APPENDIX 16-C

Wildlife Habitat Modelling Reports

APPENDIX 16-C-1

Fortymile Caribou Herd Resource Selection Function Model

A Resource Selection Function Model for the FortyMile Caribou Herd

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Executive Summary

In the 1920's the Fortymile caribou herd (FMCH) was at its peak in population size (approximately 260,000 to 580,000 caribou), and ranged across a large portion of the Yukon Territory (YT). However, by the 1970's, 90% of its range had been abandoned and the population was only approximately 6,000 animals. More recently, the FMCH has been increasing in population size and range. This expansion is of interest to wildlife and land managers in the Yukon, as there is concern that human activity in the historic FMCH range could limit future population growth and range expansion of the herd.

Here I develop a spatial model of caribou habitat across the historic FMCH range. Caribou locations obtained from 60 caribou in the FMCH range using Global Positioning System (GPS) telemetry technology from 2012 to 2016, and available digital maps of habitat resources were used to develop an empirical model of caribou habitat during the early winter (December 1st to February 26th) using a resource selection function (RSF) approach. RSFs indicate the relative probability of caribou selection of a habitat. The predictive performance of the RSF model was evaluated using a k-fold cross validation approach, where the RSF model was fit to a sub-set of the data 28 times, where each sub-set had a randomly selected individual caribou withheld from the data and the model was predicted on the withheld caribou locations.

The RSF model showed that caribou selected areas further from rivers ($\beta = 0.61$, $SE < 0.01$). They selected areas that were burned 41 to 60 years ago ($\beta = 0.61$, $SE = 0.02$), but avoided areas burned 11 to 40 years ago, 61 to 70 years ago, or that were not burned, relative to recently burned areas (<10 years ago). Caribou selected all vegetation cover types relative to barren cover, except for dense conifer forest ($\beta = -3.07$, $SE = 0.18$). Bryoids were the strongest selected vegetation cover type ($\beta = 1.44$, $SE = 0.03$). Caribou selected east ($\beta = 0.04$, $SE = 0.01$) and west ($\beta = 0.03$, $SE = 0.01$) aspects relative to north aspects, and avoided flat aspects ($\beta = -0.38$, $SE = 0.05$). They selected slopes between 20 to 30 degrees.

Caribou avoided areas with high-use road (i.e., roads used year-round) densities greater than 0.05 km/km^2 and avoided areas with low-use road (i.e., roads typically not used in the winter) densities greater than 0.10 km/km^2. They selected areas with intermediate NDVI (i.e., an index of vegetation biomass) values. Model validation statistics indicated that the RSF model had good predictive power.

This RSF model appears to be useful for predicting current caribou distribution in the historical FMCH range. Results of the RSF model indicate that the FMCH might have been selecting habitats with relatively low densities of other ungulate species (e.g., moose). Alternatively, and equally plausible, they might have been selecting habitats that were more likely to have lichen, a critical food source during the winter. This model should be considered as an exploratory analysis of caribou-habitat relationships that is ideally used in combination with other information in caribou management decisions. It may also be used to develop hypotheses and predictions on the mechanisms driving FMCH distribution for further study.

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1. Introduction

The Fortymile caribou herd (FMCH) has recently been increasing in population size and range since its population low point in the 1970's (Boertje and Gardner 1998a; McDonald and Cooley 2004). At its population peak in the 1920's (approximately 260,000 to 580,000 caribou), the FMCH ranged across a large portion of the Yukon Territory (YT), as far east as Whitehorse. However, by the 1970's 90% of its range had been abandoned and the population was only approximately 6,000 animals (Boertje et al. 2012). The population size began to increase again in the 1970's, but plateaued in the 1990's. Management objectives to further increase the size of the FMCH population were developed in the 1990's (Boertje and Gardner 1998b; Gronquist et al. 2005), and the population has been increasing in size and range since (Boertje et al. 2012).

The recent population and range expansion by the FMCH is of interest to wildlife and land managers in the YT. There is concern that recent and future resource development in the historic FMCH range could negatively influence caribou habitat, and thus negatively influence population growth and range expansion. It is unclear which portions of the historical FMCH are high-quality habitat, making it a challenge to plan and mitigate land use activities so that they do not negatively influence the FMCH expansion.

Here I develop a spatial model of caribou habitat across the historic FMCH range in the YT. I use caribou locations obtained using Global Positioning System (GPS) telemetry technology from 2012 to 2016 to develop the model using a resource selection function (RSF) approach (Boyce and McDonald 1999; Manly et al. 2007). RSFs indicate the relative, but not necessarily true, probability of wildlife selection of habitat types (Johnson et al. 2006). Human harvest of caribou, predation, food and weather have historically been key limiting factors for the FMCH population (Valkenburg et al. 1994; Boertje and Gardner 1998a; Boertje et al. 2012). I obtained available spatial data on habitat features I hypothesized could influence caribou distribution, and that might serve as proxies of these limiting factors, in the historical FMCH range in the YT. Habitat features considered in the model included roads, vegetation cover, vegetation productivity, watercourses (i.e., rivers), terrain and fire age. Roads are indicators of human use of the landscape, and therefore are typically a useful proxy for measuring the effects of human disturbance on wildlife (Muhly et al. 2011). Vegetation cover type and productivity, watercourses and recent burns may be indicators of food availability for ungulates (including caribou) and thus ungulate density and distribution, which may also therefore be indirect indicators of predator density and distribution, although this relationship has not been verified in barren ground caribou populations. I used the RSF model to spatially map relative caribou habitat value across the historical FMCH range. The map may be used by wildlife and land-use managers to plan resource development so that it minimizes its effect on the FMCH habitat as it continues to expand in population size and range.

2. Methods

2.1. Caribou Location Data

I obtained location data from 60 caribou in the FMCH range that were collected by the Alaska Department of Fish and Game and Bureau of Land Management in the United States of America, and by Environment Yukon in Canada. Location data were obtained from the YT only, from 52 GPS telemetry collars and eight ARGOS satellite telemetry collars. Location data were collected from 50 animals identified as part of the FMCH and from 10 animals identified as part of the Nelchina caribou herd, which can overlap with the FMCH during the winter. Data were collected from 55 adult females and five adult males. Location data were obtained from nine animals during the winter of 2012/2013, 32 animals during the winter of 2013/2014, 39 animals during the winter of 2014/2015 and 37 animals during the winter of 2015/2016 (i.e., locations were collected from some animals across multiple years).

2.2. Resource Selection Function Design

I calculated a second order RSF model (i.e., selection of home ranges within a population range) to model current caribou habitat selection within the historic FMCH range. I also considered calculating a third order model, however, the GPS location data (i.e., most of the sampled caribou) were censored to locations that occurred at the end of each day, between approximately 6 pm to midnight. Therefore, a third order model would have been biased towards the nighttime, when animal behaviour can be much different compared to the daytime. For the second order model, I sampled locations within caribou home ranges to define habitats used by caribou (see Section 2.3). I sampled locations within a minimum convex polygon (MCP) of all telemetry locations buffered by 50 km, but outside of caribou home ranges, to define habitats available to caribou (see Section 2.4).

2.3. Caribou Home Ranges

I produced a second order RSF model for the early winter period, which was defined as December 1st to February 26th. This corresponds to the period when caribou are generally settled on their winter range and not exhibiting migratory movements. I used early winter caribou location data to calculate 95% home range isopleths for each individual animal using the kernel density estimator with the smoothed cross validation bandwidth estimator and Gaussian kernel in the Geospatial Modeling Environment version 0.7.2 (Beyer 2010). Home ranges were only calculated for animals with a minimum of 30 locations during the early winter period (Seaman et al. 1999). Within each early winter home range, I systematically sampled habitat at locations every 250 m up to the home range boundary, starting from a random location. These were defined as locations and habitats that were “used” by caribou at the home range scale (n = 656,848).

2.4. Defining Habitat Available to Caribou

I calculated a MCP of all caribou telemetry locations each year of the analysis. I merged the annual MCPs and buffered them by 50 km and then removed the home range areas (defined above) to define the area of habitat "available" to caribou during the early winter period. I systematically sampled habitat in the available area every 250 m in the YT, starting from a random location. For each individual caribou in the analysis, I randomly selected 17,476 of the 1,048,560 sampled locations from the MCP (i.e., the total number of available locations divided by 60 caribou) and assigned them as the available habitat for that individual.

2.5. Habitat Measured at Used and Available Locations

I obtained data on vegetation cover from the Natural Resources Canada, Earth Observation for Sustainable Development of Forests vegetation cover map.[1] Vegetation cover was classified from 25-metre spatial resolution Landsat data collected in 2000. This dataset defined 39 vegetation classes, which included 14 classes that occurred in the study area (i.e., barren, bryoids, unclassified, water, shrubland, wetland, herb, dense conifer, open conifer, sparse conifer, dense broadleaf, open broadleaf, open mixedwood, and sparse mixedwood).

A mean normalized difference vegetation index (NDVI) value was calculated from NDVI datasets collected during the growing season (i.e., April 1 to September 30) from 2012 to 2014 (five scenes a year) as an indicator of vegetation productivity. NDVI data were obtained from MODIS at a 250 m spatial resolution, collected by the United States Geological Survey Earth Resources Observation and Science Center. NDVI provides a relative measure of vegetation productivity that has been used as an indicator of ungulate distribution and abundance (Petorelli et al. 2011).

[1] http://www.nrcan.gc.ca/forests/measuring-reporting/remote-sensing/13433

Slope (in degrees) and aspect were calculated from a 250 m spatial resolution digital elevation model (DEM). DEM data was downloaded from the United States National Aeronautics and Space Administration.[2] Aspect was classified into four categories: north (326 degrees to 45 degrees), east (46 degrees to 135 degrees), south (136 degrees to 225 degrees) and west (226 degrees to 325 degrees). Distance to water was calculated from a 1:50,000 Canvec topographic map produced by Natural Resources Canada.[3] Distance to water was calculated at a 250 m spatial resolution. High-use and low-use road density (km/km^2) was calculated from a 1:50,000 CanVec transportation dataset. High-use roads were defined as roads that were used year-round, including highways, and low-use roads were defined as roads that were not typically used in the winter. Road density was calculated at a 250 m spatial resolution. Data on the year and extent of fires in the YT was obtained from Geomatics Yukon.[4] Fire age was calculated by subtracting the year of each burned area from 2015. Fire ages were then classified into 10 year intervals. Fire age was calculated at a 250 m spatial resolution.

2.6. Resource Selection Function Model

I calculated a RSF (Boyce and McDonald 1999; Manly et al. 2007) as a generalized linear mixed model (GLMM) that included a random effect for individual caribou to account for variability in individual caribou resource selection and unequal location sample sizes among individuals (Gillies et al. 2006; Hebblewhite and Merrill 2008). GLMMs were fit as a binomial model using the package lme4 version 1.1-10 (Bates et al. 2015) in program R version 3.2.3 (R Core Team 2015). To simplify model fitting, continuous covariates were rescaled by subtracting each covariate value by its mean and dividing it by its standard deviation.

[2] https://asterweb.jpl.nasa.gov/gdem.asp
[3] http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/93b9a6e6-1264-47f6-ad55-c60f842c550d.html
[4] http://www.geomaticsyukon.ca/

The statistical relationship between caribou occurrence (i.e., used vs. available locations) and each continuous covariate (i.e., NDVI, slope, distance to water, high-use road density and low-use road density) was initially explored using a generalized additive model (GAM) to determine the shape of the relationship. Relationships that were linear were fit in the RSF GLMM as a single covariate, and relationships that were quadratic were fit with an additional squared term for the covariate. GAMs were fit using the package mcgv version 1.8-11 (Wood 2011) in program R version 3.2.3 (R Core Team 2015).

Prior to model fitting I tested for collinearity of habitat covariates using a Pearson correlation. None of the covariates were highly correlated (i.e., $|r| > 0.7$; Boyce et al. 2002). In addition, I calculated variance inflation factors (VIFs) and found that none of the covariates had a VIF >10, indicating they were not collinear (Neter et al. 1990). On this basis, all the covariates were retained for model selection.

2.7. Model Selection

I developed a candidate set of RSF models with different combinations of habitat covariates and compared them using Akaike Information Criterion (AIC). AIC evaluates models based on their statistical fit to the data and number of covariates in the model (Burnham and Anderson 2002). Models that fit the data with the fewest covariates receive lower AIC scores and are ranked higher in the candidate set of models. AIC difference (ΔAIC) indicates the difference in AIC score of each model to the highest ranked model (i.e., the model with the lowest AIC score). AIC models with a ΔAIC less than two are considered equally plausible and are therefore averaged (Burnham and Anderson 2002). AIC weights (AIC_w) were also calculated to determine the relative likelihood of a model being the top model in the set of models (Burnham and Anderson 2002).

I used a hierarchical approach for model selection. The set of candidate RSF models included sub-sets of models that exclusively consisted of terrain covariates only, vegetation covariates only and human disturbance covariates only. Specifically, the sub-set of terrain models only included all combinations of aspect and slope covariates (e.g., aspect only, slope only and aspect and slope together), the sub-set of vegetation models included all combinations of NDVI, vegetation cover, distance to water, and fire age covariates, and the sub-set of human disturbance models included all combinations of high-use and low-use road density covariates. I selected the top model(s) from each exclusive sub-set, as ranked using AIC, and then combined them into additional candidate models. Thus, I also analysed models that included covariates from the top-ranked terrain and vegetation models only, the top-ranked terrain and human disturbance models only, the top-ranked vegetation and human disturbance models only and the top-ranked vegetation, human disturbance and terrain models. The top-ranked model(s) from all sub-sets and sub-set combinations was determined using AIC and selected as the top RSF model for the FMCH.

2.8. Model Validation

The predictive performance of the top RSF model, as determined using AIC, was evaluated using a k-fold cross validation approach (Johnson et al. 2006). The top RSF model was fit to a sub-set of the data recursively 28 times, each time with a randomly selected individual caribou withheld from the dataset (Koper and Manseau 2012). The frequency of expected and observed RSF scores for the withheld caribou was calculated for binned RSF categories and compared using a linear regression. A linear regression with a slope of one, intercept of zero, an R^2 value of one, and a non-significant chi-square (χ^2) value indicates the model fit is proportional to probability of use and thus a predictive model (Johnson et al. 2006).

2.9. Predicting Caribou Resource Selection Across the Fortymile Caribou Herd Range

I took the fixed effects coefficients from the top-ranked RSF GLMM and calculated RSF scores across the historical FMCH range. The RSF scores indicate relative probability of caribou habitat selection across the FMCH range. To illustrate categories of relative caribou habitat value (e.g., higher versus lower value habitat categories), here RSF scores were classified into bins equal to one standard deviation of the RSF scores. A standardized approach to categorizing RSF scores to evaluate relative habitat value does not exist. However, one approach to determine relative habitat value categories could be to categorize RSF scores based on the relative frequency of actual caribou use (i.e., telemetry locations) across the range of RSF predictions.

3. Results

The top model for predicting FMCH resource selection (minimum AIC = 1,647,845) included all covariates considered in the model selection process and had an AIC_w of 1.000 (Table 1). The closest model to the top model included all vegetation and human disturbance covariates, but it had a ΔAIC of 2,333 and AIC_w of 0. Covariates in the top model included NDVI, landcover, distance to water, fire age, high-use road density, low-use road density, aspect and slope.

All RSF model coefficients (β estimates) of covariates in the top model (Table 2) had statistically significant z-scores (p-value less than 0.001), except the covariate for south aspect (p-value = 0.341). However, I caution that the standard error estimates are likely not as precise as indicated here, as random slope models are necessary to estimate appropriate standard errors in GLMM's that account for variation in animal behaviour (Schielzeth and Forstmeier 2009). Random intercept models were estimated here for practical purposes, as they take less computer processing time, and because my primary goal was to estimate habitat selection for the FMCH population, rather than to test the statistical significance of the effect, or for variance in selection across individuals.

Caribou selected home ranges further from large rivers (Table 2; β = 0.61, SE < 0.01). They selected areas that were burned 41 to 60 years ago (β = 0.61, SE = 0.02), but avoided areas burned 11 to 40 years ago, 61 to 70 years ago, or that were not burned, relative to recently burned areas (less than 10 years ago).

They selected all vegetation cover types relative to barren cover, except for dense conifer forest (β = -3.07, SE = 0.18). Bryoids were the strongest selected vegetation cover type (β = 1.44, SE = 0.03). The next most selected vegetation cover types included sparse mixedwood forest (β = 0.98, SE = 0.10), water (β = 0.96, SE = 0.02), shrubland (β = 0.90, SE = 0.02) and dense broadleaf forest (β = 0.87, SE = 0.03). Caribou selected east (β = 0.04, SE = 0.01) and west (β = 0.03, SE = 0.01) aspects relative to north aspects, and avoided flat aspects (β = -0.38, SE = 0.05).

The RSF model indicated that caribou avoided areas with high-use road densities greater than 0.05 km/km^2 (Fig. 1). Similarly, caribou avoided areas with low-use road densities greater than 0.10 km/km^2 (Fig. 2). Caribou selected areas with intermediate NDVI values (Fig. 3). Peak NDVI selection occurred at approximately 6,500. Caribou selected slopes between 20 to 30 degrees (Fig. 4). Caribou avoided areas closer to large watercourses (Fig. 5).

Model validation statistics calculated using k-fold cross validation on 28 caribou indicated that the RSF model had good predictive power of caribou locations. On average, the slope of the linear relationship between expected and observed frequency of withheld caribou locations in RSF score bins was significant (p-value = 0.0055) and was close to one (β = 1.19, SE = 0.02). The average intercept was not significantly different from zero (p-value = 0.636). The average regression R^2 value was close to one (R^2 = 0.755) and the average chi-square test indicated that expected and observed frequencies were not significantly different (χ^2 = 59, p-value = 0.248).

FMCH habitat selection was spatially predicted across the extent of the historical range plus a 50 km buffer in the YT using the RSF model (Fig. 6). Predicted RSF values (i.e., relative probability of caribou habitat selection) were typically higher in the western and southern portions of the range. RSF values were highest in the west-central portion of the range and were lowest in the northeast portion of the range. Predicted high-RSF-value habitat areas generally overlapped with early winter caribou telemetry locations and home ranges used to create the RSF model.

Table 1. Akaike Information Criterion (AIC) values of candidate caribou resource selection function models for the Fortymile caribou herd. AIC differences (ΔAIC) indicate the difference of each model from the top model (i.e., minimum AIC score) and AIC weights (AIC_w) indicate the relative likelihood of a model being the top model in the candidate set of models.

Model Set	**Model Fixed Effects**	**Random Effects**	**AIC**	**ΔAIC**	**AIC_w**
Terrain	Aspect	Caribou	1,924,930	277,085	0.000
	Slope + $Slope^2$	Caribou	1,914,374	266,529	0.000
	Aspect + Slope + $Slope^2$	Caribou	1,913,972	266,127	0.000
Vegetation	NDVI + $NDVI^2$	Caribou	1,813,170	165,325	0.000
	Landcover	Caribou	1,893,160	245,315	0.000
	Distance to Water	Caribou	1,784,895	137,050	0.000
	Fire	Caribou	1,859,069	211,224	0.000
	NDVI + $NDVI^2$ + Landcover	Caribou	1,800,529	152,684	0.000
	NDVI + $NDVI^2$ + Distance to Water	Caribou	1,702,438	54,593	0.000
	Landcover + Distance to Water	Caribou	1,759,136	111,291	0.000
	Landcover + Fire	Caribou	1,833,194	185,349	0.000
	NDVI + $NDVI^2$ + Fire	Caribou	1,758,864	111,019	0.000
	Fire + Distance to Water	Caribou	1,739,612	91,767	0.000
	NDVI + $NDVI^2$ + Landcover + Distance to Water	Caribou	1,691,899	44,054	0.000
	NDVI + $NDVI^2$ + Landcover + Fire	Caribou	1,748,348	100,503	0.000
	NDVI + $NDVI^2$ + Distance to Water + Fire	Caribou	1,664,795	16,950	0.000
	NDVI + $NDVI^2$ + Landcover + Distance to Water + Fire	Caribou	1,655,845	8,000	0.000
Human Disturbance	High-Use Road Density + High-Use Road $Density^2$	Caribou	1,924,989	277,144	0.000
	Low-Use Road Density + Low-Use Road $Density^2$	Caribou	1,918,704	270,859	0.000
	High-Use Road Density + High-Use Road $Density^2$ + Low-Use Road Density + Low-Use Road $Density^2$	Caribou	1,918,297	270,452	0.000
Top Terrain + Top Vegetation	NDVI + $NDVI^2$ + Landcover + Distance to Water + Fire + Aspect + Slope + $Slope^2$	Caribou	1,653,657	5,812	0.000

Model Set	Model Fixed Effects	Random Effects	AIC	ΔAIC	AIC_w
Top Terrain + Top Human Disturbance	High-Use Road Density + High-Use Road Density^2 + Low-Use Road Density + Low-Use Road Density^2 + Aspect + Slope + Slope^2	Caribou	1,906,466	258,621	0.000
Top Vegetation + Top Human Disturbance	NDVI + NDVI^2 + Landcover + Distance to Water + Fire + High-Use Road Density + High-Use Road Density^2 + Low-Use Road Density + Low-Use Road Density^2	Caribou	1,650,178	2,333	0.000
Top Vegetation + Top Human Disturbance + Top Terrain	NDVI + NDVI^2 + Landcover + Distance to Water + Fire + High-Use Road Density + High-Use Road Density^2 + Low-Use Road Density + Low-Use Road Density^2 + Aspect + Slope + Slope^2	Caribou	1,647,845	0	1.000

Table 2. Coefficient (β) estimates, standard errors and z-values of the top early winter (December 1st to February 26th) caribou resource selection function model covariates for the Fortymile caribou herd.

Covariate	β Estimate	Standard Error	z-value	p-value
Intercept	-1.93	0.16	-12.00	<0.001
NDVI	4.87	0.03	155.97	<0.001
$NDVI^2$	-4.17	0.03	-145.52	<0.001
Distance to Water	0.61	0.00	282.07	<0.001
Fire 11-20 years old	-0.28	0.01	-24.04	<0.001
Fire 21-30 years old	-0.65	0.01	-47.11	<0.001
Fire 31-40 years old	-1.72	0.03	-51.84	<0.001
Fire 41-50 years old	0.61	0.01	52.05	<0.001
Fire 51-60 years old	0.61	0.02	26.38	<0.001
Fire 61-70 years old	-2.75	0.04	-73.92	<0.001
Fire - Not Burned	-0.24	0.01	-23.94	<0.001
Bryoids	1.44	0.03	54.18	<0.001
Unclassified	1.04	0.02	56.30	<0.001
Water	0.96	0.02	38.69	<0.001
Shrubland	0.90	0.02	53.65	<0.001
Wetland	0.31	0.03	10.71	<0.001
Herbaceous	0.64	0.02	36.40	<0.001
Dense Conifer	-3.07	0.18	-16.78	<0.001
Open Conifer	0.68	0.02	38.46	<0.001
Sparse Conifer	0.76	0.02	44.58	<0.001
Dense Broadleaf	0.87	0.03	33.08	<0.001
Open Broadleaf	0.40	0.03	12.46	<0.001
Open Mixedwood	0.79	0.02	33.55	<0.001
Sparse Mixedwood	0.98	0.10	9.62	<0.001
Low-use Road Density	0.30	0.00	65.05	<0.001
Low-use Road $Density^2$	-0.23	0.01	-45.94	<0.001
High-use Road Density	0.08	0.01	10.61	<0.001
High-use Road $Density^2$	-0.24	0.02	-11.41	<0.001
Aspect East	0.04	0.01	6.49	<0.001
Aspect South	-0.01	0.01	-0.95	0.341
Aspect West	0.03	0.01	5.55	<0.001
Aspect Flat	-0.38	0.05	-7.33	<0.001
Slope	0.28	0.01	43.24	<0.001
$Slope^2$	-0.24	0.01	-36.37	<0.001

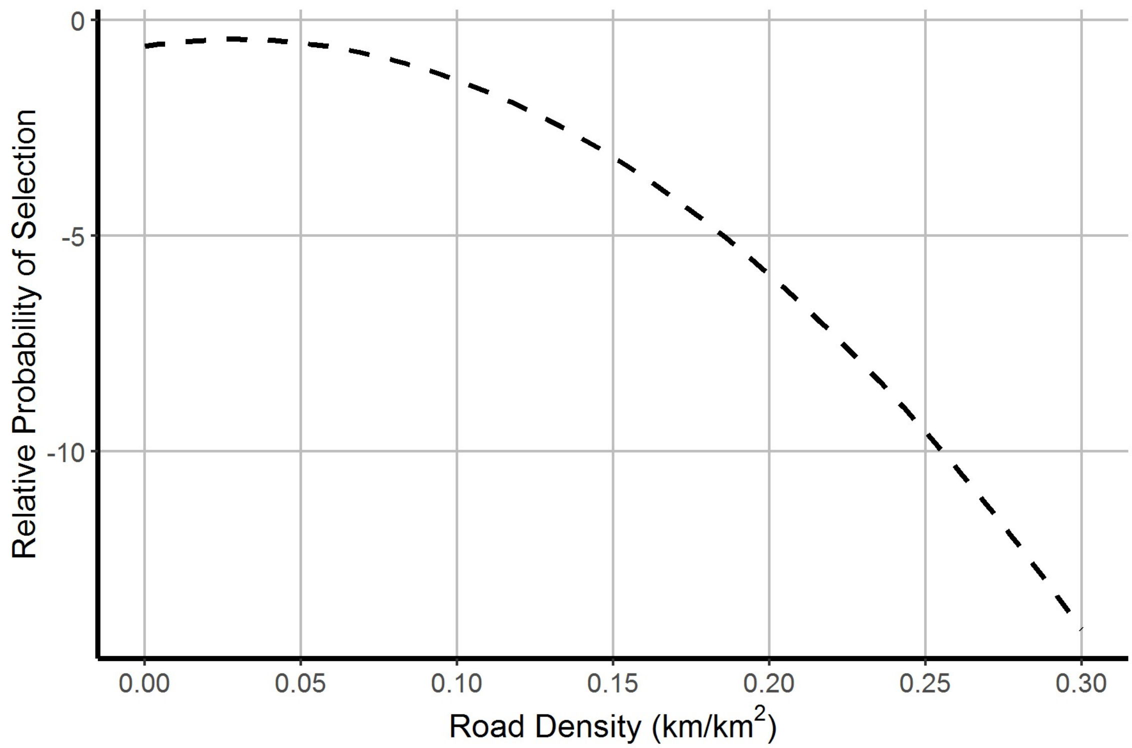

Figure 1. Predicted selection of high-use road density areas by caribou in the Fortymile caribou herd during the early winter (December 1st to February 26th) according to a second order resource selection function model.

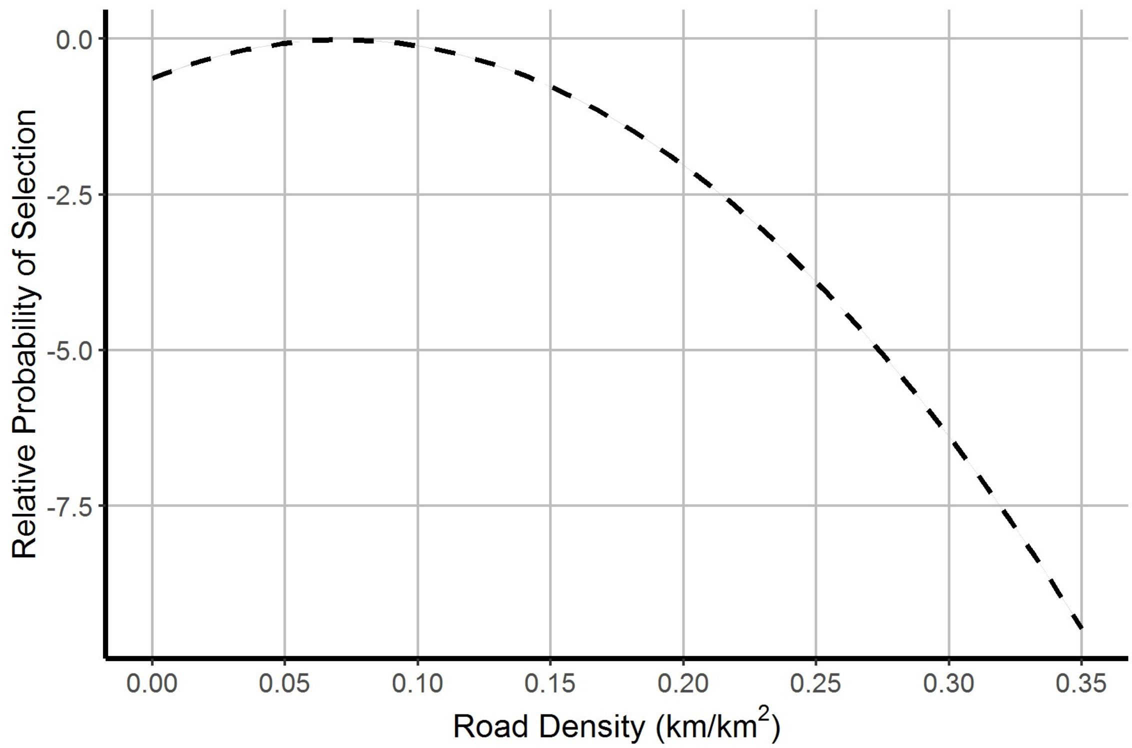

Figure 2. Predicted selection of low-use road density areas by caribou in the Fortymile caribou herd during the early winter (December 1st to February 26th) according to a second order resource selection function model.

