SolSpec
AERIAL ANALYTICS

November 1, 2019

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

Re: Transmittal Letter for SolSpec, Inc. Project Titled "*Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success In North Dakota"*

Dear Ms. Fine:

SolSpec, Inc. (SolSpec) is pleased to propose the development, validation, and automation of an aerial reclamation inspection toolkit to support North Dakota's oil and gas industry and its regulatory agencies in advancing economic efficiencies alongside environmental sustainability.

Enclosed please find the grant application titled "Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success in North Dakota." SolSpec is a Denver-based software company that specializes in the processing and analysis of geospatial data for commercial applications in oil and gas, natural resources, infrastructure, and other major land-use activities. Our project partners each hold offices and operations in North Dakota.

This transmittal letter represents a commitment by SolSpec to complete the project described in the enclosed proposal. If you have any questions, please contact me directly at (970) 541-8636.

Respectfully,

Katherine Kraft

Katherine Kraft
Director of Public Policy & Government Affairs
SolSpec, Inc.

October 31, 2019

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

Re: Proposal "*DEVELOPMENT OF OPERATIONAL AERIAL ANALYTICS FOR REMOTELY MEASURING RECLAMATION SUCCESS IN NORTH DAKOTA"*

Dear Ms. Fine:

Whiting Petroleum Corporation (Whiting) is pleased to deliver this letter announcing our support for and partnership in the ND OGRC project proposal submitted by SolSpec, Inc titled "Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success in North Dakota."

We strongly support this proposal to develop, validate, and automate an aerial analysis toolkit that operators can use to more effectively and efficiently monitor well pad conditions and budget for reclamation activities. Whiting seeks to utilize the best available technology to continuously improve the safety and sustainability of our operations. For these reasons, we are proud to be a partner in this proposed project and offer our full support for its funding.

Respectfully,

Kyle Waggoner, PG
Field Regulatory Manager
Whiting Petroleum Corporation

NORTH Dakota | Mineral Resources
Be Legendary.™

October 31, 2019

Katherine Kraft
SolSpec, INC
1630 Welton St. Suite lOOOE
Denver, CO 80202

Re: Proposal "Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success in North Dakota".

Ms. Kraft

I am sending this letter in support for SolSpec,Inc and their proposal to the ND OGRC. I am in support of new and evolving technology in the oil and gas industry and feel that this project has potential to be another tool for the industry.

Sincerely,

Cody VanderBusch
Reclamation Specialist

Oil and Gas Research Program

North Dakota

Industrial Commission

Application

Project Title:
Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success in North Dakota

Applicant:
SolSpec, Inc.

Principal Investigators:
Nathan Casler & John Norman, SolSpec, Inc.

Date of Application:
November 1, 2019

Amount of Request:
$ 163,200

Total Amount of Proposed Project:
$ 330,800

Duration of Project:
16 Months

Point of Contact (POC):
Katherine Kraft, SolSpec, Inc.

POC Telephone:
970.541.8636

POC E-Mail Address:
kkraft@solspec.io

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ABSTRACT

Objectives:
Aerial data collection and analytics offer insights that empower the oil and gas industry and its regulatory agencies to improve economic efficiencies alongside environmental sustainability. In 2018, Director of Mineral Resources Lynn Helms published a memorandum underscoring the North Dakota Industrial Commission's (NDIC) commitment to advancing the use of aerial imagery and analytics as a business and agency decision support tool for improving well site reclamation program efficiencies. However, the widespread adoption of aerial imaging and analysis technology in the oil and gas sector requires two essential actions: 1) validation of the methodology as a means of reducing costs and fulfilling compliance requirements, and 2) automation of data processing and analytics that derive meaningful information from gross aerial data. These needs form the basis of the project proposed herein.

The primary goal of this project is to develop and validate a suite of automated analytics that bring remote reclamation assessment technology to operational capacity for industry, agencies, and the interested public of North Dakota. Project objectives entail four central components:

1. *Model Development.* Build upon the findings of OGRC Project G-037-73 to develop efficient and scalable imagery analysis tools for remotely measuring the success of well site reclamation, including a preliminary vegetative cover assessment and a comprehensive suite of aerial reclamation inspection analytics. The analytics suite developed through this project will consist of the following models designed to meet reclamation standards established by North Dakota Administrative Code 43-02-03-34.1: a) vegetative continuity comparison; b) Infrastructure identification; c) problematic surface hydrology identification; d) topographic contouring assessment; and e) volumetric measurement.
2. *Model Validation*. Statistically test and validate the accuracy of aerial data and developed analytics with multiple tiers of comparative analysis and ground-truthing field inspections.
3. *Model Automation.* Automate the developed and validated analytics within a secure, open source, web-based platform in which oil and gas operators and agencies can easily upload, manage, process, analyze, visualize, and download aerially-derived information and reports for use in decision making.
4. *Cost-Effectiveness Analysis.* Analyze and compare the costs and effectiveness associated with aerial imagery collection and analysis against current well site reclamation inspection procedures.

Anticipated Results:

1. *Model Development.* We anticipate that development efforts to produce the aerial reclamation inspection toolkit above will result in analytic models capable of efficiently intaking large volumes of geospatial data and transforming it into operational decision support information for remotely inspecting reclamation success.
2. *Model Validation.* We predict that the preliminary reclamation assessment tool and the comprehensive aerial inspection analytics suite will be validated as accurate and useful methods for remotely determining reclamation success. This will inform efficient resource allocation, prioritization of site inspections, and bond release within North Dakota's well site reclamation program, thereby supporting NDIC intentions and research priorities.
3. *Model Automation.* We expect the automation of the reclamation analysis models to provide a feasible, economical, and scalable avenue for analyzing large quantities of aerial data per OGRC Project G-43-01 recommendations, enabling the operationalization of a remote reclamation inspection program in North Dakota.
4. *Cost-Effectiveness Analysis.* We anticipate that the cost-effectiveness analysis will provide evidence substantiating the business case for remote reclamation inspection and elucidate the comparative economics of aerial reclamation inspection versus traditional procedures.

Duration: February 2020 to June 2021 (16 months)

Total Project Cost: $330,800 **Amount Requested:** $163,200

Participants:
SolSpec, Inc.
Whiting Petroleum Corporation
ISight RPV Services
Duraroot Environmental Consulting

STATEMENT OF THE PROBLEM AND NEED

North Dakota leadership strives to position the State as an incubator for oil and gas technologies that both protect public and environmental health and ensure industry vitality. Since taking office in 2016, North Dakota Governor Doug Burgum has promoted the development of a safe and sustainable oil and gas economy achieved through technological innovation rather than regulation.[1] Relatedly, Governor Burgum signed a bill[2] in 2019 appropriating funds to establish a beyond-visual-line-of-sight (BVLOS) program for unmanned aircraft systems (UAS) in the state, with a focus on the Bakken oil fields as the program's first proving grounds.[3]

The arc of innovation aims for increased efficiency, and remote sensing technologies such as UAS hold true to this trajectory. Aerial data collection and analytics can offer insights that empower the oil and gas industry and its regulatory agencies to improve economic efficiencies alongside environmental sustainability. The widespread adoption of UAS in the oil and gas sector, however, requires two essential actions: 1) validation of the methodology as a means of reducing costs and fulfilling compliance requirements, and 2) automation of data processing and analytics that derive meaningful information from gross aerial data. Implementing these actions will bolster the adoption and operationalization of UAS for North Dakota's oil and gas industry and agencies. The North Dakota Industrial Commission (NDIC) highlights the state's well site reclamation program as a candidate for improving efficiencies through the adoption of remote sensing technology. Thus, the project proposed herein seeks to develop, validate, and automate aerial imaging and analysis methodologies for assessing oil and gas well site reclamation progress within the state.

