A NEW APPROACH TO RECLAMATION ASSESSMENT FOR MINE CLOSURE

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ABSTRACT

Reclamation assessments on mine sites, to determine equivalent land capability and to meet the regulatory requirements, are often reliant on large amounts of data collected throughout the growing season and often over several years. These types of assessments can be demanding of resources for both the consultant and the client. Trace Associates Inc. (Trace) collaborated with a client to develop and implement a Reclamation Assessment Protocol to effectively assess reclamation success using fewer resources, while meeting technical regulatory requirements for approval and closure.

The purpose of the Reclamation Assessment Protocol was to develop specific, measurable targets that could then be applied to reclaimed areas to determine if equivalent land capability had been achieved and reduce the need for intensive sampling across the entire mine site. The protocol was developed using existing sampling methods and criteria already accepted by regulators. These existing methods were then modified to meet the land use of the selected mine site. By basing the protocol methodology on rigorous statistics and key parameters (vegetation and soil depths), the protocol can be applied to various end land uses and ecosites. This paper provides the methods used and presents an assessment protocol that is simple and cost effective to apply and can be used to support both mine closure and reclamation sign-off.

KEY WORDS
Monitoring, key parameters, equivalent land capability, reclamation, mine, protocol

1. INTRODUCTION

Reclamation monitoring and assessments on mine sites are conducted to determine equivalent land capability (ELC), meet regulatory requirements, and evaluate on-going reclamation needs as sites approach closure. A challenge associated with these tasks is determining what ELC is and how to effectively measure it to meet regulatory requirements, while valuing the client's need for a cost-effective, timely approach to reclamation sign-off and closure.

The definition of ELC provided by Alberta Environment and Sustainable Resource Development (ESRD) (2013a) is "…the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical." The challenge lies in how to measure ELC, particularly on mine sites where extensive disturbance has occurred and soil replacement may be irregular. Often, large amounts of data are collected over multiple years and analyzed statistically to prove ELC between reclaimed and undisturbed sites. Such an approach can be resource heavy and the results may not be acceptable to the regulator or meet the requirements of the approval. This paper presents the Reclamation Assessment Protocol (the Protocol), an alternative approach that utilizes specific, measureable targets, developed using existing, scientifically sound methods and criteria that are already accepted by regulators. The Protocol was initially tested at a strip coal mine site in the Dry Mixed grass subregion of Alberta. The total mine area is approximately 7,000 hectares (ha), of which approximately 98 ha was assessed during the initial assessment. This site has an end land use goal of improved pasture (for hay production and/or cattle grazing) and is currently managed by the Special Areas Board as a grazing cooperative. The methods used were developed in cooperation between Trace, the client, the Alberta Energy Regulator (AER), and the Special Areas Board.

2. STATISTICAL METHOD

The Protocol is composed of two assessment types: an upland polygon assessment and a wetland assessment. The assessment approach is based on the premise of "acceptable criteria ranges" for select parameters from historical and/or background data. These ranges were used for comparison of conditions on the mine to determine whether ELC and conditions of the approval have been achieved.

2.1 Stratification

The initial step was to stratify the site into polygons using georeferenced aerial photographs, based on land use, soil moisture (as indicated by tonal differences), visible vegetation, wetlands, and topography. At the test site, reclamation treatments and soil placement (timing, age, and method) were also factored into the stratification process.

Once polygons were developed, they were overlaid on aerial photographs from previous and subsequent years to evaluate changes to site conditions between years, particularly the seasonal differences in surface moisture conditions and vegetation from year to year.

2.2 Statistical Accuracy

To ensure the data collected is statistically significant, the sampling intensity must be determined based on:

- Plot size;
- Key parameters; and
- Statistical analysis.