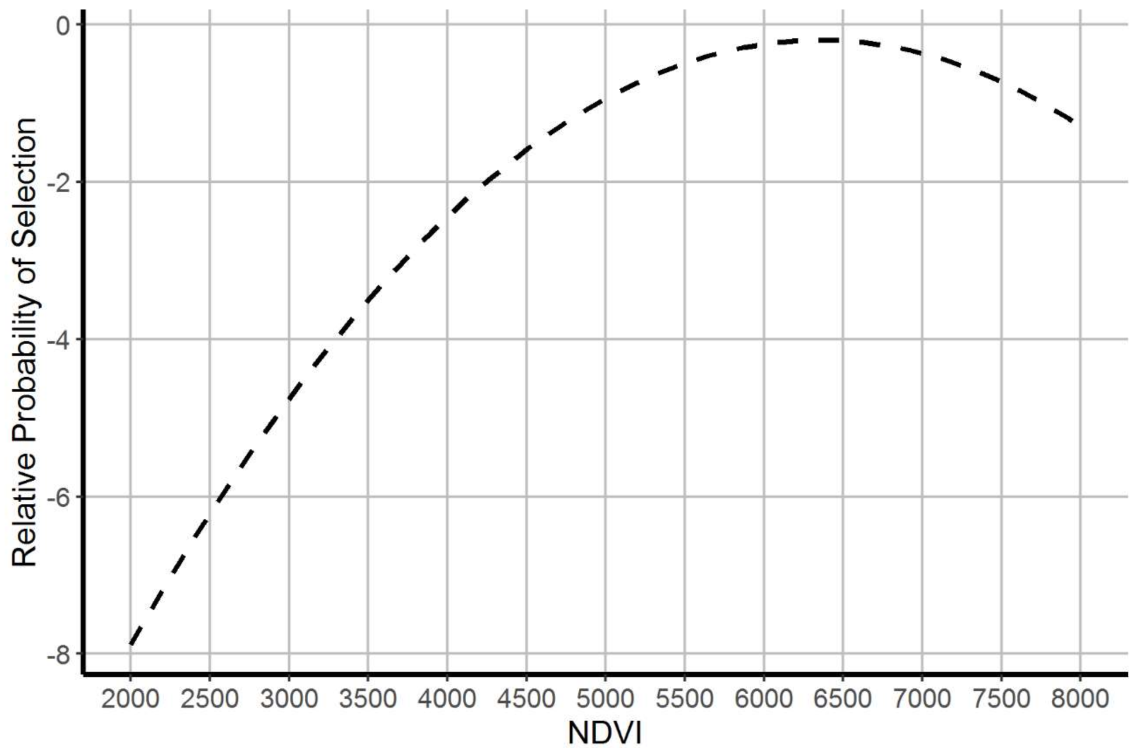

Figure 3. Predicted selection of normalized difference vegetation index (NDVI) values by caribou in the Fortymile caribou herd during the early winter (December 1st to February 26th) according to a second order resource selection function model.

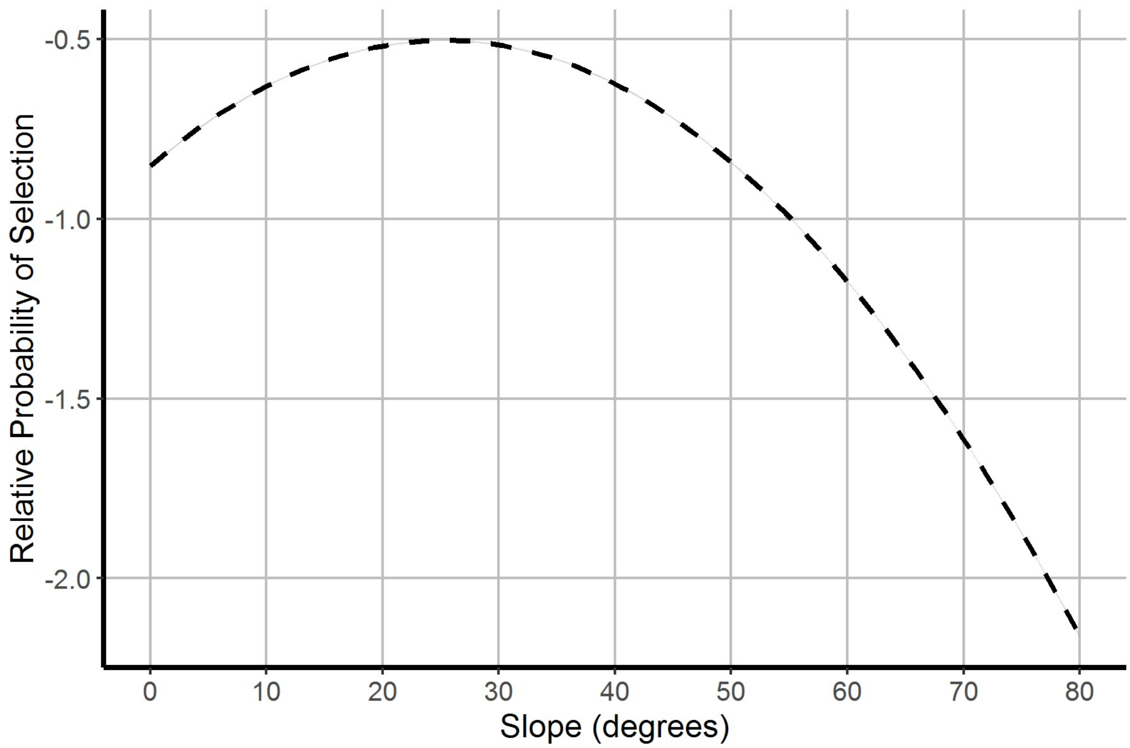

Figure 4. Predicted selection of slopes by caribou in Fortymile caribou herd during the early winter (December 1st to February 26th) according to a second order resource selection function model.

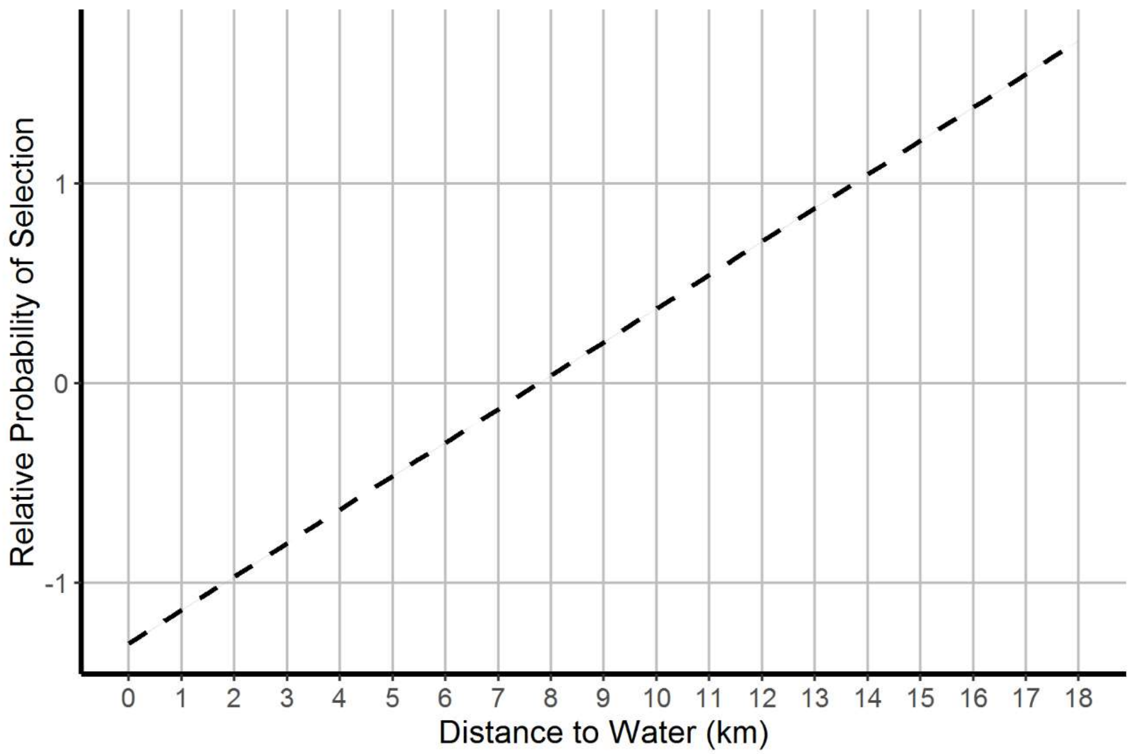

Figure 5. Predicted selection of areas near large watercourses by caribou in the Fortymile caribou herd during the early winter (December 1st to February 26th) according to a second order resource selection function model.

Table 3. Resource selection function (RSF) model validation statistics from a k-fold cross validation, where the RSF model was recalculated 28 times with a different caribou removed from the data each time. The fit of the observed to expected frequency of withheld caribou locations in RSF score bins is indicated by a linear regression model, where a slope and R^2 value equal to one, intercept equal to zero and non-significant chi-squared (χ^2) test indicates the model predicts the withheld data.

Caribou ID	Slope	Slope p-value	Intercept	Intercept p-value	R^2	χ^2	χ^2 p-value
331	1.23	0.0015	-590	0.570	0.783	54	0.256
425	1.26	0.0024	-768	0.567	0.755	63	0.243
101291	1.27	0.0029	-563	0.569	0.740	63	0.243
2012092	1.03	0.0003	-89	0.902	0.858	63	0.243
340	1.25	0.0017	-478	0.561	0.777	63	0.243
101286	1.26	0.0027	-552	0.573	0.746	54	0.256
2013032	1.20	0.0009	-412	0.586	0.810	63	0.243
353	0.97	0.0112	108	0.945	0.625	54	0.256
436	1.16	0.0005	-354	0.604	0.842	54	0.256
101282	1.17	0.0008	-506	0.625	0.818	54	0.256
2012058	1.24	0.0010	-483	0.538	0.806	72	0.230
334	1.30	0.0085	-1324	0.616	0.652	63	0.243
444	1.10	0.0005	-230	0.750	0.841	72	0.230
101296	1.30	0.0067	-884	0.604	0.673	54	0.256
2012066	1.23	0.0009	-451	0.543	0.814	54	0.256
101289	1.28	0.0061	-665	0.615	0.682	63	0.243
2012074	0.86	0.0851	353	0.843	0.365	36	0.287
346	1.26	0.0037	-699	0.596	0.723	63	0.243
411	1.07	0.0011	-249	0.832	0.800	54	0.256
101283	1.16	0.0009	-329	0.656	0.813	63	0.243
2012049	1.16	0.0010	-518	0.655	0.810	63	0.243
342	1.29	0.0006	-801	0.433	0.832	63	0.243
409	1.29	0.0042	-1340	0.576	0.712	63	0.243
101288	1.22	0.0017	-734	0.597	0.776	63	0.243
2012055	1.11	0.0008	-405	0.739	0.819	63	0.243
348	1.27	0.0046	-703	0.597	0.706	63	0.243
416	1.25	0.0019	-536	0.562	0.771	54	0.256
101293	1.22	0.0010	-528	0.564	0.809	54	0.256
Average	1.19	0.0055	-526	0.636	0.755	59	0.248

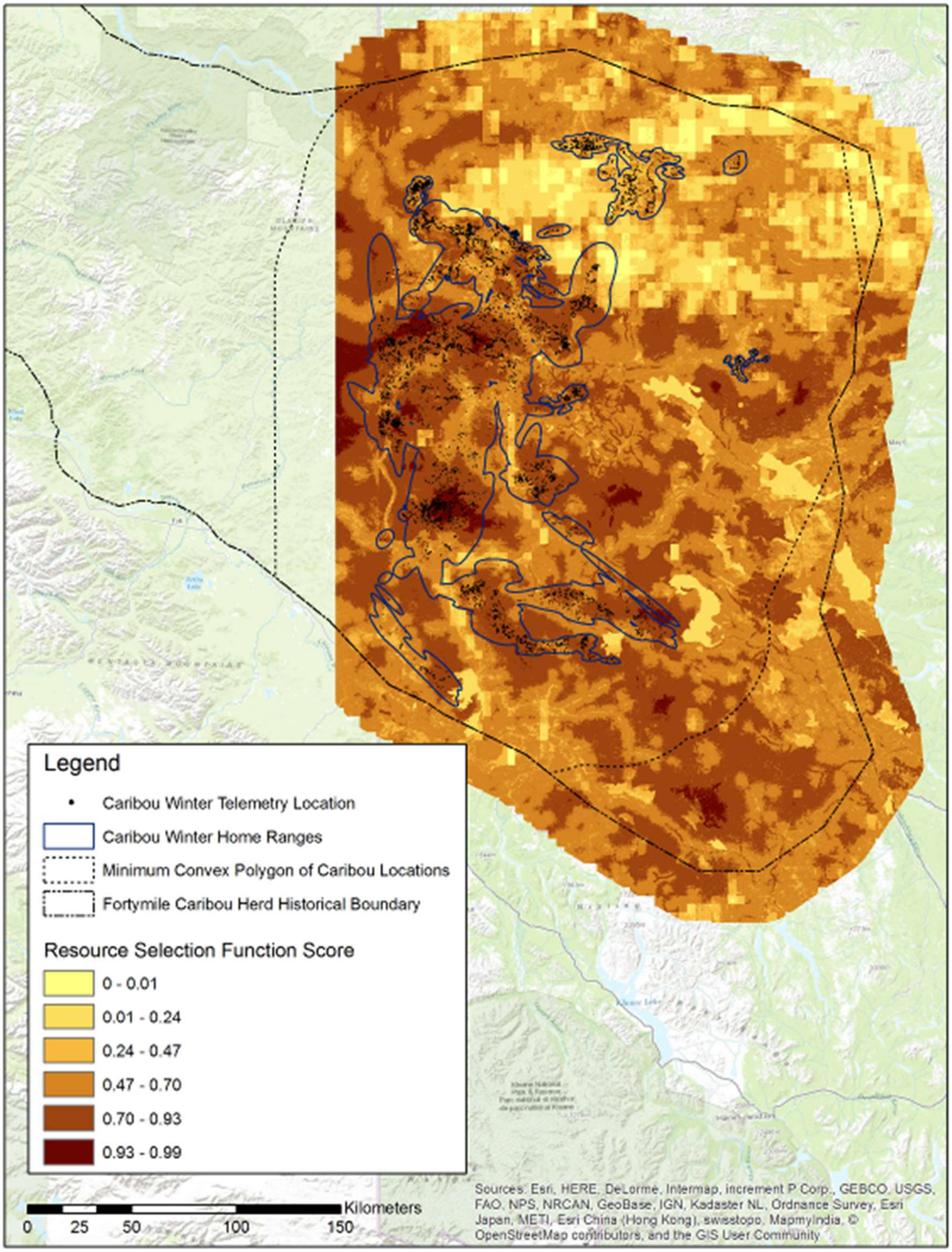

Figure 6. Predicted resource selection by caribou in the Fortymile caribou herd historical range. The middle four resource selection function (RSF) score categories are equivalent to one standard deviation of the RSF scores for the region.

4. Discussion

This model, like most RSF models, should not be viewed as a complete representation of FMCH habitat selection or occurrence. This model should be considered as an exploratory analysis of caribou-habitat relationships that is ideally used in combination with other information (e.g., traditional ecological knowledge) in caribou management decisions. In addition, when possible, further model validation with other caribou data is encouraged, particularly if caribou continue to expand their range in the YT. This RSF model should be viewed as a snapshot in time, whereas habitat selection is a dynamic process that changes as a function of habitat and population density. A long time-series of caribou location and density data and habitat data would provide an opportunity to develop a more mechanistic understanding of how the FMCH select habitat in their historic range. Model users should be cautious with making ecological inferences about the caribou-habitat relationships identified in the model. The model does not necessarily explain FMCH ecology, but it may be used to develop hypotheses and predictions on the mechanisms driving FMCH distribution for further study. Nevertheless, the RSF model appears to be useful for predicting current caribou distribution in the historical FMCH range.

An important consideration with this RSF model is that it modeled second order habitat selection only. Second order RSF model coefficients can be sensitive to how you define the available population range. I did not explore how different range sizes influenced habitat selection coefficients, and it is possible that these coefficients could change with more narrow definitions of available range. Nevertheless, the available area that I defined is ecologically plausible, as it is within the area that has historically supported the FMCH. In addition, some woodland caribou have been found to select habitat differently at different orders of selection, suggesting that models that incorporate multiple orders of selection are ideal if not necessary for fully understanding caribou resource selection (DeCesare et al. 2012). I did not calculate a third-order model here because of bias towards exclusively nighttime locations in the caribou

GPS location data. Wildlife species may switch their habitat selection between daytime and nighttime (Hebblewhite and Merrill 2008; Muhly et al. 2011; Northrup et al. 2012) and thus a third-order RSF model of the data would have produced a biased model of third order habitat selection by caribou. If daytime data become available, finer-scale RSF models could also be completed to produce a more comprehensive illustration of FMCH habitat selection. The second-order model provided here is well-positioned to be combined with a third-order model in a hierarchical modeling framework, as the definition of used locations in the second order model (i.e., all locations within caribou home ranges) could be used to define available locations for a third order model (DeCesare et al. 2012). In the absence of a third order model, the second order results described here shows how caribou select habitat at large scales, i.e., over years to decades within their historical range. A third-order model would add additional information on how caribou select habitat at finer scales, i.e., over days to months within home ranges.

The RSF model indicated that the FMCH may have been selecting habitat features related to food, predation and human disturbance during the early winter. They generally avoided large rivers and recently burned areas, and selected intermediate NDVI values. Rivers, burns and high NDVI-value habitats are often associated with higher densities of ungulates, but not necessarily caribou, and their predators. For example, moose in the Dawson City area of the YT selected burned areas 11 to 25 years old (Morrison and Wong 2012) and moose in Alaska selected recent burns (10 to 30 years old) and areas closer to rivers (Maier et al. 2005). In addition, high NDVI values are typically positively correlated with ungulate distribution and abundance (Pettorelli et al. 2011). The FMCH may avoid rivers, younger burns and high NDVI-value habitats because these habitats support higher ungulate densities and thus higher predator densities. However, the RSF does not provide adequate data to test this prediction.

Alternatively, and equally plausible is that the FMCH may have been selecting older burns and intermediate NDVI values because these represent older forests that are more likely to have higher abundances of lichen. Indeed, I found that caribou selected the bryoid vegetation cover class over all other classes. Previous analyses showed that lichen biomass and cover was highest in forest stands greater than 100 years old (Collins et al. 2011) and caribou from the Nelchina herd selected 50-year-old burns (Joly et al. 2003), which suggests caribou are selecting older forests because there is more lichen there. However, our result that the FMCH were less likely to select greater than 60-year-old burns and unburned areas was inconsistent with these results. The RSF model indicates that both food and predation may influence FMCH distribution. However, further research is needed to identify how both mechanisms influence the FMCH, as results of the RSF are correlative.

Lichen is an important food for barren-ground caribou (Boertje 1984; Collins et al. 2011). I used a preliminary lichen cover distribution model being developed for the FMCH range area to explore the relationship between caribou and lichen cover. However, the preliminary lichen model did not predict lichen abundance in burned areas. Therefore, I removed locations within burned areas from the data and fit the top RSF model with an additional covariate for percent lichen cover. The result was nonsensical, and is therefore not reported here. Nevertheless, once the lichen model is finalized it could be used for refining the caribou RSF. Burned areas make up a large proportion of the study area and therefore including them in the lichen model may improve it.

Caribou might have avoided areas with higher densities of high-use and low-use roads to avoid disturbance from humans. Caribou may avoid roads because they are disturbed by the activity on them (Dyer et al. 2001) or they may perceive roads as a risk from human hunting (Bergerud et al. 1984; Nellemann et al 2001; Frid and Dill 2002). The stronger avoidance of high-use roads than low-use roads suggests caribou may have been responding to the level of human activity on the roads, not just the roads themselves (Johnson and Russell 2014). Caribou were only lightly hunted in the YT during the study period, but they were more heavily hunted in neighboring Alaska, and therefore caribou may perceive roads and human activity on them as a predation risk. However, the RSF data and model are not appropriate for testing this hypothesis, and this inference is based on correlative analysis. Additional research is needed to determine if this mechanism is influencing FMCH distribution.

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APPENDIX 16-C-2

Moose Late Winter

Habitat Suitability Report

Coffee Gold Mine: Moose Late Winter Habitat Suitability Report

Prepared For

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EDI Project

14Y0306
September 2016

Version 1.1

Down to Earth Biology

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Suggested citation:

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REVISION SUMMARY

Version No.	Date	Revision Notes	Revision Authors
1.0	10 March 2016	Original Version	Graeme Pelchat
1.1	09 September 2016	Final Version	Todd Mahon

EXECUTIVE SUMMARY

Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson City, Yukon.

In anticipation of future regulatory requirements, wildlife baseline information has been collected and developed to assist with Project planning and mitigation, including a late winter habitat model for moose. The late winter is a limiting season for moose primarily because of reduced forage availability and increased energetic demands to move through deep or crusted snow. A late winter habitat suitability index (HSI) model was developed for moose in the vicinity of the proposed Coffee Project. The late winter moose HSI combined terrain and land cover variables to create a model of moose late winter habitat quality. Datasets used in this late winter HSI model include elevation, terrain steepness, fire history and land cover classifications. The model was validated using the late winter survey moose observations. The HSI output provides a spatially-explicit quantification of late winter moose habitat quality within the Project's Regional Study Area (RSA) which will be used to assess potential Project effects on moose during the late winter season, and develop mitigations to reduce Project effects, if required.

The model indicates that the RSA contains abundant and widespread high quality late winter moose habitat — which likely supports the higher densities of moose reported throughout the region. Model validation indicates that during late winter moose surveys, moose were observed using habitat ranked as higher quality late winter habitat by the model and were rarely observed in low quality habitats.

ACKNOWLEDGEMENTS

Government of Yukon, Department of Environment (Environment Yukon) provided land cover datasets as well as observations from the 2008 and 2012 late winter moose surveys. A number of biologists and residents of Dawson City participated in the 2014 and 2015 late winter surveys funded by Kaminak Gold Corporation. The report could not be completed without this information.

AUTHORSHIP

This report was prepared by EDI Environmental Dynamics Inc. Staff who contributed to this project include:

Graeme Pelchat, M.Sc., P.Biol. .... Author and Model Development

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Anne MacLeod, B.Sc., R.P.Bio .... Project Manager and Senior Review

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ACRONYMS AND ABBREVIATIONS

Coffee Project, the Project .... Coffee Gold Mine

DEM .... Digital elevation model

EDI .... EDI Environmental Dynamics Inc.

EOSD .... Earth observation for sustainable development

GMS .... Game management subzone

HSI .... Habitat suitability index

Kaminak .... Kaminak Gold Corporation

km^2 .... square kilometers

m .... metre

NAD83 .... North American Datum of 1983

RSA .... Regional Study Area

YESAA .... Yukon Environmental and Socio-economic Assessment Act

YESAB .... Yukon Environmental and Socio-economic Assessment Board

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1 INTRODUCTION

Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson City, Yukon (Figure 1). The Project will be accessed by road from Dawson City.

In 2014, Kaminak retained EDI Environmental Dynamics Inc. (EDI) to conduct wildlife baseline studies for the Coffee Project in anticipation of future regulatory requirements. A number of wildlife surveys have been undertaken for the Project, as well as habitat models for select species. This information will assist with Project planning and mitigation. The information provided in this report supports the Project Proposal to be submitted to the Yukon Environmental and Socio-economic Assessment Board (YESAB) Executive Committee for screening under the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA) as wells as the Quartz Mining License and Type A Water License applications.

The late winter season is often a difficult time of year for moose, primarily because of the limited forage availability and increased energetic demands to move through deep or crusted snow. For this reason, a late winter habitat suitability index (HSI) model was developed for moose in the vicinity of the proposed Coffee Project to identify areas with high quality late winter habitat. The HSI model output quantifies the amount of late winter moose habitat in each habitat class (low, low–moderate, moderate–high and high) within the Project's Regional Study Area (RSA). This information will be used to assess potential Project effects on moose during the late winter season, and develop mitigations to reduce Project effects, if required.

A habitat suitability index model, also referred to as a knowledge-based habitat suitability model (Clark 2012), is a common method for assessing habitat quality for wildlife species. The modelling process uses spatial datasets such as land cover, elevation, and topography and ranks available habitats according to their ability, in their current state, to support a selected species. The habitat rankings can be based on a variety of sources including survey data, local knowledge, expert knowledge, or traditional knowledge. These models can be based on one suitability index or the combination of multiple suitability indices to quantify the quality of habitat for the species (Dijak and Rittenhouse 2009). The combination of all suitability inputs creates the HSI.

This report describes how the moose late winter HSI model was completed and includes all applicable requirements of YESAB's *DRAFT Proponents Guide: Model Documentation Report* (YESAB 2015).

1.1 OBJECTIVE

The objective of the HSI is to quantify the distribution and availability of late winter habitat for moose in the Coffee Project's RSA.