In 2018, Director of Mineral Resources Lynn Helms published a memorandum[4] underscoring the NDIC's commitment to advancing the use of aerial imagery as a business and agency decision support tool for improving well site reclamation program efficiencies. The memorandum described some of the shortcomings of the current well site inspection process, which can be cumbersome for industry, agencies, and the public:

"Site review scheduling delays and lack of standardization in the evaluation process can result in final site clearance and bond release being delayed unnecessarily. The public, which has a stake both in the protection and restoration of the landscape, also seeks a consistent and sustainable reclamation program to help support an active oil and gas industry."[5]

North Dakota is currently host to 15,571 active wells whose sites must be reclaimed according to federal and state requirements.[6] State law stipulates that any land disturbed by oil and gas activity "shall be reclaimed as close as practicable to its original condition as it existed before the construction of the well site or other disturbance."[7] The NDIC endeavors to annually inspect each plugged well site until reclamation standards are met. Depending on site conditions, the full reclamation process of a single site can take anywhere from three to ten years.[8]

As of September 2019, the State counted approximately 1,500 wells in some stage of reclamation, with NDIC's 32 field inspectors splitting annual field inspection visits to each. Inspections typically take place during a 90-day window in the late summer and early fall, and when the weather supports a site visit during that period an inspector typically spends an hour examining the area by foot. Depending on the varying backlog of sites needing inspection, a single inspector is responsible for covering approximately 50 sites per year, many of which are dispersed across a large, discontinuous area; the Bakken oil field and its wells stretch across nearly 30,000 square miles of North Dakota.

Helms's memorandum emphasized the need for new imaging technologies that can aid the process of certifying successful site reclamation and thus eliminate backlogs of sites at which reclamation is believed to have occurred, but the NDIC has not yet been able to inspect. Additionally, the NDIC is considering proportional bond release for interim reclamation as an

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[1] Miller, P.C. ND Burgum inspires, challenges oil and gas industry. *North American Shale*. Published July 17, 2017. Retrieved from http://northamericanshalemagazine.com/articles/2021/nd-gov-doug-burgum-inspires-challenges-oil-and-gas-industry

[2] North Dakota H.B. 1018 Sec. 12. Signed May 1, 2019.

[3] Jean, R. Bakken likely to be tagged first in North Dakota's new radar system for beyond visual line of sight drones. *Williston Herald Media.* Published May 29, 2019. Retrieved from https://www.willistonherald.com/news/farm_and_ranch/bakken-likely-to-be-tagged-first-in-north-dakota-s/article_893ed5f0-8173-11e9-a33c-530c3cd45040.html

[4] Helms, L. 2018. Memorandum: NDIC Intent to gain efficiencies and improve procedures concerning the well site reclamation program.

[5] Helms, L., pg. 1.

[6] As of October 29, 2019.

[7] North Dakota Century Code 38-08-04.12(1), pg. 8.

[8] VanderBusch, C., Reclamation Specialist, Oil and Gas Division, North Dakota Department of Mineral Resources. Personal communication, September 12, 2019.

incentive for operators to initiate and continue reclamation activities while a well is active[9]—an initiative that would also require efficient site inspection tools.

Reclamation inspections are resource-intensive for the NDIC and are further complicated by the subjectivity inherent to ocular inspection. Boots-on-the-ground monitoring means that a site's reclamation progress—and whether or not a site is deemed sufficiently reclaimed for clearance—is determined by visually assessing and summarizing if the site has been restored as closely as practicable to original conditions. Though field protocols and inspection forms help to control for subjectivity and variation among many different field inspectors' assessment techniques, it is still extremely difficult to standardize human interpretations of a landscape.

Subjectivity in the reclamation inspection process impedes consistent and accurate site monitoring through time. Given that well site operators in North Dakota must fulfill reclamation obligations to recover surety or cash bonds and avoid penalties, industry has a stake in improving the consistency and accuracy of reclamation inspection.[10] Moreover, a dependable and transparent reclamation inspection program provides better certainty of site conditions that, in turn, enables improved budgeting and resource allocation for attaining compliance attainment and avoiding penalties.

In addition to NDIC's reclamation requirements, the North Dakota Construction Stormwater General Permit also imposes reclamation obligations for oil and gas construction activities that discharge pollutants into state waters.[11] The National Pollutant Discharge Elimination System of the Clean Water Act mandates that industry operators perform site inspections at least once every 14 days and within 24 hours after a rain event exceeding 0.25 inches within a 24-hour period.[12] Operators must perform and report self-inspections until the disturbed site is sufficiently stabilized and seeded to prevent erosion and achieve 70% of pre-existing vegetative cover within three years without active maintenance. During the period between site stabilization and the point when the background vegetative cover conditions are reached, the operator must inspect the site once per month. Once the target cover is met, the stormwater permit may be closed and its inspection obligations discontinued. For operators of well sites with stormwater permits that must self-inspect and report on site conditions until vegetative cover is restored, there is a demand for more consistent, accurate, and efficient methods of inspection.

The North Dakota Department of Environmental Quality (NDDEQ), which administers stormwater permits and inspects sites for permit compliance, also stands to benefit from improved inspection reporting and efficiency. During the Bakken drilling spike in the mid-2010s, up to 25% of construction stormwater permit applications were for oil and gas activities.[13] With no language preventing aerial inspection in its mandates and an upcoming permit renewal scheduled for spring of 2020, the NDDEQ is interested in learning more about aerial imaging and analysis as a potential method of well site construction stormwater monitoring for both operators and the agency.[14]

The North Dakota Oil and Gas Research Council (OGRC) recently funded a project[15] which demonstrated that remote sensing technology is indeed an effective method for evaluating reclamation progress relative to North Dakota Administrative Code criteria for oil and gas activities,[16] including: removal of infrastructure, remediation and reestablishment of land contours, and reestablishment of native vegetation. While the project proved the viability of aerial imagery for reclamation assessment, its methods are non-conducive to efficient, broad-scale operations. The study employed a supervised classification methodology requiring extensive, subjective human intervention and interpretation. A team of analysts was needed to manually examine, identify, and annotate features within the digital imagery, while field

[9] Helms, L., pg. 1.
[10] North Dakota Century Code 38-08-04.11(1), pg. 8.
[11] North Dakota Pollutant Discharge Elimination System Construction General Permit NDR 10-0000, effective April 1, 2015 to March 31, 2020.
[12] Clean Water Act, 33 USC § 1342 et seq., National Pollutant Discharge Elimination System.
[13] Grossman, D., Stormwater Program, Division of Water Quality, North Dakota Department of Environmental Protection. Personal communication, October 8, 2019.
[14] Grossman, D.
[15] Jackson, M. Collection and Development of Actionable Reclamation Data Using Aerial Remote Sensing, Contract No. G-037-73, Final Report prepared for the North Dakota Industrial Commission. Hell Creek Environmental LLC. Submitted January 15, 2018. Retrieved from https://cms.oilresearch.nd.gov/image/cache/Contract_G-037-73_Final_Report_HellCreek_HESS.pdf
[16] North Dakota Administrative Code Section 43-02-03-34.1

scientists were required to collect ground truth data for model training. These attributes limit the scalability, replicability, and cost-effectiveness of the methodology across time and space.

Another recent OGRC project exploring emerging technologies for pipeline inspection concluded that automation can help resolve issues that inhibit the operational performance of aerial imagery:

"Huge amounts of data can be collected, but those data require appropriate analysis. To make analysis of large quantities of data economical, automated data processing and analysis must be employed."[17]

If remote sensing technologies are to perform to the optimal benefit of North Dakota's oil and gas industry, agencies, and public, big data collected in the field must be efficiently transformed into decision tools at the desktop. The transformation process that turns remotely-sensed data into operational intelligence for reclamation assessment requires automated, scalable, and statistically robust methods and infrastructure. These needs form the basis of the project we propose herein.

