PRIORITIZING ZONES FOR CARIBOU HABITAT RESTORATION IN THE CANADA'S OIL SANDS INNOVATION ALLIANCE (COSIA) AREA. Version 2.0.

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Prepared for Canada's Oil Sands Innovation Alliance (COSIA)
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Preface

This report represents Version 2.0 of a project designed to prioritize townships for the restoration of caribou habitat in northeast Alberta. The specific study area occurs within the purview of the Canadian Oil Sands Innovation Alliance (COSIA). Version 1.0 was completed in July 2016, but it was recognized at the time that several iterations were needed to incorporate new information and as new ideas were developed. This report (Version 2.0) is intended to be a stand-alone product, but for the full context, Version 1.0 can be used as a reference (ABMI 2016).

Executive Summary

The objective of this project was to prioritize townships for the restoration of caribou habitat in northeast Alberta. The study area included five caribou ranges (Red Earth, Richardson, West Side Athabasca River, East Side Athabasca River, and Cold Lake) that were subdivided into townships for analysis. Townships were classified into five Zones of decreasing priority and the percent of disturbed habitat was tracked as we simulated the restoration of each Zone. In Version 1.0 of this project, two of five caribou ranges achieved the federal target of 35% disturbance[1] once all five Zones were restored (i.e. once all seismic lines were restored[2]). In Version 2.0, four additional analyses were undertaken:

1. Prioritize townships so that rankings occur within *each* caribou range. Version 1.0 was conducted across the entire COSIA project area, without any stratification by caribou range.
2. Calibrate the proportion of disturbed habitat so that disturbance values are based on the same scale as measured by Environment Canada (EC), with and without fire. Disturbance values in Version 1.0 were based on 2012 ABMI human footprint data, which is needed for accurate prioritization, but produces higher disturbance values relative to the federal analysis, which was conducted at a coarser resolution.
3. Include the restoration of semi-permanent footprint in addition to seismic lines, with and without fire. The rationale for this approach is that if a township is slated for restoration based (in part) on the abundance of seismic lines, other footprint types (e.g., well pads, trails, pipelines) may also be restored to take advantage of equipment and personnel.
4. Consider alternate criteria of weighting economic values and habitat values.

By stratifying prioritization within each caribou range, high priority townships were spread evenly across the landscape and across ranges, instead of being concentrated in the northwest part of the study area in the Red Earth range. Stratifying by caribou range is more in-line with federal and provincial criteria of attempting to conserve all caribou ranges, rather than focusing on those that have more caribou and less disturbance.

Calibrating ABMI's Wall-to-Wall human footprint mapping to EC's Landsat imagery revealed that EC significantly and consistently underestimated disturbance. For example, if ABMI estimated disturbance as 65 %, the calibration revealed disturbance decreased to 43, 45, 50, 53, and 46 % for Red Earth,

[1] The federal target of 35% disturbance includes fires up to 40 years old as disturbances.

[2] excluding approved, operating, and applied-for project boundaries from the Government of Alberta's Oil Sands Information Portal

Richardson, West Side Athabasca River, East Side Athabasca River, and Cold Lake, respectively. These results were expected because of variance in the spatial resolution in the datasets, where EC's data uses coarse Landsat imagery that can not accurately discern features that are less than 30-m wide (Environment Canada, 2011). Understanding how ABMI's more accurate and precise human disturbance data relates to EC's is important moving forward, as range planning will look to each province to provide up to date disturbance and demographic data.

By considering the logistical feasibility of restoring all semi-permanent features when restoring townships, four of five caribou ranges met the 35 % disturbance target when Zones 1 through 4 were restored, when not including fire as a disturbance. These values are further improved when disturbances values were calibrated to EC's data; all five ranges met the 35% disturbance threshold when Zones 1 through 3 were restored. These results suggest that a working landscape that maintains both resource industry and caribou is possible. However, the inclusion of fire when calculating percent disturbance reduced the benefit restoration; only the West Side Athabasca River range met the federal target if all semi-permanent features from Zones 1 through 5 were restored and values were calibrated to EC's data. However, many of the larger fires are almost 40 years old so disturbance values will drop naturally within a decade.

In Version 1.0, an inverse weighting was applied to resource valuation, which was multiplied by the gain in undisturbed habitat (GIU). Alternate metrics were considered, but they tended to favour townships with low to no GIU. It was decided that the algorithm used in Version 1.0 would be maintained, because it used an equal weighting for GIU and future economic potential.

These analyses were performed to compliment the Version 1.0 prioritization exercise, and can be used for further optimization of restoration schedules for seismic lines and other semi-permanent human footprint types.

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Introduction

Seismic lines and other linear features created by humans are thought to negatively impact woodland caribou (McKenzie et al. 2012, Apps et al. 2013). It is estimated that there are *c*. 100,000 km of conventional seismic lines in caribou ranges located within the Canada's Oil Sands Innovation Alliance's (COSIA; Fig 1.) area of interest. However, only a fraction of that amount can be restored each year because of high costs, limited equipment and continued access requirements to current and future oil sands projects. Given these constraints, prioritizing which seismic lines are to be restored has been identified as an important planning exercise for the recovery of woodland caribou and their habitat (Environment Canada 2012, Ray 2014). In 2016, COSIA partnered with the Alberta Biodiversity Monitoring Institute (ABMI) to develop a method for prioritizing seismic line restoration (ABMI 2016). The method was based on prioritizing townships within caribou range that maximize gain in undisturbed habitat at a minimal cost. Townships with the highest gain:cost ratio would be the first to be restored, and those with successively lower ratios would be categorized into lower priority. It was recognized that this approach was a first step to focus restoration, and further refinements would be needed. Based in part on recommendations from the first report (hereafter termed Version 1.0), four modifications are addressed in this report (termed Version 2.0). These modifications are:

1) Change the prioritization of townships so that rankings occur within *each* caribou range. Version 1.0 was conducted across the entire COSIA project area (Figure 1), without any stratification by caribou range. This approach resulted in some caribou ranges having a disproportionate amount of highly ranked townships for restoration, whereas other ranges were under-represented. By stratifying rankings within caribou ranges, each range will have an equal proportion of townships represented in each Zone. The original product is valuable for regional planning at a broad scale, but given that caribou will be managed at the range level, and the federal criteria states that all ranges should achieve self-sustaining populations to the extent possible (Environment Canada 2012), it is also appropriate to prioritize restoration within each range.
2) Calibrate the proportion of disturbed habitat so that disturbance values with and without fire are based on the same scale as measured by Environment Canada. The Federal Recovery Strategy has recommended a maximum amount of disturbance to occur within caribou ranges (35%), but these analyses were based on 1:50,000 Landsat images. In Alberta, disturbance is tracked at a finer resolution, based on data compiled by ABMI. The end result is that disturbance values based on ABMI data layers are higher than what was used by Environment Canada. With this step, values calculated from 2012 ABMI Wall-to-Wall Human Footprint maps can be more directly related to the federal target.
3) Include the restoration of semi-permanent features in addition to seismic lines with and without fires. In practice, when a township is slated for restoration based on the amount of seismic lines, many other types of human footprint can, and will, be restored (Michael Cody, Cenovus Inc., Personal Communication). These additional features include well sites, trails, transmission lines, pipelines, gravel roads and borrow pits. As well, options exist to facilitate the recovery of forestry cutblocks. None of these features were considered for restoration in Version 1.0.
4) Consider alternate criteria of weighting economic values and habitat values. In Version 1.0, economic values were measured using a Resource Valuation layer (RVL) that estimated the potential recoverable reserve of oil sands and conventional oil and gas resources. Habitat values were measured using gains in undisturbed (GIU) habitat by restoring seismic lines. The two were

combined by multiplying the inverse of the RVL by the GIU-per-cost metric. In Version 2.0, we were tasked with considering alternate methods of weighting the two values and comparing outcomes.