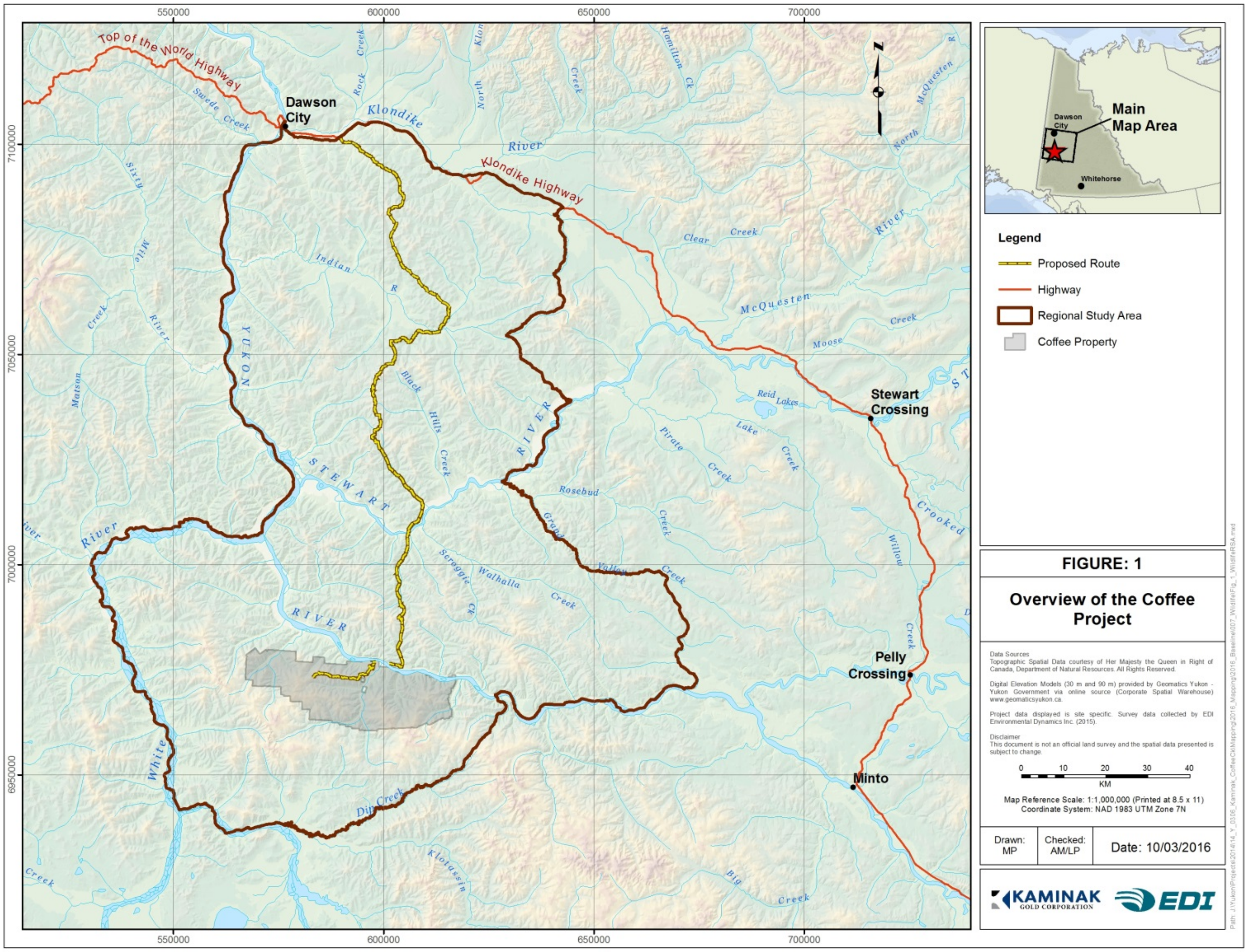


Figure 1. Overview of the Coffee Project.

1.2 BACKGROUND

In west-central Yukon, during the early winter, moose are often found in the extensive shrub communities of the subalpine zone (O'Donoghue *et al.* 2013a) — when snow loads are low, moose may remain in these habitats year-round; however, with deeper snows moose are forced down into lower elevation areas during the late winter (Environment Yukon 2014a). According to the Dawson Regional Planning Commission (2013), in west-central Yukon, late winter habitats may not be used every year, but in high snow years these areas are critical to moose survival.

Moose select habitat based on three criteria: food availability, predator avoidance, and snow conditions (Dussault *et al.* 2005). During the winter, moose feed on the twigs of deciduous trees and shrubs including aspen, birch, and alder; however, willows are the primary winter food for moose. Risenhoover (1989) found that willows accounted for more than 94% of the winter diet of moose in Denali National Park and Preserve. Willows are well adapted to wetter soils and are commonly found in wetland and riparian habitats.

Willows are also an early successional species, and as such the shrub is often abundant in early seral habitats resulting from human disturbed areas (e.g., placer mines and exploration camps) and burns. Moose have been reported selecting previously burned habitats that are 10–30 years old (Maier *et al.* 2005) and less than 40 years old (Wasser *et al.* 2011), and areas within 100 m of streams and waterbodies (Wasser *et al.* 2011), presumably as a result of the abundant forage.

Moose population growth and density in Yukon is thought to be limited by wolves (Hayes *et al.* 2003). Consequently, moose may avoid habitats that increase the potential for encounters with wolves; although, predator avoidance may be a larger factor in habitat selection at the landscape scale than within a home-range (Dussault *et al.* 2005). Habitat types with taller and denser vegetation likely provide some protection from wolves during winter. Habitat types that provide cover from predators may also contain taller trees that intercept snow reducing snow depth and, consequently, reducing the energy required to move.

During the winter, moose are influenced by snow depth as well as density and hardness, and moose movements are often impeded at snow depths equal to or greater than 70 cm (Coady 1974). Based on snow depth measurements from King Solomon Dome, snow depths at the higher elevations of the RSA may exceed 70 cm during the late winter (Environment Yukon 2016a) and consequently be limiting to moose. Snow depth and hardness may also contribute to limit moose movement at high elevations. However, previous surveys in the region have indicated that snow depths within the RSA may not be as restrictive as in other parts of Yukon, and that during the late-winter season moose may be distributed over a wider range of elevations as compared to other areas where late-winter moose habitat is limited to low elevations along stream and river valleys (O'Donoghue *et al.* 2013b). Within the RSA, late winter surveys have documented moose occurring at all elevations below treeline.

The HSI was developed for the RSA based on professional opinion, and the availability of suitable datasets. Two terrain variables (elevation and slope) and two land cover datasets (vegetation and fire history) are considered for the HSI. Other variables, such as distance to waterbodies, were not included in the model as they were assumed to be correlated with the vegetation cover types or were not available for the extent of the model.

1.3 STUDY AREA

The extent of the moose late winter HSI is the RSA (Figure 1). The RSA was established to assess the abundance and distribution of most large wildlife species in the Project area and was delineated to include any game management subzone (GMS) that intersects the proposed Project. The RSA is 13,661 km².

The RSA is characterized by smooth topped ridges bisected by deep, narrow, v-shaped valleys. Major landscape features in the RSA include the northern portion of the Dawson Range and the Yukon and Stewart rivers. The study area contains no significant lakes or wetland complexes, though small waterbodies and wetlands are common along streams as well as the Yukon and Stewart rivers. The area hosts a range of vegetation communities and habitat types from low elevation boreal forests along river valleys to high elevation subalpine and alpine habitats on ridge crests. Below treeline, the vegetation pattern reflects the discontinuous distribution of permafrost with stunted black spruce woodlands on cold, north facing slopes with mixed forests or grasslands on warm south-facing slopes (YEWG 2004). Subalpine habitats are dominated by a dense shrub layer with an open canopy of coniferous trees, while alpine areas support a variety of dwarf shrubs, herbs, mosses and lichen.

The region has an active wildland fire regime and has experienced large and frequent large burns. More than one third (4,700 km^2) of the RSA has burned in the past 30 years and the largest wildland fires within the region exceed 400 km^2 (Environment Yukon 2016b). Climate in the area is characterized by long cold winters and short warm summers, and most of the annual precipitation comes during summers (YEWG 2004).

The region has a long history of placer gold mining. The RSA includes many historic and active placer mines. Human access to the RSA is primarily along the extensive road network throughout the area and the Yukon and Stewart rivers that intersect and bound the RSA.

2 METHODS

2.1 DATA AQUISITION

The spatial dataset and sources used to develop the moose late winter HSI are described in Table 1. Environment Yukon provided an updated land cover dataset that was developed for the Dawson land use planning region and covers the entire late winter moose habitat study area (i.e. the RSA). The updated land cover data were developed in 2014 and reflect conditions in the region during 2008 and 2009. The remaining dataset are freely available on the internet through a number of spatial data repositories.

Four late winter moose surveys have been conducted relatively recently in the region. Baseline studies conducted for the proposed Coffee Project included late winter surveys for moose and caribou in 2014 and 2015. Environment Yukon conducted late winter surveys in 2008 and 2012 as part of a moose population inventory. The Kaminak and Environment Yukon survey extents are inconsistent because the purposes of the surveys were different, but the information is comparable as the survey methods were identical.

Table 1. Spatial databases used in the development of the moose late winter HSI.

Dataset	Source	Description
DEM	Natural Resources Canada (2012)	Raster database 30 m cell size Published: 2012
Fire history	Geomatics Yukon, Environment Yukon (2016b)	Vector database Updated: Jan 2016
Land cover	Environment Yukon (2014b)	Raster database 30 m cell size Imagery: 2008 and 2009 Developed: 2014
Land cover, EOSD	Canadian Forest Service, Pacific Forestry Centre	Raster database 30 m cell size Imagery: circa 2000 Developed: 2006
Moose late winter survey observations	The Project and Environment Yukon acquired data	Vector database Environment Yukon data 2008 and 2012 Coffee Project data 2014 and 2015

2.2 DATA PREPARATION

Datasets used to create the late winter habitat suitability model were limited to those that covered the entire RSA (Table 1). The 2014 land cover dataset was supplemented by the Earth observation for sustainable development (EOSD) land cover dataset where cloud cover created holes. The Yukon fire history dataset was filtered then converted from vector to raster data with fire age as the cell values. A digital elevation model (DEM) was used to describe elevation and develop the steepness datasets.

We used fuzzy membership functions with a linear transformation between the suitable and unsuitable attributes to create suitability indices for the continuous variables. Boolean functions were used to create a suitability index for the land cover variables.

All analyses were completed using NAD83 Yukon Albers projected coordinate reference system (EPSG: 3578). Analyses and management of spatial data was completed using ArcGIS Desktop 10.2 with the Spatial Analyst extension.

2.2.1 ELEVATION

Elevation is used as an important variable in habitat use. Moose were rarely observed in the alpine and subalpine during late winter baseline surveys, though shrubs are abundant, particularly within subalpine habitats. Consequently, the elevation dataset was used to exclude high elevation habitat as potentially suitable. Snow condition is not included as a variable in the HSI, though snow condition in the alpine and subalpine may be the ultimate cause of the absence of moose at higher elevation habitats. However, snow depth is assumed to be correlated to elevation in the model.

Elevation within the RSA was represented by the DEM. The elevation dataset was treated as a continuous variable in the habitat model. A fuzzy membership function was created to identify an elevation suitability index for moose late winter habitat using expert opinion. Elevation below treeline was considered suitable as moose late winter habitat, while elevation above treeline was considered unsuitable. Treeline was estimated at 1,100 m, based on bioclimate data set. Treeline is not solid boundary between forested and alpine ecosystems and varies within landscapes; consequently, we created a 100 m altitudinal buffer for a linear transition from suitable to unsuitable habitat (Figure 2). The fuzzy membership model rates terrain up to 1,000 m as suitable habitat, followed by a linear transition to unsuitable habitat at 1,200 m (Figure 2, Equation 1).

Equation 1: $$f(x) = \begin{cases} 0, & x \geq 1200 \\ \left(\frac{x-1200}{1000-1200}\right), & 1200 > x > 1000 \\ 1, & x \leq 1000 \end{cases} \qquad x \in X$$

2.2.2 TERRAIN STEEPNESS

Terrain steepness (i.e., slope) likely restricts moose habitat availability as steep terrain is simply unavailable for moose. Moose were assumed to use flatter terrain more than steep terrain.

The steepness of terrain within the RSA was estimated by creating a slope dataset from the DEM. The slope database provides steepness in degrees and was treated as a continuous variable in the habitat model. A fuzzy membership function was created to identify a steepness suitability index for late winter moose habitat using the expert opinion. Terrain with less than or equal to a 20 degree slope was assumed to be suitable as moose winter habitat and slope greater than 70 degrees was assumed to be unsuitable (i.e., unavailable).

Slopes in between the criteria were assumed to decrease in suitability with increasing slope (Figure 2, Equation 2).

Equation 2:
$$f(x) = \begin{cases} 0, \ x \geq 70 \\ \left(\frac{x-70}{20-70}\right), \ 70 > x > 20 \\ 1, \ x \leq 20 \end{cases} \qquad x \in X$$

2.2.3 FIRE HISTORY

The burn age dataset was treated as a Boolean variable in the habitat model. Fires that burned 11–30 years ago were selected from the vector dataset and then converted to a raster data format. The selected fires were classified as suitable (1) late winter habitat and all other areas were classified as unsuitable (0).

2.2.4 LAND COVER

The merged land cover dataset was grouped into broad habitat classes based on dominant forest types. An accuracy assessment of the land cover dataset provided by Environment Yukon revealed that the data poorly mapped most land covers types, but more accurately reflected broader land cover categories (ASL 2014). A Boolean membership function was used to identify a suitability index for moose late winter habitat. All land cover types were rated as suitable (1) or unsuitable (0) for moose foraging and predator avoidance value (Table 2). Conifer without a shrub component, unvegetated, and herb or lichen dominated land cover types were assumed to be unsuitable foraging habitat for moose during the late winter period. All other land cover types were assumed to have the potential to contain forage species and were considered suitable foraging cover types. Unvegetated and herb or lichen dominated land cover types were assumed to be unsuitable predator avoidance cover types. All other land covers were assumed to have some potential value for predator avoidance. We combined values to create the land cover suitability index by taking the smallest forage or predation rating (i.e., product).

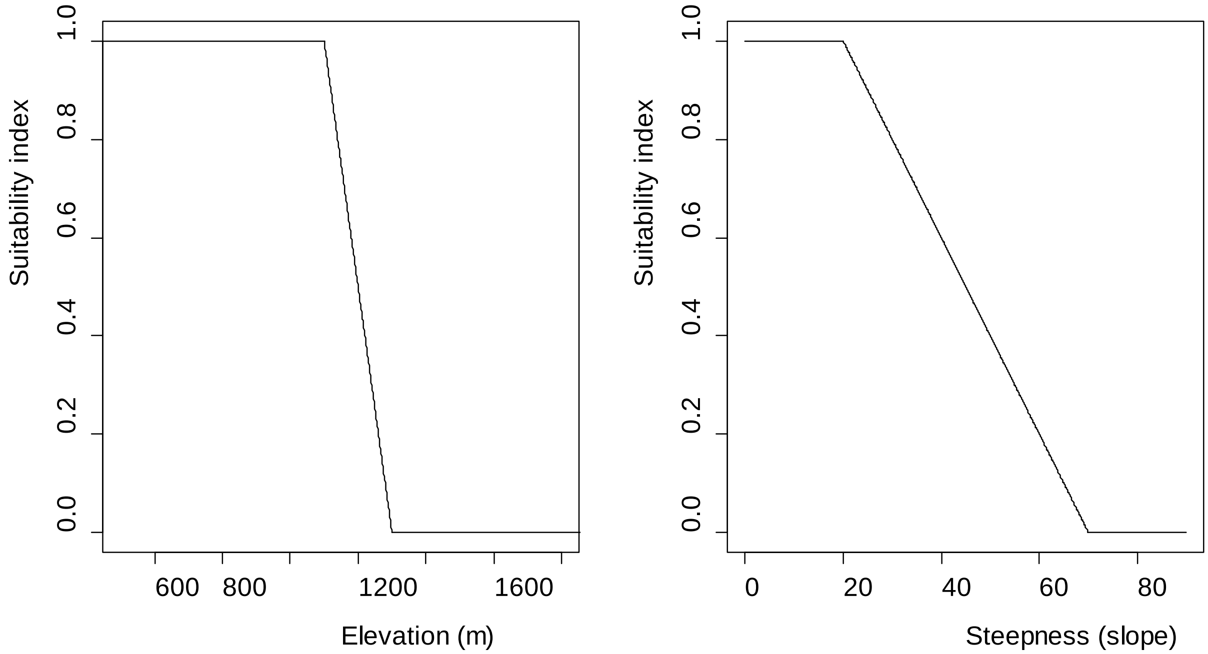


Figure 2. The suitability of moose late winter habitat as a function of elevation (left panel) and steepness (right panel).

Table 2. The suitability of moose late winter habitat as a function of vegetation types.

Land Cover Value[1]	Land Cover Description	Forage Rating	Predation Rating	Suitability Index
11, 12	Cloud or Shadow	N/A	N/A	N/A
20, 31-33	Unvegetated	0	0	0
50	Shrub dominated	1	1	1
81-83	Wetlands	1	1	1
100, 101, 41-43	Herb or lichen dominated	0	0	0
211-215, 217-218, 240-241	Conifer without shrub	0	1	0
216, 219	Conifer with shrub	1	1	1
221-229	Broadleaf Dense	1	1	1
231-239	Mixed-wood Dense	1	1	1
232-239	Mixed-wood Open	1	1	1

Note: Land cover values are the digital numbers in the land cover datasets that represent different land cover types.

2.3 MODEL DEVELOPMENT

The late winter moose HSI was developed by combining the terrain and land cover variables to create a model of moose late winter habitat quality. The steepness and elevation suitability indices were combined using an 'AND' overlay function, which retains the minimum cell value of the combined datasets. The overlay is appropriate for combining the terrain suitability indices because the terrain attributes are assumed to be limiting for moose, and the overlay function keeps the lower value of the combined datasets. The vegetation cover and fire history suitability indices were combined using an 'OR' overlay, which retains the maximum cell value of the combined datasets. The overlay is appropriate for combining the land cover suitability indices because the method retains the highest value of the two datasets; for example, if an area is burned (i.e. suitable) but the vegetation cover is rated as unsuitable (Table 2), the land cover suitability index is rated as suitable habitat.

The final moose habitat suitability model was created by combining the terrain and the land cover into one layer using a "PRODUCT" overlay. The overlay is appropriate in this case because it is a decreasive operation. The purpose in using this function was to ensure that values representing no or poor suitability from either input layer was maintained; for example, if an individual pixel in the terrain layer represented poor habitat, then that rating had a large influence on the final HSI. The resulting output dataset represented the final moose habitat suitability model.

In consideration of the scale that moose select habitat, we used a focal statistics tool (mean statistic) with a 1 km search radius (Oehlers *et al.* 2011). The focal statistics is also a method of smoothing raster datasets and is appropriate when there is uncertainty in the exact observation location. Moose observations were acquired during aerial surveys so the accuracy of the observation is likely ± 100 m. Figure 3 is a graphical representation of the model development.

The model equation produced HSI scores ranging from 0 to 1. Scores were categorized into four qualitative categories, High, Moderate, Low and Very Low, reflecting occurrence patterns of moose from historic survey data (n=1102 animals from 722 unique locations) relative to habitat availability. This ratio corresponds to a simple selection index: proportion of moose locations / proportion of area by HSI class, where positive value reflect selection (use>availability) and negative values reflect avoidance (use<availability). High was assigned to HSI scores with a selection index > +0.10 (positive selection). Moderate was assigned to HSI scores with a selection index between +0.10 and -0.10 (neutral selection). Low was assigned to HSI scores with a selection index between -0.10 and -0.50% (avoidance), and Very Low was assigned to HSI scores with a selection index <-0.50% (strong avoidance).

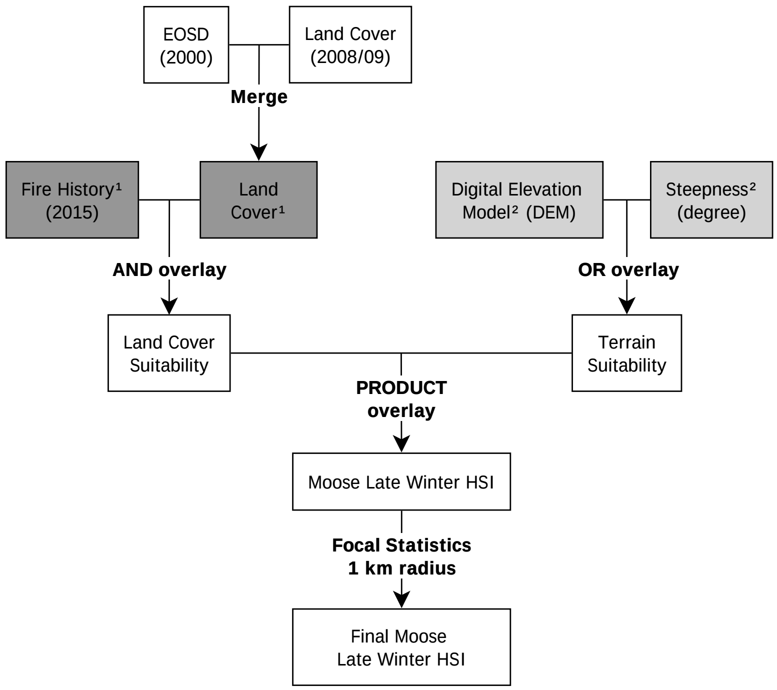


Figure 3. Moose late winter habitat suitability modeling flow chart. The dark gray[1] and light gray[2] boxes identify the Boolean and fuzzy membership functions, respectively.

2.4 STATISTICAL VALIDATION

The model was validated using the moose late winter survey observations. We binned habitat into two classes for the purpose of validating the model: values above and below the median HSI (median =0.78). Areas with HSI values greater or equal to the median are where moose are expected to occur compared to areas with HSI values below the median. We used a simple one-sample proportions test with continuity correction to compare the observed proportion of moose observations within higher HSI areas to the proportion of available habitat within the study area. Used habitat was determined based on 679 moose observations within the RSA collected during Environment Yukon late winter surveys in 2008 and 2012 and baseline late winter surveys in 2014 and 2015 late winter surveys. Statistical tests were conducted using R version 3.1.3 (R Core Team 2015).

3 RESULTS AND DISCUSSION

Model validation indicates that moose were non-randomly distributed during the late winter within the RSA as they occurred more often in areas with higher HSI values (X squared = 195.13, df = 1, $p<2.2e-16$). The results show that the model did a better job at predicting moose locations than random. The proportion of moose from historic survey data also increased consistently with increasing HSI scores, with approximately 72% of moose observations located in areas with High and Moderate HSI categories (Table 3 and Figure 4).

Some portions of the RSA identified as high quality late winter habitat had few survey observations of moose; in particular, a large portion of the RSA south of the Indian River and west of the proposed route. The area burned in the 2004 and the survey observations used to validate the model in that area were collected in 2008. At the time of the survey the area would not have been identified as high quality habitat because the burn was only 3 years old; however, the habitat model presented here represents the current conditions (i.e., late winter 2016). This burn is now 11 years old and we predict that late winter surveys conducted during the next 20 year will observe high densities of moose in this area.

The model indicates that the RSA contains abundant and widespread high quality late winter moose habitat (Table 3). The extensive High and Moderate quality late winter moose habitat availability is primarily due to the common and extensive wildland fires that occur frequently throughout the region (Figure 5) and the abundance of mid- and low elevation habitats (i.e., the RSA contains a very limited high elevation alpine habitats). The abundant high quality late winter moose habitat suggested by the HSI could be one of the key factor in the higher than average density of moose reported in the region (Cooley e*t al*. 2012). The largest concentration of lower quality habitats occur in the southern portion of the RSA where there are higher elevation areas associated with the northern portion of the Dawson Range (Figure 4).

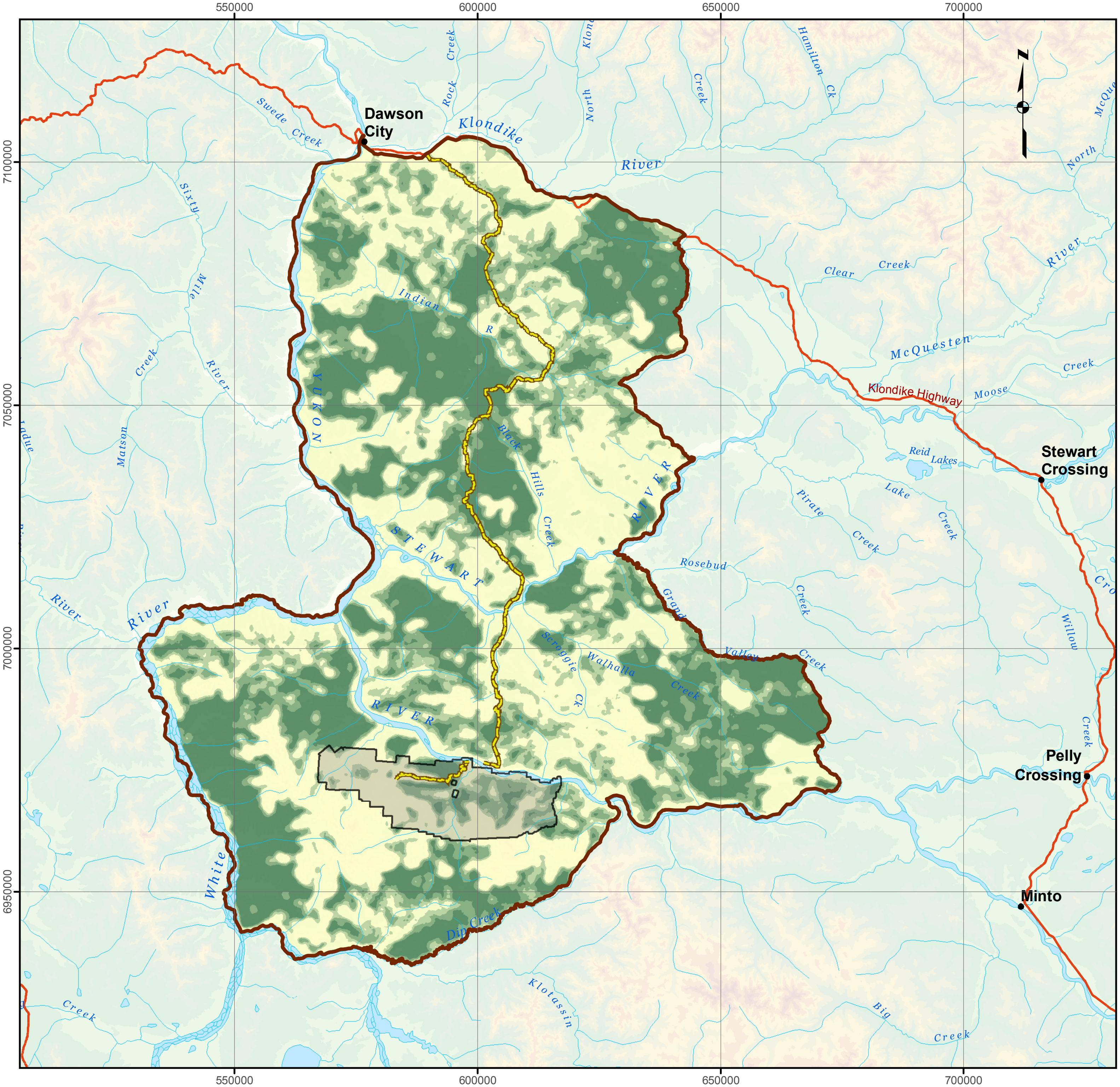
Table 3. Relative availability of late winter moose habitat within the Coffee Project RSA.

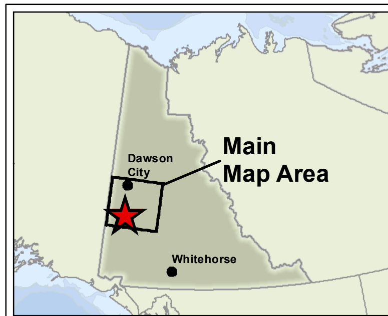
Habitat Class	Habitat Suitability Index Scores	Area (km^2)	Moose Observations	Selection Index
Very Low	0 – 0.7	5,867 (42.9%)	171 (15.5%)	-0.64
Low	0.7 – 0.8	1,964 (14.4%)	132 (12.0%)	-0.17
Moderate	0.8 – 0.9	2,245 (17.4%)	192 (17.4%)	+0.05
High	0.9 - 1	3,585 (26.2%)	607 (55.1%)	+1.10
Total		13,661	1102	

3.1 LIMITATIONS

The HSI is a knowledge-based model; consequently, biases in the knowledge and opinions of the authors are reflected in the model. The HSI model validation is simplistic and based on presence only data and alternative models were not tested. Land cover variables included are correlated with one or both of the terrain inputs. However, the terrain variables were mostly used to restrict the more extreme terrain, so would not substantially affect the suitability of late winter moose habitats.

HSI models are most accurate when animals have very specific habitat requirements and those habitat types are easily mapped. Animals that do not exhibit clear habitat selection, like moose, are more difficult to model accurately. Models of habitat use at the scale of large landscapes is particularly challenging because the availability of spatially explicit data is often missing or coarse.





Legend

- Proposed Route
- Regional Study Area
- Coffee Property

Moose Late Winter Habitat Suitability

- Very Low
- Low
- Moderate
- High

FIGURE 4

Moose late winter habitat suitability

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Moose late winter suitability model produced by EDI (2016).

Project data displayed is site specific. Survey data collected by EDI Environmental Dynamics Inc. (2015).