The number of plots established within the polygon was dependent on the plot size and variability of the key parameters – topsoil depth, subsoil depth, and total percent desirable foliar cover. Plot size was based on a circular plot with a radius of 1.78 metres (10 square metres [m^2]) to reduce the effect of edge.
A 10 m^2 plot represents the most frequent plot size used for sampling grassland vegetation. For a

homogeneous polygon, a minimum of six assessment locations per polygon was required to ensure collected data is statistically significant. In a study by Elzinga et al (1998), it was identified that precision increased with sample size, but not proportionately, and that the statistical benefits of increasing sample size diminished once the number of samples required reached 30. The sharpest diminishment occurred between 2 and 6.

It was recognized that polygons with greater variability may require more than the minimum number of plots to meet the required statistical accuracy. The following calculations were used to ensure that a sufficient number of plots were assessed within all polygons.

<u>Definitions</u>

The following symbols are provided to describe formulae utilized in the determination of the number of plots required per polygon to achieve statistical significance:

n	number of plots assessed or required
µ	population mean
□	standard deviation from the mean
X	individual data values
∑	sum
t	the standard t-table value for the appropriate degrees of freedom and the desired confidence interval (SJSU, 2007)
d	the desired difference between the sample mean and the population (actual) mean
df	degrees of freedom

<u>Accuracy Standards</u>

The aim of the assessment was to achieve the statistical accuracy standards below:

- A confidence interval of 12.5%.
- A confidence level of 95%.
- Key parameters
  - Topsoil depth variance (based on the Block as described in the mine's Approval).
  - Subsoil depth variance (based on the Block as described in the mine's Approval).
  - Percent desirable foliar cover variance of +/-10% of the population mean for a polygon.

<u>Calculating Sampling Intensity</u>

Adequate sample intensity was achieved when a sufficient number of plots were assessed so that the accuracy standards prescribed above achieved 95% confidence, and that the sample mean for soil depth or percent total vegetation foliar cover were within 10% of the true population mean. The minimum number of plots required to achieve the prescribed level of precision was calculated by the sampling intensity formula (Ministry of Forests and Range, 2009) below:

1) Calculate the population mean:

$$\mu = \sum (X / n)$$

2) Calculate the standard deviation of the mean:

$$\square = \sqrt{\sum (X - \mu)^2 / n}$$

3) Calculate the number of plots required to meet statistical accuracy:

$$n = \square^2 t^2 / d^2$$

4) Round up after calculating n to achieve the required accuracy; for example, if n = 9.1, the number of plots required was 10.

The example below (using topsoil depth) illustrates how the sampling intensity was used to determine the required number of plots based on data gathered from a 6 plot sample.

- Number of plots assessed was 6
- Sample population mean is 9.5 centimetres (cm)
- Sample standard deviation of the mean was 1.47
- Goal was the sample mean topsoil depth was to be within +/- 3.0 cm of the actual depth 95% of the time.
- Using the standard t-table 5 df and a 95% confidence level, the value of t = 2.571
- $n = (1.47^2)(2.571^2)/(3.0^2) = 1.59$

In this example, two plots would be sufficient to assess the polygon's topsoil; therefore, the (minimum) six plots sampled provided sufficient data to meet prescribed statistical accuracy. The key to using the calculation successfully was ensuring that the appropriate t-value (based on the desired confidence level) was being used, as the total number of plots may vary between polygons. Choosing one t-value as a proxy will skew the value of n.

2.3 Plot Spacing and Intensity

Plot spacing and intensity was established in the office using calculations (Table 1) and Geographical Information System (GIS). The number of plots was determined using several methods to provide comparisons for the 'Trace Prescribed' number of plots. Assumptions made included:

- Every plot must have a minimum of six plots, based on the information provided in Section 2.2, above.
- A maximum number of plots was calculated based on 1.5 plots/ha.
- Calculations using the ESRD Reforestation Standards of Alberta (2013b) process (a conservative approach) provided an adequate number of plots for establishing a square grid pattern to a selected polygon.
- Calculations using the Ministry of Forests and Range (Ministry of Forests and Range, 2009) guide to assessing rangelands as described in Section 2.2, above, to provide an alternative sampling intensity (where □□□□estimated standard deviation shown in Table 1, t = 2.093, and d = 10).