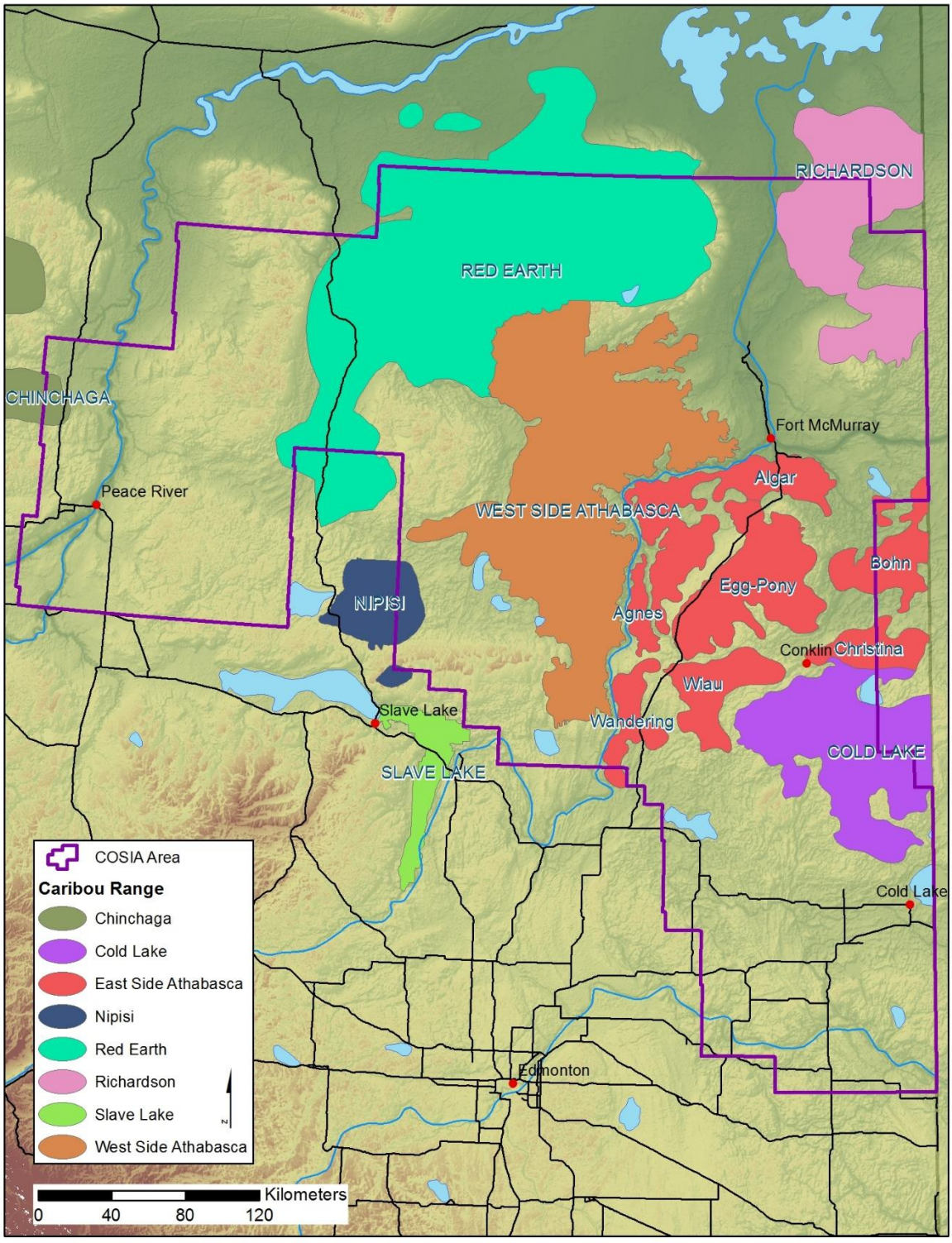


Figure 1. The COSIA area of interest for development of priority restoration Zones, showing the COSIA boundary (purple polygon) and caribou ranges considered for analyses (those with > 75 % inside the area of interest; does not include Slave Lake, Nipisi, or Chinchaga ranges, or the two isolated segments of the Red Earth range to the northwest).

Prioritize townships within each caribou range

To prioritize areas for restoration in Version 1.0, each township was ranked based on dividing the gain in undisturbed (GIU) habitat (i.e. the "bang") by the density of seismic lines in each township (the cost, or "buck"). This GIU-for-Cost value was then discounted by the economic value of that township (ABMI 2016). In Version 1.0, an equal number of townships were placed into restoration Zones labelled 1 through 5, with 1 being the highest priority Zone for restoration, and 5 being the lowest. Zones were split based on cutpoints, and values for the cutpoints were based on the GIU-for-Cost metric. Cutpoints and corresponding Zones were calculated across the entire COSIA area. This approach provided a broad-scale prioritization system, allowing the identification of areas within the COSIA area that provide the highest bang-for-buck. However, because caribou will be managed by each range and habitat disturbance will be evaluated for each range, it is also appropriate to prioritize areas independently within each range.

