SolSpec

March 31, 2020

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

Re: First Quarterly Report for OGRP Project No. G-051-099 entitled "*Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success in North Dakota*"

Dear Ms. Fine:

SolSpec, Inc. (SolSpec) is pleased to provide the first status report on 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 first Quarterly Report submitted for OGRP Project No. G-051-099 entitled "Development of Operational Aerial Analytics for Remotely Measuring Reclamation Success in North Dakota." This Quarterly Report describes project advances achieved between the dates of March 13 (date of contract execution) and March 30, 2020.

If you have any questions, please contact me by phone at (970) 227-9738 or email at msever@solspec.io.

Sincerely,

Mike Sever
Contract Manager

Project No. G-051-099

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

Progress Report for Quarter 1, 2020

Prepared for the North Dakota Industrial Commission
Oil and Gas Research Program
By SolSpec, Inc.

I. Progress Achieved

As stated in the project proposal, 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. The following actions were listed to be in progress during Quarter 1 of 2020 (which was limited to March 13-30 due to contract execution timeline constraints) according to the timetable of the proposal submitted.

A. Develop: preliminary vegetation cover comparison, vegetative continuity comparison, infrastructure identification, problematic surface hydrology identification, topographic contouring assessment, and volumetric measurement models.
B. For each model: automate data aggregation, dissemination, derivative generation, analytic process, and validation.

In alignment with action goals, preliminary model development has been completed on a small subset of data for the analysis tools; information regarding progress and accomplishments is detailed below.

Data collection and aggregation for preliminary model development were completed using National Agricultural Imagery Program (NAIP) data; Colorado Oil and Gas Conservation Commission (COGCC) data; North Dakota Oil and Gas Division data; and drone-based imagery available to SolSpec. Due to time and logistical constraints, drone-based imagery was collected and processed from the Denver-Julesburg (DJ) Basin in Northeastern Colorado. Orthomosaics and Digital Surface Models (DSM) were generated at <10-centimeter resolution for the pads flown during the DJ data collection. NAIP imagery was downloaded for the DJ Basin in quadrants and aggregated into a seamless imagery surface at 1-meter resolution. The resulting dataset is intended only for initial model development and testing.

The COGCC and North Dakota Oil and Gas Division well databases were mined for applicable spatial and non-spatial data. Well sites were filtered by status and dates to develop a statistically valid sample design within the “test extent.” These data were also used to further stratify locations by the status of production or interim reclamation, abandoned but not yet released, or plugged and abandoned.

The data in the “test extent” are intended for preliminary model development and to test feasibility and progress on analytical tools. This foundational work will facilitate late phases of the project, for example, in helping inform field data collection to better inform model development while validating outputs.

The following list provides an overview of the work completed in model methodology, development, and scoping:

1. Researched and reviewed analytic feasibility and methods of vegetation condition and identification analytics that are operational and scalable. SolSpec’s vegetation condition assessment research has three facets that focus on calculating vegetation spectral and structural characteristics on and off the well pad and evaluating the correlation between the two locations. This method requires robust spectral and structural indices, informative statistical measures, and defined off-pad representative vegetation zones.

    a. Vegetation analytics topics reviewed and selected within the greater literature:

        i. Vegetation Vigor Indices - Deriving vegetation health (vigor) and spectral relationships using red, green, blue (RGB) and near-infrared (NIR) spectral bands from drone and NAIP imagery.

           This research yielded six vegetation indices (listed below) that are robust across grasslands, shrubland, and forested areas. This is important because development of a fully automated vegetation analysis requires vegetation indices that are numerically flexible across multiple biomes, stable across different sensor platforms, and based on RGB spectrums. We did include NDVI, which uses NIR, for the landscape-level assessment using NAIP imagery.

           - Triangular Greenness Index (TGI) (Hunter et al. 2013)
           - Normalized Difference Vegetation Index (NDVI) (Rouse et al. 1974)
           - Visible Atmospheric Resistant Index (VARI) (Gitelson et al. 2002)
           - Green Leaf Index (GLI) (Gnyp et al. 2015)
           - Red-Green-Blue Vegetation Index (RGBVI) (Bendig et al. 2015)
           - Normalized Green Red Difference Index (NGRI) (Tucker 1979)

Figure 1. Example of vegetation vigor analysis around an operating well pad based on red, green, and blue (RGB) drone imagery. Green indicates healthy vegetation (i.e., high levels of chlorophyll), while red and orange colors indicate vegetation that is senescent or has low levels of chlorophyll. This analysis was developed using a modified version of the TGI index that utilizes components of the GLI and NGRI indices.

ii. Vegetation Structure Indices - Deriving vegetation structure characteristics is a critical component in the vegetation assessment automation process. This is because it adds a set of dimensions that allows statistical models to better separate vegetation dynamics that are more complex than just spectral reflectance. Such dynamics include vegetation height, shape, canopy volume and density using DSM filtering techniques to determine woody vegetation from grass/forbs.