PROJECT DESCRIPTION

Goals:
Our primary goal is to develop and validate a suite of automated analytics that bring remote reclamation assessment technology to operational capacity for industry, agencies, and the interested public of North Dakota.

Additionally, we aim for this project to maximize returns on investment for the State of North Dakota by addressing NDIC research priorities identified in Helms's 2018 memorandum[18] on improving well site reclamation program efficiencies, including:

Data Management

a. Consideration of which data storage architecture is optimum for data management needs.
b. Development of a trusted third-party data organization system accessible by industry and regulators.

Decision Tools

c. Consideration of how image processing can produce decision support tools from gross data.
d. Consideration of what data are visualized and provided to leaders for decision making.
e. Development of imagery analysis tools that enable cost estimates for completing site reclamation.

Cost-Effectiveness Analysis

f. Analysis of the cost-effectiveness of using remote sensing technologies for well site reclamation assessment compared to current procedures employed by industry and agencies.

Objectives:
Guided by the goals and priorities described above, this project, titled *Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success In North Dakota,* seeks to develop, validate, automate, and examine the cost-effectiveness of aerial imaging and analysis methodologies for use in establishing an operational remote reclamation assessment program that serves industry, agencies, and the public. Our objectives entail four central components:

1. *Model Development.* Build upon the findings of OGRC Project G-037-73[19] to develop efficient and scalable imagery analysis tools for remotely measuring the success of well site reclamation, including:
    a. Preliminary vegetative cover comparison
    b. Aerial reclamation inspection analytics:
        i. Vegetative continuity comparison
        ii. Infrastructure identification

[17] Energy and Environmental Research Center. Liquids Gathering Pipelines: Survey of Emerging Technologies and Applications of Risk Assessment to Increase Pipeline Integrity, pg. 18, Contract No. G-43-01, Final Report prepared for the North Dakota Industrial Commission and the Energy Development and Transmission Committee. University of North Dakota. Submitted September 2018. Retrieved from https://cms.oilresearch.nd.gov/image/cache/G-43-01_FR.pdf
[18] Helms, L.
[19] Jackson, M.

iii. Problematic surface hydrology identification
iv. Topographic contouring assessment
v. Volumetric measurement

2. *Model Validation*. Statistically test and validate the accuracy of aerial data and developed analytics with multiple tiers of comparative analysis and ground-truthing field inspections.

3. *Model Automation.* Automate the developed and validated analytics within a secure, open source, web-based platform in which oil and gas operators and agencies can easily upload, manage, process, analyze, visualize, and download aerially-derived information and reports for use in decision making.

4. *Cost-Effectiveness Analysis.*
    a. Analyze and compare the costs and effectiveness associated with aerial imagery collection and analysis against current well site reclamation inspection procedures.
    b. Analyze and compare the costs and effectiveness of data collection performed by a battery-powered, multirotor UAV and a gas-powered, fixed-wing UAV capable of BVLOS.

Alignment with OGRC Priorities:
This project aligns with the following OGRC priorities:

Generate information and knowledge that will have the highest probability of bringing new oil and gas companies and industry investment to North Dakota.

a. Access to validated remote reclamation assessment technology with proven cost savings for industry will be attractive to upstream oil and gas companies.
b. A more efficient and objective reclamation inspection program will increase the speed and predictability by which final and potentially partial bonds are released, which will be attractive to upstream oil and gas companies.
c. Access to a validated aerial construction stormwater inspection method will increase the efficiency and accuracy of stormwater self-inspection, reporting, and permit clearance, which will be attractive to upstream oil and gas companies.
d. Aerial imagery analysis tools developed specifically for oil and gas well site reclamation assessment in North Dakota will enable companies to better budget for expedient completion of reclamation requirements and avoid fines, which will be attractive to upstream oil and gas investment.
e. The remote reclamation assessment program validated and automated for use by upstream oil and gas operators will be adaptable for midstream oil and gas reclamation monitoring, budgeting, and compliance purposes, which will be attractive to that market segment.
f. This project contributes to the successful implementation of the “innovation instead of regulation” market-based model for attaining safety and stewardship objectives, which is attractive to all facets of the oil and gas industry, as well as other business sectors.
g. A portion of this project’s aerial imagery will be collected by a newly-released gas-powered, fixed-wing UAV designed for endurance flight and BVLOS operations. North Dakota is investing in infrastructure to support the establishment of a BLVOS program in the Bakken, which will be attractive for industry investment in the region. The project’s testing of a BVLOS-capable drone for imagery capture in the Bakken helps prove the value of the state’s investment initiative.

Maximize the market potential for oil, natural gas, and the associated byproducts.

a. A more efficient inspection process for final and partial reclamation will support faster bond release, thus freeing industry funds for reallocation toward new exploration and production activities.
b. Remotely measuring reclamation success and vegetative cover enables operators to more efficiently monitor and report when a site has been sufficiently stabilized and reseeded according to their stormwater permit requirements, thereby reducing the resource-intensiveness and potential frequency of self-inspections that operators must perform, and releasing human and financial resources for investment in market development.
c. Access to imagery analysis tools for comprehensive reclamation assessment and planning will help industry budget for and direct resources toward sites that need them most and away from sites that do not, thereby improving financial efficiencies within companies and enabling further investment in market development.
d. Analysis of the cost-effectiveness of using remote sensing technologies for well site reclamation assessment compared to current procedures employed by industry and agencies will provide operators and agencies with the

data they need to make informed decisions regarding reclamation inspection methods and expenditures. This contributes to fulfilling the central economic principle that market transparency improves market performance.

Improve the overall suitability of the oil and gas energy industry in North Dakota through the development of new environmental practices that will help to reduce the footprint of oil and gas activities.

a. Aerial data collection is a non-invasive inspection technique that minimizes the impacts of human and vehicle disturbance on and near an under-construction (for stormwater inspection) or reclaimed well site.
b. The efficient clearance of well sites from the reclamation inspection schedule and release of bonds, as well as tools that enable the remote inspection of interim reclamation and the partial release of bonds, will better incentivize reclamation activities.
c. Tools that enable efficient, objective self-inspection of well sites for the purposes of reclamation and stormwater permit requirements will enable more accurate self-assessments of environmental conditions, thus empowering operators in their environmental stewardship and compliance efforts.
d. A statistical measurement of on-site vegetative cover in relation to background and reference area conditions will provide a trusted, objective, and impartial means of assessing reclamation progress and informing management decisions.

Develop baseline information that will lead to other projects, processes, ideas, and activities.

a. As developments in technology and regulations make BVLOS operations for UAS a reality, the demand for efficiently transforming big data into actionable intelligence will rise. This project will inform and stimulate further research and development of statistically robust and automated tools for processing and analyzing aerial imagery, thus driving additional business opportunities and technology innovation and adoption in North Dakota.
b. A small portion of this project's aerial imagery will be collected by a newly-released gas-powered, fixed-wing UAV designed for endurance flight and BVLOS operations. North Dakota is investing in infrastructure to support a BVLOS program in the Bakken. The project's testing of a BVLOS-capable drone for imagery capture in the Bakken will help inform and prove the value of the State's investment initiative, thus further stimulating the market for UAS and BVLOS technologies in North Dakota.
c. Helms's 2018 memorandum[20] encouraging the study of aerial imaging and analysis for reclamation assessment defined several NDIC research priorities, including consideration of: optimal data storage architecture; accessible data organization; data processing that produces actionable results; and data visualization designed for decision makers. This project will provide industry and agencies direct interaction with an operational example of each of these components, thereby providing baseline information for the further advancement of software for aerial data processing, management, and analysis in the state.

Methodology:

The research design is compartmentalized into two tiers: data collection and analytics. The first tier consists of a preliminary reclamation analysis conducted with publicly available data and does not require the acquisition of new aerial imagery. The second tier includes the development of a suite of reclamation inspection tools reliant on the acquisition of current aerial imagery. **Whiting Petroleum Corporation (Whiting)**, a project partner and upstream operator in North Dakota, is permitting access to and assessment of their well sites as an essential component of this project. The following section describes the methodology for carrying out this research proposal.