Methods

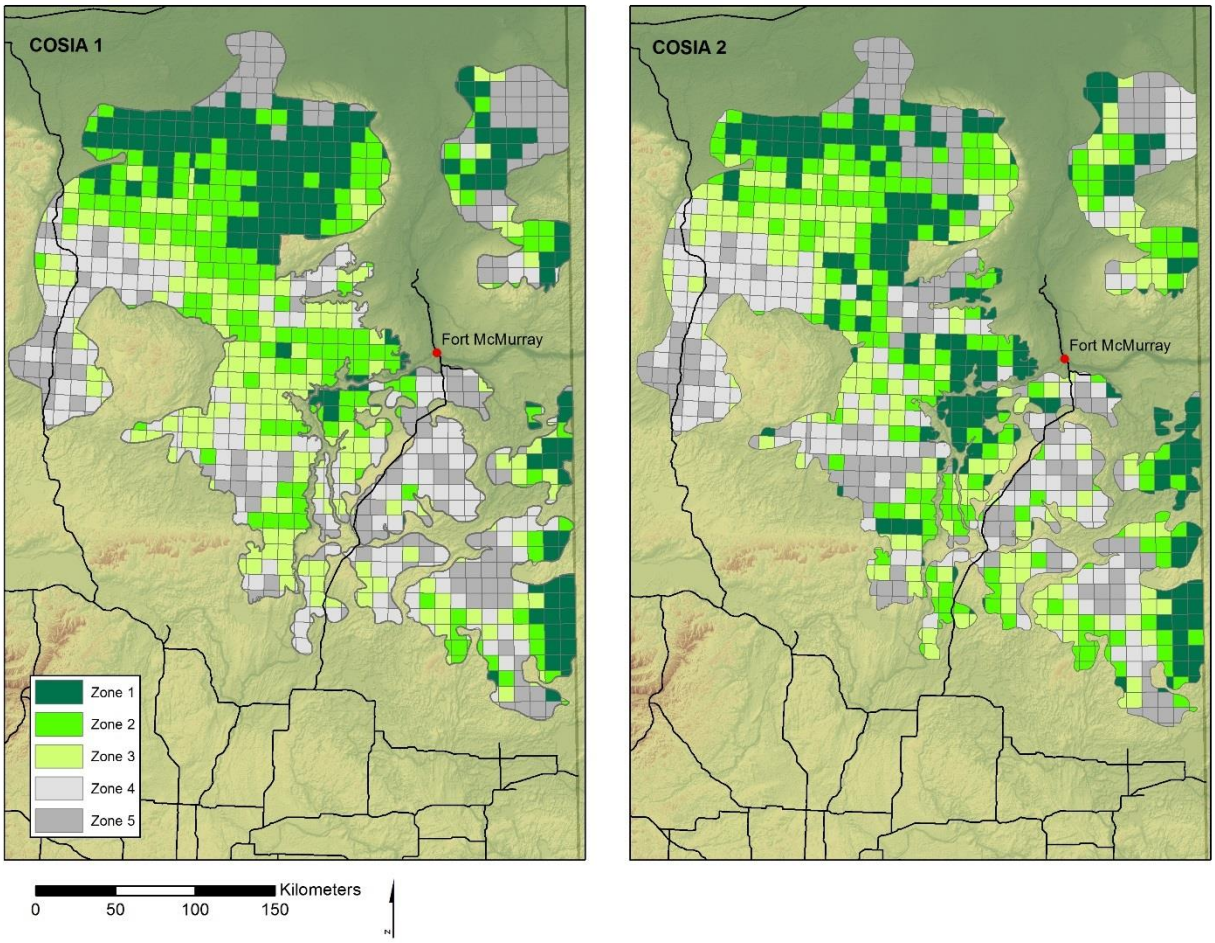
In Version 2.0, a unique cutpoint had to be calculated for each caribou range, so that each range contained approximately the same proportion of townships in Zones 1 through 5. In addition, we used the updated 2015 OSIP boundaries with the status applied, announced, approved and operating, and buffered those boundaries by 500 m.

Results and discussion

By stratifying rankings within caribou ranges, higher priority Zones (e.g. Zones 1 & 2) are no longer concentrated in Red Earth, but are more evenly distributed across all 5 caribou ranges (Figure 2). The biggest redistribution of higher priority Zones occurred from Red Earth to West Side Athabasca River (WSAR), and to the Algar herd within East Side Athabasca River range (ESAR; Figure 2). Rankings within the Cold Lake range and Christina herd did not change substantially because GIU-for-Cost values were high enough to maintain their priority, regardless of whether the regional or range-based rankings were considered.

The regional vs. range-based rankings necessarily produced different results, yet how this information is used will depend on the management context. For example, Schneider et al. (2010) and Hebblewhite (2017) argue for a triage approach to caribou recovery, where decisions must be made whether to recover caribou populations that have little chance of becoming sustainable and consume a disproportionate amount of conservation resources. In contrast, the Federal Recovery Strategy states that all boreal ranges are to be recovered where feasible (Environment Canada 2012), so the regional perspective and the triage philosophy are less relevant.

Version 2.0 does not consider areas inside the Oil Sands Information Portal's (OSIP) applied, announced, approved, and operating project boundaries available for restoration. These areas are assumed to be operational in the near future and are delegated to low priority for restoration. However, in some cases only a portion of the township overlaps with OSIP boundaries. Therefore, some portion of the township is still available for restoration and can still be classified as high priority for restoration.



(a) (b)

Figure 2. Townships ranked by priority Zone by (a) the regional approach (Version 1.0), and (b) and the by-range priority zonation. Zonation is determined by combining the GIU-for-Cost and the economic value of each townships (ABMI 2016).

Calibrating disturbance

Comparing various human footprint assessments requires similar methods over similar time frames. Therefore, to evaluate how restoration prioritization performs against the Federal Recovery Strategy's identified threshold of under 35% disturbed[3] habitat, data used for the COSIA analyses must be comparable to those used within the Federal Recovery Strategy (Environment Canada, 2011, 2012). While ABMI sets a standard for fine-resolution human footprint mapping across Alberta by using 2.5-m SPOT imagery[4], this resolution is not available across all of Canada. Instead, the data used for the Federal Recovery Strategy had to be comparable across the country, and therefore relied on coarse-

[3] The federal target of 35% disturbance includes fires up to 40 years old as disturbances. In this report, we report the percent disturbance with and without the inclusion of fires

[4] ABMI Human Footprint Inventory for 2012 conditions (Version 3) metadata. 2012. Alberta Biodiversity Monitoring Institute. Retrieved from http://www.abmi.ca.

resolution satellite imagery; 30-m Landsat imagery. Features that are less than 30 m wide are often missed by interpretation of Landsat imagery, therefore underestimating linear features by 60% (Environment Canada, 2011).

In addition to the spatial miss-match, temporal inconsistencies between data used for mapping can lead to differences in footprint quantification. Environment Canada (EC)'s recruitment analyses were conducted using data collected from various years to match caribou demographic data (ranging from 2002 to 2010 for Alberta, 1993 to 2010 nationally; Environment Canada 2011), but were updated to 2008 to 2010 Landsat imagery. Conversely, ABMI mapped disturbances using data collected in 2012. Comparing footprint maps that match in both time and space is ideal, and will be explored in future analyses using EC's updated mapping once it becomes available.

Methods

Disturbances used by the Federal Recovery Strategy were obtained from Environment Canada (Environment Canada, 2011); one dataset included only anthropogenic disturbances (all human footprint identifiable at a 1:50 000 scale using Landsat imagery) and one dataset included fires in addition to human footprint. Environment Canada's human disturbance data were collected at coarser scales than the ABMI data; EC used 30 m Landsat pixels from various years to match caribou demographic data (Environment Canada, 2011), whereas ABMI's data were collected using fine-scale SPOT imagery updated to 2015. Additionally, EC's fire data included fires less than 40 years old as of 2010 whereas ABMI's data were updated to fires less than 40 years old as of 2014. The percent human disturbance was calculated for each township within each range both including and excluding fires.