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

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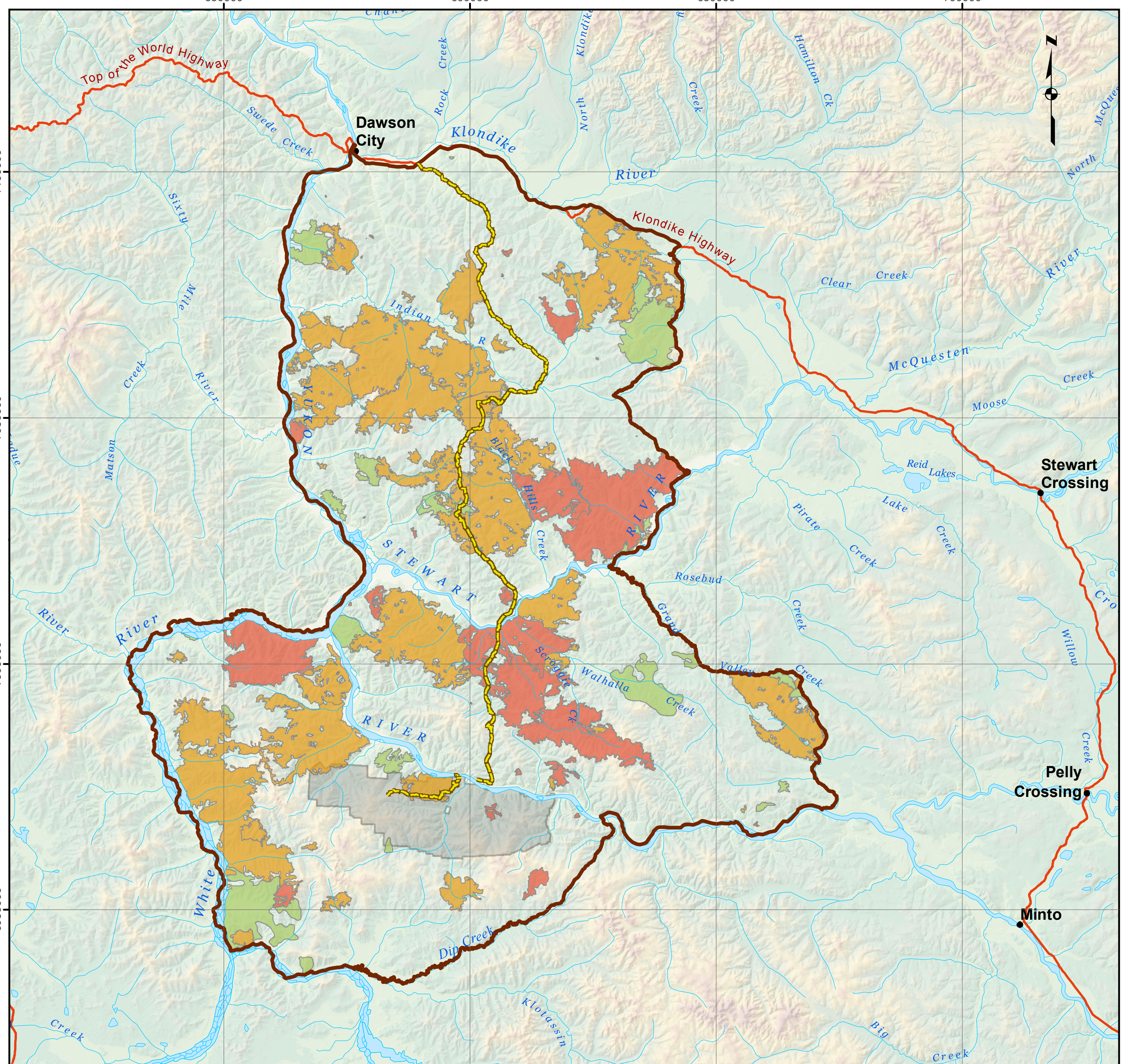

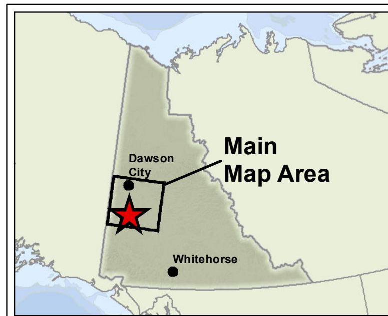

Legend

- Proposed Route
- Highway
- Regional Study Area
- Coffee Property

Fire Occurrence (10 year intervals)

- 1986 - 1995
- 1996 - 2005
- 2006 - 2015

FIGURE: 5

Distribution of wildland fires within the RSA since 1986

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Fire history data provided by Geomatics Yukon - Yukon Government via online source www.geomaticsyukon.ca. (Accessed Jan 15, 2016)

Project data displayed is site specific. Survey data collected by EDI Environmental Dynamics Inc. (2015).

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

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APPENDIX 16-C-3

Thinhorn Sheep

Habitat Suitability Report

Coffee Gold Mine: Thinhorn Sheep Habitat Suitability Model Report

Prepared For
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EDI Project
14Y0306
September 2016

Version 1.1

Down to Earth Biology

ENVIRONMENTAL DYNAMICS INC.

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Suggested citation:

EDI Environmental Dynamics Inc. 2016. Coffee Gold Mine: Thinhorn Sheep Habitat Suitability Report. Version 1.1. Prepared for Kaminak Gold Corporation, Vancouver, BC. EDI Environmental Dynamics Inc., Whitehorse, YT. September 2016.

Revision Summary

Version No.	Date	Revision Notes	Authors
1.0	28 July 2016	Original Version	Todd Mahon
1.1	9 Sept 2016	Final Version	Todd Mahon

EXECUTIVE SUMMARY

Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson, Yukon. The Project will be accessed by road from Dawson.

In anticipation of future regulatory requirements, wildlife baseline information was collected and analyzed to assist with Project planning and mitigation, including a habitat model for thinhorn sheep. The habitat model follows a knowledge-based, habitat suitability index (HSI) approach. That approach involved selecting specific habitat variables relevant to thinhorn sheep in the Project area, developing suitability ratings for each variable, and combining the ratings for each variable into a final composite rating. The variables used in the model were terrain steepness, aspect, distance from escape terrain, land cover, and distance from the Yukon River. The outputs were classified into four ordinal habitat classes corresponding to relative habitat quality: Nil (unsuitable), Low (suitability unknown), Moderate (suitable but suboptimal), and High (optimal).

Generally, the model results corresponded well with information about habitat use by thinhorn sheep in the study area. The amount and distribution of modeled sheep habitat is quite limited; High and Moderate rated habitats accounted for only 1% of the total study area. Suitable habitats were identified in relatively small extents, concentrated on steep, non-forested, south aspect hillslopes, with rocky bluff complexes, along the north side of the Yukon River. The model predictions corresponded well with the three known sheep occurrence areas in the region and identified several other potential habitat areas between them. Confidence in the model is considered moderate. High confidence associated with specialized habitat requirements by sheep (i.e. escape terrain) and good ability to map those areas is offset by having limited data from sheep in the area to build and validate the model.

The HSI output provides a spatially-explicit quantification of thinhorn sheep habitat within the Regional Assessment Area for thinhorn sheep which will be used to assess potential Project effects on sheep habitat, and develop mitigations to reduce Project effects, if required.

AUTHORSHIP

This report was prepared by EDI Environmental Dynamics Inc. Staff who contributed to this project include:

Todd Mahon, M.Sc., R.P. Bio.. .... Author and Model Development

Matt Power, A.Sc.T .... GIS Analysis and Mapping

Lea Pigage, B.Sc., R.P.Bio., PMP .... Wildlife Discipline Lead and Senior Review

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ACRONYMS AND ABBREVIATIONS

Coffee Project ....Coffee Gold Mine

DEM....Digital Elevation Model

EDI ....EDI Environmental Dynamics Inc.

EOSD ....Earth Observation for Sustainable Development

GMS....Game Management Subzone

HSI ....Habitat Suitability Index

Kaminak ....Kaminak Gold Corporation

km ....kilometer

km^2 ....square kilometers

m....metre

n....number/count

NAD83....North American Datum of 1983

Project....Coffee Gold Mine

RSA ....Regional Study Area

RAA ....Thinhorn Sheep Assessment Area

VRI....Vector Ruggedness Index

WKA....Wildlife Key Area

YESAA....Yukon Environmental and Socio-economic Assessment Act

YESAB ....Yukon Environmental and Socio-economic Assessment Board

1 INTRODUCTION

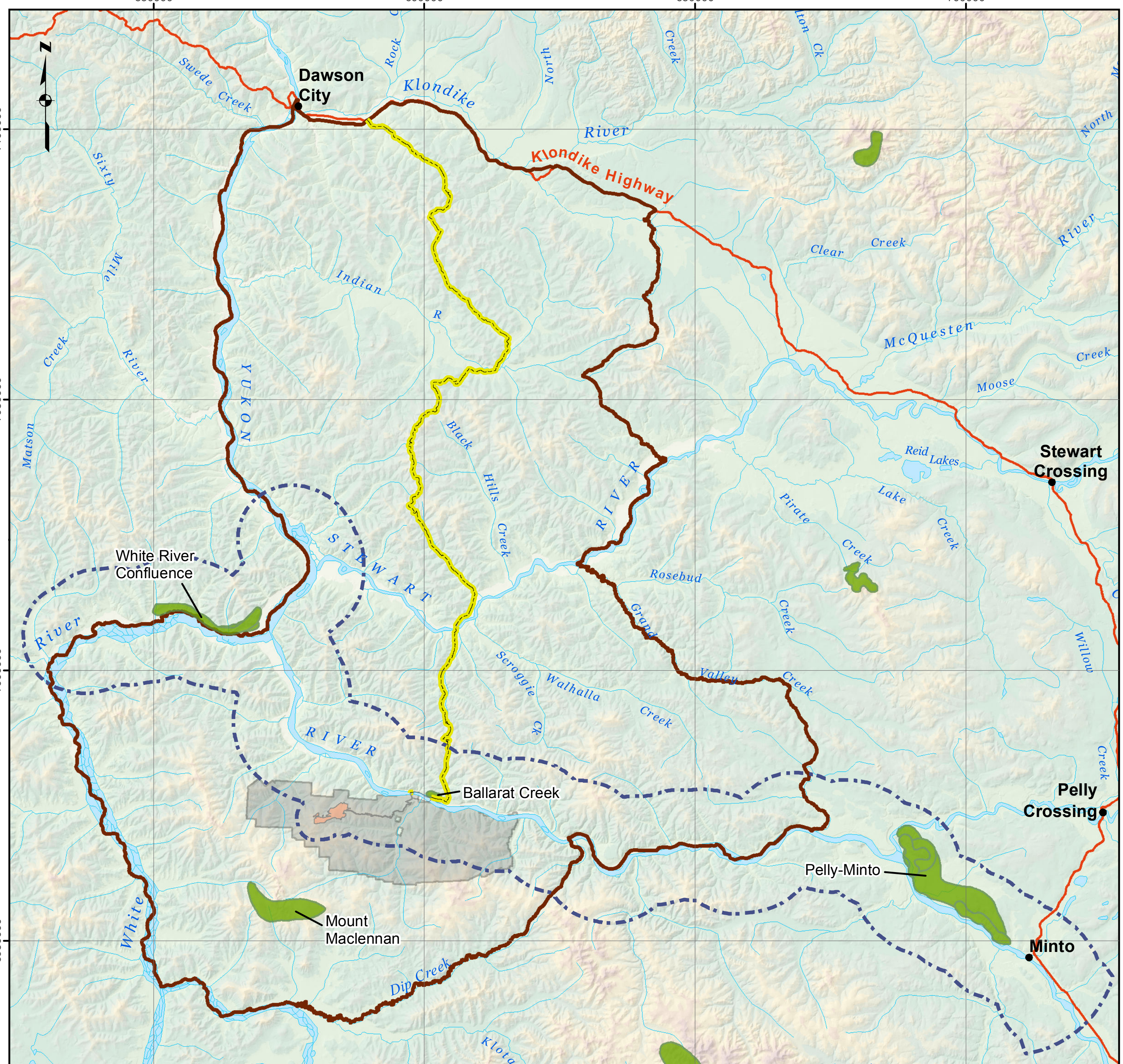
Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson, Yukon (Figure 1). The Project will be accessed by road from Dawson and via regular charter flights for personnel.

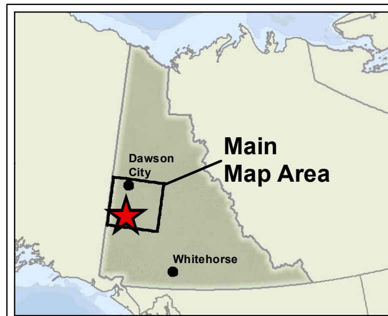
In 2014, Kaminak retained EDI Environmental Dynamics Inc. (EDI) to conduct wildlife baseline studies for the Coffee Project in anticipation of future regulatory requirements. A number of wildlife surveys have been undertaken for the Project, as well as habitat models for select species. This information will assist with Project planning and mitigation. The information provided in this report supports the Project Proposal to be submitted to the Yukon Environmental and Socio-economic Assessment Board (YESAB) Executive Committee for screening under the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA) as well as the Quartz Mining License and Type A Water License applications.

A small number of thinhorn sheep occur at one known location within the Project's wildlife Regional Study Area (RSA), on steep, south aspect hillslopes with rock bluff complexes along the north side of the Yukon River, east and west of Ballarat Creek (Figure 1). Thinhorn sheep are also known to occur at two additional locations in similar habitats along the Yukon River, just outside the RSA. A small group is known to occur 45 km to the northwest of Ballarat, just north of the White and Yukon River confluence (Russell *et al*. 2011). The second area is 85 km east of Ballarat, on a series of hillslopes between Minto Landing and the Pelly River confluence (O'Donoghue and Winter-Sinnott 2014). The year-round occurrence of sheep in these mid-elevation settings is unique in Yukon; most populations of sheep in the territory use alpine or subalpine habitats and exhibit seasonal movement between winter and summer ranges (Sheep Management Team 1996). The degree to which sheep may travel among the three known occurrence areas is unknown. However, the numbers of sheep at the Ballarat and White River confluence occurrence areas are much smaller than what would normally be considered a minimum viable population (Berger 1990; Beissinger and Westphal 1998), without at least occasional emigration from other sources.

The purpose of this modelling exercise was to quantify the amount, quality and location of potential sheep habitat within close proximity to the Project.

The approach used to model thinhorn sheep followed a Habitat Suitability Index (HSI) methodology (US Fish and Wildlife 1981). A HSI model, also referred to as a knowledge-based habitat suitability model (Clark 2012), is a common method for assessing habitat quality for wildlife species. The modelling process uses spatial datasets such as land cover, elevation, and topography and ranks available habitats according to their ability, in their current state, to support a selected species. The habitat rankings can be based on a variety of





Legend

- Highway
- Proposed Route
- Project Footprint
- Coffee Property
- Thinhorn Sheep Wildlife Key Areas
- Thinhorn Sheep Regional Assessment Area
- Regional Study Area

FIGURE: 1

Overview of the Coffee Project

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

Wildlife Key Areas provided by Environment Yukon - Yukon Government.

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

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Map Reference Scale: 1:1,000,000 (Printed at 8.5 x 11)
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Path: J:\Yukon\Projects\2014\14_Y_0306_Kaminak_CoffeeCk\Mapping\2016_MiscMaps\Wildlife\SheepModel\Fig_1_Overview.mxd sources including survey data, information from published studies, local knowledge, expert knowledge, or traditional knowledge. These models can be based on one suitability index or the combination of multiple suitability indices to quantify the quality of habitat for the species (Dijak and Rittenhouse 2009). The combination of suitability ratings for each individual variable creates the HSI.

This report describes how the thinhorn sheep HSI model was developed and includes all applicable requirements of YESAB's *DRAFT Proponents Guide: Model Documentation Report* (YESAB 2015).

1.1 OBJECTIVES

The objective of this model is to assess the quantity, quality and distribution of thinhorn sheep habitat within the thinhorn sheep regional assessment area. The primary intended use of this information is to assist with planning and mitigation of the Project, including an assessment of potential Project-related effects on thinhorn sheep.

1.2 BACKGROUND

Thinhorn sheep have very specific habitat requirements. Foremost is the need for steep, rugged rock cliffs that they use as 'escape terrain' to avoid predators (Geist 1971). They also require seasonal foraging areas and secluded lambing areas in association with escape terrain. Foraging areas are predominantly grass and forb dominated habitats (Seip and Bunnell 1985), such as alpine tundra, south aspect hillslopes, and, occasionally, low elevation meadows. Mineral licks can also be important habitat features for many sheep populations (Simmons 1982). Most sheep in the Yukon make annual movements or migrations among these habitat types (Sheep Management Team 1996). Winter range is typically used from early September to May, and consists of foraging habitat, in association with escape terrain, with characteristics that reduce snow accumulation. These characteristics can include lower elevation, south aspect, and wind prone slopes, often in combination. In May, sheep typically begin moving away from their winter range, following the progression of new plant growth to higher elevations. Pregnant ewes normally seek steep, secluded areas away from other sheep in May and June to birth and rear their lambs before regrouping with other sheep in the summer. Summer range tends to be the most widespread of seasonal sheep habitats and includes a variety of foraging types in association with escape terrain. Summer range often is at the highest elevations, but can include a range of elevations and can overlap with winter range. Mineral licks are used during the spring and summer, but use is typically highest in June and July. Sheep may travel several kilometers away from escape terrain and through forested areas to access mineral licks (Simmons 1982). Most sheep in Yukon occur in mountain alpine zones, where grass and forb dominated meadows, occur in association with mountain cliffs and ridges that provide escape terrain (Sheep Management Team 1996; Hayes 2015).

Within the thinhorn sheep RSA, thinhorn sheep occur in low densities at sporadic, isolated locations. The primary limiting factor for sheep in the area appears to be the amount of suitable habitat, especially escape terrain (Hayes 2015). One historic and three currently occupied occurrences of thinhorn sheep are known in the thinhorn sheep RSA: Mt. Maclennan (historic), Ballarat Creek, White River confluence, and Pelly-Minto occurrence areas. All occurrence areas have been mapped as Wildlife Key Areas (WKAs) for thinhorn sheep (Environment Yukon 2016; Figure 1). The Mount Maclennan historic occurrence area, located approximately 14 km south of the proposed mine site, was noted as having a historic population of 12–15 sheep, that 'may have been hunted out' (Environment Yukon 2016). No sheep have been recorded there since 1990. The other three occurrence areas are on steep, non-forested, south aspect hillslopes with rock bluff complexes, along the north side of the Yukon River. The occurrence area closest to the Project is Ballarat Creek. Ballarat Creek area was first surveyed by Environment Yukon biologists in July 2010, when six sheep were observed, and repeated in February 2011, when eight sheep were observed (Russell *et al.* 2011). During the same surveys another small group of sheep (n=13 in July 2010 and n=17 in February 2011) was observed 45 km to the northwest, near the White and Yukon River confluence. The third known sheep occurrence is 85 km west of Ballarat, between the Pelly/Yukon river confluence and Minto Landing which has been monitored annually between 2000 and 2014 (O'Donoghue and Winter-Sinnott 2014). Between 2000 and 2014, counts have ranged between 31 and 129 sheep, with a generally increasing trend from approximately 45 animals in the early 2000's to approximately 100 animals over the last three years (O'Donoghue and Winter-Sinnott 2014).

The active three occurrence areas of sheep along the Yukon River valley slopes are in a unique setting for thinhorn sheep in the Yukon. Most sheep are associated with alpine or subalpine areas (Sheep Management Team 1996; Hayes 2015). There are several factors associated with the Yukon River setting that may affect the habitat use, movement patterns and population dynamics of the sheep using those areas: small size of the habitat areas (a few kilometers long and few hundred metres wide); small numbers of sheep at each area (at least for Ballarat [n=8] and White River [n=16]); far distances among occurrence areas (45–85 km); located below treeline; and year-round use of the same areas (Russell *et al.* 2011; O'Donoghue and Winter-Sinnott 2014; EDI 2016).

Based on the existing survey information, it is unclear if the three occurrence areas are separate subpopulations or if there is occasional movement of animals among the three areas. The distances between the three areas are farther than sheep normally move on an annual basis (45 km from White River confluence to Ballarat and 85 km from Ballarat to Pelly-Minto), however, individual animals or small groups have been observed making occasional dispersal movements over those distances (Geist 1971). In other parts of North America several sheep populations have been described as having metapopulation structures (Bleich *et al.* 1996; Epps *et al.* 2005; Akçakaya *et al.* 2007), that are characterized by isolated subpopulations, in discreet occurrence areas separated by unsuitable habitat, that exhibit a pattern of extirpation and recolonization of individual areas over a period of many years. If a metapopulation dynamic is occurring along the Yukon River, the Ballarat occurrence area might be considered a 'satellite' subpopulation (Hanski and Gyllenberg 1993) that is likely to experience more frequent extirpations, and longer vacancies, due to its small geographic size and small subpopulation number. The Pelly-Minto occurrence area might be a 'core' subpopulation that is rarely extirpated and which is a regular source of emigrating animals to recolonize or supplement satellite areas like Ballarat. Without immigration to supplement or recolonize the Ballarat occurrence area, long term persistence of sheep is uncertain. Berger (1990) predicted that populations with less than 50 sheep will go extinct, on average, within 50 years. Empirical observations of small sheep populations have observed both extinctions and persistence over periods of several decades, and the factors that affected those outcomes varied widely among populations (Krausman 1997).

If thinhorn sheep do travel among the three known occurrence areas, the most likely movement corridor is along a series of steep hillslopes and ridges that occur on the north side of the Yukon River. Those hillslopes offer good foraging habitat but limited escape terrain (EDI 2016). During five aerial sheep surveys conducted between 2010 and 2015 along the Yukon River hillslopes between the Pelly-Minto occurrence area and the White River confluence area, no sheep were detected outside of the known occurrence areas (Russell *et al.* 2011; EDI 2016). Ground surveys and trail monitoring conducted in the Ballarat Creek valley during the summers of 2015 and 2016 identified lightly used trails along the ridgelines on both the east and west sides of Ballarat Creek and two areas with concentrated use (i.e. numerous pellet groups, bedsites, and disturbed ground leading to escape terrain (EDI 2016). In addition to the relatively far distances between occurrence areas, sheep would have to cross either the Pelly River or the Yukon River to travel between occurrence areas.

1.3 STUDY AREA

The study area for thinhorn sheep HSI modelling is defined as the thinhorn sheep regional assessment area (RAA; Figure 1). The RAA was modified from the RSA to include known sheep occurrence areas to the east and west of the RSA along the Yukon River, and to exclude the northern and southern portions of the RSA where sheep have not been recorded. The thinhorn sheep RAA is defined by a 10 km buffer on either side of the Yukon River, including sections outside the RSA to encompass the White River and Pelly-Minto WKAs. The thinhorn sheep RAA is 5,263 km².

The thinhorn sheep RAA occurs within the Klondike Plateau Ecoregion and is dominated by rolling, forested terrain bisected by deep, narrow, v-shaped valleys. Alpine areas above 1200 m a.s.l. account for less than 5% of the landbase and mostly consist of rounded mountains and smooth topped ridges with very limited rockland (Smith *et al.* 2004). Below treeline, the vegetation pattern reflects the discontinuous distribution of permafrost with stunted black spruce woodlands on cold, north facing slopes and mixed forests or grasslands on warm south-facing slopes (Smith *et al.* 2004). The most prominent physiographic feature in the thinhorn sheep RAA is the Yukon River, which runs east-west through the assessment area. The Yukon River, and many tributaries that join it, have cut deeply into the plateau's surface. The steep hillslopes associated this erosion pattern provide areas of escape terrain for sheep.

The climate in the area is characterized by long cold winters and short warm summers, and most of the annual precipitation comes during summers (Smith *et al.* 2004).

Road access in the thinhorn sheep RAA is limited to the Pelly-Minto area and a single road and barge crossing of the Yukon River near Ballarat Creek. The Yukon River is a popular canoe route during the summer and motorized boats are used by miners, guides and First Nations people. Helicopter access associated with mineral exploration has been widespread across the area over the last decade.

2 METHODS

2.1 MODEL OVERVIEW

The thinhorn sheep HSI model is a deterministic model that estimates relative habitat quality for sheep across the assessment area. The model is based on four variables described in the literature as being relevant to habitat use and selection by sheep (terrain steepness, aspect, proximity to escape terrain, and land cover), and one modifier variable developed specifically for this Project (proximity to the Yukon River).

2.1.1 LIFE REQUISITES AND SEASONS

The model identifies associations of escape terrain and foraging areas as a combined habitat type that meets key life requisites of security and forage. The model is tailored to steep, south aspect hillslopes below treeline along the Yukon River that are used year-round by sheep (Russell *et al.* 2011; O'Donoghue and Winter-Sinnott 2014).

2.1.2 GEOGRAPHIC AND ECOLOGICAL CONTEXT

The thinhorn sheep HSI model was designed specifically for the environmental conditions and patterns of occurrence of thinhorn sheep along the Yukon River between Minto Landing and the White River. Potential sheep habitat in the area is characterized by a series of discontinuous, steep, non-forested, south aspect hillslopes with rock bluff complexes along the north side of the Yukon River. Selection of variables to include in the model, parameter ratings within variables, and the method in which ratings for each variable were combined to produce the overall HSI rating were tailored to conditions within the thinhorn sheep RAA. Although the model identifies potential sheep habitat outside the Yukon River corridor, in more traditional mountain settings, such as areas on Mount Maclennan, the model was not calibrated or evaluated for those types of areas.

2.2 HABITAT VARIABLES

Information used to develop the thinhorn sheep HSI is primarily from literature about habitat use and selection by sheep and from habitat characteristics associated with the three known sheep occurrence areas within the thinhorn sheep RAA. Studies of thinhorn sheep in Yukon were used to the extent possible, however, because local information is limited, studies of thinhorn and bighorn sheep in other regions of North America was also considered.

Numerous studies have examined habitat selection by wild sheep in other regions (e.g. Divine *et al.* 2000; McKinney *et al.* 2003; DeCesare and Pletscher 2006; Walker *et al.* 2007) and there is one study of thinhorn sheep in the Ogilvie Mountains and Nahoni Range in Yukon (Barker 2012). Habitat variables identified in the literature as being important to sheep, and which were considered for this HSI model, are summarized in Table 1. Details about each variable, including references, are provided in the sections following.

Table 1. Habitat variables considered for the thinhorn sheep HSI.

Variable	Relationship to selection or use by wild sheep	Incorporated in HSI / Rationale
Terrain Steepness (slope)	Key variable associated with escape terrain for sheep; minimum slope values vary somewhat among studies, 31 degrees (60%) frequently referenced.	Yes / Steep slopes correspond to known sheep occurrence areas and potential escape terrain elsewhere in the RAA.
Terrain Ruggedness Index (TRI)	TRI is a measure of how topographically uneven an area is. Several studies have observed selection by sheep for areas with high TRI values.	No / High TRI value areas (ridges and draws) occur extensively across RAA that are not associated with escape terrain.
Elevation	In mountainous areas sheep often select for higher elevations (i.e. alpine areas); seasonal shifts in elevation also frequently occur in some populations.	No / Occurrence areas exhibit a relatively narrow elevation band, from valley bottom to hilltop, which appear to be used year-round.
Distance from escape terrain	Several studies have observed that the majority of sheep locations are within <300 m of escape terrain.	Yes / 150 m buffer established around steep slope areas to account for potential foraging habitat and thermal cover.
Aspect	Often a significant variable in habitat studies of sheep; relationships vary depending on regional climate and vegetation; consistent use and selection for warm aspects in Yukon.	Yes / All occurrence areas are associated with warm aspect hillslopes dominated by grass and forbs (high forage value); warm aspect also important for reducing snow depths in winter.
Land Cover, EOSD	Sheep forage is dominated by grass and forbs.	Yes / Grass and forb dominated habitats at occurrence areas correspond to non-forested types in the EOSD dataset.
Distance from the Yukon River	Based on patterns of small size and isolation of potential habitat patches and professional opinion that distance from Yukon River bluffs reduces habitat suitability.	Yes / Areas on the south side of the Yukon River and >5 km from the river on the north side were downgraded by one class. Corresponds to lack of sheep observations in these areas.