Model Development I. *Preliminary vegetative cover comparison.* The preliminary vegetative cover comparison tool will analyze and rank the population (n=2,219) of well sites operated by Whiting in North Dakota based on the extent to which the well sites exhibit vegetative cover conditions similar to that of their environmental or agricultural context.
The preliminary assessment will draw data inputs from publicly available sources, including the NDIC for well site locations and the National Agricultural Imagery Program (NAIP) red, green, blue, and near infrared imagery. SolSpec will compute a Normalized Difference Vegetation Index (NDVI) based on 0.6-meter NAIP imagery (USDA, 2018) and then perform k-statistic and cumulative frequency distribution calculations to measure the statistical difference in spectral reflectance between well pad sites and their adjacent areas within a buffer and radius zone (appropriate buffer and radius distances to be determined in conjunction with NDIC and Whiting).

Results include tabular and geospatial data ranking the population of well sites according to their level of vegetation cover reestablishment. When interpreting statistical results, a minimal difference between on- and off-pad spectral reflectance

[20] Helms, L.

will indicate a high continuity in ground cover and, thus, a high level of reclamation success. Conversely, a large difference in spectral reflectance between the well pad and adjacent area will imply a discontinuity in ground cover and a lower level of reclamation success. Thus, the preliminary assessment method should enable operators and agencies to quickly and cost-effectively assess well site reclamation success across a large population and landscape according to the vegetative conditions present during the most recent NAIP data collection.

Though the NAIP dataset provides a relatively recent assessment of vegetative cover, it fails to account for changes that have occurred since the imagery collect, which can span up to five years. The second tier of remote reclamation assessment addresses those limitations and more.

Aerial Data Collection. Aerial imagery for the development of the reclamation inspection tools will be acquired by **ISight RPV Services (ISight)**, a Grand Forks-based UAS services provider. ISight will collect imagery for all study well sites using the batter-powered, multirotor Inspire 2 Pro UAV made by DJI. A small portion of well sites will be double sampled using the BVLOS-capable, gas-powered, fixed-wing V2 UAV manufactured by Hybrid Project, a USA manufacturer. Each UAV will be mounted with a gimbaled 100-megapixel camera for capturing four-band imagery including red, green, blue, and near infrared at a resolution of three to five centimeters. Upon collecting the imagery, ISight will upload data to SolSpec's secure, web-based platform for aerial data management, processing, analysis, and visualization. Imagery from the two drone models will be compared as part of the cost-effectiveness analysis component of this study.

Model Development II. *Aerial reclamation inspection analytics.* The second tier of remote reclamation assessment tools will be developed using temporally-relevant, sub-decimeter resolution imagery captured with UAS during the aerial data collection phase of this project. The current, high-resolution aerial data will support the development, validation, refinement, and automation of a comprehensive suite of reclamation analytics that assess each variable contributing to a site's reclamation success, including vegetation reestablishment, infrastructure removal, erosion control, recontouring, and stockpile removal.

Whiting has approved a sample of 100 well sites for inclusion in this imagery collection and analysis portion of the project. The sample, drawn from NDIC data, consists of: a) 40 active well sites that have been partially reclaimed; b) 50 plugged well sites in progress toward or near final reclamation and pending NDIC certification; and c) ten well sites that have been fully reclaimed and certificated by the NDIC (see Appendix A). The active well sites will allow for study of aerial inspection for the purposes of interim reclamation and potentially partial bond release. Additionally, Whiting performs voluntary stormwater monitoring on two of the sample's active sites, though a stormwater permit was not required for their construction. The 50 plugged but uncertificated well sites will support examination of aerial inspection methods for final reclamation and bond release purposes. The ten fully reclaimed and certificated well sites will serve to validate the concurrence of aerial inspection outputs with NDIC certification decisions.

Vegetative continuity comparison. SolSpec will process the spectral imagery captured of the 98 well sites to generate a digital surface model (DSM) using photogrammetric methods. The spectral data will be transformed into several vegetation indices representing leaf chlorophyll content and vegetative health Structural data derived from the DSM will be organized by relative vegetation height and roughness and used as a surrogate for vegetation community composition. An area equal to and bounding the pad will serve as the well site's reference area representing background conditions. (The appropriate size and extent of the original area of disturbance will be determined in conjunction with NDIC and Whiting.)

Anomalous features such as access roads, salt kills, or open pits that exist within the well sites' reference areas have the potential to skew the comparison between on- and off-site vegetative continuity. For instance, the model could misinterpret an unreclaimed access road in the reference area as naturally barren vegetative cover. To remedy this, SolSpec will develop and automate a computer vision model to identify anomalous surface conditions including access roads, salt kills, open pits, and adjacent well pads from the reference areas. These features will be flagged for further investigation and extracted from the well site reference areas of analysis to prevent anomalous surface conditions from being erroneously incorporated into on- and off-site ground cover comparisons.

Next, SolSpec will calculate a statistical similarity index based on how similar spectral vegetative indices and vegetative structure cumulative distribution functions are between the well sites and their reference areas. Like the preliminary assessment, more similar spectral and structural scores between on- and off-pad samples will indicate a closer relationship between the well site and reference area, or background, vegetative conditions.

Infrastructure identification. SolSpec will employ the DSM and spectral data derived from the well site photogrammetry as inputs to the infrastructure identification model. The model will employ several moving windows at multiple scales to identify variability in the elevation and spectral signatures specific to human-modified features. The model will then isolate these areas of the data and aggregate them into polygons representing each infrastructure feature. Geospatial outputs of the model will include identified infrastructure, while tabular outputs will indicate the existence and number of infrastructure instances on a well site pad.

Problematic surface hydrology identification. The problematic surface hydrology identification model will identify sites where surface water runoff can cause erosion, channeling, rilling, and sedimentation that negatively impacts the site or surrounding environment. Using the DSM derived from photogrammetric imagery, the model will evaluate surface flow patterns for areas of significant hydrologic convergence, accumulation, and drainage on a well site—areas where erosion, channeling, rilling, and sedimentation are likely to occur. The geospatial outputs will include problematic surface hydrology flow lines predicted by the model, while tabular results will indicate the existence and extent of problematic flow lines for each well site. The resulting tool will be capable of informing the installation and measuring the effectiveness of erosion control devices.

Topographic contouring assessment. The topographic contouring model will be developed to identify disparities in slope between a well site and its surrounding landscape. Using several moving windows at multiple scales to examine variability within the DSM, the model will be trained to recognize and measure distinct differences in slope and elevation between a well site and its surrounding area. Geospatial outputs of the model will include zones of significant contouring disparity between the well site and adjacent landscape, and tabular outputs will indicate the existence and extent of contouring disparities on a site.

Volumetric measurement. The volumetric measurement model will be developed as an interactive user tool that enables software users to demarcate and measure the volume of above-ground or below-ground material. The model will allow for a user to first define the surface-level circumference of the above-ground material (i.e., existing stockpile) or below-ground material (i.e., desired pit) that the user wants to measure the volume of. Next, the tool will mathematically interpolate a theoretical elevation of the user-defined circumference to calculate the volume of the material or pit. While not essential for remote reclamation inspection by state agencies, the volumetrics measurement tool will allow operators to inventory and estimate the volume of material they need to move, and thus the resources required, to fulfill reclamation obligations.

