holes will be continuously cored from surface to total depth at 200ft below surface sampling the Harmon, Hanson and H-bed seams. The 600ft total program includes geophysical wireline logging throughout the length of the drillhole.

Core samples will be provided to the UND/Microbeam team for testing. Expected turnaround for the REE test results will be approximately two (2) weeks after drilling which itself is expected to take one (1) week. A further one (1) week would be required to assess the laboratory results to determine which, if any, of the three sites would be best suited for higher density drilling in Phase 2 and to determine, using the new data, if there will be any practical constraints on proposed bulk sampling in Phase 3.

The following pre-drilling activities would be required in Task 2:

- preparing formal tender bid documentation for drillers;
- adjudication of tenders prior to any driller mobilization;
- preparing drilling and sampling standard operation procedures (SOP) and technical specification; and
- coordinating road access and road construction, if need.

The pre-drilling activity, other than coordinating road access and construction, will be for both Phase 1 drilling and subsequent Phase 2 Site-Focused Resource Assessment.

Table 1 lists the estimated costs for Phase 1 separated by task and relevant activity. The Phase 1 work program is expected to take approximately ten (10) weeks and be completed by mid-May 2021.

Table 1 Phase 1 Initial Resource Assessment Cost Estimate

Activities		Estimated Cost ($)			
		GNP	Stantec	Contractors	Total
Task 1	Surface Owner Permission	13,000			13,000
	Modeling & Site Inspection		22,895		22,895
	Permit Application		4,320		4,320
	GNP Management	2,250			2,250
	Total	**15,250**	**27,215**	**0**	**42,465**
Task 2	Pre-Drilling Activities		8,160		8,160
	Drilling		18,945	54,000	72,945
	GNP Management	1,500			1,500
	Total	**1,500**	**27,105**	**54,000**	**82,605**
Total Phase 1		**16,750**	**54,320**	**54,000**	**125,070**

Estimated costs presented in Table 1 are based on a review of tenders Stantec received to complete two (2) 200ft holes in late November 2021 that was ultimately shelved in favor of this proposed program. Drilling costs are expected to be lower over the spring drilling season as opposed to winter due to higher productivity and lower heating costs. These costs savings have been factored into the estimates presented above, however new tenders for the Spring drilling would be required for a more accurate estimate of costs.

Core samples will be taken in the immediate roof as well as throughout the coal seams and will be tested for both REE concentration, raw proximate coal quality and other parameters as determined by the UND/Microbeam team. Costs for the assays are not included in Table 2. The number and locations of samples within the stratigraphic column will be determined in collaboration with UND/Microbeam to meet the requirements for both REE resource assessment and downstream processing.

There is no guarantee that the results of the Phase 1 exploratory drilling program will provide the information necessary to support further development of the project. Work may also be terminated at GNP's discretion following Phase 1 should new data gleaned from field observations and/or sample analyses reveal a meaningful departure from anticipated geology and/or REE-grade.

Reference: **North Dakota REE Study Work Plan for 2021 – revision 3**

Phase 2 Site-Focused Resource Assessment

The Phase 2 site-focused resource assessment is split into two (2) tasks as described below.

Task 1 – Exploratory Drilling

For Task 1 of Phase 2 the drilling contractors used in Phase 1 will be re-mobilized to complete ten (10) closely-spaced large diameter (LD) core drilling holes at one (1) of the three (3) sites identified for further study in Phase 1.

The purpose of the LD drilling is to:

- determine short-spaced variability in REE-grade and seam/mining interval thickness;
- provided sufficient data to build a geologic model and conceptual mine plan; and
- provide 1,000 pounds of sample for REE recovery testing by the UND/Microbeam team.

As in Phase 1 the core samples will be provided to the UND/Microbeam team for REE concentration, proximate coal quality and plant process testing among other analyses selected by the team. The costs for these tests are not included in this proposal. The number and locations of samples to be collected will be determined in collaboration with UND/Microbeam.