To calibrate ABMI's 2012 disturbance calculations, we regressed EC's 2011 percent human disturbance against the percent disturbance calculated using ABMI's data for each range and a simple linear model. Two models were created for each range: 1) EC's percent disturbance was regressed against ABMI's percent disturbance and 2) EC's percent disturbance including fires was regressed against ABMI's percent disturbance including fires. The resulting mathematical equations describing the relationship between EC and ABMI's disturbances were then used to calculate the percent disturbance expected using EC's data for Table 4 in Version 1.0 (ABMI 2016; Table 1), and any values of percent disturbance presented within this report.

Results and discussion

EC percent disturbance was highly correlated with ABMI's percent disturbance without fire (Table 2, Figure 3) and with fire (Table 2, Figure 4). EC significantly under-estimated human disturbance cover compared to ABMI for all ranges by 11 to 23 % when fires were not included as well as when fires were included. For all future analyses, we report on ABMI human disturbance values and the calibrated EC human disturbance value, so as to compare to the federal targets using 2011 EC data.

Table 1. The total human disturbance by caribou range calculated using ABMI's 2012 Wall-to-Wall Human Footprint mapping and the calibrated 2011 EC data. Areas overlapped by 2015 OSIP boundaries (applied, approved, announced and operating) are considered disturbed.

Range	TOTAL % disturbed (current)		
	ABMI[5]	Calibrated (EC 2011)	Difference
RED EARTH	71.8	47.9	23.9
RICHARDSON	36.1	22.6	13.5
WSAR	84.6	68.3	16.3
ESAR	87.5	76.6	10.9
COLD LAKE	84.6	70.9	13.7

Table 2. The relationship between EC's 2011 disturbance and ABMI's 2012 disturbance for each caribou range, with and without fire. Model coefficients, standard error, and P-values are shown for simple linear regressions between EC and ABMI's disturbance data for each caribou range.

Range	Variable	Human Footprint			Human Footprint and Fire		
		Coefficient	SE	P	Coefficient	SE	P
Richardson	Intercept	-5.394	2.463	0.031	-44.998	10.111	< 0.001
	ABMI % Disturbance	0.775	0.047	< 0.001	1.392	0.109	< 0.001
Cold Lake	Intercept	-35.209	5.172	< 0.001	0.233	7.657	0.976
	ABMI % Disturbance	1.255	0.060	< 0.001	0.926	0.084	< 0.001
ESAR	Intercept	-14.106	3.124	< 0.001	-13.163	3.054	< 0.001
	ABMI % Disturbance	1.037	0.035	< 0.001	1.059	0.034	< 0.001
WSAR	Intercept	-10.006	3.590	0.006	-9.128	3.689	0.014
	ABMI % Disturbance	0.925	0.043	< 0.001	0.922	0.044	< 0.001
Red Earth	Intercept	-7.578	2.212	0.001	1.887	3.867	0.626
	ABMI % Disturbance	0.773	0.029	< 0.001	0.762	0.046	< 0.001

[5] ABMI disturbance values in Version 2.0 are different than values reported on in Version 1.0 because Version 2.0 used the more recent 2015 OSIP boundaries.

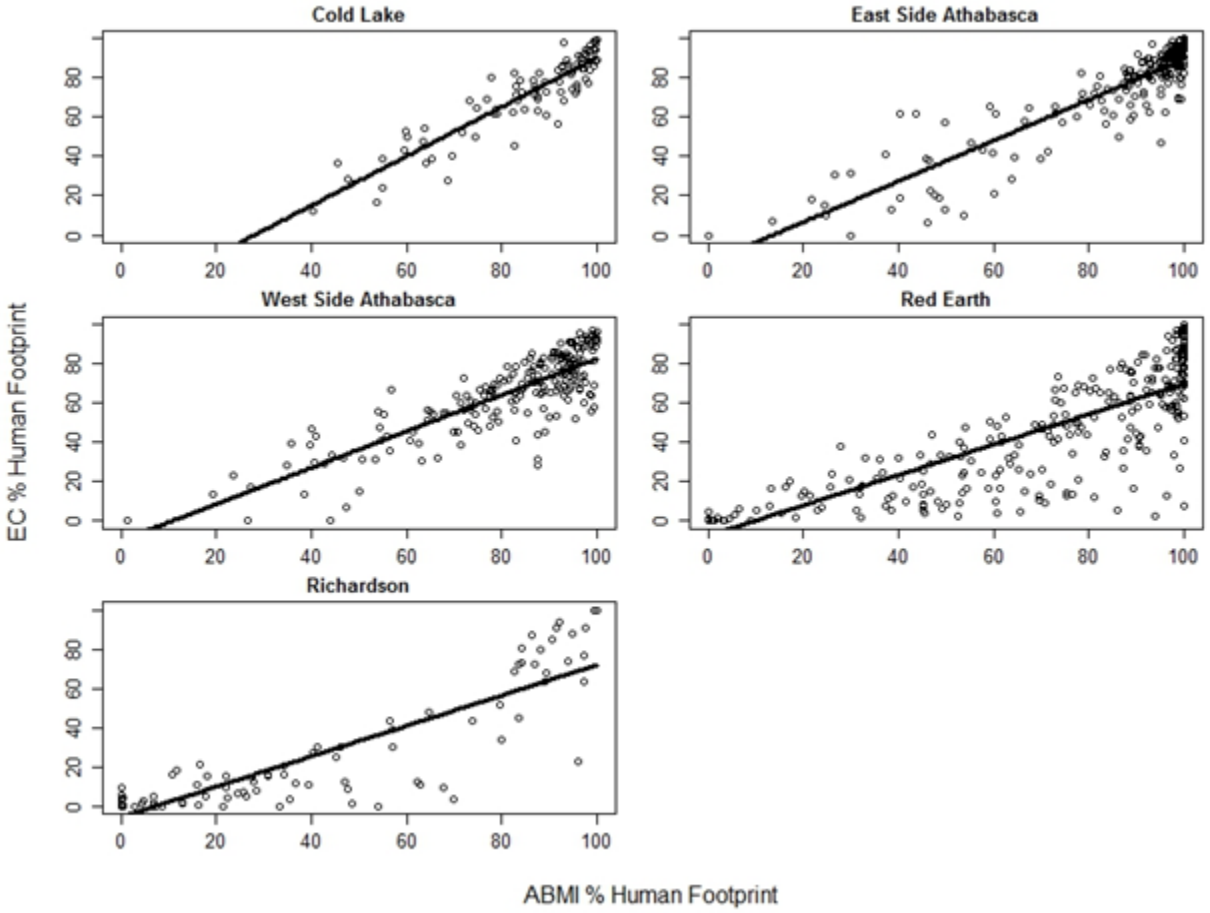


Figure 3. Environment Canada percent (%) human footprint (buffered by 500 m; 2011) as a function of ABMI percent (%) human footprint (buffered by 500 m; 2012). Each point represents a township within each range, and the solid line represents the modelled relationship.