2.2.1 TERRAIN STEEPNESS (SLOPE)

Steep slopes are a key predictor of conditions that provide escape terrain for sheep (Geist 1971; McKinney *et al.* 2003). The value at which steep slopes begin to offer escape terrain varies somewhat depending on the geology, geomorphology, climate, and vegetation associated with different regions. In addition, factors associated with the spatial dataset, notably data resolution, can result in bias between the spatial data and the actual conditions on the ground (Divine *et al.* 2000). Notwithstanding these sources of variation, 60% gradient (31 degrees) is frequently referenced in the literature as a value at which slopes begin to offer escape terrain for sheep (Holl 1982; Smith *et al.* 1991; McCarty and Bailey 1994; Andrew *et al.* 1999; McKinney *et al.* 2003).

To assess the appropriateness of slopes values in identifying escape terrain within the RAA, sensitivity analysis was conducted using 31, 35, and 38 degree slopes as threshold values at which potential escape terrain becomes available. For each value the resulting extent with slopes greater than that value was evaluated relative to 1) potential escape terrain identified in satellite imagery, 2) field conditions observed by biologists conducting aerial sheep surveys, and 3) the boundaries of thinhorn sheep WKAs (Environment Yukon 2016). The goal of the exercise was to select the slope that included all, or almost all, potential escape terrain (i.e. to minimize errors of omission) while avoiding slopes that are too gentle which would result in overestimating the amount of actual escape terrain (i.e. committing errors of commission). The slope that performed best relative to the three evaluation criteria was 35°. At 31° the associated coverage appeared to include extensive areas where no escape terrain was visible in satellite imagery or noted during the surveys. Conversely, 38° slope appeared to be too steep a slope and areas of potential escape terrain noted in satellite imagery or during surveys were being missed. Although 35° slope seemed to perform the best over the majority of the RAA, it may underestimate potential sheep habitat in the Pelly-Minto area, based on the boundaries of the WKA identified for that area. Potential explanations for the different pattern at Pelly-Minto are not clear but may include terrain expressions that are occurring at a resolution finer than the 30 m Digital Elevation Model (DEM).

2.2.2 ASPECT

The combination of steep slopes and warm aspect on hillslopes along the Yukon River and adjacent drainages results in grass and forb dominated ecosystems that offer productive forage for sheep, which plays an important role in determining suitability for sheep in the RAA. Steep south slopes can also play an important role in winter forage availability by reducing snow pack (Goodson *et al.* 1991). Warm, south aspect slopes are frequently associated with both summer and winter range for thinhorn sheep in Yukon (Sheep Management Team 1996; Barker 2012; Hayes 2015).

Aspect was used in the model, in combination with steep slopes, to identify associations of escape terrain and foraging areas as a combined habitat type. The criteria used to define warm aspects (90 to 270 degrees), corresponds to the observed pattern of non-forested slopes in the thinhorn sheep RAA.

2.2.3 PROXIMITY TO ESCAPE TERRAIN

Sheep have a strong affinity to escape terrain, and will restrict the distances they move away from it to forage. The distances sheep regularly forage away from escape terrain vary among studies, sex-age cohorts, and seasons. Most studies report significantly reduced frequency of use by sheep at distances between 50 and 200 m from escape terrain. For example Poole (2013) observed 90% of locations of bighorn sheep were within 95 m of escape terrain. For this model, an intermediate distance of 150 m, following McKinney *et al.* (2003), was used to identify potential foraging habitat around High value habitat previously classified using steep slopes and warm aspect.

2.2.4 LAND COVER

Thinhorn sheep forage primarily on a variety of grasses and forbs (Seip and Bunnell 1985). Within the thinhorn sheep RAA, ecosystems with the highest abundance of grass and forbs are predominantly non-forested sites, notably the steep, south aspect hillslopes on the north side of the Yukon River. The EOSD land cover dataset (Wulder *et al.* 2008; Dawson Regional Planning Committee 2013) is the only land cover dataset available across the thinhorn sheep RAA. It was evaluated for patterns of correspondence between land cover categories and known and potential sheep habitat identified on satellite imagery. Predominantly, the steep, south aspect, non-forested hillslopes that are used by sheep were classified as herb and shrub categories in the EOSD.

Ratings for EOSD were incorporated into the model by downgrading forested areas that were rated High or Moderate according to slope, aspect and buffer distance criteria by one class. The ecological rational for this downgrade is that if the area is forested it probably does not offer escape terrain and the potential suitability for foraging is reduced. Areas already rated Low (steep slopes on cool aspect), were not downgraded to Nil. A description of EOSD land cover categories and associated ratings downgrades used in the model are provided in Table 2. An accuracy assessment of the land cover dataset provided by Yukon Government revealed that the data had poor accuracy for the finest classification level (i.e. land covers types) but more accurately reflected broader land cover categories used in this model (ASL 2014). Including this variable in the model had a relatively weak influence on model outcomes because the land cover types of interest were strongly correlated to conditions of slope and aspect already reflected in the model.

Table 2. Habitat ratings for EOSD land cover categories.

Note: A score of -1 corresponds to a rating downgrade of one class (e.g. High to Moderate).

Land Cover Value[1]	Land Cover Description	Rating Modifier
11, 12	Cloud or Shadow	0
20, 31-33	Unvegetated	0
40-43, 100, 101	Herb or lichen dominated	0
50-58	Shrub dominated	0
81-83	Wetlands	-1
211-219, 240-241	Conifer dominated	-1
221-229	Broadleaf dominated	-1
232-239	Mixed-wood	-1

[1] Land cover values are the digital numbers in the land cover datasets that represent different land cover types

2.2.5 DISTANCE FROM THE YUKON RIVER

Model outputs using the previous four variables appeared to be somewhat biased towards overestimating potential sheep habitat in two geographic settings relative to the Yukon River. The first situation was in the 2 to 5 km zone along the south side of the Yukon River. Within that zone the extent and quality of foraging habitat appeared be overestimated. This situation appeared to result from a broad-scale effect of aspect that is not included in the model. In the model, aspect is used at a relatively fine, 30 m resolution. That scale is appropriate for capturing fine scale aspect effects, such as differences in vegetation types on the north and south side of ridges. However, the zone in question appears to be affected by a broader-scale north aspect effect associated with the landscape sloping down to the Yukon River. This broader-scale effect results in poorer quality foraging habitat (more forested and partly forested ecosystems on south aspect slopes), which is poorly reflected in the EOSD data.

The second situation was for areas greater than 5 km from the Yukon River, on both sides of the valley. In this situation the majority of potential escape terrain features identified by the model were very small (<200 m long), isolated patches, whose potential suitability was reduced by small size and distance between patches.

In both of these situations the apparent bias in the model to overestimate habitat there was supported by the lack of known occurrences of sheep in those areas. To reduce the potential bias in these areas (i.e. areas on the south side of the Yukon River and areas on the north side >5 km from the river), model ratings of High and Moderate were reduced by one class. Low ratings were not reduced to ensure potential habitat was not completely omitted. Adding this modifier into the model retained all areas identified by previous model criteria, but reduced the suitability rating to account for the potential bias that the model was overestimating suitability in these areas.

2.2.6 TERRAIN RUGGEDNESS INDEX

Terrain ruggedness refers to areas that are topographically complex, uneven or broken. Several studies of habitat use by sheep have found selection for areas with higher ruggedness index values (Andrew *et al.* 1999; Divine *et al.* 2000; Sappington *et al.* 2007; Barker 2012). High ruggedness values can correspond to at least two terrain conditions used by sheep. These include areas on steep slopes, where high ruggedness is associated with gentler benches or ridges that are used for foraging and bedding, and on modest slopes, where high ruggedness is associated with enhanced escape terrain.

A terrain ruggedness model was built and evaluated for the thinhorn sheep RAA following the vector ruggedness approach developed by Sappington *et al.* (2007). That approach incorporates variability in both the aspect and gradient of a DEM to produce a ruggedness index. This produces an index that is less correlated to slope than earlier methods of computing ruggedness (Andrew *et al.* 1999, Divine *et al.* 2000).

Evaluation of the vector ruggedness index (VRI) indicated relatively poor correspondence with escape terrain in the thinhorn sheep RAA. High VRI values in the thinhorn sheep RAA were primarily associated with ridges and confined valley draws. While these high VRI areas often bordered high quality escape terrain and associated foraging areas, the VRI values for the steep, south aspect hillslopes where the escape terrain and foraging areas occurred, were moderate. In addition, high VRI ridges and draws occurred extensively across the thinhorn sheep RAA, not just in association with sheep habitat. For these reasons the VRI was not included in the model.

2.2.7 ELEVATION

Several studies in other regions have observed relationships between elevation and habitat selection by sheep (DeCesare and Pletscher 2006; Epps *et al.* 2006; Walker *et al.* 2007). These include desert regions where water and forage is more available at higher elevations (Epps *et al.* 2000), and in montane areas where sheep were selecting alpine areas above forested valleys (Walker *et al.* 2007; Barker 2012).

Within the thinhorn sheep RAA, sheep occur at low to mid elevations where the presence of escape terrain and forage is primarily driven by steep, south aspect hillslopes, and associated rocky bluffs, along the north side of the Yukon River. Suitable habitat within those areas, and limited information about how sheep use those areas, does not appear to vary with elevation (i.e. areas from valley bottom to hilltop can have escape terrain and/or foraging habitat). Therefore elevation was not included within the model.

2.3 MODEL IMPLEMENTATION

The thinhorn sheep habitat model is based on the HSI methodology (US Fish and Wildlife Service 1981). That modeling approach involved selecting specific habitat variables relevant to thinhorn sheep in the RAA, developing suitability ratings for each variable, and combining the ratings for each variable into a final composite rating for combined escape terrain and foraging habitat. The model works by first generating a base rating based on slope steepness, aspect, and distance from steep terrain and then applying downgrades for suboptimal (forested) land cover categories and for distance from the Yukon River, as described above. A conceptual model outlining the way ratings for individual variables are integrated into the final HSI rating is outlined in Figure 2.

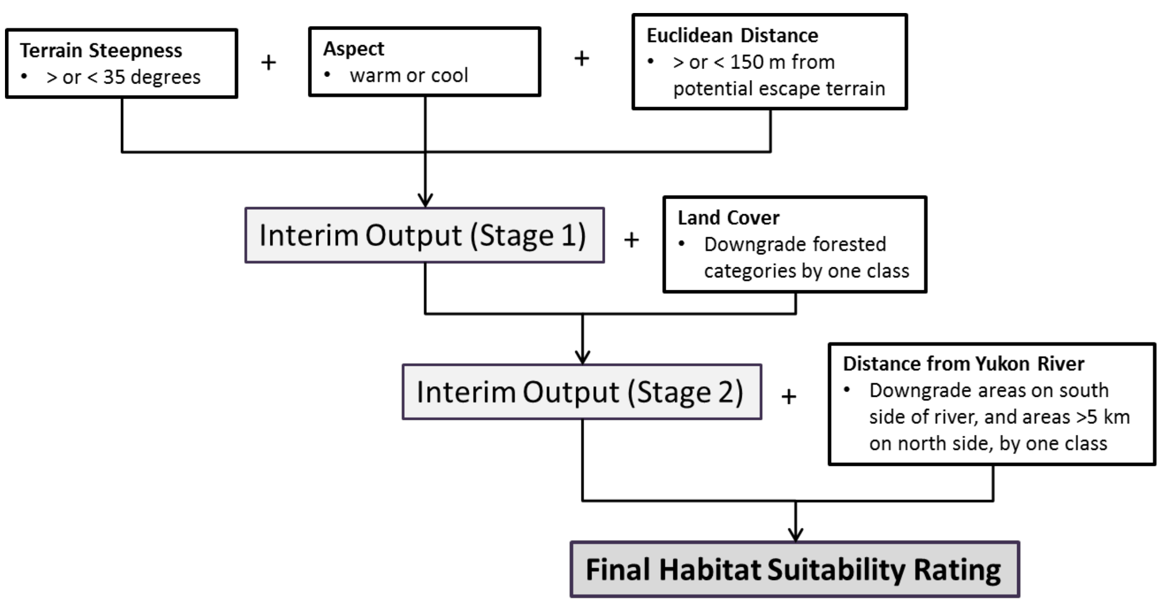


Figure 2. Thinhorn sheep habitat suitability modeling flow chart.

2.4 MODEL RATING SCHEME

The thinhorn sheep HSI model uses a 4-class rating scheme (RISC 1999). The rating categories correspond to qualitative predictions of relative habitat quality. Where sheep occur, frequency of use is expected to correlate to the ordinal habitat classes, but data is not available to test that expectation. Habitat conditions and suitability interpretations for each rating class are provided in Table 3.

Table 3. Description of habitat rating classes used in the thinhorn sheep HSI model.[1]

Habitat Rating	Habitat Conditions	Interpretation
High	Potential escape terrain on warm aspect with potential foraging habitat (herb, shrub or rock land cover).	Suitable. Optimal combination of escape terrain and foraging habitat.
Moderate	Potential escape terrain on warm aspect with forested land cover. or Potential foraging habitat (herb, shrub or rock land cover) within 150 m of High rated habitat.	Suitable. Either the quality of foraging habitat is reduced or proximity to escape terrain is increased, resulting in reduced habitat quality.
Low	Potential escape terrain on cool aspects. or Forested habitat within 150 m of escape terrain.	Suitability unknown. Suboptimal escape terrain or foraging habitat; use of these areas by sheep is undocumented in study area.
Nil	All areas farther than 150 m from escape terrain.	Unsuitable. Areas do not provide access to critical escape terrain.

[1] For simplicity, descriptions here exclude a one class downgrade for areas >5 km from the Yukon River.

2.5 DATA ACQUISITION AND PREPARATION

The spatial datasets, with their sources, used to develop the thinhorn sheep HSI are described in Table 4. A digital elevation model (DEM) was used to generate the slope and aspect datasets. The land cover was an updated dataset developed for the Dawson land use planning region and is based on imagery from 2008 and 2009 that had areas of cloud and shadow filled in with earlier data from 2000. Information used to define the occurrence areas used by sheep was from two survey reports by Yukon Environment biologists (Russell *et al.* 2011; O'Donoghue and Winter-Sinnott 2014) and baseline surveys as part of this Project (EDI 2016a and 2016b).

Table 4. Spatial databases used in the thinhorn sheep HSI model.

Dataset	Source	Description
Digital Elevation Model (DEM) (including slope and aspect)	Natural Resources Canada	Raster database 30 m cell size Published: 2012
Dawson Land Cover	Environment Yukon, Yukon Government	Raster database 30 m cell size Imagery: 2008 and 2009 Developed: 2014
Land Cover, EOSD	Canadian Forest Service, Pacific Forestry Centre	Raster database 30 m cell size Imagery: circa 2000 Developed: 2006
Thinhorn sheep survey data	YG and Project acquired data	Vector database YG data 2010-2014 Coffee Project data 2014 and 2015

All analyses were completed using NAD83 Yukon Albers projected coordinate reference system (EPSG: 3578). Analyses and management of spatial data was completed using ArcGIS Desktop 10.2 with the Spatial Analyst extension (ESRI 2013).

2.6 MODEL EVALUATION

Survey data for sheep in the RAA were insufficient to validate model performance. Two stages of model evaluation were conducted. The first stage consisted of iterative reviews of model outputs and adjustment of parameter ratings during model development. Information used during evaluation and calibration exercises included 1) satellite imagery, 2) field conditions observed by biologists conducting aerial sheep surveys, and 3) the boundaries of thinhorn sheep WKAs (Environment Yukon 2016). The goal of model calibration exercises were to specify model parameters so that the model included all, or almost all, areas with potential escape terrain (i.e. to minimize errors of omission) while avoiding ratings that were too liberal, which would result in overestimating the amount of escape terrain that really occurred (i.e. committing errors of commission). The evaluation and calibration exercises conducted for each variable in the model, and associated outcome, are provided in Table 5.

The second stage of model evaluation consisted of informal field assessments conducted in June 2016, following model construction. Field evaluations were limited to areas within 15 km of Ballarat Creek and were focussed on the Ballarat occurrence area and Coffee Creek bluffs. Evaluations focussed on three issues:

- Whether any areas of escape terrain were being missed by the model.
- Assessing the slope steepness that was associated with escape terrain.
- The appropriateness of the 150 m buffer distance used around potential terrain.

The findings of the field evaluations were that, overall, the model was performing well and that model revisions were not required. No instances were observed where the model missed areas of suitable escape terrain in the field. Overall the model appeared biased to overestimating potential habitat relative to field conditions. This resulted from two factors. One was that the 35 degrees slope value used in the model appeared to be somewhat too low. Areas of escape terrain measured in the field had slopes of at least 38 degrees and mostly >40 degrees. The second factor was that the buffer distance of 150 m around escape terrain was farther than sign was observed. All concentrated sheep sign occurred <100 m from escape terrain. These biases were primarily expressed as areas of modelled habitat being larger than they really were in the field. They also resulted in some instances where habitat was predicted but none actually occurred, but these instances were generally of very small areas.

Concentrated sheep sign (trails, pellets, and beds) was limited to the largest rocky bluff complex on the western portion of the Ballarat occurrence area, although occasional sign was observed along the length of the ridge top along the west Ballarat area. Ground surveys were not conducted in the eastern portion of the Ballarat occurrence area but four sheep that were observed there via aerial surveys were similarly associated with the largest extent of escape terrain. No sheep sign was observed along the Coffee Creek bluffs.

The decision was made not to revise the model based on the field observations because the findings were consistent with the desired objective of the model being slightly biased to over-predicting potential habitat than to potentially missing habitat areas.

Table 5. Evaluation and calibration exercises conducted for each variable included in the thinhorn sheep HSI.

Variable	Calibration Exercises Conducted	Outcome
Terrain Steepness (slope)	31, 35 and 38 degrees were evaluated as minimum slopes for identifying potential escape terrain.	35 degrees selected as best overall value for identifying potential escape terrain.
Aspect	The range of aspects associated with steep, non-forested hillsides associated with the three known sheep occurrence area were measured.	Warm aspects defined as 90-270 degrees; cool aspects as 0-90 and 270-360.
Distance from escape terrain	Information about sheep occurrence relative to distance from escape terrain summarized from the literature; 100-300 m buffers around potential escape terrain were examined for known and potential occurrence areas across the RAA.	150 m buffer selected, based primarily on patterns of sheep use from literature.
Land Cover, EOSD	Correspondence between land cover categories and potential sheep habitat was assessed; known occurrence areas were dominated by herb, shrub and non-vegetated categories.	Rating downgrades were applied to forested land cover categories.
Distance from the Yukon River	None. Distances based on patterns of small size and isolation of potential habitat patches and professional opinion that those characteristics reduced habitat suitability.	

3 RESULTS AND DISCUSSION

The distribution of thinhorn sheep habitat predicted by the model across the RAA is shown in Figure 3. The amount of High and Moderate rated habitat is very limited and accounts for only 1% of the total area of the RAA (Table 6). Generally, model predictions correspond well with our knowledge of sheep occurrence and habitat use in the area:

- The amount of suitable sheep habitat in the area is limited in extent and concentrated along the Yukon River corridor.
- The highest value, and most extensive patches of sheep habitat occur on the steep, non-forested, south aspect hillslopes with rock bluff complexes on the north side of the Yukon River.

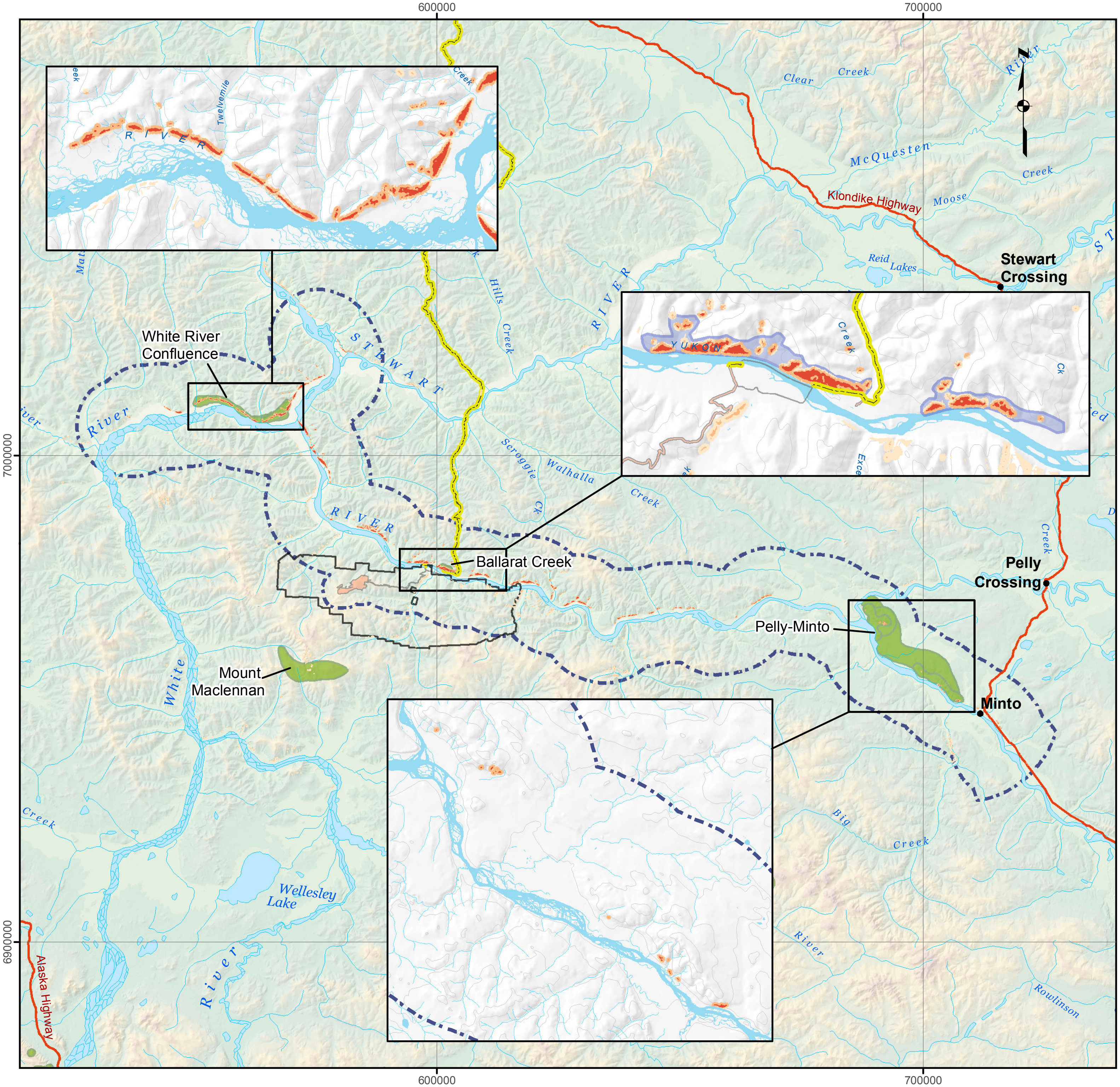
The extent of modelled habitat corresponds well with habitat identified on satellite imagery and with field surveys for the Ballarat and White River confluence areas. The model may be underestimating the extent of suitable habitat at the Pelly-Minto occurrence area. The reason for this issue at Pelly-Minto is not clear, but it may be at least partly due to the size of some of the escape terrain features that occur there being too small to be detected by the 30 m resolution DEM used in the model.

In addition to the three known sheep occurrence areas, the model predicts several additional potential habitat areas along the north side of the Yukon River that are comparable in extent of suitable habitat to Ballarat. Although sheep were not detected at those areas during past surveys (Russell *et al.* 2011; EDI 2016a; EDI 2016b), based on the similarity of habitat quality and extent to Ballarat, it is possible those areas could be occupied intermittently, or that they are used as travel and stopover habitats by sheep moving among the known occurrence areas. Surveys of those areas may be useful to verify the quality and extent of suitable habitat and to search for signs of use by sheep.

The model also predicts several smaller, lower rated, and more isolated patches of concentrated habitat along the south side of the river. These include clusters of potential habitat along Independence, Coffee, and Britannia Creeks, as well as areas along the Yukon River. Assessment of satellite imagery for those areas and incidental observations while flying over them, suggests that escape terrain is very limited at those areas. No records of sheep have been reported at the areas south of the Yukon River, however, to the best of our knowledge, systematic surveys of the areas have not been conducted.

Table 6. Availability of thinhorn sheep habitat by suitability class within the RAA.

HSI Rating Class	Area (ha)	Percent
Nil	515,642	98.0%
Low	5,582	1.1%
Moderate	3,639	0.7%
High	1,450	0.3%
Total	526,313	100%



Legend

- Highway
- Proposed Route
- Project Footprint
- Thinhorn Sheep Wildlife Key Areas
- Thinhorn Sheep Regional Assessment Area
- Thinhorn Sheep Local Assessment Area

Habitat Suitability Index

- Nil
- Low
- Moderate
- High

FIGURE: 3

Thinhorn sheep habitat suitability

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Thinhorn sheep habitat suitability model produced by EDI (2016).

Project data displayed is site specific.

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

0 10 20 30 40
KM

Map Reference Scale: 1:1,000,000 (Printed at 8.5 x 11)
Coordinate System: NAD 1983 UTM Zone 7N

Drawn: LG	Checked: TM/MAS	Date: 09/09/2016

KAMINAK GOLD CORPORATION EDI

Path: J:\Yukon\Projects\2014\14_Y_0306_Kaminak_CoffeeCk\Mapping\2016_Mapping\2016_Baseline\007_Wildlife\SheepModel_mxd\Fig_3_SheepHSI_DW_160803.mxd

3.1 LIMITATIONS AND ASSUMPTIONS

Confidence in the thinhorn sheep model is somewhat limited by the nature of the HSI approach and by the limited amount of data for sheep, to both support model development and validate model performance. The HSI is a knowledge-based model; consequently, biases in the knowledge and opinions of the authors are reflected in the model. Generally, quantitative models that are directly estimated from data, such as resource selection functions, are considered more rigorous (Boyce *et al.* 2002) and, in some circumstances, have been shown to perform better than HSI models (Johnson and Gillingham 2005). Although the existing sheep occurrence data was useful for guiding HSI development, the amount of data and spatial accuracy associated with it was insufficient to build a data-driven model or to conduct quantitative validation of the HSI model.

Despite the knowledge-based nature of this model, and the lack of data to validate the model, overall confidence in the model is moderately high. That is because thinhorn sheep have very specific requirements for escape terrain and characteristics of that habitat type are easily mapped with the available DEM datasets in GIS. HSI models are most accurate when animals have very specific habitat requirements and those habitat types are easily mapped (Brooks 1997). Model confidence was improved by the June field surveys to verify key assumptions in the model, including the range of slopes that correspond to escape terrain and evidence of distance of use from escape terrain by sheep.

Certain factors of the model limit the precision and accuracy of model outputs. The model uses discreet categorizations to rate input variables, which are reflected in model outputs. For example a buffer of 150 m was used as the distance away from escape terrain that sheep were likely to use. In reality, most patterns of use by wildlife are expressed as some form of gradient or dose response (e.g. linear, logistic, or quadratic functions) to a variable of interest. In the case of distance from escape terrain, the more precise relationship of use by sheep is probably a logistic curve (Poole 2013). Categorical classifications were used in this model for simplicity and transparency (i.e. model parsimony), and because the suitability ratings for most variables exhibited threshold responses over narrow parameter ranges. For example, the slope at which escape terrain becomes available varies by only a few degrees. The aspect angles that affect important vegetation types for sheep forage also appear to transition over a narrow range. One of the consequences of this categorical approach is that actual habitat use by sheep is expected to show somewhat more of a graduated response than what is reflected in the model. Another consequence is that while model predictions appear slightly biased to overestimating habitat overall, accuracy at specific sites is expected to vary.

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APPENDIX 16-C-4

Grizzly Bear

Habitat Model Report

Coffee Gold Mine:
Grizzly Bear Habitat Model Report

Prepared For

Kaminak Gold Corporation
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Prepared By

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EDI Project

14Y0306
September 2016

Down to Earth Biology

EDI ENVIRONMENTAL DYNAMICS INC.

Suggested citation:

EDI Environmental Dynamics Inc. 2016. Coffee Gold Project: Grizzly Bear Habitat Model Report. Prepared for Kaminak Gold Corporation, Vancouver, BC by EDI Whitehorse, YT. September 8, 2016.