Model Validation. The suite of aerial analytics designed for remotely measuring well site reclamation success in North Dakota will be ground-truthed and validated through a multi-tiered validation process of three steps:

1. The preliminary vegetative cover comparison model outputs will be compared against the aerial reclamation inspection outputs to determine the effectiveness of the preliminary model in predicting reclamation success based on the spectral reflectance of vegetative cover on- and off-site. (It should be noted that the preliminary vegetative cover comparison method is based on the best available NAIP data, which may vary across time and location.)
2. The outputs of the aerial reclamation inspection analytics, including vegetative continuity, infrastructure, problematic hydrology, contouring, and volumetrics, will be compared against ground-truthed data collected by **Duraroot Environmental Consulting (Duraroot)**, a project partner, to verify the accuracy of the model in remotely inspecting the well site conditions that determine reclamation success. Duraroot will visit a subset (n=30) of sites representing 30% of the study sample to assess vegetative recovery, infrastructure presence, stormwater conditions, surface recontouring, and overall well site reclamation success. The subset of sites visited will be comprised of: a) 20 plugged sites that are deemed in-progress toward or near final reclamation but that the NDIC has not yet certificated, and b) ten active sites representing partial, or interim, reclamation status. The active site sample will include the two sites for which Whiting performs stormwater monitoring.
3. The study will collaborate with the NDIC for a final tier of validation. Contingent upon the NDIC's resources and availability, an NDIC reclamation inspector will visit the 20 well sites surveyed by Duraroot that were deemed at or near final reclamation but still await NDIC approval. The sites inspected by NDIC will represent 20% of the aerial inspection study sample and 67% of the sites ground truthed by Duraroot. NDIC will evaluate reclamation conditions and compliance according to agency field inspection protocol. The aerial reclamation inspection results will be compared against the NDIC's and Duraroot's reclamation condition determinations to evaluate the effectiveness of the aerial reclamation inspection analytics' ability to remotely measure reclamation success.

Model Automation. Upon the development of the preliminary vegetative cover comparison and the comprehensive suite of aerial reclamation inspection analytics, but prior to field validation, each of the models' components will be automated within the SolSpec platform. This process will include the automation of the following steps for each model: data aggregation, dissemination, derivative generation, and model validation. The model validation step will provide a significance value based on initial training data. Field validation of the models will provide an opportunity to test the robustness of the models in comparison to on-site observations. Field validation results will be used to further train and improve the models' accuracy levels.

Cost-Effectiveness Analysis. A cost-effectiveness analysis is an economic tool for comparing the relative costs and outcomes of different courses of action that aim to achieve a similar goal. In this study, we will evaluate the relative costs and outcomes for industry and agencies associated with aerial imagery collection and analysis against manual well site reclamation and inspection procedures.

To calculate the costs of the status quo reclamation and inspection process, the study will survey both Whiting and the NDIC regarding the resources and expenditures each entity has dedicated to achieving successful reclamation certification on at least ten Whiting well sites in the past five years that were not included in the aerial inspection sample group. This retroactive sample will serve as the control group for the purposes of the cost-effectiveness analysis. SolSpec will interview Whiting and the NDIC to collect cost data for each of the ten or more sites included in the cost-effectiveness analysis study, including personnel time, equipment use, mobilization costs, information management, and other observed inputs. Additionally, outcomes of the status quo reclamation inspection process will be recorded for each of the ten or more sites, including reclamation inspection data quality, quantity, and consistency, among other observed outputs.

Similarly, SolSpec will record costs and outcomes associated with aerial data collection and inspection in the experimental group. The costs associated with model development, internal validation and automation, as well as ground truthing performed by Duraroot will not be included in the cost-effectiveness analysis, as those costs are not representative of what the aerial inspection process would cost operators and agencies once operational. Costs considered in the cost-effectiveness analysis will include data collection, processing, analysis, and interpretation. Effectiveness will be determined by the quality, quantity, and consistency of data outputs for assessing reclamation conditions and compliance.

SolSpec will compile the cost and outcome data from the control and experimental groups and develop a comparative summary between the two groups, focusing on cost inputs and the quality, quantity, and consistency of outputs for the purpose of assessing reclamation conditions and compliance. SolSpec will solicit feedback from both Whiting and the NDIC to confirm that the data interpretation and comparative summary are accurate and representative of their reclamation inspection experience.

The cost-effectiveness analysis will be based on data collection with the battery-powered, multirotor Inspire 2 Pro UAV made by DJI. The battery-powered, multirotor UAV is among the most commonly used UAV models at present for its maneuverability, dependability, and overall ease of use. The model is limited, however, in the distance, speed, and duration it can fly due to design and battery life. These limitations have not yet been fully felt in the UAS world because of BVLOS restrictions, which keep the UAV within eyesight of its pilot. North Dakota's investment in establishing a legal BVLOS program in the state will soon drive demand for UAVs capable of long-range flights. Therefore, this project will incorporate the use of ISight's gas-powered, fixed-wing V2 UAV for sampling a portion (n=5) of sites that are also sampled with the multirotor UAV. The double sampling of sites, albeit a small number, will support a comparative analysis of the costs and effectiveness between the two UAV models. In addition to assessing resource inputs for each drone model in collaboration with ISight, SolSpec will compare the models' data quality and quantity outputs for use in reclamation success monitoring.

Anticipated Results:
Model Development. We anticipate that development efforts to produce the aerial reclamation inspection tools described above will result in analytic algorithms/instruments capable of efficiently intaking large volumes of geospatial data and transforming it into operational decision support information for remotely inspecting reclamation success.

Model Validation. We predict that the preliminary reclamation assessment tool and the comprehensive aerial inspection analytics suite will be validated as ac\curate and useful methods for remotely determining reclamation success. This will

inform efficient resource allocation, prioritization of site inspections, and bond release within North Dakota's well site reclamation program, thereby supporting NDIC intentions and research priorities.[21]

Model Automation. We expect the automation of the reclamation analysis models to provide a feasible, economical, and scalable avenue for analyzing large quantities of aerial data per OGRC Project G-43-01 recommendations,[22] enabling the operationalization of a remote reclamation inspection program in North Dakota.

Cost-Effectiveness Analysis. We anticipate that the cost-effectiveness analysis will provide evidence substantiating the business case for remote reclamation inspection and elucidate the comparative economics of aerial reclamation inspection versus traditional procedures. Additionally, we predict that the study will provide information regarding the potential costs and benefits of using a multirotored UAV versus a BVLOS-capable, fixed-wing UAV for aerial reclamation inspection.

Facilities:
Aerial data collection and validation will take place on approximately 200 well pad sites operated by Whiting all located within western North Dakota. Data will be managed, processed, analyzed, and visualized at SolSpec's headquarter office in Lakewood, CO, with distributed computing infrastructure.

Resources:
The primary resources deployed to this project will be SolSpec's personnel and computer hardware; ISight's personnel, UAVs, vehicles, and field equipment; and Duraroot's and Whiting's personnel, vehicles, and field equipment supporting ground truthing, data collection, and cost calculations.

Techniques to Be Used, Their Availability and Capability:
Photogrammetry is a measuring technique for triangulating among photographs of a point of interest taken from at least two different locations to mathematically extract 3-dimensional (3D) coordinates of the point of interest. Developments in digital camera chips with high megapixel levels and improvements in software have enabled the production of high-accuracy 3D coordinates through photogrammetric techniques.

Environmental and Economic Impacts while Project is Underway:
One of the benefits of non-invasive remote sensing technologies is the minimal impact that aerial data collection poses to the environment. On-ground visits to sites to validate the models developed in this research will pose some minor, temporary environmental disturbance as a result of in-situ soil or vegetation classification within the bounds of traditionally accepted environmental inspection protocols. There are no foreseeable adverse economic impacts while the project is underway.

Ultimate Technological and Economic Impacts:
This research project will produce tools for improving both technological and economic efficiencies for North Dakota's oil and gas industry and its agency collaborators. The potential economic impacts of the adoption of remote reclamation assessment tools will be further revealed as a result of the cost-effectiveness analysis portion of the project.