Required pre-drilling activities will be limited to coordinating road access and road construction. Average depth of the holes is estimated at 200ft for the 2,000ft total program. Geophysical wireline logging will be completed throughout the length of the drillholes.

Task 2 - Geological Modeling and Conceptual Mine Plan

For Task 2 of Phase 2 information received from the proposed and prior drilling programs will be used to build a geologic model that will form the basis of a conceptual mine plan to support a 3 Million ton (Mt) per year run-of-mine (ROM) coal operation. The exploration data received at this stage would not be sufficient to report REE resources to support a mine plan at or beyond ten (10) years production. As such, the conceptual mine plan will have to rely on projections of REE grade and mine height beyond the boundaries of the target area into adjacent 640-acre sections that may include Federal lands. Mining methods to be considered include surface, highwall and underground CM[1] operations.

Table 2 lists the estimated costs for Phase 2 separated by task and relevant activity. The Phase 2 work program is expected to take approximately ten (10) weeks and be completed by end-July 2021.

[1] Continuous Miner

Reference: **North Dakota REE Study Work Plan for 2021 – revision 3**

Table 2 Phase 2 Site-Focused Resource Assessment Cost Estimate

Activities		Estimated Cost ($)			
		GNP	Stantec	Contractor	Total
Task 1	Surface Owner Permission	3,000			
	Pre-Drilling Activities		2,720		2,720
	Drilling		33,680	160,000	193,680
	GNP Management	1,500			1,500
	Total	**4,500**	**36,400**	**160,000**	**197,900**
Task 2	Geological Modeling		13,600		13,600
	Conceptual Mine Plan		18,880		18,880
	GNP Management	2,250			2,250
	Total	**2,250**	**32,480**	**0**	**34,730**
Total Phase 2		**6,750**	**68,880**	**160,000**	**232,630**

There is no guarantee that the results from both the Task 1 drilling and Task 2 modeling in Phase 2 will support further investment in the project and at GNP's discretion, further work could be terminated at conclusion of Phase 2.

Phase 3 Bulk Sample Collection

In Phase 3 the geologic model and conceptual mine plan developed in Phase 2 will be used to assist in identifying an area suitable for the excavation of a 100-ton bulk sample from surface exposure.

The purpose of the bulk sample is to:

- Provide UND/Microbeam coal from the proposed mining interval identified in the conceptual mine plan to best simulate practical REE and byproduct recoveries that may be expected from a full-scale processing facility.
- Assess to what extent REE concentrations would be affected from a large sample mass as compared to drill core samples.
- Assess impacts of minor waste rock dilution on REE grade that would be unavoidable in a practical mining operation.
- Provide pre-development infrastructure for a proposed mine portal (entry) should further exploration drilling in subsequent phases reveal sufficient REE resources to support a 3 Mt per year ROM coal mine for 20 years or more.

Prior to sampling Stantec will undertake a field reconnaissance survey of the proposed bulk sample collection site identified from the geologic model to determine requirements for road access and extent of surface disturbance. For this proposal, Stantec has assumed two three-acre (3) pads for a disturbance footprint at a theoretical bulk sample location with 10-acres for road access. Necessary permissions from surface owners will have been previously obtained by GNP and Stantec will work with regulatory authorities prior to field activities in order to obtain required approvals. The sample will be collected using local earth moving contractors under the field supervision of Stantec. Transportation of the bulk sample to the UND facility and site reclamation would also be completed as part of the overall program.

Estimated cost to complete Phase 3 is outlined in Table 3. The estimated time and cost for REE assay and processing tests are not included here. Time to complete Phase 3 bulk sample for testing is approximately four (4) weeks with completion estimated to be end-August 2021.

Table 3 Phase 3 Bulk Sample Collection Cost Estimate

Activities	Estimated Cost ($)			
	GNP	**Stantec**	**Contractor**	**Total**
Surface Owner Permission	5,000			
Pre-Sampling Activities		20,445	15,000	35,445
Bulk Sample		72,090	28,300	100,390
Reclamation		14,070	12,876	26,946
Consumables/Misc.			6,500	6,500
GNP Management	1,500	1,500		3,000
Total Phase 3	**6,500**	**108,105**	**62,676**	**172,281**

Please note that the estimated costs to complete the bulk sample collection as shown in Table 3 assume that the target coal intervals will be reasonably accessible from crop. Geological modeling undertaken in Phase 2 will be used to determine the degree of difficulty and associated costs involved in accessing the coal for a bulk sample. Costs and time to complete the bulk sample may be ultimately be different than those presented in Table 3.