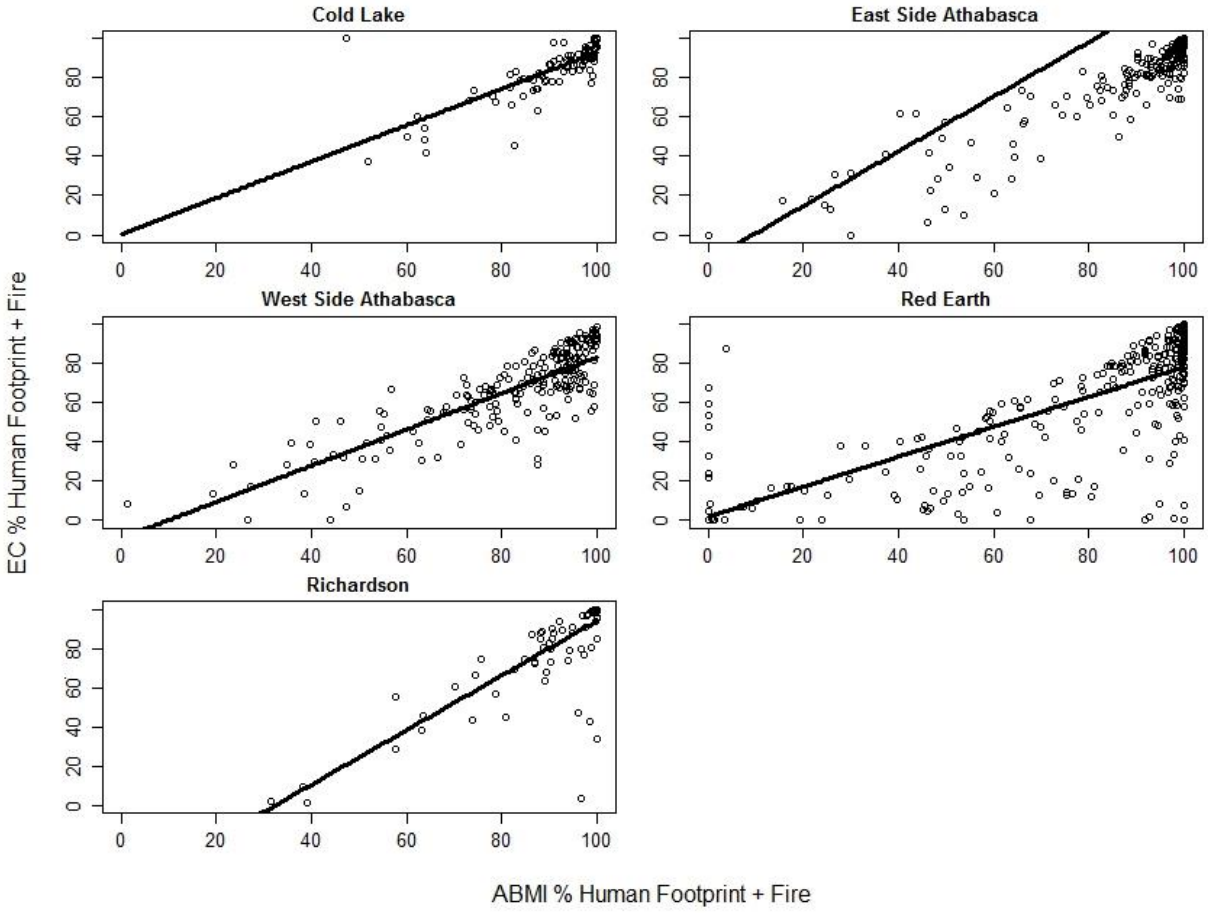


Figure 4. Environment Canada percent (%) human footprint (buffered by 500 m; 2011) with fire (less than 40 years as of 2010) as a function of ABMI percent (%) human footprint (buffered by 500 m; 2012) with fire (less than 40 years as of 2014). Each point represents a township within each range, and the solid line represents the modelled relationship.

Restoring semi-permanent features

While Version 1.0 simulated the recovery of only conventional seismic lines, in Version 2.0 we consider additional types of human footprint to restore. If a township is slated for restoration based (in part) on seismic line density, then it makes sense to take advantage of the equipment and personnel that have been mobilized to restore additional types of footprint that would typically be restored at a project's "end-of-life" (e.g., well-pads, pipelines). The types of footprint that would be restored at "end-of-life" are sometimes referred to as "semi-permanent". The ABMI 2012 Wall-to-Wall Human Footprint inventory used for this project identified 20 different types of human footprint within the study area. We grouped the disturbance classes into 10 categories based on their abundance, similarities (for example roads and their vegetated verges) and potential to be restored (Table 3).

Methods

As a first step to restoring additional footprint, we conducted a sensitivity analysis on each of the 10 categories, one at a time, to determine which had the greatest effect on gaining undisturbed habitat. We then restored footprint types numbered 1 through 7 (Table 3), because those were deemed to be semi-permanent and therefore reasonable candidates for restoration (Michael Cody, personal communication). Footprint types 8 to 10 (major roads, etc.) were considered permanent and therefore not suitable for restoration. Restoration priority zones were created using seismic line density only (i.e., the same cutpoints were used as the regional analysis), but percent disturbance remaining was calculated using all semi-permanent features. This enables restoration to still be prioritized by seismic line density (as seismic lines have the largest impact on total disturbance), while understanding the effect of restoring all semi-permanent disturbance types.

We calculated the percent disturbance in each range as Zones 1 through 5 were restored in succession following the methods of Version 1.0. However, we prioritized townships within *each* caribou range separately, and updated data to the 2015 OSIP boundaries (applied, announced, approved and operating; buffered by 500 m) and 2016 fire data (from 1977-2016) as described above. Percent disturbance was calculated with and without fire, and calibrated to EC's 2011 data.

Table 3. Human footprint types and their percent cover within the COSIA area of interest. A sensitivity analysis was completed using each of the 10 categories independently. Additionally, categories 1 through 7 were considered semi-permanent feature types that would be restored under this scenario. See Appendix A for definition of human footprint feature types.