The grid based on the ESRD process was then overlaid on the polygon and the number of plots, prescribed by Trace, required for statistical accuracy was determined based on the variability of the polygon. Plot numbers were then randomly assigned across the polygon and the coordinates uploaded to a global positioning system (GPS) for use in the field (Figure 1). Both plot locations (prescribed plots) and contingency assessment plots were provided on the map in the event that contingency plots were required.

Table 1. Example Plot Number Calculations Comparing Various Methods Analyzed

		Vegetation			Number of Plots				
Polygon	Polygon Area (ha)	Variability*	Predicted Stocking*	Estimated Standard Deviation	Minimum	Maximum	Calculated based on AESRD (2013b)	Calculated based on MoFR (2009)	Trace Prescribed
1	7.27	15	80	20	6	11	45	18	11
2	9.41	10	85	15	6	14	36	10	10
3	3.18	10	85	15	6	5	36	10	6
5	30.08	5	90	10	6	45	26	5	6
7	3.94	5	90	10	6	6	26	5	6
8	19.58	5	90	10	6	29	26	5	6
9	24.46	10	85	15	6	37	36	10	10
10	9.05	10	85	15	6	14	36	10	10
11	35.61	10	85	15	6	53	36	10	10
Total	**142.58**				**54**	**214**	**303**	**83**	**75**

* By percent cover – open versus closed.

Figure 1. Example of Proposed Plot Locations for a Polygon using the Reclamation Assessment Protocol

3. UPLAND POLYGON ASSESSMENT METHOD

Assessment methodology was chosen based on a review of existing, accepted methods for data collection and evaluation of reclaimed land. The 2010 Reclamation Criteria for Wellsites and Associated Facilities (the Criteria) (ESRD, 2013a) was used to determine parameters and assessment methods appropriate for the evaluation of landscape and soil. Currently, this criteria is the accepted method across Alberta to assess landscape, soil, and vegetation parameters on oil and gas (and related) facilities in the province. As there is currently no stated method for mines, this method is occasionally applied to mines in Alberta. The criteria are an effective tool as they are:

- Science-based.
- Reproducible and testable.
- Provide a practical assessment approach which promotes efficiency and recognizes constraints.
- Provide explicit performance measures.
- Aim to achieve fair results for all stakeholders.

The Criteria is available for Cultivated Lands (includes annual cropland, tame pasture, and agroforestry), Native Grasslands, Forested Lands, and Peatlands. For the purposes of the test site, the Criteria for Cultivated Lands were used.

The Range Health Assessment (Adams et al, 2009) was identified as a benchmark assessment tool for the vegetation assessment parameters and methodology because it is best suited to evaluating ecosystem function, range condition, and quantifying plant community responses to disturbance (e.g., grazing). Many of the parameters measured for vegetation in the Criteria were drawn from the Range Health Assessment parameters; however, the Range Health Assessment also evaluates the parameters as a whole to determine an overall plant / community health score. At the time of the trial, a modified scorecard was developed by combining the Range Health Assessment scoresheet and the Vegetation Inventory Form from the Range Survey Manual for Alberta Rangelands (ASRD, 2007) because the control and reclaimed polygons did not solely consist of native species. The seed mix used by the Special Areas Board is similar to that often used for mine site reclamation and is composed of a mix of tame and native species.

3.1 Landscape Assessment

The landscape assessment for each polygon collected data for the following parameters:

- Drainage
- Erosion
- Site stability
- Bare areas
- Operability
- Debris

3.2 Soil Assessment

The assessed mine site had topsoil and subsoil depth replacement requirements prescribed in its approval based on the Block in which the polygon was located; therefore, replacement depths were measured for both topsoil and subsoil. Collected data was compared to "acceptable ranges" developed based on literature review and/or control/background data. The following parameters were assessed for each soil pit:

- Topsoil depth and distribution
- Subsoil depth
- Topsoil colour
- Soil texture
- Soil consistence
- Soil structure
- Rooting restrictions