Reference: **North Dakota REE Study Work Plan for 2021 – revision 3**

Potential Next Steps

If the resource is selected as a feedstock for a commercial-scale REE extraction facility, then additional work will be required for development of a commercial mining operation. That additional work will include:

1. Additional Drilling Permit Applications
2. Resource Assessment Drilling
3. Resource Estimate and Mine Plan
4. Mine Permit Application

Estimated time and costs for these additional steps cannot be determined at this stage as these costs are contingent on the results of the conceptual mining study. A summary of the work required to complete these additional phases is provided below.

Additional Drilling Permit Applications

This would require the application of drilling permits in adjacent areas to support a resource assessment-scale drilling program necessary to complete development of a formal mine plan and REE reserve estimate to s the commercial extraction facility operations. Should these adjacent areas include Federal lands, then the drilling permit application requirements would be more significant in terms of time and resources when compared to private or State land permit applications.

Resource Assessment Drilling Program

The infill resource assessment drilling project would be designed to fill-in the information gaps necessary to advance the Phase 2 conceptual mining study to a REE resource and mine plan (reserve) study. The quantity and location of resource drillholes cannot be accurately determined at this time. Drilling methods would likely be a combination of full coring and spot coring, i.e. coring only through target intervals. Most sample assays and process testing would be undertaken at UND facilities and the same or similar pre-drilling activities listed in Phase 2 would also be required.

Resource Estimate and Mine Plan

Resource assessment drilling results will be used to update the Phase 3 geological model that will, when completed, be used to estimate REE resources using industry best practice guidelines. The same model will be used as basis for a mine plan and reserve estimate necessary to support a 3 Mt per year ROM coal mining operations for 20 years or more.

Mine Permit Application

Should the mine plan economics and associated reserve estimates meet the stakeholder (investor) targets then the mine permitting application process can start. This multi-disciplinary process would likely take one year to gather the baseline data and an additional year or so to complete the permitting process depending on surface ownership and site conditions.

Reference: **North Dakota REE Study Work Plan for 2021 – revision 3**

Conclusion

The total estimated costs for Phase 1 through 3 for the REE Study Work Plan for 2021 is presented in Table 4 and the approximate timeline for each phase is shown in Chart 1. Total estimated time in Chart 1 is six (6) months.

Table 4 Total REE Study Work Plan Costs

Phase	Cost ($)
1. Initial Resource Assessment	125,070
2. Site Focused Resource Assessment	232,630
3. Bulk Sample	172,281
Total	**529,981**

Chart 1 2021 REE Study Work Plan Timeline

Phase	March		April		May		June		July		August	
1	Initial Resource Assessment											
2						Site-Focused Resource Assessment						
3											Bulk Sample	

Please let me know if you have any questions or concerns regarding the assumptions or conclusions of this memo.

Stantec Consulting Services Inc.