REVISION SUMMARY

Version No.	Date	Revision Notes	Revision Authors
1.0	April 6, 2016	Original Version	
1.1	September 8, 2016	Final Version	Lea Pigage

EXECUTIVE SUMMARY

Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson, Yukon. In anticipation of future regulatory requirements, wildlife baseline information was collected and wildlife habitat models were developed to assist with Project planning and mitigation, including a suite of models to describe baseline grizzly bear (*Ursus arctos*) habitat.

To help characterize the effects of existing human developments on grizzly bear habitat, three models were created — each determining an aspect of habitat availability considering current human development in the Project's Regional Study Area (RSA):

1. Habitat Effectiveness — evaluates habitat quality as a relationship of topographic features, vegetative features, and proximity to human infrastructure and activities to estimate the effectiveness of habitat for grizzly bears.

2. Security Areas — estimates if available habitat is secure (i.e. areas where grizzly bears can forage for 24–48 hours without interacting with humans).

3. Linkage Zones — identifies areas of potential movement for bears between habitat patches based on landscape factors and proximity to human infrastructure and activities.

A denning habitat suitability model was also created to identify and quantify areas suitable for grizzly bear denning. Together these four models provide spatially-explicit quantifications of grizzly bear habitat quality within the RSA.

At baseline, the habitat effectiveness model indicated that overall habitat in the RSA is 92.3% effective during green-up (peak greenness in July) and 91.8% effective during green down (senescence in September). The security areas model identified that at baseline 94.7% of the RSA is 'secure' for grizzly bears. The linkage zone model identified that 92.5% of the RSA was modelled to be in the minimal danger category. The grizzly bear denning habitat model estimates that 0.5% and 9.1% of areas within the RSA have high and moderately-high habitat suitability for denning, respectively.

ACKNOWLEDGEMENTS

Thanks to Ramona Maraj, Carnivore Biologist with Environment Yukon for her advice and assistance on grizzly bear habitat modelling methods.

AUTHORSHIP

This report was prepared by EDI Environmental Dynamics Inc. Staff who contributed to this project include:

Lee Hawkings, B.Sc. .... Primary Author and Model Development

Graeme Pelchat, M.Sc., P.Biol. .... Model Development

Matt Power, A.Sc.T .... GIS Analysis and Mapping

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Mike Setterington, M.Sc., R.P.Bio., C.W.B. ....Senior Review

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ACRONYMS

AV .... Aspect variability

BEU .... Broad ecosystem unit

BMU .... Bear management unit

Coffee Gold Mine .... Coffee Project, the Project

DEM .... Digital elevation model

EDI .... Environmental Dynamics Inc.

ELC .... Ecological land classification

GMS .... Game Management Subzone

GIS .... Geographic information system

HE .... Habitat effectiveness

Kaminak Gold Corporation .... Kaminak

km .... kilometre

km^2 .... square kilometre

m .... metre

PH .... Potential habitat

RH .... Realized habitat

RSA .... Regional Study Area

TM .... Thematic mapper

TRI .... Terrain Ruggedness Index

USDA .... United States Department of Agriculture

Wh/m^2 .... Watt-hour per square meter

YESAA .... *Yukon Environmental and Socio-economic Assessment Act*

YESAB .... Yukon Environmental and Socio-economic Assessment Board

% .... percent

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1 INTRODUCTION

Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson, Yukon (Figure 1). The Project will be accessed by road from Dawson.

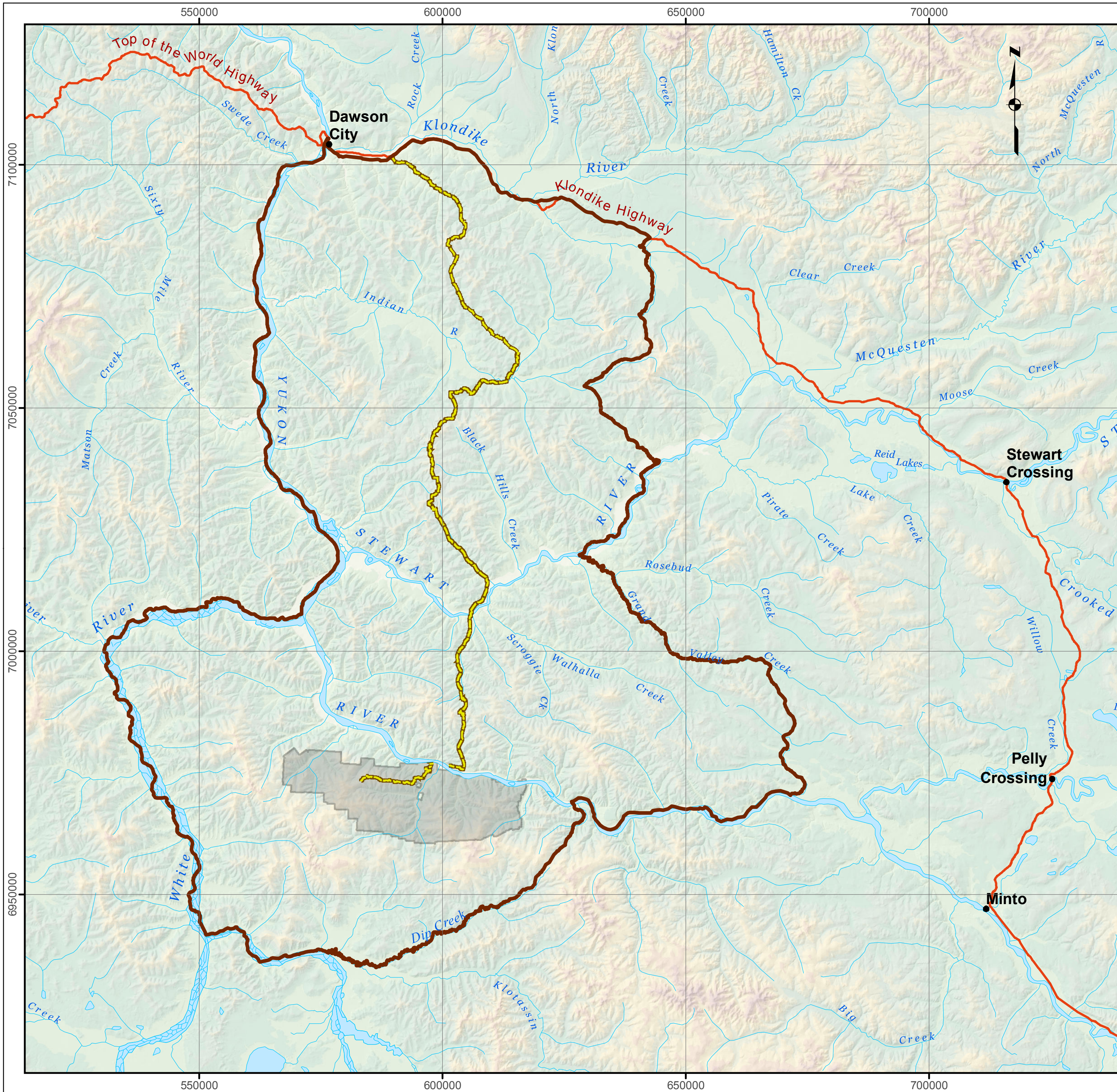
In 2014, Kaminak retained EDI Environmental Dynamics Inc. (EDI) to conduct wildlife baseline studies for the Coffee Project in anticipation of future regulatory requirements. A number of wildlife surveys have been undertaken for the Project — as well as habitat models for select species. This information will support the Project Proposal to be submitted to the Yukon Environmental and Socio-economic Assessment Board (YESAB) Executive Committee for screening under the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA); the Quartz Mining License application; and Type A Water License application.

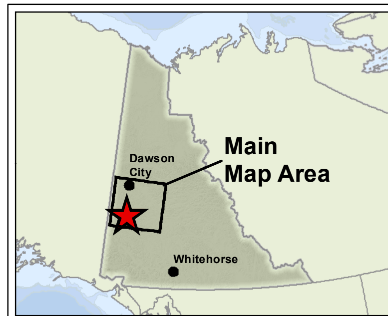
Grizzly bears (*Ursus arctos*) were identified as a focal study species for the Project since they are a species of Special Concern (COSEWIC 2012), were identified by Yukon Government, Department of Environment (Yukon Environment) as a species of interest (Suitor 2015) and are a species valued by local and First Nations people. Given the inherent difficulties with studying grizzly bears in the field, habitat modelling is a useful tool to determine Project interaction with this species. Four spatially-explicit models were developed to determine the existing availability of effective grizzly bear habitat in the Project's Regional Study Area:

- Habitat effectiveness model
- Security zones model
- Linkage zones model
- Denning habitat suitability model.

Each model aims to predict an aspect of grizzly bear habitat requirements and together these models have been used for grizzly bear cumulative effects assessments (USDA Forest Service 1990, Purves and Doering 1998, Gibeau *et al.* 1996). This report does not include an effects assessment; the models aim to evaluate baseline quantity and quality of grizzly bear habitat currently within the Regional Study Area (RSA). The RSA was established to assess the abundance and distribution of most large wildlife species in the Project area. Many of the wide-ranging mammals that occur in the Project area are managed as big game species within Game Management Subzones (GMS). Accordingly, the RSA was delineated to include any GMS that intersect, or are in close proximity to, the proposed Project footprint.

The RSA was divided into Bear Management Units (BMUs) for habitat modelling (Figure 2). These BMUs were delineated using watershed boundaries to divide the RSA into areas suitable for a female grizzly home range, approximately 300 km^2 (Maraj 2007). The 28 BMUs created for this assessment ranged in size from 328 to 707 km^2. This report describes how the grizzly bear habitat models were completed and includes all applicable requirements of YESAB's *DRAFT Proponents Guide: Model Documentation Report* (YESAB 2015).





Legend

- Proposed Route
- Highway
- Regional Study Area
- Coffee Property

FIGURE: 1

Overview of the Coffee Project

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

0 10 20 30 40
KM

Map Reference Scale: 1:1,000,000 (Printed at 8.5 x 11)
Coordinate System: NAD 1983 UTM Zone 7N

Drawn: MP	Checked: AM/LP	Date: 02/09/2016

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EDI

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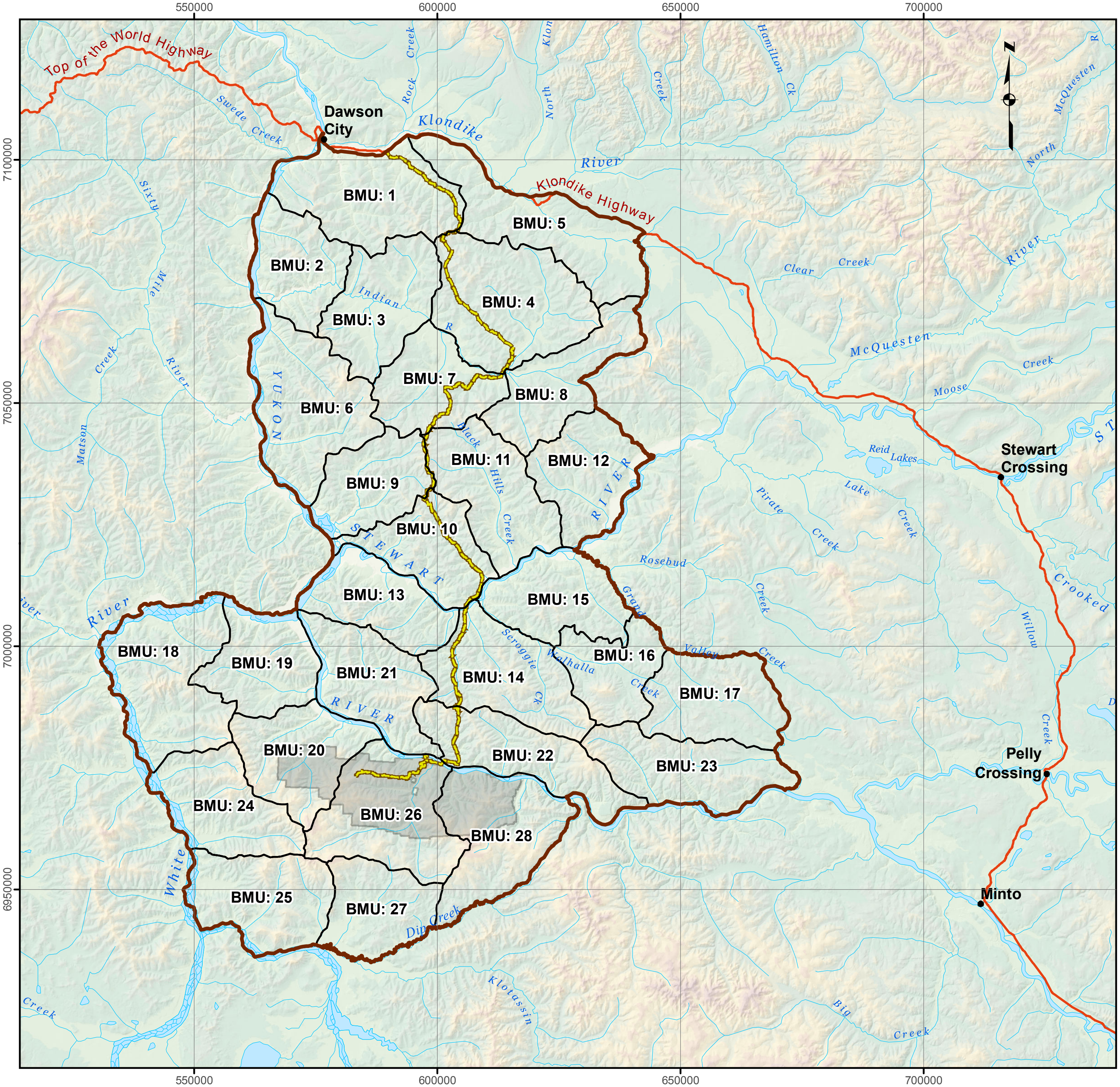

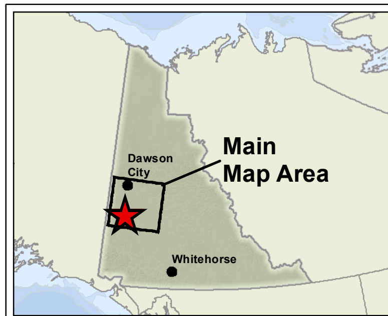

Legend

- Proposed Route
- Highway
- Bear Management Unit
- Regional Study Area
- Coffee Property

FIGURE: 2

Grizzly bear management units within the RSA

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

Disclaimer
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KM

Map Reference Scale: 1:1,000,000 (Printed at 8.5 x 11)
Coordinate System: NAD 1983 UTM Zone 7N

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KAMINAK GOLD CORPORATION
EDI

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1.1 OBJECTIVE

The objective of the grizzly bear habitat models is to quantify potential habitat availability and distribution in a spatially-explicit format to describe pre-Project baseline conditions. Results of these models will be used for assessing potential Project effects on the regional grizzly bear population.

2 HABITAT EFFECTIVENESS MODEL

The habitat effectiveness (HE) model accounts for habitat and human disturbance. Methods for this model were adapted from Maraj (2007) and Purves and Doering (1998). The potential habitat component aims to evaluate the proportion of an area that has the potential to be effective as seasonal habitat given the natural biophysical conditions. The disturbance component identifies areas that may be unavailable or have reduced habitat quality as a result of human disturbance. These two components are used to calculate the habitat effectiveness for the study area.

2.1 HABITAT EFFECTIVNESS MODEL METHODS

2.1.1 POTENTIAL HABITAT

Potential habitat (PH) is the potential of a landscape unit to provide grizzly bear habitat based solely on the biophysical properties of that landscape. In Purves and Doering (1998), ecological landscape classification (ELC) polygons were assigned a habitat value based on the results of a large scale vegetation and bear use study conducted in Banff, Jasper, Kootenay, and Yoho National Parks (Kansas and Riddell 1995). These ratings ranged from zero to one for each month of the year with a zero representing no habitat potential and one representing the best available habitat.

In the absence of similarly-derived ELC polygons for the full extent of the Project's RSA, and the unknown relative contributions of particular forage plants and non-plant foods to grizzly bear habitat use in the RSA, a different approach was needed. To evaluate habitat potential in the RSA, habitat modelling methods were adapted from Maraj's (2007) study on grizzly bears in southwest Yukon.

Two models were created, one for green-up (peak greenness in July) and one for green-down (senescence in September) using Landsat imagery. The two best cloud-free Landsat 5 Thematic Mapper (TM) images (scenes) of the RSA for green-up and green-down were taken on July 22, 1994 and September 4, 2010 respectively and were used for this model. Explanatory variables used were as similar as possible to those used in Maraj (2007) and included brightness, greenness, wetness, wetness^2, diversity, solar, solar^2, cover, water, streams, terrain and terrain^2. Human use was not used as an explanatory variable as that is applied later in the HE model through the disturbance component. All sources of spatial data used in model development are listed in Table 1.

Table 1. Spatial databases used in the development of the grizzly bear Potential Habitat (PH) model.

Dataset	Source	Description
Landsat 5 TM scenes: LT50630161994203PAC00 LT50630151994203PAC00 LT50630152010247GLC01 LT50630162010247GLC01	United States Geological Survey	Raster database 30 m cell size Imagery: 1994 and 2010
Global Digital Elevation Model (DEM)	Ministry of Economy, Trade and Industry (of Japan) and United States National Aeronautics and Space Administration	Raster database 30 m cell size Published: 2011 Accessed: March 7, 2016
Dawson Land Cover	Environment Yukon, Yukon Government	Raster database 30 m cell size Imagery: 2008 and 2009 Developed: 2014
West-Central Yukon Broad Ecosystem Units	Environment Yukon, Yukon Government	Raster database 30 m cell size Published 2012
CanVec 50k Water features	Natural Resources Canada	Vector database Published: 2008

2.1.1.1 Explanatory Variables

A Tasselled Cap Transformation (Crist *et al.* 1986) was completed on all Landsat 5 TM scenes. To do this, the Landsat 5 TM digital numbers were transformed to top of atmosphere reflectance values using the i.landsat.toar tool (Tizado 2014) in GRASS GIS 7.0 (GRASS Development Team 2015). Mosaics were created using the reflectance values of each band for each period. Greenness, Brightness and Wetness were calculated using the tasselled cap transformation:

$$\textit{Brightness} = (0.2909 * \text{Band 1}) + (0.2493 * \text{Band 2}) + (0.4806 * \text{Band 3}) + (0.5568 * \text{Band 4}) + (0.4438 * \text{Band 5}) + (0.1706 * \text{Band 7})$$

$$\textit{Greenness} = (-0.2728 * \text{Band 1}) - (0.2174 * \text{Band 2}) - (0.5508 * \text{Band 3}) + (0.7221 * \text{Band 4}) + (0.0733 * \text{Band 5}) - (0.1648 * \text{Band 7})$$

$$\textit{Wetness} = (0.1446 * \text{Band 1}) + (0.1761 * \text{Band 2}) + (0.3322 * \text{Band 3}) + (0.3396 * \text{Band 4}) - (0.6210 * \text{Band 5}) - (0.4186 * \text{Band 7})$$

A land cover diversity layer was created to capture landscape variability within a 7x7 moving window with a 30 m pixel resolution. The West-Central Yukon Broad Ecosystem Units (BEU) was converted into 12 broad land cover classes: coniferous, broadleaf, mixed-wood, lichen/herb, wetland treed, wetland shrub, wetland herb, low shrub, exposed, water, cloud, and no data. The Land Change Modeller tool for IDRISI 17: Selva was used to calculate normalized entropy (Shannon's diversity index) for each pixel.

The Spatial Analyst Area Solar Radiation tool for ArcGIS version 10.2.2 was used to calculate the incoming solar radiation (Wh/m^2) for the entire RSA. Inputs for this tool include a digital elevation model (DEM) and the specified time period (in this case from Julian day 90 to 270). Average latitude of 63° N was used for the RSA.

A cover layer was created by classifying tall shrub and forested habitat from the Dawson Land Cover layer as cover and all other land cover types as non-cover. The Euclidian Distance tool for ArcGIS version 10.2.2 was used to create a distance to cover surface.

Two water layers were created from CanVec 50K data. The Euclidian Distance tool for ArcGIS version 10.2.2 was used to create a distance to water surface (waterbodies greater than 20 m between banks) and a distance to stream surface (watercourses less than 20 m wide).

A terrain ruggedness index (TRI) layer was created using a DEM of the RSA. Methods used were the same as used in Maraj (2007). A 10 x 10 pixel moving window was used for analysis with a 30 m pixel resolution. TRI was calculated using the formula:

$$TRI = \frac{Average\ Slope * AV}{Average\ Slope + AV}$$

Where *Average Slope* is the average slope in degrees calculated in the moving window and *AV* is the Aspect Variability, calculated using the formula:

$$AV = \left(\frac{n}{nmax}\right) * 100$$

Where *n* is the number of different aspect classes in the moving window and *nmax* is the maximum number of aspect classes in the study area. For *nmax* 361 classes were used, one class for each degree of aspect as well as a 'no aspect' class for slopes under five degrees.

The ranges and units of all explanatory variables are summarized in Table 2.

Table 2. Explanatory variable and range of values.

Explanatory Variable	Unit	Value Range in RSA
Brightness	-	0.089 to 0.381
Greenness	-	-0.036 to 0.16
Wetness	-	-0.111 to 0.044
Diversity	Shannon Index	0 to 0.555
Solar	Watt hour per m² (Wh/m²)	440858 to 781411
Cover	Meters	0 to 241
Water	Meters	0 to 11314
Stream	Meters	0 to 1320
Terrain	Terrain Ruggedness Index (TRI)	0.193 to 10.8

2.1.1.2 Selection Coefficients

Selection coefficients were taken from Maraj's (2007) base models for each of four cohorts (adult male, adult female, family groups and subadults).

2.1.1.3 Model Structure

The model took the following structure:

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_i x_i)$$

Where *w(x)* was the habitat selection function and β_i were the selection coefficients based on explanatory variables, x_i. The habitat selection function was normalized to a value between 0 and 1 using:

$$Tw(x) = \frac{w(x)}{1 + w(x)}$$

From eight base models (one for each cohort for green-up and green-down), two final PH models were created by averaging the *Tw(x)* values for all cohorts for each season to create an overall green-up PH model and an overall green-down PH model.

2.1.2 DISTURBANCE COMPONENT AND REALIZED HABITAT

Realized habitat (RH) is habitat that is available to grizzly bears once displacement and degradation of habitat from human disturbances is taken into account. Realized habitat is modelled by adjusting the potential habitat models by a disturbance coefficient from a human disturbance spatial dataset. The spatial data sources used in the GIS analysis are listed in Table 3.

Table 3. Spatial databases used in the development of the grizzly bear disturbance component and Realized Habitat (RH) model.

Dataset	Source	Description
National Road Network YT	Natural Resources Canada	Vector Database Published: 2014
CanVec 1:50K Transportation Features	Natural Resources Canada	Vector Database Published: 2012
Anthropogenic Surface Disturbance Features (Areal/Linear)	Yukon Government – Environment Yukon	Vector Database Published 2015
Existing Project Roads	Kaminak Gold Corporation	Vector Database Published: 2016
High Use Linear Features Digitized	Project Aerial Photography (2011)	Vector Data Digitized: February 2016

Feature attributes from the human disturbance data were queried and disturbance features were categorized as done by Purves and Doering (1998) and USDA Forest Service (1990) (summarized in Stenhouse *et al.* 2003). Categories were either motorized or non-motorized use, point, line or polygon type, and high or low intensity. High intensity is defined as >100 events per month while low intensity is <100 events per month. These categories are typically broken down further by high or low cover; however, due to a lack of data associated with our disturbance features we assumed that all features had no cover as a more cautious approach. Feature use statistics are not available for the disturbance data used so high and low intensity was assigned with educated guesses about the features within the RSA and given a default high value if unknown. Each disturbance category was assigned a disturbance coefficient and zone of influence buffer (Table 4) based on data collected in Yellowstone National Park and used by Purves and Doering (1998). Disturbance coefficients range between zero and one with zero representing total displacement and one representing no habitat degradation.

Table 4. Classification, disturbance coefficient and zone of influence buffer for disturbance features.

Disturbance Type		Classification	Disturbance Coefficient	Zone of influence (m)
Anthropogenic Surface Disturbance (Areal)	Agriculture	Non-motorized Polygon Low Non-cover	0.83	400
	Airstrip	Motorized Polygon Low Non-cover	0.64	800
	Building	Non-motorized Polygon High Non-cover	0.33	400
	Clearing	Non-motorized Polygon Low Non-cover	0.83	400
	Forestry	Non-motorized Polygon Low Non-cover	0.83	400
	Gravel Pit	Non-motorized Polygon Low Non-cover	0.83	400
	Homestead	Non-motorized Polygon High Non-cover	0.33	400
	Landfill	Non-motorized Polygon High Non-cover	0.33	400
	Mining	Motorized Polygon High Non-cover	0.16	800
	Open Pit	Motorized Polygon High Non-cover	0.16	800
	Placer Claim	Motorized Polygon High Non-cover	0.16	800
	Placer Mining	Motorized Polygon High Non-cover	0.16	800
	Pond		0	0
	Quartz Claim	Motorized Polygon High Non-cover	0.16	800
	Quartz Mining	Motorized Polygon High Non-cover	0.16	800
	Recreation Area	Non-motorized Polygon High Non-cover	0.33	400
	Residential	Motorized Polygon High Non-cover	0.16	800
	Rural Residential	Motorized Polygon High Non-cover	0.16	800
	Tower	Non-motorized Polygon Low Non-cover	0.83	400
	Unknown	Motorized Polygon High Non-cover	0.16	800
	Urban	Motorized Polygon High Non-cover	0.16	400
	Wellpad	Motorized Polygon Low Non-cover	0.64	400
Anthropogenic Surface Disturbance (Linear)	Access Road	Motorized Line High Non-cover	0.16	800
	Arterial Road	Motorized Line High Non-cover	0.16	800
	Electric Utility Corridor	Non-motorized Line Low Non-cover	0.83	400
	Local Road	Motorized Line High Non-cover	0.16	800
	Survey/ Cutline	Non-motorized Line Low Non-cover	0.83	400
	Trail	Motorized Line Low Non-cover	0.64	800

Table 4. Classification, disturbance coefficient and zone of influence buffer for disturbance features.

Disturbance Type		Classification	Disturbance Coefficient	Zone of influence (m)
	Unknown	Non-motorized Line Low Non-cover	0.83	400
	Unpaved Road	Motorized Line High Non-cover	0.16	800
Canvec 50K Transportation Feature	Cut line	Non-motorized Line Low Non-cover	0.83	400
	Ford	Motorized Line Low Non-cover	0.64	800
	Limited-use road	Motorized Line High Non-cover	0.64	400
	Road	Motorized Line High Non-cover	0.16	800
	Trail	Motorized Line Low Non-cover	0.64	800
National Road Network YT	Local Street	Motorized Line High Non-cover	0.16	800
	Resource / Recreation	Motorized Line High Non-cover	0.16	800
	Local / Strata	Motorized Line High Non-cover	0.16	800
	Expressway/ Highway	Motorized Line High Non-cover	0.16	800
	Collector	Motorized Line High Non-cover	0.16	800
	Alleyway / Lane	Motorized Line High Non-cover	0.16	800
	Arterial	Motorized Line High Non-cover	0.16	800
	Ramp	Motorized Line High Non-cover	0.16	800
	Service Lane	Motorized Line High Non-cover	0.16	800
Existing Project Road (Java)	Road	Motorized Line High Non-cover	0.16	800
Other High Use Linear Features	Road	Motorized Line High Non-cover	0.16	800

Disturbance coefficients were applied to the PH value in each pixel within the zone of influence of a feature to calculate a RH value. Realized habitat is the modelled potential or productivity of a habitat unit once human influences are considered. For each pixel, the PH value (0.0 <= n>= 1.0) is multiplied by the disturbance coefficient (0.0 <= n>= 1.0) to get a value for RH (0.0 <= n>= 1.0) with a one being best possible habitat and a zero representing unsuitable habitat.

2.1.3 HABITAT EFFECTIVENESS CALCULATION

The proportion of potential habitat that is available to grizzly bears once human influences are considered is the HE. To calculate the HE for each BMU, the sum of all RH values within the BMU is divided by the sum of all PH values within the BMU. The overall structure of the habitat effectiveness model is summarized in Figure 3.