Disturbance Type	Percent Cover	Area Cover (ha)	Category
Seismic line	0.83	55568	1
Cutblocks	1.46	97808	2
Road/Trail (Vegetated)	0.06	4293	3
Well Site	0.36	24245	4
Pipeline	0.38	25532	5
Transmission Line	0.03	2260	6
Borrow-Pits/Dugouts/Sumps	0.02	1100	7
Industrial Site Rural	0.11	7262	7
Road – Hard Surface	0.04	2736	8
Road – Vegetated Verge	0.07	4722	8
Mine Site	0.02	1521	9
Other Disturbed Vegetation	0.01	837	9
Peat Mine	0.02	1148	9
Cultivation (Crop/Pasture/Bare Ground)	0.01	944	10
High Density Livestock Operation	0.00	1	10
Municipal (Water and Sewage)	0.00	70	10
Rail – Hard Surface	0.00	82	10
Rail – Vegetated Verge	0.00	115	10
Reservoirs	0.00	52	10

Rural (Residential/Industrial)	0.01	687	10
Urban	0.00	92	10

Results and Discussion

Table 4 shows the effect of each footprint type on the percent disturbed. Predictably, seismic lines are by far the greatest factor affecting the amount of disturbed habitat. Restoring other footprint types, without addressing seismic lines, has little measurable effect on the % disturbed.

Table 4. Percent disturbance remaining within each caribou range as each disturbance type is removed independently from other disturbance types, excluding fire. Total current disturbance is included for reference, excluding fire.

Disturbance Type	% Disturbed				
	COLK	ESAR	Red Earth	Richardson	WSAR
Current Disturbance	84.6	87.5	71.8	36.1	84.6
Seismic	56.3	59.2	28.1	22.2	46.7
Cutblocks	84.5	86.3	71.6	36.1	84.2
Trails	83.7	86.1	67.5	35.3	84
Well Pads	84.3	87.3	71.8	35.2	84
Pipelines	82.7	86.7	71.7	36.1	83.4
Transmission Lines	84.6	87.5	71.8	36.1	84.6
Industrial Sites	84.6	87.5	71.8	36.1	84.6
Roads	84.6	87.5	71.8	36	84.6
Mine and Other Disturbed	84.6	87.5	71.8	36.1	84.6
Cultivation Reservoirs Railways and Urban	84.6	87.5	71.8	36.1	84.6

However, by restoring all semi-permanent footprint types (i.e. types 1 through 7) simultaneously, substantial improvements can be made over restoring only seismic lines. Tables 5 and 7 show the percent disturbance by range with and without semi-permanent footprint types, and with and without fires, as Zones 1 through 5 are restored; calibrated values are also shown. A similar comparison is shown graphically in Figure 5. In addition, Table 6 shows the km of seismic lines required to be restored within each Zone and the cumulative km of seismic lines as restoration progresses through Zones.

Disturbance excluding fire

The different level of disturbance achieved between restoring individual footprint types (Table 4) vs. restoring all semi-permanent footprint (Table 7; Figure 5) is primarily caused by the 500-m buffer on seismic lines overlapping with other footprint types. Restoring other features such as well pads and pipelines produces little GIU unless seismic lines are also restored. For the WSAR, ESAR, and Cold Lake ranges, restoring seismic lines for Zones 1 through 4 means that the % disturbed values would be 49, 61 and 57 (Table 5), but those values would decrease to 29, 34 and 36 respectively, if all semi-permanent features were restored in those Zones (Table 7). This means that restoring semi-permanent features

along with seismic lines would result in all 5 caribou ranges meeting the federal target[6] by restoring Zones 1 through 5, and all but one range by restoring Zones 1 through 4. Even more notably, restoring all semi-permanent features results in all 5 caribou ranges meeting the federal target by only restoring Zones 1 through 3, *if calibrated disturbance values are used* (Figure 5). These findings contrast with Version 1.0, where even if Zones 1 through 5 were completely restored, only 2 of 5 ranges (Red Earth and Richardson) would meet the federal target. Nonetheless, this will require substantial effort, because not only will seismic lines have to be restored, but so will all other footprint types considered as semi-permanent (i.e. labeled 1 through 7 in Table 3).

When progressing from higher to lower priority Zones, the difference between restoring seismic lines only vs. additional disturbance types (1 through 7), grows. For example, restoring Zone 1 of seismic only (Table 5) is similar to restoring Zone 1 of all features (Table 7). However, as lower priority Zones are restored, such as Zones 1 through 4, the difference becomes much higher, diverging up to 27%. High priority Zones, areas characterized by high seismic line density but high GIU-for-Cost, intuitively have high Gain-In-Undisturbed habitat after seismic lines are removed because they do not have substantial coverage of other human disturbance types. Areas lower in priority are characterized by low GIU-for-Cost because of the presence of other disturbance features such as pipelines and wellpads that are correlated with areas of higher resource value and commercial *in-situ* development. Therefore, as we start restoring areas that have seismic lines and semi-permanent human disturbance, there is only a gain in undisturbed habitat when all disturbance feature types are restored.

Disturbance including fire

The inclusion of fire reduces the overall benefit that restoring seismic and other semi-permanent features can have on the percent disturbed for each range. When including fire as a disturbance, and restoring only seismic lines, no ranges meet the threshold *even if values are calibrated* (Table 5). If all semi-permanent features were restored in all 5 Zones, leaving only fire disturbances, one of five ranges meets the federal target *if calibrated disturbance values are used* (WSAR; Table 7). The Red Earth, ESAR, Richardson and Cold Lake ranges will not reach the target even if all semi-permanent features are restored *and if values are calibrated*. However, Red Earth and ESAR are within 4 % of the target, and 18 % of the Cold Lake range is covered by fires from 1977-1986 and will be considered below the threshold within 10 years as these burned areas continue to age. Conversely, much of the Richardson range is covered by a fire from 2011 (the “Richardson” fire). Given the 50 to 100-year timeline set out for caribou range plans, and the use of a 40-year time lag to recovery following fire, all of the fire disturbance that is currently delineated on the landscape will be considered recovered when thresholds are due for evaluation. A certain degree of fire disturbance must be expected on the future landscape, and it may be most appropriate to model scenarios with predictions of future fire disturbance (e.g. 15 to 30 %). How fires, and the various characteristics of fires such as intensity, modify vegetation regrowth on seismic lines is currently unknown. It is therefore possible that the fire in 2011 re-set the successional trajectory of seismic lines and other disturbances similar to those of surrounding non-human disturbed habitat.

[6] The federal target of 35% disturbance includes fires up to 40 years old as disturbances.

Table 5. The effect of restoring seismic lines on the % disturbance (excluding and including fire) as restoration progresses from Zone 1 through 5. Each caribou range has a different set of cutpoints such that there are an equal number of townships in each of the 5 Zones within each caribou range.