Derek Loveday
Project Manager

Phone: 801 384 0958
derek.loveday@stantec.com

Attachments: Figure 1 REE Target Drilling Sites

c. Thomas Suchoski

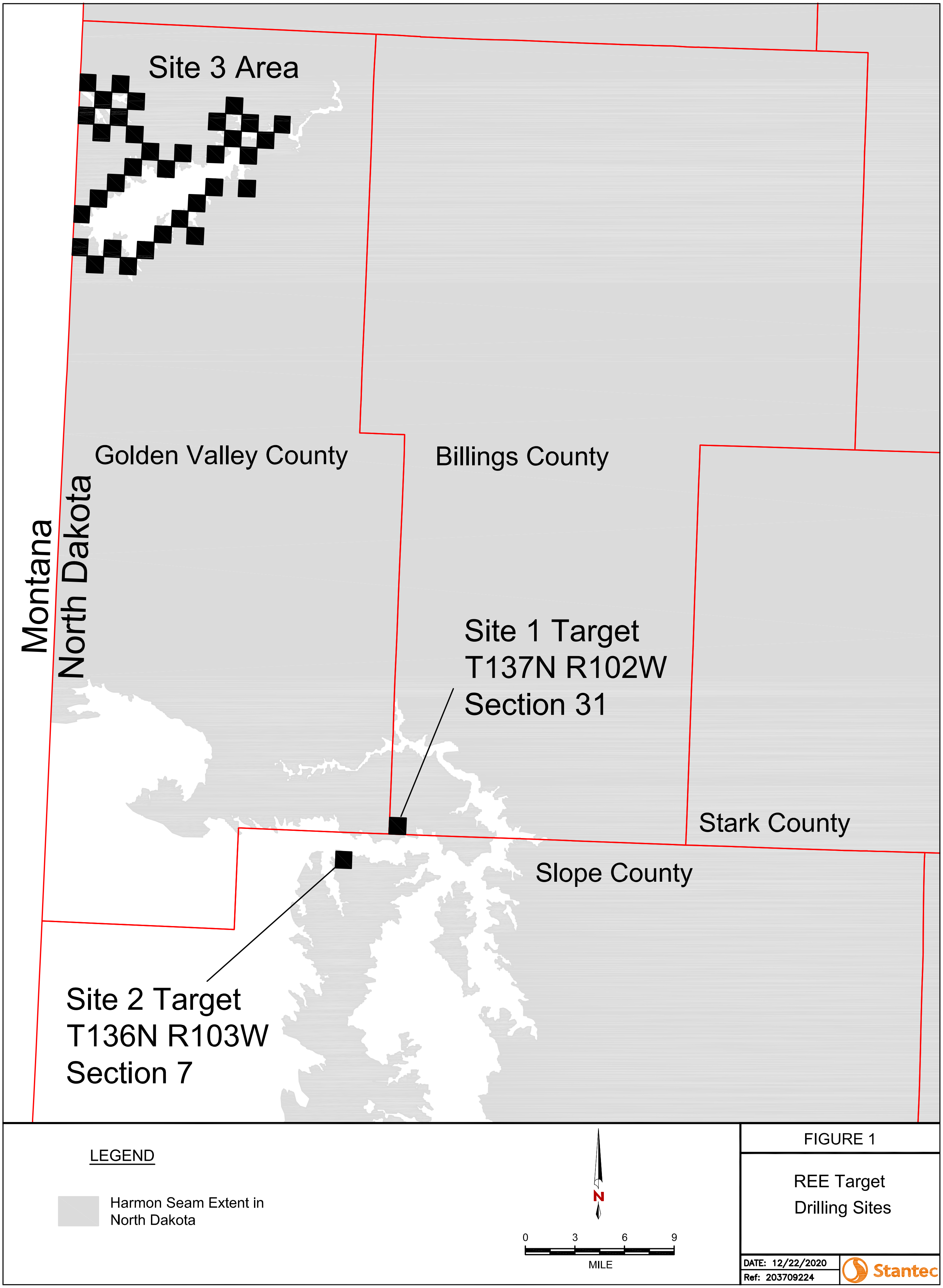

FIGURE 1

REE Target Drilling Sites

DATE: 12/22/2020
Ref: 203709224
Stantec

14.4 MLJ Consulting Proposal

MLJ Consulting, LLC
841 Orchard Circle
Grand Forks, ND 58201
701-739-1419
Jones_ml2003@yahoo.com

February 2, 2021

Mr. Alex Benson
Microbeam Technologies Incorporated

Re: Support of the proposal entitled "North Dakota Rare Earth and Critical Element Resource Evaluation" submitted to North Dakota Industrial Commission.