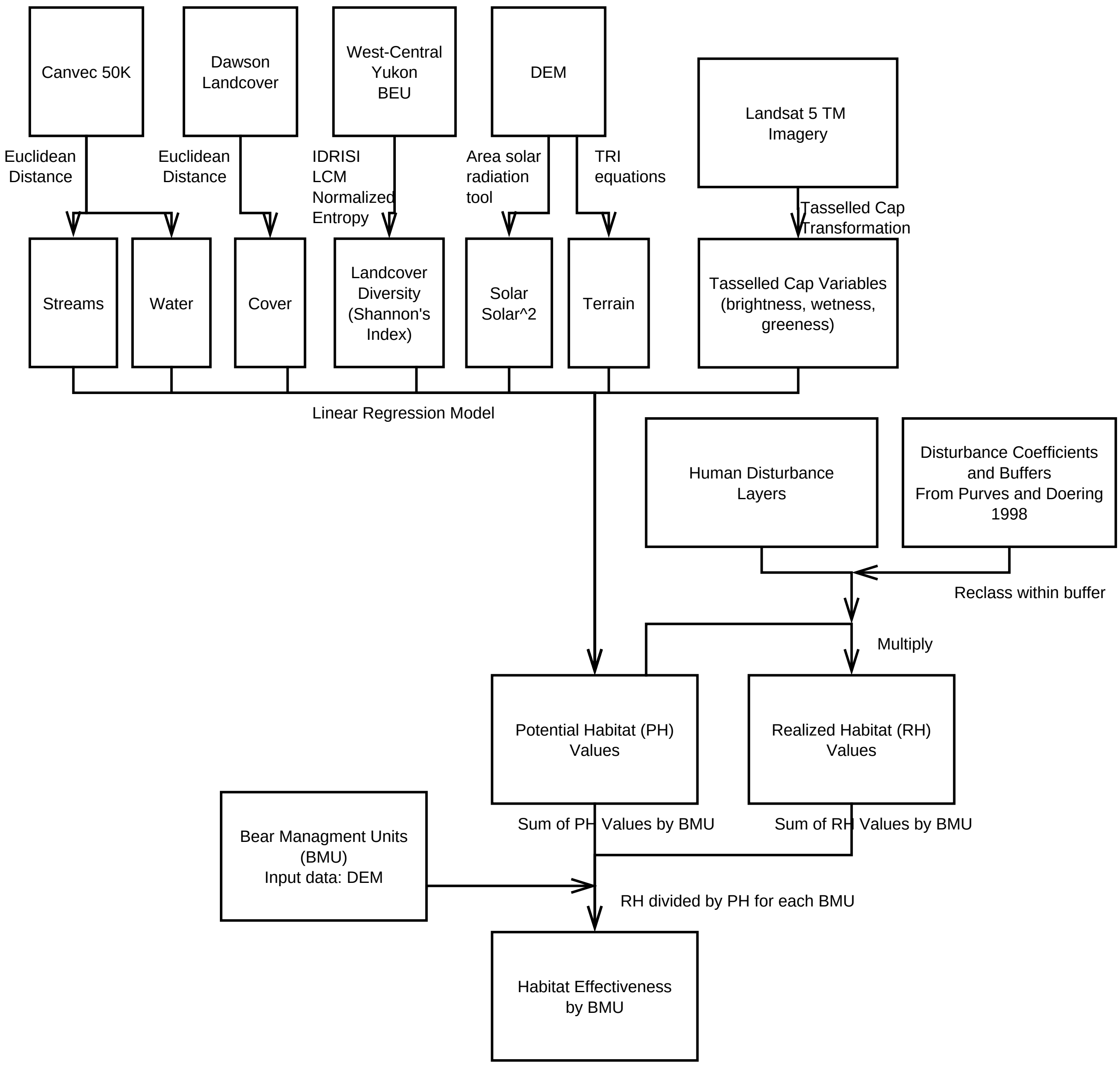


Figure 3. Grizzly bear habitat effectiveness model flow chart.

2.2 HE MODEL RESULTS

Modelled habitat effectiveness for each BMU was calculated for the green-up period and the green-down period. HE ranged from 67.5% to 100% for the green-up period and 66.7% to 100% for the green-down period (Table 5). Habitat effectiveness was lowest in those BMUs with high human development near Dawson and in the Dawson goldfields area (BMUs 1, 4, 5, 7). Generally, habitat effectiveness was slightly lower in the green-down period than the green up period. This is likely because lower elevation, wet, riparian areas are selected more in the green-down period for their berry presence. Most human disturbance in the region is placer related, therefore located in riparian areas. Overall modelled HE for the RSA was 92.3% for the green-up period and 91.8% for the green-down period.

Table 5. Habitat effectiveness results by BMU.

Bear Management Unit	Habitat Effectiveness (%)	
	Green-up	Green-down
1	67.5	66.7
2	97.0	97.2
3	87.9	87.8
4	73.6	72.7
5	85.9	86.2
6	99.6	99.6
7	77.3	75.8
8	92.7	92.4
9	94.2	93.7
10	95.9	95.8
11	93.5	93.3
12	100.0	100.0
13	99.9	99.9
14	87.1	86.8
15	97.6	97.5
16	96.0	95.7
17	95.8	95.7
18	100.0	100.0
19	97.9	97.5
20	97.6	96.7
21	92.8	92.5
22	94.5	94.2
23	99.5	99.3
24	100.0	100.0
25	100.0	100.0
26	94.2	93.4
27	100.0	100.0
28	92.3	92.1
Total	**92.3**	**91.8**

2.3 ASSUMPTIONS

This HE model used available datasets, some of which were different than the datasets used in the Purves and Doering (1998) model which this analysis method is based on. Limitations of the data and assumptions required to complete the modelling include:

- Grizzly bear potential habitat is reasonably represented by the model described in Section 2.1.1.
- Surface disturbance layers reasonably represent the spatial extent of human activity in the area.
- Surface disturbance classifications reasonably represent human activity associated with each disturbance feature.
- Disturbance coefficients and zone of influence buffers used by Purves and Doering (1998) reasonably represent habitat displacement and degradation in Yukon context.
- Potential habitat and realized habitat is rated relative to the availability within the RSA and is not a measure of habitat quality in the absolute sense (i.e. if the whole area is poor grizzly habitat, some areas would still be a given a high rating because they are the best available habitat).

3 SECURITY AREAS MODEL

The security areas model determines whether available habitat is secure, away from human disturbance where bears can remain for longer periods of time. This is different from the HE model which only looks at if habitat is available. A secure area is defined as an area where an adult female grizzly bear can forage for 24–24 hours without being disturbed (Purves and Doering 1998). In other jurisdictions this has been estimated to be areas that are larger than approximately 9 km^2 in size (Gibeau 2000). This analysis removes any available habitat that exists in isolated patches smaller than 9 km^2.

3.1 SECURITY AREAS METHODS

In this model, security areas were defined as:

1. Areas below 1,900 m and vegetated;
2. Areas greater than 500 m from human activity where activity use is greater than 100 disturbance events per month; and
3. Contiguous areas greater than 9 km^2.

The methods for this model were adapted from the methods used by Purves and Doering (1998). BMUs, described in Section 1 were used for the analysis. Spatial data layers used for GIS analysis are listed in Table 6.

Table 6. Spatial databases used in the development of the grizzly bear security area model.

Dataset	Source	Description
West-Central Yukon Broad Ecosystem Units (BEU)	Environment Yukon, Yukon Government	Raster database 30 m cell size Published 2012
Digital Elevation Model (DEM)	Natural Resources Canada	Raster database 30 m cell size Published: 2012
National Road Network YT	Natural Resources Canada	Vector Database Published: 2014
1:50,000 Canvec Transportation	Natural Resources Canada	Vector Database Published: 2012
Anthropogenic Surface Disturbance Features (Areal/Linear)	Yukon Government – Environment Yukon	Vector Database Published 2015
Existing Project Roads	Kaminak Gold Corporation	Vector Database Published: 2016
High Use Linear Features Digitized	Project Aerial Photography (2011)	Vector Data Digitized: February 2016

To calculate the amount of secure areas, the west-central Yukon BEU layer was edited to remove areas over 1,900 m and areas that are unvegetated. Grizzly bears were seldom found at elevation higher than 1,900 m in studies conducted in the southwest Yukon (Maraj 2007). The human disturbance layers categorized as high use (>100 times per month) were then applied with a 500 m zone of influence. All areas within this zone of influence were removed as this is not secure habitat for bears due to human disturbance.

Based on work by Mike Gibeau in Banff National Park, Purves and Doering (1998) employed a threshold of 9 km^2 as the smallest contiguous habitat unit that could be considered secure. The next step of analysis is to remove any isolated habitat fragments that are smaller than 9 km^2. Lastly, for each BMU, area of secure habitat was totalled and compared with the total area to give a percentage of secure habitats for each BMU. Figure 4 summarizes the overall security areas model construction.

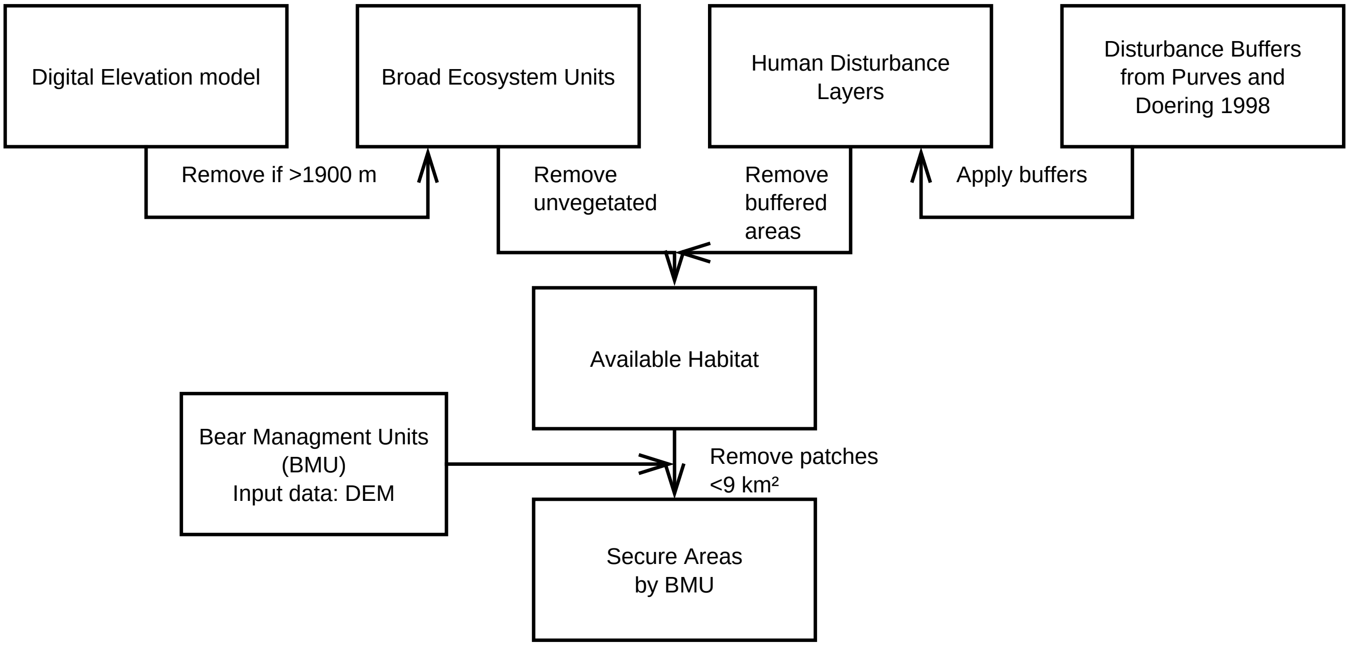


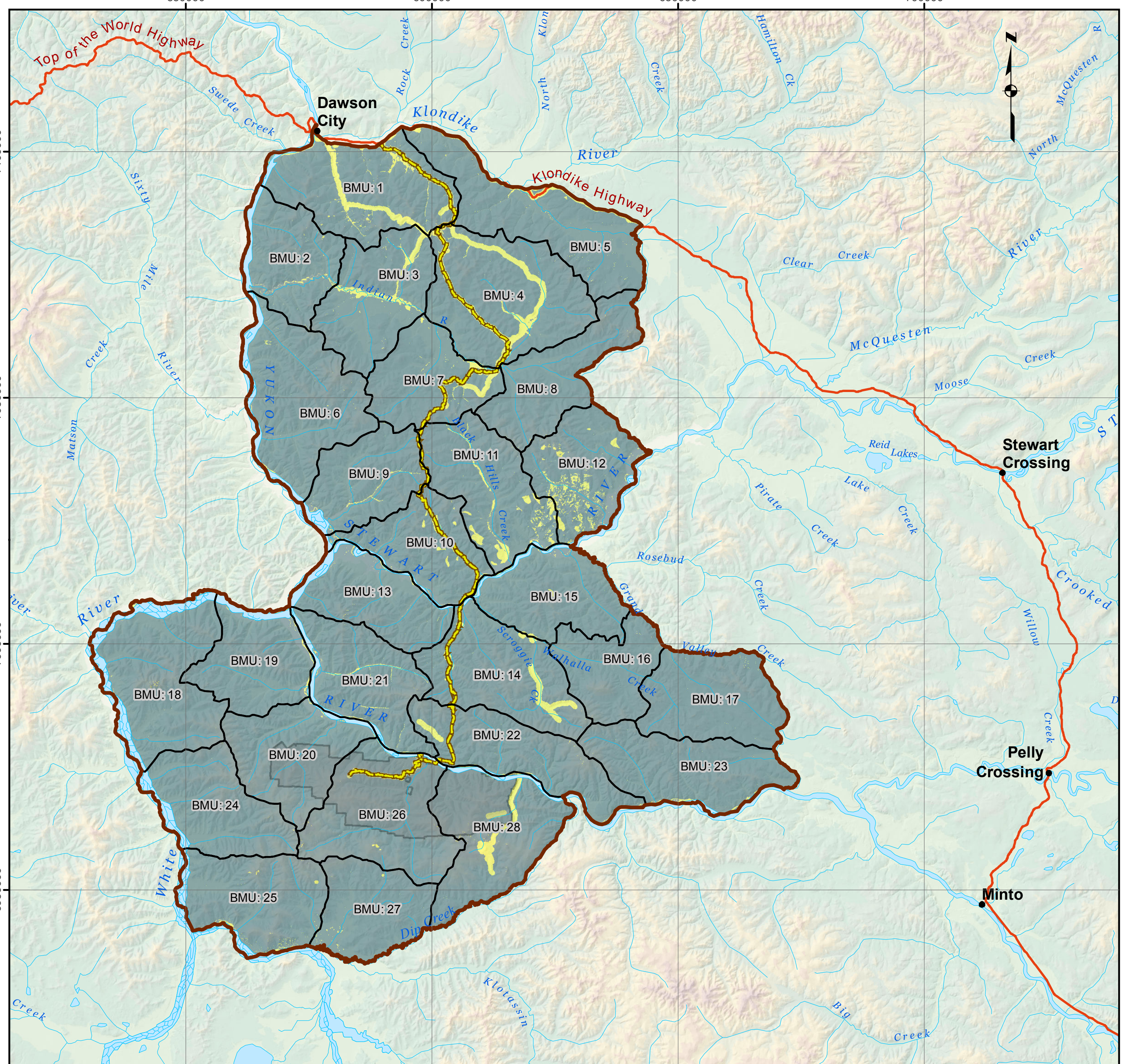
Figure 4. Grizzly bear security area prediction modelling flow chart.

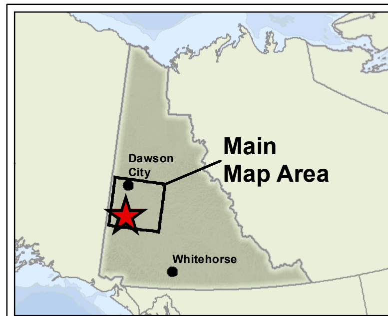
3.2 SECURITY AREAS RESULTS

The results of the security areas model are summarized in Table 7. The spatial distribution of secure habitat areas in the Project RSA is displayed in Figure 5. Within the entire RSA, 94.7% (12,937 km^2) of the area is considered secure and 5.3% (724 km^2) is considered not secure. BMUs with the lowest percentage of secure habitat were between the Indian River and Dawson as well as near the Stewart River in BMUs 1, 4 and 12 (85.0%, 86.7% and 90.8%, secure respectively). These areas have relatively high levels of human activity as a result of their proximity to Dawson and placer mine operations.

Table 7. Security area model results by BMU.

Bear Management Unit	Total Area (km²)	Secure Area (km²)	% of Secure
1	608	517.0	85.0%
2	385	371.3	96.4%
3	479	447.6	93.5%
4	707	612.4	86.7%
5	599	563.6	94.0%
6	654	628.3	96.1%
7	402	366.8	91.2%
8	430	429.3	99.9%
9	384	376.0	98.0%
10	394	374.5	95.0%
11	508	470.6	92.7%
12	432	391.8	90.8%
13	404	387.5	95.8%
14	542	506.8	93.5%
15	428	420.5	98.1%
16	328	328.2	100.0%
17	470	469.7	99.9%
18	662	620.8	93.7%
19	411	389.5	94.9%
20	463	455.5	98.4%
21	463	442.9	95.6%
22	477	459.5	96.4%
23	500	489.9	98.1%
24	469	452.8	96.6%
25	499	478.3	95.8%
26	613	585.3	95.5%
27	382	379.6	99.5%
28	568	520.6	91.7%
Total	**13,661**	**12,937**	**94.7%**





Legend

- Proposed Route
- Highway
- Regional Study Area
- Coffee Property
- Bear Management Unit

Grizzly Bear Security Areas

- Not Secure
- Secure

FIGURE: 5

Grizzly bear security areas

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

0 10 20 30 40
KM

Map Reference Scale: 1:1,000,000 (Printed at 8.5 x 11)
Coordinate System: NAD 1983 UTM Zone 7N

Drawn: MP	Checked: AM/LP	Date: 02/09/2016

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3.3 ASSUMPTIONS

This security areas model used available datasets, some of which were different than the datasets used in the Purves and Doering (1998) model which this analysis method is based on. Limitations of the data and assumptions required to complete the modelling include:

- In west-central Yukon 1,900 m is a reasonable elevation cut-off for bear habitat availability;
- All vegetation types below 1,900 m are "available" habitat;
- Surface disturbance layers reasonably represent the spatial extent of human activity in the RSA;
- Yukon bears are secure in 9 km² habitat units.

4 LINKAGE ZONE PREDICTION MODEL

Linkage zones are areas that provide foraging habitat, connectivity between home ranges and avenues of dispersal (Riddell 2005). Linkage zone analysis determines the degree and extent of habitat fragmentation caused by human activity. This model is useful to assess possible movement corridors, particularly in areas where intense human activity and high quality bear habitat overlaps.

4.1 METHODS

This linkage zone prediction model is adapted from the model presented in Purves and Doering (1998). In their model, four spatial data layers were considered when assigning a "danger" score to each pixel in the landscape. Purves and Doering (1998) considered four inputs: access route density, intensity of developed sites, presence or lack of hiding cover and proximity to riparian areas. The model presented here only considers the first two inputs as grizzly bears can and will travel through areas that lack cover and are outside the riparian zone when they are not influenced by human disturbance. Cover and proximity to riparian zone are particularly important in highly fragmented landscapes. By leaving out these two variables we are taking a conservative approach by likely overestimating the danger of human disturbed areas that have cover or are near riparian zones. All sources of spatial data used for the creation of the linkage zones model are listed in Table 8.

Table 8. Spatial databases used in the development of the grizzly bear linkage zone prediction model.

Dataset	Source	Description
National Road Network YT	Natural Resources Canada	Vector Database Published: 2014
1:50,000 Canvec Transportation	Natural Resources Canada	Vector Database Published: 2012
Anthropogenic Surface Disturbance Features (Areal/Linear)	Yukon Government – Environment Yukon	Vector Database Published 2015
Project Roads	Kaminak Gold Corporation	Vector Database Published: 2016
High Use Linear Features Digitized	Project Aerial Photography (2011)	Vector Data Digitized: February 2016

Access route density was calculated using the same human disturbance layers as described in Section 2.1 but only motorized polyline features were used. A disturbance raster layer was created at 10 m x 10 m resolution, assigning all pixels with a high use feature (>100 disturbance events/month) a value of one and all other pixels a value of zero. Once the raster was created, spatial analysis was performed to obtain a density of access in units of km/km^2 using ArcGIS 10.2.2 Spatial Analyst Tool: Focal Statistics. The neighborhood was set to circular with a radius of 564 m which represents the radius of a 1 km^2 circle. The statistics type was set to SUM. Access route density values were finally reclassified into four classes:

- Class 2: 0 km/km^2;
- Class 3: 0 – 0.625 km/km^2;
- Class 4: 0.625 – 1.250 km/km^2;
- Class 5: >1.250 km/km^2.

Intensity of developed sites uses the point and polygon layers from the human disturbance layers described in Section 2.1 (Table 4). Low use point and polygons were buffered by 120 m while high use point and polygon features were buffered by 240 m. Only existing disturbances were considered for this baseline model — proposed Project activities and future developments were not included. All buffered features were merged into one file for analysis. The Euclidian distance tool for ArcGIS 10.2.2 was applied to the buffered feature layer to create a raster file with distance from the buffered area. This raster file was reclassified to represent a danger classification as follows:

- Class 6: within buffered feature;
- Class 5: within 100 m of a buffered feature;
- Class 4: within 100–200 m of a buffered feature;
- Class 2: beyond 200 m of a buffered feature.

The access route density and intensity of developed sites layers where added together to give a single combined danger score ranging from 4 to 11. This final layer was analyzed to determine the area within each BMU in each of four danger categories:

- Minimal = 4–5
- Low = 6–7
- Moderate = 8–9
- High = 10–11.

Figure 6 summarizes the overall linkage zone prediction model construction.

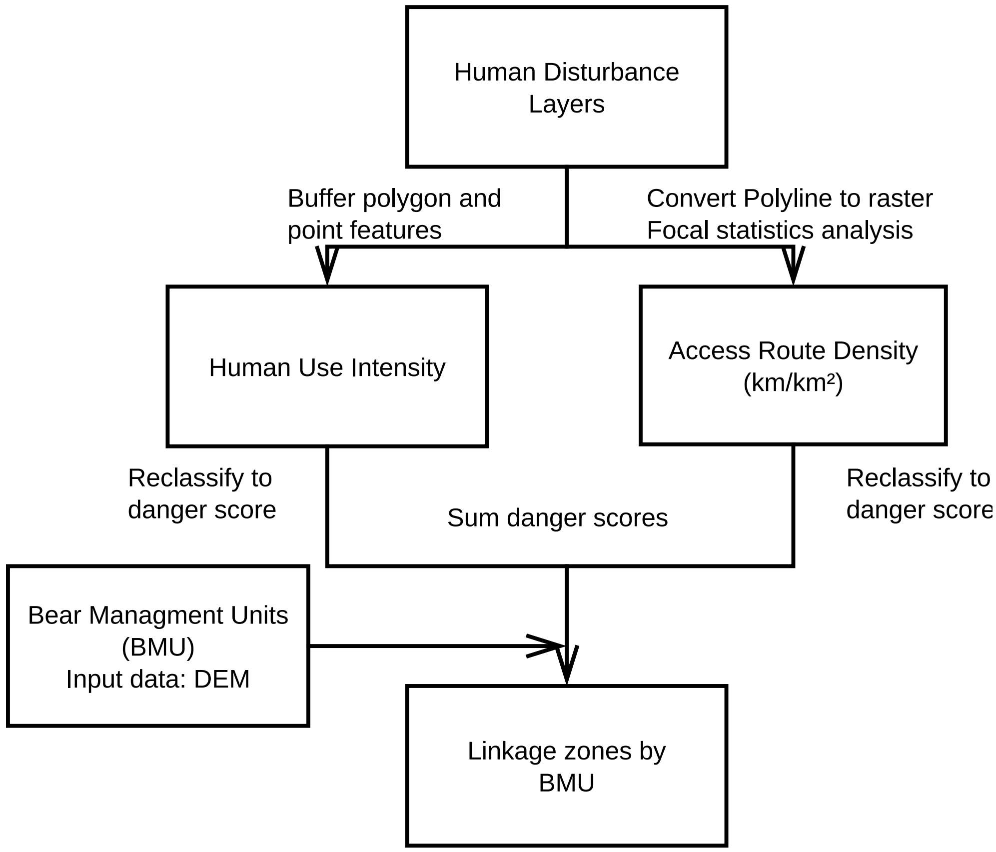


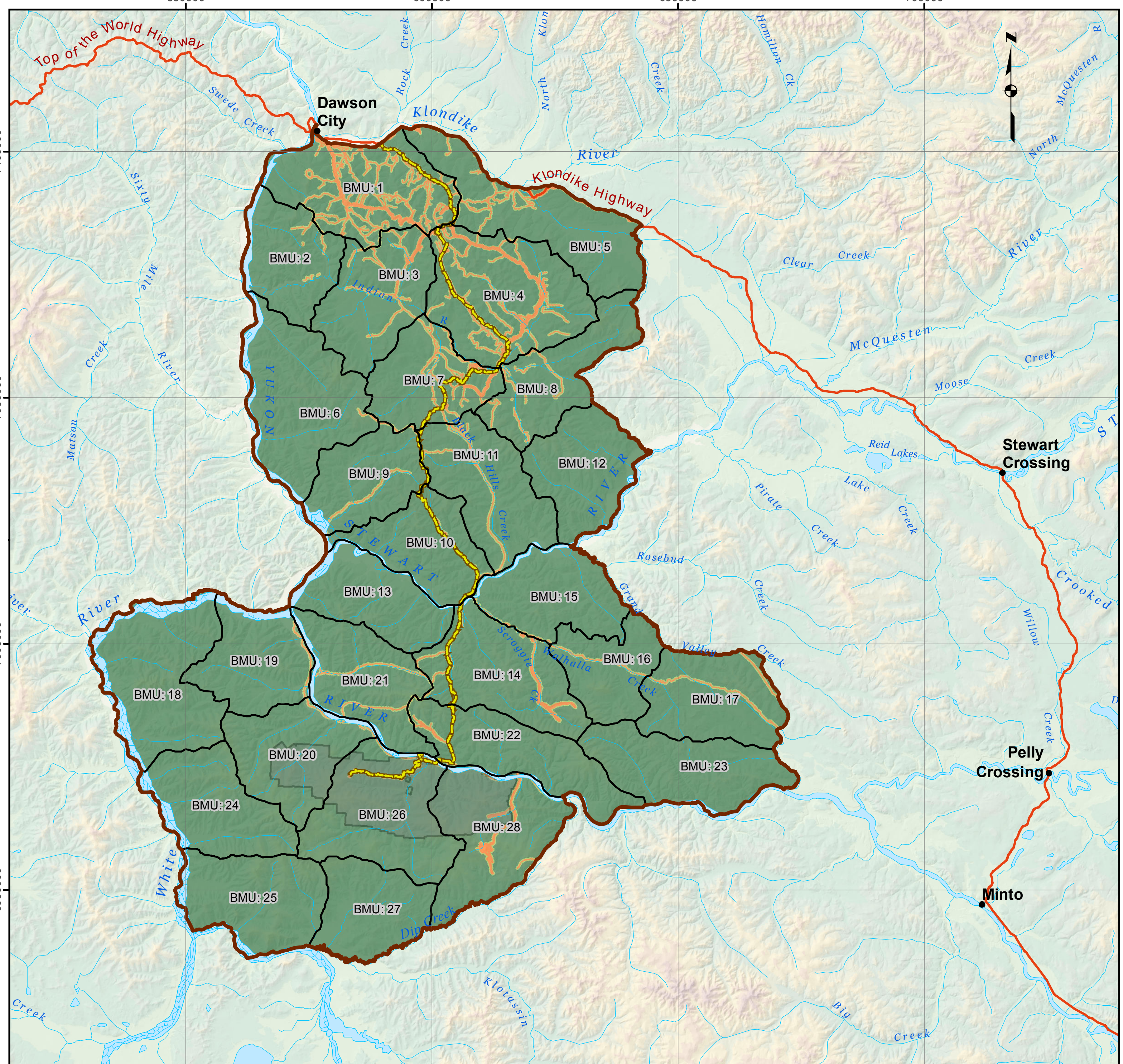
Figure 6. Linkage zone prediction modelling flow chart.