Range	TOTAL % disturbed (current)		Zone 1 Restored		Zones 1 and 2 Restored		Zones 1 through 3 Restored		Zones 1 through 4 Restored		Zones 1 through 5 Restored	
			% remaining disturbed		% remaining disturbed		% remaining disturbed		% remaining disturbed		% remaining disturbed	
	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)
Excluding Fire												
RED EARTH	71.8	47.9	64.4	42.2	53.2	33.6	39.9	23.3	29.7	15.4	28.1	14.1
RICHARDSON	36.1	22.6	33.8	20.8	27.5	15.9	22.9	12.4	22.1	11.7	22.1	11.7
WSAR	84.6	68.3	76.2	60.5	66.7	51.7	56.4	42.2	49.4	35.7	46.6	33.1
ESAR	87.5	76.6	80.0	68.9	71.5	60.0	65.0	53.3	60.8	49.0	59.0	47.1
COLD LAKE	84.6	70.9	75.5	59.5	66.7	48.5	60.0	40.1	56.9	36.2	56.1	35.2
Including Fire												
RED EARTH	83.2	65.3	78.8	62.0	73.8	58.1	66.3	52.4	57.9	46.0	56.6	45.0
RICHARDSON	90.8	81.4	89.8	80.0	88.2	77.7	85.2	73.6	84.4	72.5	84.4	72.5
WSAR	86.1	70.3	78.7	63.4	70.2	55.6	60.0	46.2	53.3	40.0	50.7	37.6
ESAR	89.8	81.9	83.5	75.3	77.1	68.5	73.4	64.6	70.9	61.9	70.0	61.0
COLD LAKE	92.7	86.1	88.3	82.0	82.3	76.5	77.7	72.2	75.6	70.3	74.8	69.5

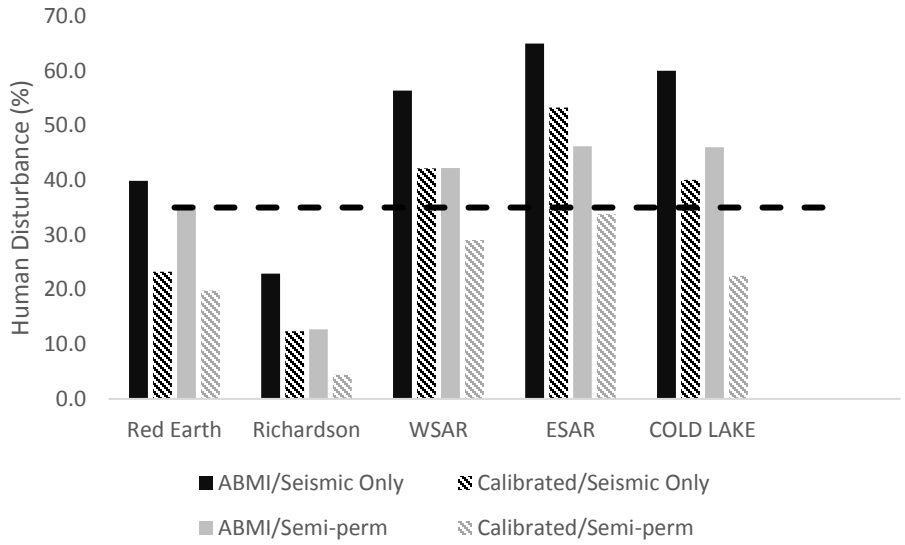
Table 6. The km of seismic lines required to be restored within each Zone, and the cumulative km of seismic lines required to be restored as restoration progresses from Zone 1 through 5. Each caribou range has a different set of cutpoints such that there are an equal number of townships in each of the 5 Zones within each caribou range.

Range	TOTAL % disturbed (current)		Zone 1 Restored		Zones 1 and 2 Restored		Zones 1 through 3 Restored		Zones 1 through 4 Restored		Zones 1 through 5 Restored	
	ABMI	Calibrated (EC 2011)	km seismic	cumulative km seismic	km seismic	cumulative km seismic	km seismic	cumulative km seismic	km seismic	cumulative km seismic	km seismic	cumulative km seismic
RED EARTH	71.8	47.9	2238	2238	4850	7088	8848	15936	16752	32688	9424	42112
RICHARDSON	36.1	22.6	151	151	783	934	1216	2150	893	3043	2	3045
WSAR	84.6	68.3	2399	2399	3484	5883	4773	10656	4498	15154	3336	18490
ESAR	87.5	76.6	1468	1468	3771	5239	4149	9388	3973	13361	4304	17665
COLD LAKE	84.6	70.9	788	788	1221	2009	1487	3496	983	4479	481	4960
Total			7044	7044	14109	21153	20473	41626	27099	68725	17547	86272

Table 7. The effect of restoring seismic lines and all semi-permanent footprint on the % disturbance (excluding and including fire) as restoration progresses from Zone 1 through 5. Each caribou range has a different set of cutpoints such that there are an equal number of townships in each of the 5 Zones within each caribou range.

Excluding Fire												
Range	TOTAL % disturbed (current)		Zone 1 Restored		Zones 1 and 2 Restored		Zones 1 through 3 Restored		Zones 1 through 4 Restored		Zones 1 through 5 Restored	
			% remaining disturbed		% remaining disturbed		% remaining disturbed		% remaining disturbed		% remaining disturbed	
	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)	ABMI	Calibrated (EC 2011)
RED EARTH	71.8	47.9	64.2	42.1	52.0	32.6	35.4	19.8	17.4	5.9	12.3	1.9
RICHARDSON	36.1	22.6	32.8	20.0	23.7	13.0	12.7	4.4	6.7	0.0	5.1	0.0
WSAR	84.6	68.3	73.3	57.8	58.8	44.4	42.2	29.0	28.9	16.7	19.7	8.2
ESAR	87.5	76.6	76.7	65.4	61.6	49.8	46.2	33.8	34.1	21.3	26.2	13.1
COLD LAKE	84.6	70.9	74.0	57.6	60.5	40.7	46.0	22.5	35.8	9.7	32.7	5.8
Including Fire												
RED EARTH	83.2	65.3	78.7	61.9	73.2	57.7	63.6	50.4	48.6	38.9	44.4	35.7
RICHARDSON	90.8	81.4	89.8	80.0	87.6	76.9	81.1	67.9	76.4	61.3	76.4	61.3
WSAR	86.1	70.3	76.1	61.1	62.8	48.8	46.5	33.8	33.7	21.9	25.0	13.9
ESAR	89.8	81.9	80.8	72.4	69.6	60.5	60.5	50.9	53.1	43.1	49.2	38.9
COLD LAKE	92.7	86.1	87.6	81.4	78.5	72.9	68.5	63.7	61.2	56.9	58.2	54.1

(a)



(b)