Dear Mr. Benson:

MLJ Consulting is pleased to provide support for the above project to Microbeam Technologies Incorporated. It has been rewarding to see this technology develop over the past couple of years, and I am happy to help as you work with GNP and their team to explore the opportunity for economically viable, and environmentally benign technology to concentrate rare earth elements from North Dakota lignite owned by GNP.

I understand I would be part of the team as a consultant providing input on all tasks in the activity as requested. Please find attached a budget for $25,000 for these consulting services.

I am looking forward to helping you explore the commercially viable opportunity to extract REE from ND Lignite.

Sincerely,

Michael L. Jones, PhD.
President, MLJ Consulting
701-739-1419

Budget for MLJ Consulting

Labor
Michael Jones 140 Hours@$175,000/hour $24,500

Travel
Estimated $500

Total **$25,000**

14.5 University of North Dakota Proposal

UNIVERSITY OF UND NORTH DAKOTA

OFFICE OF THE DEAN
COLLEGE OF ENGINEERING AND MINES
UPSON II ROOM 165
243 CENTENNIAL DRIVE – STOP 8155
GRAND FORKS, NORTH DAKOTA 58202-8155
PHONE (701) 777-3411 FAX (701) 777-4838
www.engineering.und.edu

February 5, 2021

Dr. Steven A. Benson
Microbeam Technologies Inc.
4200 James Ray Drive, Ste. 193
Grand Forks, ND

RE: Support of proposal entitled "North Dakota Rare Earth and Critical Element Resource Evaluation" submitted under North Dakota Lignite Research Program Special Session, February 2021.

Dear Dr. Benson:

We are pleased to team with Microbeam on this proposal application to evaluate the total rare earth element (REE and critical element (CE) content of the Great Northern Properties lignite, as well as the extractability and processing of this lignite within our patented process. Work will be conducted by the University of North Dakota Institute for Energy Studies and Microbeam. The scope of the UND activities is summarized as follows:

- **Task 1 – Management and Reporting** – UND will support efforts in management and reporting associated with attendance at all project meetings, development of report sections associated with UND activity, and reviewing of reporting documents prior to submission to funding agency.

- **Task 3 – Target Area Drilling and Analysis** – UND will leverage equipment and expertise relating to REE analysis within lignite in this task, including the sample digestion equipment and ICP-OES required for trace element analysis in coal, as well as the extractability of the elements. UND will also help in the identification of the specific samples for analysis within the drill cores supplied by GNP/Stantec. Finally, UND will develop an economic model on the samples based upon the samples and the UND REE extraction process.

- **Task 4 – Exploratory Drilling and Analysis** – UND will assist in this task via use of the aforementioned equipment for full element content and extractability analysis of the REE/CE within the lignite samples, and a bulk sample comprising the drill cores estimated of 1,000 lbs will be utilized on UND's bench-scale REE processing equipment for further analysis. Updating to the economic projections will be done in this phase.

- **Task 5 – Geologic Model and Conceptual Mine Planning** – UND will assist MTI/Stantec in this task via interpreting of data and providing information on the construction and transportation required for a REE processing plant.

- **Task 6 – Bulk Sample Collection and Extraction Simulation** – UND will utilize the 100-ton bulk sample provided by Stantec as feed materials for the UND pilot facility currently operating DE-FE0031835 to process the 100-ton sample, generating steady-state data on extractability and processing information for detailed process economics updating.

- **Task 7 – Technical and Economic Assessment of Recovery of REE-CM** – This task will utilize the combined data from tasks 2, 4, and 6 to evaluate the conceptual mine plan and REE processing plant as a total economic landscape. UND will assist in this task via expertise with the processing plant costs and economic understanding.

The cost of the proposed effort is $127,922, with a budget breakdown summarized in the attached budget form. The anticipated period of performance is March 10, 2021 to February 9, 2022. Nolan Theaker will serve as UND's Principal Investigator for this project and can be reached at (701) 777-6298.

Sincerely,

Michael D. Mann

Michael D. Mann, Ph.D.
Executive Director
Institute for Energy Studies

Karen Katrinak

Karen Katrinak, Proposal Development Officer
Research and Sponsored Program Development