Why the Project is Needed:
Development. Prior OGRC research (Project G-037-73, 2016) validated the feasibility of image collection as a means of determining reclamation success. Yet existing methods for remotely analyzing vegetative cover data, including those used in the OGRC study, are scale-limited and technologically cumbersome, impeding the widespread adoption of aerial imagery technology in reclamation monitoring. Tools for efficiently interpreting aerial imagery for the purpose of comprehensive well site reclamation assessment, including recontouring, infrastructure removal, and erosion control, have not yet been developed or validated. In order for remote sensing technologies to bring efficiencies to the reclamation inspection and bond release process as desired by the NDIC,[23] well site operators and regulatory agencies need access to a toolkit of efficient, scalable, and statistically robust methods for remotely analyzing reclamation success.

Validation. Helms's memorandum underscored that among the NDIC's priorities for its reclamation program is the development of aerial imagery "technology applications that are trusted by both industry and regulatory agencies."[24] In

[21] Helms, L.
[22] Energy and Environmental Research Center.
[23] Helms, L.
[24] Helms, L., pg. 1.

order for industry, agencies, and the interested public to be confident and trust that aerial reclamation inspection effectively supports reclamation monitoring and budgeting, regulatory compliance, and the sustainability of oil and gas production in North Dakota, the methodology must be statistically tested and validated in the field by third parties—a central objective of this project.

Automation. Aerial imagery collection provides operators with an overwhelming amount of raw data, often requiring the employment of specialized teams of analysts to process and interpret the data into meaningful information. In order for the analysis of aerial imagery to be cost-effective and scalable—both precursors to adoption of the technology throughout the oil and gas industry—data management, processing, and analysis must be automated.

Cost-Effectiveness Analysis. In addition to having information about the accuracy and speed with which aerial reclamation inspection can be accomplished, industry and agencies require access to information about the potential cost-savings or cost-burden that the methodology entails. Industry and agencies alike must make decisions with cost and benefit tradeoffs in mind. The cost-effectiveness portion of this study will help all parties understand the comparative tradeoffs between aerial reclamation inspection and traditional inspection methods. To a lesser degree, this project will also investigate the cost-effectiveness of using battery-powered, multirotor UAVs versus gas-powered, fixed-wing UAVs capable of BVLOS for reclamation success monitoring—information that will serve the State's investment in BVLOS infrastructure.

STANDARDS OF SUCCESS

Measurable deliverables and success reporting
Success will be achieved when the suite of remote reclamation inspection tools is statistically validated at an acceptable level of accuracy and automated to enable efficient, scalable data processing and analysis by operators and agencies.

Core deliverables include:

1. Quarterly reports to NDIC highlighting ongoing research activities and results;
2. Final report summarizing research achievements, challenges, conclusions, recommendations, and cost-effectiveness analysis findings;
3. Statistically validated, automated toolkit for remote inspection of well site reclamation conditions and compliance, including the following tools:
    a. Preliminary vegetative cover comparison
    b. Aerial reclamation inspection analytics
        i. Vegetative continuity comparison
        ii. Problematic surface hydrology identification
        iii. Topographic contouring assessment
        iv. Volumetric measurement

Value to North Dakota and public and private use of results
North Dakota's oil and gas industry, agencies, and public will derive benefit from the results of this research.

1. Industry will gain awareness of and access to affordable, statistically sound, best available technology developed for and tested in the Bakken.
    a. This project will provide upstream operators access to quantitative methods for proactively monitoring reclamation progress, developing reports for NDIC, and proving readiness for bond release. The technology may also be used for compliance with construction stormwater permits.
    b. The study will provide industry, agencies, and the public with valuable information about the cost-effectiveness of aerial imaging and analytics technology for reclamation inspection, which will inform and influence consideration of the technology for other applications.
2. Industry use of the aerial analytics tools produced in this project will translate to increased efficiencies within oil and gas regulatory agencies.
    a. The NDIC well site reclamation program will have the option of receiving aerial-based statistical measurements of reclamation conditions and compliance through time, thus streamlining the inspection process. For instance, the NDIC may be able and willing to accept aerial inspection reports from operators in lieu of the state inspectors making annual visits to sites in progress toward final reclamation, limiting field visits to those sites where there are significant problems or where final certification is likely.

   b. Increased efficiencies gained by the NDIC may be also be accessible to the NDDEQ.
3. Industry use of the aerial analytics tools developed in this project will translate into benefits for the public and the environment.
   a. As stated by Helms, "*the public, which has a stake both in the protection and restoration of the landscape, also seeks a consistent and sustainable reclamation program to help support an active oil and gas industry.*"[25] This project's aim is to produce tools that support a more consistent and sustainable well site reclamation program in the state.

Commercial Use
Remote sensing technology has dramatically changed the way that many sectors, including energy, agriculture, mining, infrastructure, and government, do business. As developments in technology and regulations make BVLOS UAS flights possible, so will rise the demand for efficiently transforming mountains of data into actionable intelligence to guide decisions. This project will produce technological advances that make gross data meaningful for the oil and gas industry. Results will inform and inspire further development of statistically robust and automated tools for processing and analyzing aerial imagery, thus stimulating innovation and business opportunities in a much-needed space. Additionally, the aerial analytics tools derived from this project will enhance the use of remote sensing technologies in the state, thereby further fortifying the UAS industry.

How the project will enhance the education, research, development, and marketing of North Dakota's oil and natural gas resources
North Dakota's vision for its oil and gas industry is to achieve safety and stewardship through innovation rather than regulation. This research aims to prove the effectiveness and efficiency of market-based approaches in creating a sustainable and thriving oil and gas industry. The project will demonstrate that market-based safety and stewardship tools can be affordable, trusted, and produce net gains for operators by facilitating compliance, informing budgets, and quickening the pace of bond release.

How it will preserve existing jobs and create new ones
Successful execution of this project will fortify the remote sensing industry in North Dakota—from UAS imagery collection to processing to analytics. It will encourage the certification and employment of more FAA 107-licensed pilots among oil and gas personnel, agency inspectors, and third-party service providers. It will also stimulate and drive further technological innovations and applications among North Dakota's public, private, and academic sectors for turning big data into actionable intelligence.

BACKGROUND/QUALIFICATIONS

SolSpec, Inc.
SolSpec is a Denver-based software company that specializes in the processing and analysis of geospatial data. With a principal focus on the scalability and automation of remotely sensed data processing and analysis, SolSpec productizes analytics for commercial applications in natural resources, infrastructure, and other major land-use industries. Having mapped and analyzed more than 1.5 million acres, SolSpec's product and prediction models have become increasingly accurate, reliable, and user-friendly.

John Norman, MS, Principal Spatial Scientist, SolSpec (Principal Investigator)
https://www.researchgate.net/profile/John_Norman6
John Norman specializes in remote sensing, ecology, and spatial statistical analysis. His interdisciplinary expertise in soil, water, and vegetation combined with his tenure as a research scientist have made him proficient at the predictive modeling of terrestrial and hydrological systems.

Nathan Casler, MS, Director of Development, SolSpec (Principal Investigator)
https://www.researchgate.net/profile/Nathan_Casler
Nathan Casler specializes in geospatial programming, distributed database design, and High-Performance Computing (HPC). His technical literacy in both spatial statistical analysis and distributed databases make him exceptional at building HPC workflows for performant large-scale analysis.

[25] Helms, L. pg. 1

Bryan Crowe, Chief Operating Officer, SolSpec
Bryan Crowe's experience includes tenure at MarkWest Energy Partners as a regional manager with overall responsibility for pipeline operations in five states (~12% of the nation's gas) in the Appalachian region.

David Mueller, MS, Spatial Scientist, SolSpec
David Mueller specializes in remote sensing, ecology, fisheries and wildlife biology, and spatial statistical analysis. His experience working for both federal and state land management agencies lends greatly to the development and enhancement of spatial models used in regulatory decision-making processes.