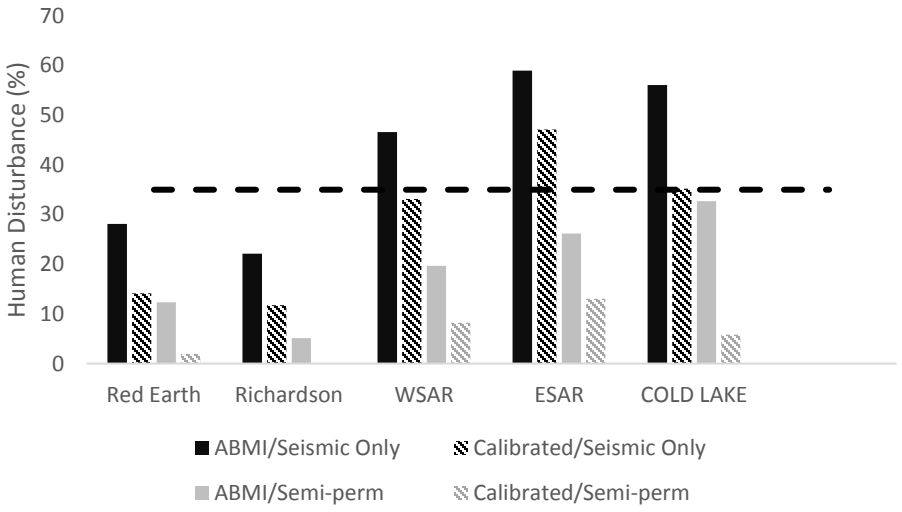


Figure 5. The remaining % disturbed after restoring (a) Zones 1 through 3 and (b) Zones 1 through 5, of seismic lines only and seismic lines plus all other semi-permanent human footprint types, with both ABMI 2012 disturbance data and the EC 2011 calibrated disturbance data. The black dashed line is the 35% disturbance threshold identified in the Federal Recovery Strategy.

Weighting economic and habitat value

Incorporating the economic value for habitat restoration is intended to support a working landscape, where restoration is directed away from areas with high resource value and increased potential for

future industrial development. In Version 1.0, economic value was estimated in each township by the Canadian Association of Petroleum Producers (CAPP), and was a measurement of the potential recoverable reserve of oil sands and conventional oil and gas resources. These data, summarized in the Resource Valuation Layer (RVL), were combined with habitat values by multiplying the inverse of the normalized RVL by GUI-by-Cost for each township (ABMI 2016). However, we were tasked with exploring alternative weighting options to ensure RVL and improvement to caribou habitat were equally weighted.

Methods

To ensure this approach equally-weights both RVL and habitat values, we re-assessed the methods used in Version 1.0 and explored alternative approaches for further optimization of the RVL. Specifically, we investigated two alternatives:

1. Combined ranking system for RVL and GIU-for-Cost, where townships were independently ranked based on RVL values (highest rank = lowest RVL value and lowest rank = highest RVL value) and GIU-for-Cost values (highest rank = highest GIU-for-Cost value and lowest rank = lowest GIU-for-Cost value). These two rankings were then multiplied, creating a unique ranking for each township based equally on RVL ranking and GIU-for-Cost ranking.

2. Normalizing GIU-for-Cost values as well as the RVL, by using this equation:

Normalized GIU-for-Cost = GIU-for-Cost/GIU-for-Cost $_{max}$, and multiplying this new value for each township by the normalized RVL.

Results and Discussion

Although the combined ranking system further decreased priority of townships with moderate-to-high RVL, it also redistributed some of the high priority townships to areas with zero Gain-in-Undisturbed habitat. Though this method reduces the chance of restoration taking place in areas with high RVL, it also guides restoration to areas with presumably little benefit to caribou (i.e., zero GIU).

When GIU-for-Cost values were normalized, townships were no longer equally-weighted by habitat and economic values. Instead, some townships were disproportionately weighted by habitat depending on the GIU-for-Cost value. For example, even townships with a high RVL were typically increased in priority by up to 4 Zones, discounting the weighting of its economic value.

After re-assessing the original methods from Version 1.0, it was determined to be the most appropriate, because that equal weighting is given to RVL and GIU-for-Cost, while normalizing the high variability in RVL values (from $0 to $16814 MM CDN). As intended, the original approach modifies the priority of a township based on its economic value, and directs restoration toward other areas with low RVL.

It should be noted that the RVL data layer developed by CAPP was generated based on publicly available data that is up to 12 years out of date, and companies operating within the COSIA area of interest may have higher-quality or more current resource information within their individual project boundaries.

Limitations

Data currency

GIS data will always be out of date, but is it important to highlight significant updates in digital basemaps that occurred part way through the completion of this project. ABMI 2014 Wall-to-Wall human footprint data became available in January of 2017. These data need to be included early in the GIS process, which was not feasible within the current workplan. These data will be included in subsequent iterations.

Resource Valuation Layer (RVL)

The RVL is not intended to present the amenability to protection of habitat from resource development in townships/areas with lower valuation. In addition, that restoration, within the working landscape context, does not imply sterilization of access to resources. The RVL base data (AER ST-98) is between 5 and 12 years out of date and informed by well data only. Data presents an average value of the entire township.

Future anthropogenic disturbance (non-energy)

Future petroleum and natural gas development and yet to be announced oil sands projects are not considered in this analysis.

Liability for reclamation and restoration

Dispositions for use of public land are issued by the Government of Alberta, whether in the form of formal dispositions, authorizations or approvals, and these dispositions set out specific requirements for closure. In many cases dispositions have met closure requirements yet remain apparent as 'disturbance' on the landscape as defined in the Recovery Strategy for Woodland Caribou (Environment Canada 2012). Assessment and prioritization of features on the landscape for restoration does not imply that liability for restoration, which differs from reclamation, lies with the current or former disposition holder.

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Appendix A Definitions of ABMI human footprint feature-types

Human Footprint Type	Definition	Considered Permanent (P) or Semi-permanent (SP)
Seismic line	Area where vegetation is disturbed due to identified seismic line	SP
Cut Blocks	Area with trees harvested for industrial purposes	SP
Road/Trail (Vegetated)	Road/trail without gravel or pavement	SP
Well Site	Well pads created by the energy industry	SP
Pipeline	Area where vegetation is disturbed due to identified pipeline	SP
Transmission Line	Area where vegetation is disturbed due to identified transmission line	SP
Borrow-Pits/Dugouts/Sumps	Features created to extract fill, or for livestock watering	SP
Industrial Site Rural	Rural area developed for industrial use	SP
Road – Hard Surface	Paved or gravel road	P
Road – Vegetated Verge	Vegetated strips along paved or gravel roads	P
Mine Site	Area where vegetation is disturbed due to identified mining activities	P
Other Disturbed Vegetation	Recreation areas and other vegetated areas created for human use, including golf courses, grave yards, vegetated edges of airports, and any other disturbed areas that have recovered vegetation	P
Peat Mine	Area where vegetation is disturbed due to identified peat mining activities	P
Cultivation (Crop/Pasture/Bare Ground)	Any area where evidence of cultivation is visible during the photo interpretation	P
High Density Livestock Operation	Confined feeding operation and other high density livestock area	P
Municipal (Water and Sewage)	Features identified as created for municipal purposes	P
Rail – Hard Surface	Main part of railway, typically gravel	P
Rail – Vegetated Verge	Vegetated strips along railways	P
Reservoirs	Man-made lakes	P
Rural (Residential/Industrial)	Small rural development (mostly residential but some industrial features)	P
Urban	Cities and towns	P