3.3 Vegetation Assessment

Informal vegetation assessments will occur over multiple years to determine an "acceptable range' for vegetation health assessment scores and seasonal variability until the vegetation within a polygon is ready for a reclamation certificate assessment. A polygon would be considered ready when the vegetation is self-sustaining, weed free, and is on trajectory to the desired plant community for the intended land use objective. A health score was assigned to each polygon using the following parameters:

- Percent desirable cover
- Species composition
- Plant community structure
- Litter accumulation and function
- Site stability and erosion
- Weed presence and distribution

4. WETLAND ASSESSMENT METHOD

Wetlands were classified during the stratification process using the Stewart and Kantrud Wetland Classification System (Stewart and Kantrud, 1971). Each wetland greater than 0.05 ha that was impacted by cattle at the time of the field assessment was assessed using the Riparian Health Assessment field sheet developed by Cows and Fish (Ambrose et al., 2009). An overall Health Score for each wetland was determined using the following parameters:

- Total vegetation cover
- Noxious weed presence and distribution
- Undesirable herbaceous species

- Presence of woody vegetation
- Use of woody vegetation
- Disturbance-caused physical alteration
- Disturbance-caused bare ground

5. FIELD TRIAL RESULTS

The Protocol was field tested in 2015 to evaluate the effectiveness of the Protocol and determine if any changes to the methodology would be required during practical application. The vegetation assessment method was modified to accommodate the tame pasture that was present at both the reclaimed and control assessment locations.

Table 2 shows the results for topsoil depth, subsoil depth, and total percent desirable foliar cover for two of the assessed polygons. The statistics show that the prescribed number of plots was sufficient to accurately assess the polygons and no contingency plots were required.

Table 2. Example of Statistical Accuracy Standards Based on Key Parameter Data

	Polygon 3 Block #: 1			Polygon 5 Block #: 1		
Plot #	Topsoil Depth (cm)	Subsoil Depth (cm)	Total Percent Desirable Foliar Cover (%)	Topsoil Depth (cm)	Subsoil Depth (cm)	Total Percent Desirable Foliar Cover (%)
1	9	30	70	10	41	50
2	8	33	75	10	33	40
3	8	28	55	9	40	35
4	9	29	70	7	34	35
5	8	28	50	8	38	25
6	8.5	42	70	11	28	40
stdev	0.49	5.39	10.00	1.47	4.93	8.22
μ	8.25	29.50	70.00	9.50	36.00	37.50
n	0.12	2.60	4.38	1.05	2.17	2.96

When comparing the number of plots required for statistical accuracy "n" in Table 2 to the estimated number of plots other methodologies required, as shown in Table 1, the number of plots assessed using the Protocol was greatly reduced from other standard assessment methods - 76% reduction from the ESRD process, and 10% reduction from the Ministry of Forest and Range process - while still providing a statistically accurate data set.

6. SUMMARY

The field trial of the Protocol was considered to be successful at providing an accurate assessment of the landscape, soils, and vegetation on reclaimed areas of the mine. Two of the key findings were:

- The key parameters (topsoil and subsoil depths and total percent desirable foliar cover) utilized in assessing statistical accuracy confirmed the number of plots assessed was sufficient to achieve statistical accuracy.
- Polygon stratification was important to minimize the variability between polygons, thus reducing the number of plots required.

The total number of sampling points was reduced by using a set minimum number of plots, prescribing additional plots when needed based on site variability, and utilizing statistics to support the outcome. This, in turn, reduced the overall costs of the assessment program by using fewer person-hours and less time in the field. Reduced field time also results in fewer disbursement, hotel, and meal costs. By utilizing statistics to develop a site-specific sampling plan, along with data collection methods that are already accepted by regulators, the Protocol can be adapted to a variety of ecosites by simply adjusting the specific data to be collected. By using the Protocol, the client is able to apply for reclamation certification for reclaimed areas of the mine and meet the closure requirements outlined in their approval in a timely and cost-effective manner.

7. CLOSING

This paper is prepared as a part of the presentation with the same name to be given at the annual British Columbia Technical and Research Committee on Reclamation to be held in Penticton, September 19-22, 2016.

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