ISight RPV Services
Grand Forks-based ISight provides Remotely Piloted Vehicle operations to customers including energy and engineering firms, agricultural producers, DOD contractors, NASA and the North Dakota and Nevada FAA UAS Test Sites. As part of its ongoing work, ISight has inspected over 175 miles of oil pipeline utilizing drones. ISight successfully completed work with the OGRC in titled "UAS Aerial Observation to Support Oil & Gas Pipeline Construction Restoration Efforts." ISight and the Unmanned Applications Institute, in collaboration with ONEOK, Barr Engineering, and the Public Service Commission, provided high fidelity imagery for use in improving ONEOK's restoration activities.

Tommy Kenville, Chief Executive Officer, ISight RPV Services
Tommy Kenville has over 25 years in aviation-related experience, including 15 years at the University of North Dakota Aerospace Foundation and as founder of the Unmanned Applications Institute (the first institute for research, testing, and consulting in the emerging UAV industry in North Dakota, founded in 2010) prior to merging with ISight in 2016.

Whiting Petroleum Corporation
As a company, Whiting has reclaimed nearly 100 facilities in the past three years in North Dakota alone. Whiting's Regulatory, Permitting, and Environmental Departments have worked closely with the NDIC and United States Forest Service (USFS) to successfully fulfill requirements for proper site reclamation.

Mark Keyes, Environmental Compliance Supervisor, Whiting
Mark Keyes has 6 years of experience working and supervising Whiting's environmental compliance in the Williston and DJ Basins of North Dakota and Colorado. In 2016, Mark and Whiting teamed with SolSpec and the Colorado Oil and Gas Conservation Commission on a pilot study using remote sensing to evaluate reclamation success. Mark and his counterparts at Whiting continue to use remotely-sensed data and the SolSpec Platform for the inventory, maintenance planning, and execution of reclamation activities.

Duraroot Environmental Consulting
With decades of experience in the energy and environmental industries, Duraroot provides consulting services for soil, plant, and water sciences. Duraroot provides site-specific reclamation and monitoring plans for large pipeline and E&P facilities. Since 2014, Duraroot has sampled over 50,000 acres of soil and vegetation on oil and gas facilities.

Aaron DeJoia MS CPSS, Environmental Soil Scientist/Agronomist and Director, Duraroot
Aaron DeJoia is a North Dakota Professional Soil Classifier and board-certified Professional Soil Scientist and Agronomist with 18 years of experience providing support in permitting, operations, reclamation, remediation, and expert witness testimony to clients in the oil and gas sectors.

MANAGEMENT

Management of this research project will be led by SolSpec and includes time and milestones tracking, budgetary reporting, fund accounting, and contract services. SolSpec employs the Agile Method for project management that is common in software development. Agile uses incremental, iterative work sequences known as "sprints" to assist collaborative teams in responding to the unpredictability of constructing software. The project objectives will be broken into smaller tasks that will be incorporated into sprints with built-in twice-monthly evaluation points.

TIMETABLE

The proposed project will take place over the course of 16 months.

Key Milestones	Responsible Party	Month(s)	Year(s)
Model Development			
Develop: preliminary vegetation cover comparison, vegetative continuity comparison, infrastructure identification, problematic surface hydrology identification, topographic contouring assessment, and volumetric measurement models.	SolSpec	Feb-Aug	2020
Model Automation			
For each model: automate data aggregation, dissemination, derivative generation, analytic process, and validation.	SolSpec	Feb-Aug	2020
Aerial Data Collection			
Collect aerial imagery with UAS: 100 sites	ISight	Aug-Sept	2020
Manage access to and supervise site: 100 sites	Whiting	Aug-Sept	2020
Model Validation			
Perform ground-truthing field inspections: 30 sites	Duraroot	Aug-Sept	2020
Manage access to and supervise site: 30 sites	Whiting	Aug-Sept	2020
Perform agency field inspections: 20 sites	NDIC	Aug-Oct	2020
Test and refine models according to field observations	SolSpec	Nov-April	2020-2021
Reports			
Quarterly Report 1	SolSpec	March	2020
Quarterly Report 2	SolSpec	June	2020
Quarterly Report 3	SolSpec	Sept	2020
Quarterly Report 4	SolSpec	Dec	2020
Quarterly Report 5	SolSpec	March	2021
Final Report	SolSpec	June	2021
Briefings to NDIC/OGRC	SolSpec	As requested	2020-2021

BUDGET

The below expenses will be necessary to carry out the objectives and activities outlined in this research proposal. If less funding is available than that requested, the project may be reduced in scope.

Project Activity & Responsible Party	NDIC's Share	Description	Applicant's Share (In-Kind)	Partners' Share (In-Kind)	In-Kind Description
Model Development - *SolSpec*	$ 22,500	Labor, equipment, facilities	$ 35,000		Labor, equipment, facilities
Model Automation - *SolSpec*	$ 19,000	Labor, equipment, facilities	$ 22,000		Labor, equipment, facilities
Aerial Data Collection - *ISight*	$ 70,000	Labor, equipment at $700 per site		$ 34,000	Mobilization at $20k; 5 sites flown with fixed-wing UAV at $700 per site; Site discount at $100 per site for 105 sites
Aerial Data Collection - *Whiting*				$ 32,000	Site manager at $320 per site for 100 sites
Ground-Truthing Inspection - *Duraroot*	$ 26,900	Labor, equipment at $896.66 per site			
Ground-Truthing Inspection - *Whiting*				$ 9,600	Site manager at $320 per site for 30 sites
Model Validation - *SolSpec*	$ 4,500	Labor, equipment, facilities	$ 10,500		Labor, equipment, facilities
Model Refinement - *SolSpec*	$ 9,500	Labor, equipment, facilities	$ 12,500		Labor, equipment, facilities
Project Management & Reporting - *SolSpec*	$ 10,800	Labor, equipment, facilities	$ 12,000		Labor, equipment, facilities
		Applicant's & Partners' Subtotal Share:	$ 92,000	$ 75,600	
NDIC's Total Share:	**$ 163,200**	**Applicant's & Partners' Total Share:**	**$ 167,600**	**Total Project Cost:**	**$ 330,800**

CONFIDENTIAL INFORMATION

There is no confidential information contained within this document.