- Mitchell et al. 2012

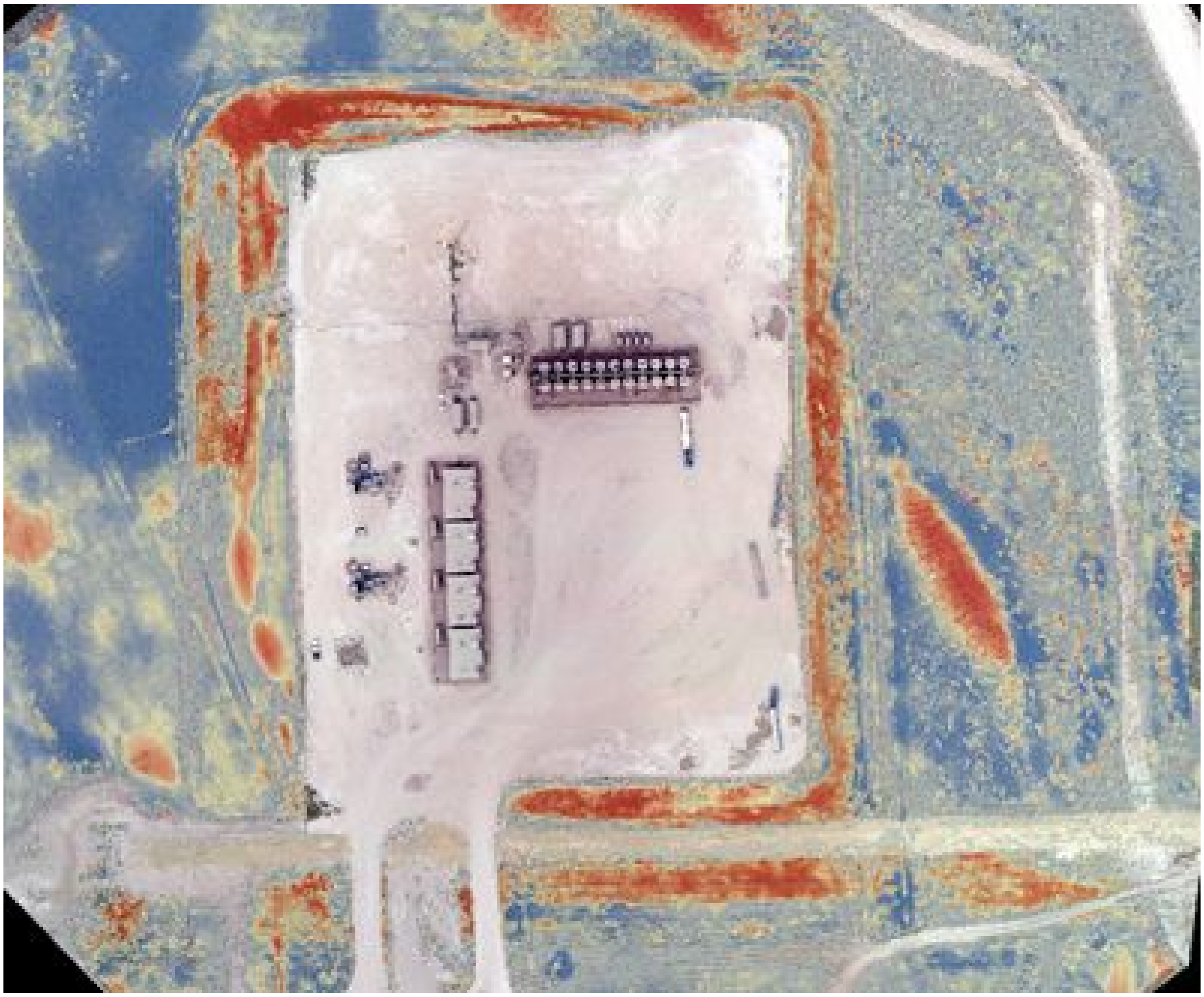

Figure 2. Example of vegetation structure around an operating well pad based on a Digital Surface Model (DSM) derived from red, green, and blue (RGB) drone imagery utilizing photogrammetric methods. Red colors indicate taller woody vegetation, while blue colors indicate grass/forb vegetation heights.

iii. Statistical Analysis - Development of statistically-based comparison methods that utilize vegetation spectral and structural information to determine well pad vegetation representativeness compared to a reference community.

- Perrson's r correlation coefficient (***r***)
- Analysis of variance (ANOVA) test
- Principal Component Analysis (PCA)
- Kolmogorov-Sminirnov (KS) test

b. Utilized BLM and NRCS Ecological Site Descriptions (ESD) to determine a well pad's reference community to develop vegetation condition assessments.

i. Determining representative ESDs within the study area that will serve as reference vegetation zones that the vegetation community comparison metrics will be based on. This work utilized the USDA-NRCS Soil Survey Geographic database (SSURGO) (Soil Survey Staff 2020) to assess dominant ESDs within the study area. Based on terrain characteristics ESD locations were defined. These locations will be given to the USDA-NRCS field office in the region to determine most representative areas for a given ESD. These areas will be used as the reference community locations for the condition assessment.

2. Preliminary Vegetative Cover Comparison
   a. Developed initial methods to isolate and define areas for analysis (e.g. on-pad, off-pad reference area) from point wellhead locations.
   b. Developed initial vegetation classification model and tested on training data.
   c. Performed ocular validation to assess vegetation classification model accuracy.
   d. Created final tool that defines analysis areas and runs vegetation classification.

3. Vegetative Continuity Comparison
   a. Developed initial model workflow.

4. Other Analytic Tools
   a. Development and testing of infrastructure identification, problematic surface hydrology identification, topographic contouring assessment, and volumetric measurement models were not advanced during this progress period due to time constraints placed on the project by delays in contract execution.

5. Model Automation
   a. Automation, dissemination, process development and validation for all the models have not been completed at this point. This will begin once proof of concept model has been developed and determined that it's operational. Once a model is determined operational then the automation and validation components will be developed for dissemination.

II. Deviations from Proposal

During Quarter 1, there were no significant deviations from the proposed methodology and timeline that will impact project deliverables.

III. Expenditures

The project is funded by the NDIC at $163,200 with $160,910.27 remaining (expense documentation and invoice sent separately). Cost Share (In-Kind) is $167,600 with $167,600 remaining. No cost-share funds have been received as of the date of this report. Total project cost is $330,800 with $328,510.27 remaining.

IV. References

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