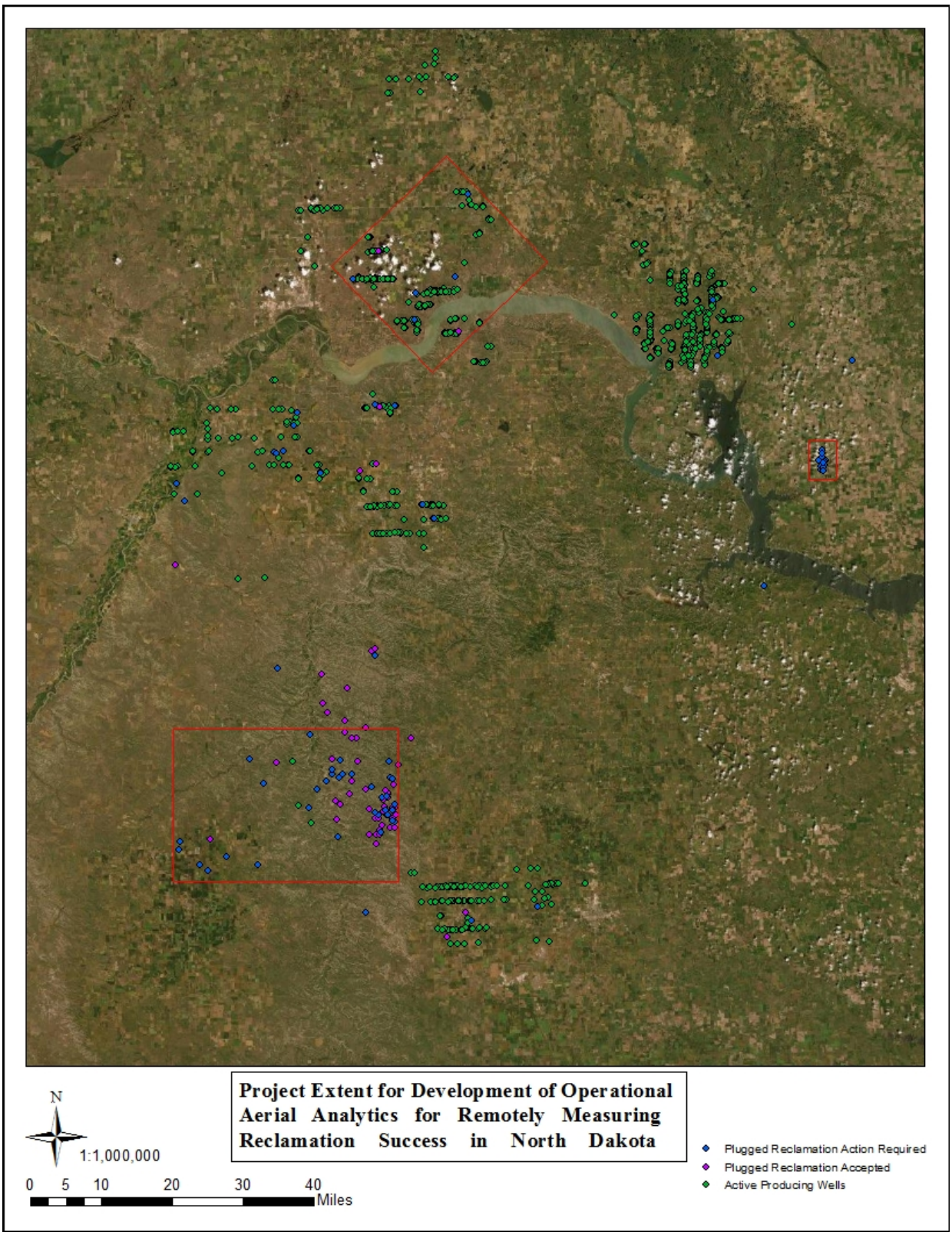
PATENTS/RIGHTS TO TECHNICAL DATA

SolSpec is a Licensed Software provider. "Licensed Software" includes SolSpec's confidential and proprietary SolSpec cloud-based software, algorithms, programs, and tools designed to analyze, manipulate, and process data into reports in a usable and presentable manner that is valuable to users, including, without limitation, any applicable application programming interfaces (API and any and all updates and upgrades).

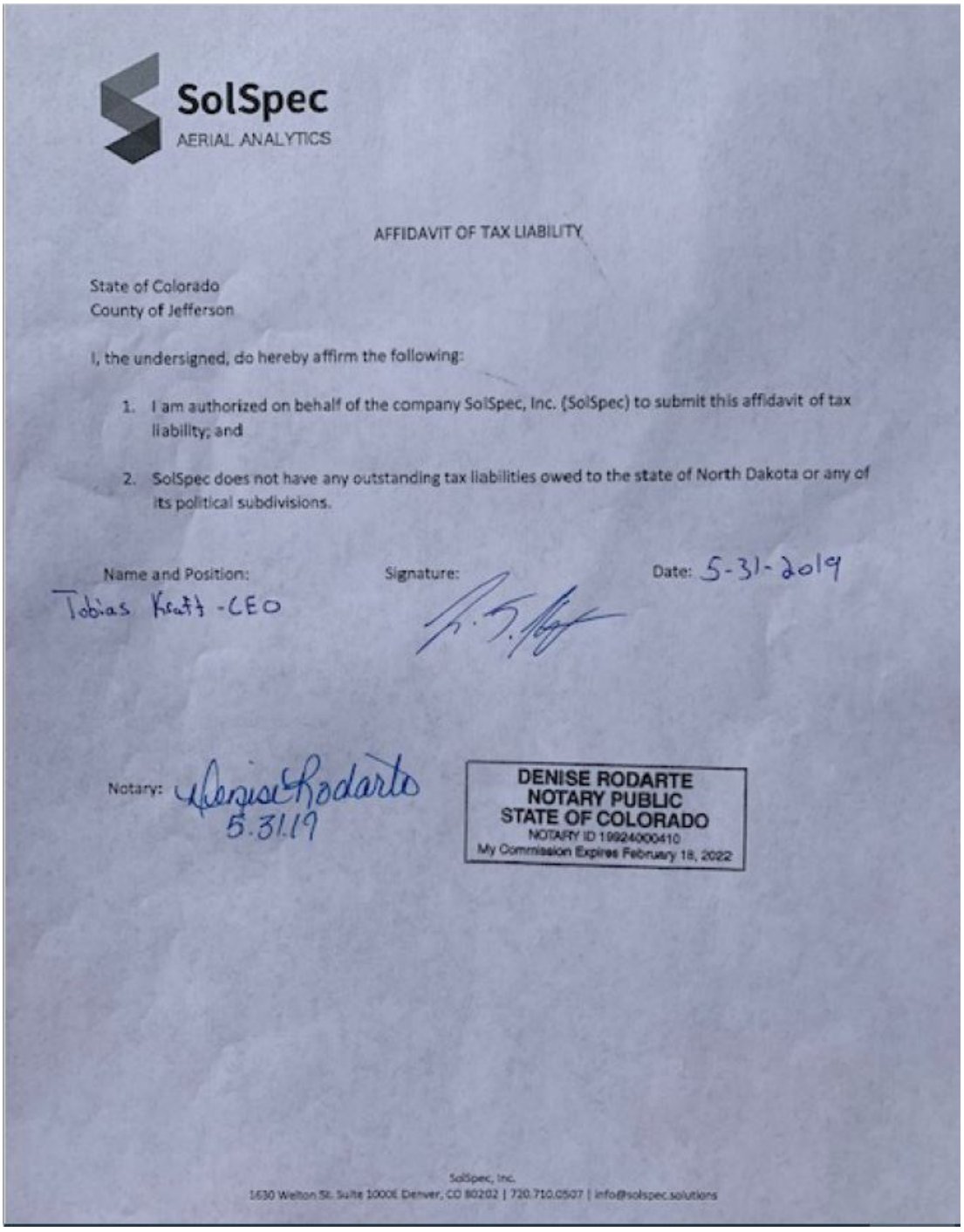
SolSpec is in the process of filing a provisional patent application directed toward its unique methods of advanced multi-view photogrammetry, which is the core engine of the company's software platform. The provisional patent will preserve SolSpec's ability to file a regular, nonprovisional patent application within the next 12 months.

APPENDICES

Appendix A. Map of 100 well sites operated by Whiting on which aerial imagery collection and analytics validation will take place.



Appendix B. Affidavit of tax liability



SolSpec
AERIAL ANALYTICS

AFFIDAVIT OF TAX LIABILITY

State of Colorado
County of Jefferson

I, the undersigned, do hereby affirm the following:

1. I am authorized on behalf of the company SolSpec, Inc. (SolSpec) to submit this affidavit of tax liability; and
2. SolSpec does not have any outstanding tax liabilities owed to the state of North Dakota or any of its political subdivisions.

Name and Position: Tobias Keaty - CEO

Signature:

Date: 5-31-2019

Notary: Denise Rodarte 5.31.19

DENISE RODARTE
NOTARY PUBLIC
STATE OF COLORADO
NOTARY ID 19924000410
My Commission Expires February 18, 2022

SolSpec, Inc.
1630 Welton St. Suite 1000E Denver, CO 80202 | 720.710.0507 | info@solspec.solutions

Appendix C. Status of Ongoing Projects (If Any)

SolSpec has not received prior funding from the OGRC grant program.