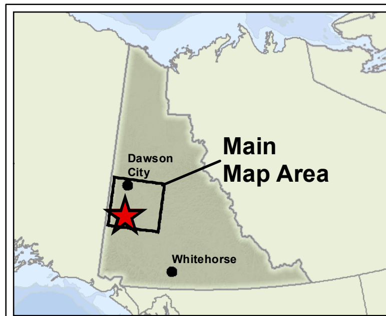
4.2 RESULTS

Overall 92.5% of the RSA was modelled to be in the minimal danger category. In the northern RSA between the Indian River and Dawson, BMUs 1, 4, and 7 all had relatively high levels of moderate danger areas with 20.2%, 14.4% and 11.8% respectively. BMU 1 was the only BMU to have any area in the high danger category (<0.1%) and had the lowest level of minimal danger area (63.4%). Results for all BMUs in km^2 and % of BMU are listed in Table 9 and the spatial distribution of the four danger categories is displayed in Figure 7.

Table 9. Grizzly bear habitat linkage zone model results by BMU.

Bear Management Unit	Danger Categories							
	Minimal		Low		Moderate		High	
	Area (km²)	% of BMU	Area (km²)	% of BMU	Area (km²)	% of BMU	Area (km²)	% of BMU
1	385.3	63.4	99.6	16.4	123.0	20.2	0.6	<0.1
2	371.6	96.5	8.7	2.3	4.7	1.2	0.0	0.0
3	421.0	87.9	31.1	6.5	26.6	5.6	0.0	0.0
4	535.8	75.8	69.4	9.8	101.5	14.4	0.0	0.0
5	526.6	87.9	31.4	5.2	41.2	6.9	0.0	0.0
6	650.4	99.5	2.3	0.3	1.4	0.2	0.0	0.0
7	315.1	78.4	39.4	9.8	47.7	11.8	0.0	0.0
8	395.3	91.9	21.3	5.0	13.2	3.1	0.0	0.0
9	359.3	93.6	15.3	4.0	9.3	2.4	0.0	0.0
10	373.7	94.8	12.6	3.2	7.7	2.0	0.0	0.0
11	468.0	92.1	23.8	4.7	16.1	3.2	0.0	0.0
12	431.6	100	0.0	0.0	0.0	0.0	0.0	0.0
13	404.3	100	0.2	<0.1	<0.1	<0.1	0.0	0.0
14	486.7	89.8	27.4	5.1	27.8	5.1	0.0	0.0
15	418.5	97.8	5.4	1.2	4.5	1.0	0.0	0.0
16	313.3	95.5	9.0	2.7	6.0	1.8	0.0	0.0
17	440.0	93.6	18.4	3.9	11.8	2.5	0.0	0.0
18	662.3	100	0.0	0.0	0.0	0.0	0.0	0.0
19	399.6	97.2	6.8	1.8	4.2	1.0	0.0	0.0
20	450.6	97.3	7.7	1.7	4.7	1.0	0.0	0.0
21	427.9	92.4	21.6	4.6	13.9	3.0	0.0	0.0
22	458.3	96.1	10.4	2.2	7.8	1.7	0.0	0.0
23	499.1	99.9	0.4	0.1	0.0	0.0	0.0	0.0
24	468.8	100	0.0	0.0	0.0	0.0	0.0	0.0
25	499.2	100	0.0	0.0	0.0	0.0	0.0	0.0
26	583.6	95.2	10.3	1.7	19.0	3.1	0.0	0.0
27	381.6	100	0.0	0.0	0.0	0.0	0.0	0.0
28	510.0	89.8	28.2	5.0	29.8	5.2	0.0	0.0
Total	**12,637.5**	**92.5%**	**500.7**	**3.7%**	**521.9**	**3.8%**	**0.6**	**<0.1%**





Legend

- Proposed Route
- Highway
- Regional Study Area
- Coffee Property
- Bear Management Unit

Grizzly Bear Linkage Zone Class

- Minimal Danger
- Low Danger
- Moderate Danger
- High Danger

FIGURE: 7

Grizzly bear linkage zone model results

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

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4.3 ASSUMPTIONS

This linkage zone model used available datasets, some of which were different than the datasets used in the Purves and Doering (1998) model which this analysis method is based on. Limitations of the data and assumptions required to complete the modelling include:

- Surface disturbance layers reasonably represent the spatial extent of human activity in the RSA;
- Surface disturbance classifications reasonably represent actual human activity associated with each disturbance feature;
- Danger scores and zone of influence buffers used by Purves and Doering (1998) are reasonably representative of human influence in Yukon context.

5 DENNING HABITAT SUITABILITY MODEL

Bears hibernate in dens which are often excavated in alpine or subalpine slopes. Other characteristics of suitable denning habitat are limited to a lack of permafrost, low soil moisture, deep soils, and vegetation root structures. All these characteristics contribute to dry and stable den sites. The objectives of the denning spatial analysis were twofold:

1. To increase efficiency of the planned denning surveys and increase probability of locating dens; and
2. To estimate the amount of suitable denning habitat available in the RSA.

5.1 METHODS

Denning habitat was modelled using GIS and available spatial data for the entire RSA. Criteria used to determine suitable denning habitat were based on data collected from other bear denning sites found by EDI biologists who have conducted similar surveys in other areas of Yukon. This criteria is similar to criteria provided by Environment Yukon's Carnivore Biologist during previous environmental assessments in the central Yukon (EDI 2013; EBA 2011). The spatial data layers used are listed in Table 10.

Table 10. Spatial databases used in the development of the grizzly bear denning habitat model.

Dataset	Source	Description
West-Central Yukon Broad Ecosystem Units	Environment Yukon, Yukon Government	Raster database 30 m cell size Published 2012
Digital Elevation Model (DEM)	Natural Resources Canada	Raster database 30 m cell size Published: 2012

The DEM was analyzed for slope and areas were reclassified to give a habitat value of 3 to slopes 25° to 38° and a habitat value of 2 to slopes 4° to 25° and 38° to 46°. All other slopes were classified as 1. Aspect was also analyzed from the DEM and reclassified giving a value of 3 to aspects 174° to 212° and a value of 2 to aspects 212° to 346° and 114° to 174°. All other aspects were reclassified with a value of 1. The aspect and slope layers were summed together and categorized into five categories:

- High = 6
- Moderate-High = 5
- Moderate = 4
- Moderate-Low = 3
- Low = 2

The West-central Yukon BEU layer was reclassified to give all pixels that were water, rock, ice or bare soil cover types values of 0. All areas below 600 m elevation were also given a value of 0. Treeline in this area occurs at approximately 1,100 m. Females and family groups typically den in alpine and subalpine habitat while males often den in treed areas that are lower in elevation. All layers were multiplied together to create a final denning suitability layer with categories from 0 (nil) to 6 (high). Overall model structure for the denning habitat suitability model is shown in Figure 8.

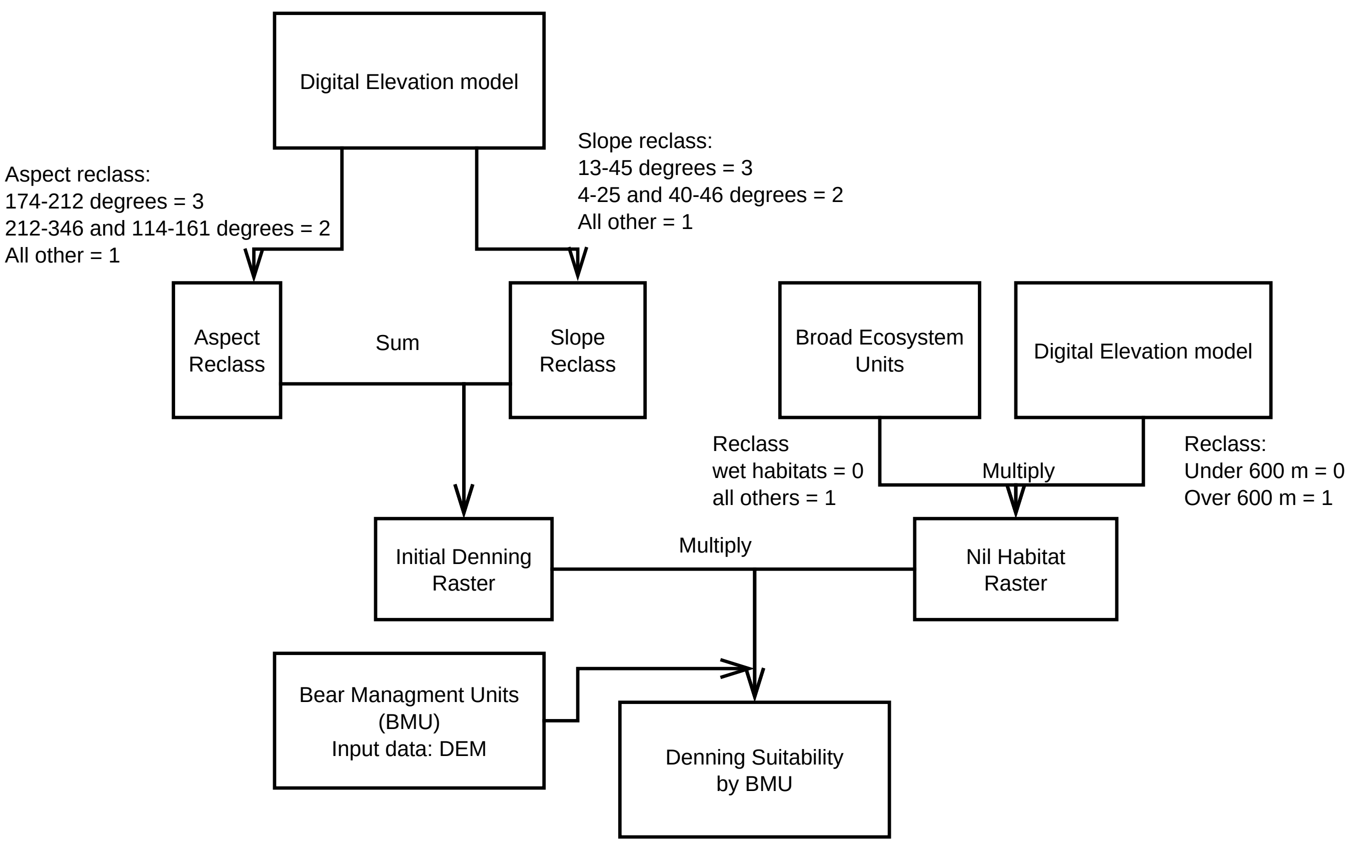


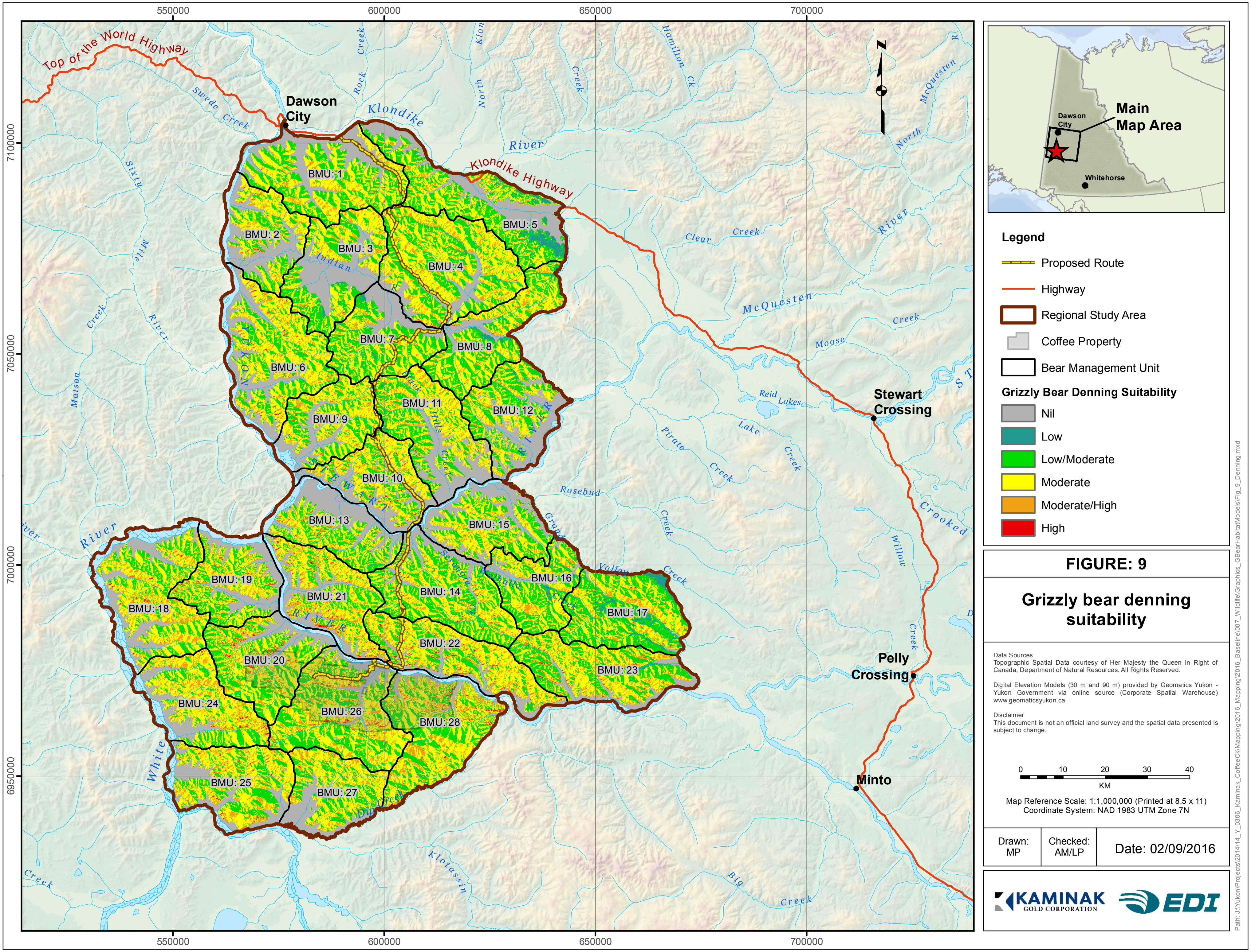
Figure 8. Grizzly bear denning suitability model analysis flow chart.

5.2 RESULTS

Within the entire RSA, 22.8% of the RSA was modelled to have no denning habitat suitability (i.e. nil), 1.6% was low suitability, 27.1% was low-moderate suitability, 38.9% was moderate suitability, 9.1% was moderate-high suitability, and 0.5% was high suitability. Many BMUs had over 30% nil denning habitats due to low elevations. In general the BMUs with the highest percent availability of moderate-high and high denning suitability were in the southern portion of the RSA, south of the Yukon River where there are more high elevation, mountainous areas. All denning suitability results are reported by BMU in Table 11 and shown in Figure 9.

Table 11. Grizzly bear denning habitat suitability with the study area.

	Nil		Low		Low-Moderate		Moderate		Moderate – High		High	
BMU	**Area (km²)**	**% of BMU**	**Area (km²)**	**% of BMU**	**Area (km²)**	**% of BMU**	**Area (km²)**	**% of BMU**	**Area (km²)**	**% of BMU**	**Area (km²)**	**% of BMU**
1	167.1	27.5	3.2	0.5	173.6	28.5	228.8	37.6	35.2	5.8	0.8	0.1
2	147.3	38.3	1.6	0.4	69.5	18.0	136.2	35.4	28.5	7.4	1.8	0.5
3	161.3	33.7	6.8	1.5	121.5	25.3	159.6	33.3	29.1	6.1	0.4	0.1
4	83.4	11.8	8.7	1.2	204.2	28.9	341.9	48.4	67.9	9.6	0.7	0.1
5	178.0	29.7	45.2	7.5	195.8	32.7	159.1	26.6	21.0	3.5	0.1	<0.1
6	181.6	27.8	4.5	0.7	133.0	20.3	278.1	42.5	53.5	8.2	3.4	0.5
7	90.4	22.5	10.2	2.5	143.3	35.7	139.3	34.6	19.0	4.7	0.2	<0.1
8	31.9	7.4	14.5	3.4	158.4	36.8	188.6	43.9	35.8	8.3	0.6	0.2
9	86.8	22.6	3.3	0.9	91.7	23.9	166.4	43.3	34.6	9.0	1.1	0.3
10	125.5	31.9	2.1	0.5	73.4	18.6	150.4	38.2	39.3	10.0	3.3	0.8
11	131.7	25.9	5.6	1.1	121.6	23.9	200.6	39.5	47.7	9.4	0.8	0.2
12	150.0	34.7	5.6	1.3	118.1	27.4	127.4	29.5	29.7	6.9	0.8	0.2
13	169.7	42.0	3.3	0.8	94.8	23.4	112.4	27.8	22.3	5.5	1.9	0.5
14	79.2	14.6	6.0	1.1	197.4	36.4	218.7	40.4	38.0	7.0	2.7	0.5
15	150.1	35.1	3.8	0.9	107.6	25.1	139.4	32.5	26.9	6.3	0.6	0.1
16	35.8	10.9	10.0	3.0	124.3	37.9	131.9	40.2	25.7	7.8	0.6	0.2
17	13.2	2.8	43.6	9.3	211.9	45.1	166.6	35.4	34.4	7.3	0.5	0.1
18	212.7	32.1	3.0	0.4	127.1	19.2	251.2	37.9	65.9	10.0	2.6	0.4
19	129.1	31.4	4.4	1.1	99.6	24.3	138.9	33.7	36.6	9.0	1.9	0.5
20	77.9	16.8	3.6	0.8	149.4	32.3	184.2	39.8	43.1	9.3	4.7	1.0
21	113.1	24.4	1.5	0.3	81.1	17.5	191.6	41.4	67.8	14.6	8.2	1.8
22	79.1	16.6	2.5	0.5	97.0	20.4	220.9	46.3	68.7	14.4	8.3	1.8
23	73.4	14.7	10.2	2.1	158.2	31.7	194.6	38.9	59.5	11.9	3.5	0.7
24	102.0	21.8	1.8	0.4	85.1	18.1	216.1	46.1	60.5	12.9	3.3	0.7
25	126.2	25.3	1.8	0.3	103.1	20.6	204.5	41.0	59.2	11.9	4.3	0.9
26	64.8	10.6	5.4	0.9	200.6	32.7	266.6	43.5	70.6	11.5	4.9	0.8
27	95.0	24.9	5.2	1.4	88.7	23.2	152.4	39.9	39.5	10.4	0.6	0.2
28	59.0	10.4	3.8	0.7	173.3	30.5	245.2	43.2	80.4	14.1	6.3	1.1
Total	**3,115.3**	**22.8%**	**221.2**	**1.6%**	**3,703.3**	**27.1%**	**5,311.6**	**38.9%**	**1,240.4**	**9.1%**	**68.9**	**0.5%**


550000
600000
650000
700000
7100000
7050000
7000000
6950000
Top of the World Highway
Klondike Highway
Dawson City
Stewart Crossing
Pelly Crossing
Minto
Whitehorse
Main Map Area
Klondike River
McQuesten River
Stewart River
Yukon River
White River
Sixty Mile River
Swede Creek
Rock Creek
Indian R
Hamilton Ck
Clear Creek
Moose Creek
Reid Lakes
Lake Creek
Pirate Creek
Rosebud Creek
Crooked Creek
Willow Creek
Big Creek
Klotassin
Matson Creek
Grand Valley Creek
BMU: 1
BMU: 2
BMU: 3
BMU: 4
BMU: 5
BMU: 6
BMU: 7
BMU: 8
BMU: 9
BMU: 10
BMU: 11
BMU: 12
BMU: 13
BMU: 14
BMU: 15
BMU: 16
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BMU: 18
BMU: 19
BMU: 20
BMU: 21
BMU: 22
BMU: 23
BMU: 24
BMU: 25
BMU: 26
BMU: 27
BMU: 28
N
Legend
Proposed Route
Highway
Regional Study Area
Coffee Property
Bear Management Unit
Grizzly Bear Denning Suitability
Nil
Low
Low/Moderate
Moderate
Moderate/High
High
FIGURE: 9
Grizzly bear denning suitability
Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.
Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.
Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.
0 10 20 30 40
KM
Map Reference Scale: 1:1,000,000 (Printed at 8.5 x 11)
Coordinate System: NAD 1983 UTM Zone 7N
Drawn: MP
Checked: AM/LP
Date: 02/09/2016
KAMINAK GOLD CORPORATION
EDI
Path: J:\Yukon\Projects\2014\14_Y_0306_Kaminak_CoffeeCk\Mapping\2016_Mapping\2016_Baseline\007_Wildlife\Graphics_GBearHabitatModels\Fig_9_Denning.mxd

5.3 ASSUMPTIONS AND LIMITATIONS

As with other models completed in this report, the denning spatial analysis requires a number of assumptions including:

- BEU mapping accurately predicts the spatial extent of wet ecosystems, rock/rubble and water in the RSA;
- Criteria used to define denning habitat is valid in the west-central Yukon context;
- Denning habitat is selected at a course scale and is not based on microhabitat selection which a 30 m resolution cannot capture;
- Permafrost areas, which cannot be delineated with available data, do not represent a significant portion of modelled suitable denning habitat.

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Grizzly Bear Denning Model

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APPENDIX 16-C-5

Wolverine Denning Habitat Model Report

Coffee Gold Mine: Wolverine Denning Habitat Model Report

Prepared For
Kaminak Gold Corporation
1020 – 800 West Pender Street
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Prepared By
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EDI Project
14Y0306
September 2016

Version 1.1

Down to Earth Biology

EDI ENVIRONMENTAL DYNAMICS INC.

Suggested citation:

EDI Environmental Dynamics Inc. 2016. Coffee Gold Mine: Wolverine Denning Habitat Model. Prepared for Kaminak Gold Corporation, Vancouver, BC by EDI Whitehorse, YT. September 1, 2016.

REVISION SUMMARY

Version No.	Date	Revision Notes	Revision Authors
1.0	11 March 2016	Draft Version	
1.1	1 September 2016	Final Version	Lea Pigage

EXECUTIVE SUMMARY

Wolverine (*Gulo gulo*) is a valuable furbearer species that is actively trapped in Yukon. It is assessed as a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; COSEWIC 2014). Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson City, Yukon which intersects habitat used the local wolverine population.

The availability of denning habitat has been suggested as a limiting factor for wolverine populations. A wolverine denning habitat model was developed to identify suitable denning habitat in relation to the Project. The denning habitat model identifies the suitability of denning habitat based on the presence of late spring snow cover. Daily snow cover estimates were accessed from satellite imagery produced by the National Snow and Ice Data Center (NSIDC).

Deep snow has consistently been described as the most important parameter for predicting wolverine den sites. The model shows that the majority (85%) of the area had snow cover through the spring during at least one year of the ten years analyzed in this model. Areas where late snow persisted during most of the study years are those areas where wolverine denning is most likely. Potential denning habitat is distributed throughout the study area, but concentrated within the higher elevation habitats. The model suggests that the study area contains limited wolverine denning habitat.

AUTHORSHIP

This report was prepared by EDI Environmental Dynamics Inc. Staff who contributed to this project include:

Graeme Pelchat, M.Sc., P.Biol. .... Author, GIS Analysis

Matt Power, A.Sc.T .... Mapping

Lea Pigage, B.Sc., R.P.Bio., PMP .... Project Manager and Review

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ACRONYMS AND ABBREVIATIONS

asl....above sea level

Coffee Project ....Coffee Gold Mine

COSEWIC....Committee on the Status of Endangered Wildlife in Canada

EDI ....EDI Environmental Dynamics Inc.

EOSDIS ....Earth Observing System Data and Information System

GMS....Game Management Subzone

Kaminak....Kaminak Gold Corporation

km ....kilometers

km^2 ....square kilometers

m....metre

MODIS ....moderate resolution imaging spectroradiometer

NDSI ....normalized difference snow index

NSIDC ....National Snow and Ice Data Center

Project....Coffee Gold Mine

RSA....Regional Study Area

YESAA....Yukon Environmental and Socio-economic Assessment Act

YESAB....Yukon Environmental and Socio-economic Assessment Board

1 INTRODUCTION

Kaminak Gold Corporation, a wholly owned subsidiary of Goldcorp Inc. (Kaminak; the Proponent) is proposing to develop a gold mine, known as the Coffee Gold Mine (Coffee Project; the Project) located 130 km south of Dawson City, Yukon (Figure 1). The Project will be accessed by road from Dawson City.

In 2014, Kaminak retained EDI Environmental Dynamics Inc. (EDI) to conduct wildlife baseline studies for the Coffee Project in anticipation of future regulatory requirements. A number of wildlife surveys have been undertaken for the Coffee Project, as well as habitat models for select species — including this wolverine (*Gulo gulo*) denning habitat model.

Concerns have been raised about potential Project effects on wolverine. Wolverine are considered to be a valuable furbearer, which is actively trapped in Yukon. It assessed as a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; COSEWIC 2014).

The wolverine denning habitat model was developed to identify suitable denning habitat within the Project's Regional Study Area (RSA). This information will assist with Project planning and mitigation. The information provided in this report supports the Project Proposal to be submitted to the Yukon Environmental and Socio-economic Assessment Board (YESAB) Executive Committee for screening under the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA), and applications to be submitted for a Quartz Mining Licence and a Type A Water Licence from the Yukon Water Board, among other permits and licences.

This report describes how the wolverine denning model was completed and includes all applicable requirements of YESAB's *DRAFT Proponents Guide: Model Documentation Report* (YESAB 2015).

1.1 OBJECTIVES

The objective of the wolverine denning habitat model is to quantify potential denning habitat availability and distribution in a spatially explicit format for assessing potential Project effects on the regional wolverine population.

1.2 BACKGROUND

Wolverines occupy the northern hemisphere and have adapted to exist in diverse habitats and landscapes throughout their circumpolar range. Habitats occupied by wolverines include the boreal forest, alpine, and high arctic tundra (Copeland *et al.* 2010). Wolverines are able to exist where there is suitable prey; consequently, they are not selective for foraging habitat as they simply persist where sufficient food is available. Female wolverines, however, are selective when choosing denning habitat. Wolverine dens are considered critical habitat but are often difficult to find (Dawson Regional Planning Commission 2013). Wolverine dens have been almost exclusively reported above treeline within deep snowdrifts. Dens within forested habitats are uncommon (Magoun and Copeland 1998).

Wolverines have been described using natal and maternal dens (Magoun and Copeland 1998). Natal dens are dens used during parturition (the process of giving birth) and immediately post-partum. Natal dens are composed of snow tunnels and caves, which may access boulders or other vegetative structures under the snow (Magoun and Copeland 1998, May *et al.* 2012). Maternal dens are used during the weaning period once the natal den becomes unsuitable. Maternal dens are established in the same general vicinity as natal dens and have been documented up to 3.8 km from natal dens (Magoun and Copeland 1998). Maternal dens are located in similar conditions as the natal dens as they are excavations in snowbanks, and the snow tunnels commonly access the boulders or other vegetative structures under the snow (Magoun and Copeland 1998, May *et al.* 2012).

Dens require deep snow and are reported in large snowdrifts greater than 1 m deep (Magoun and Copeland 1998). Snow cover through the denning season has been suggested as a primary factor driving den site selection and a potential limitation to the distribution of wolverines throughout their global range. Copeland *et al.* (2010) hypothesized that the global distribution of wolverine populations is limited in part by available denning habitat, and that late spring (April and May) snow cover is the primary landscape characteristic limiting denning habitat. Their results support this hypothesis.

For the Coffee Project, we replicate the approach described by Copeland *et al.* (2010) to model the distribution of potential wolverine denning habitat. Late spring snow cover is assumed to be a proxy for deep snow and indicative of potential wolverine denning habitat. We model the variation in potential wolverine denning habitat using remotely sensed snow cover data for multiple years through the spring season. The output of the model describes the distribution and variability of potential wolverine denning habitat.

1.3 STUDY AREA

1.3.1 SPATIAL BOUNDARY

The RSA was established to assess the abundance and distribution of most large wildlife species in the Project area and was delineated to include any game management subzone (GMS) that intersects the proposed Project. The RSA is 13,661 km².

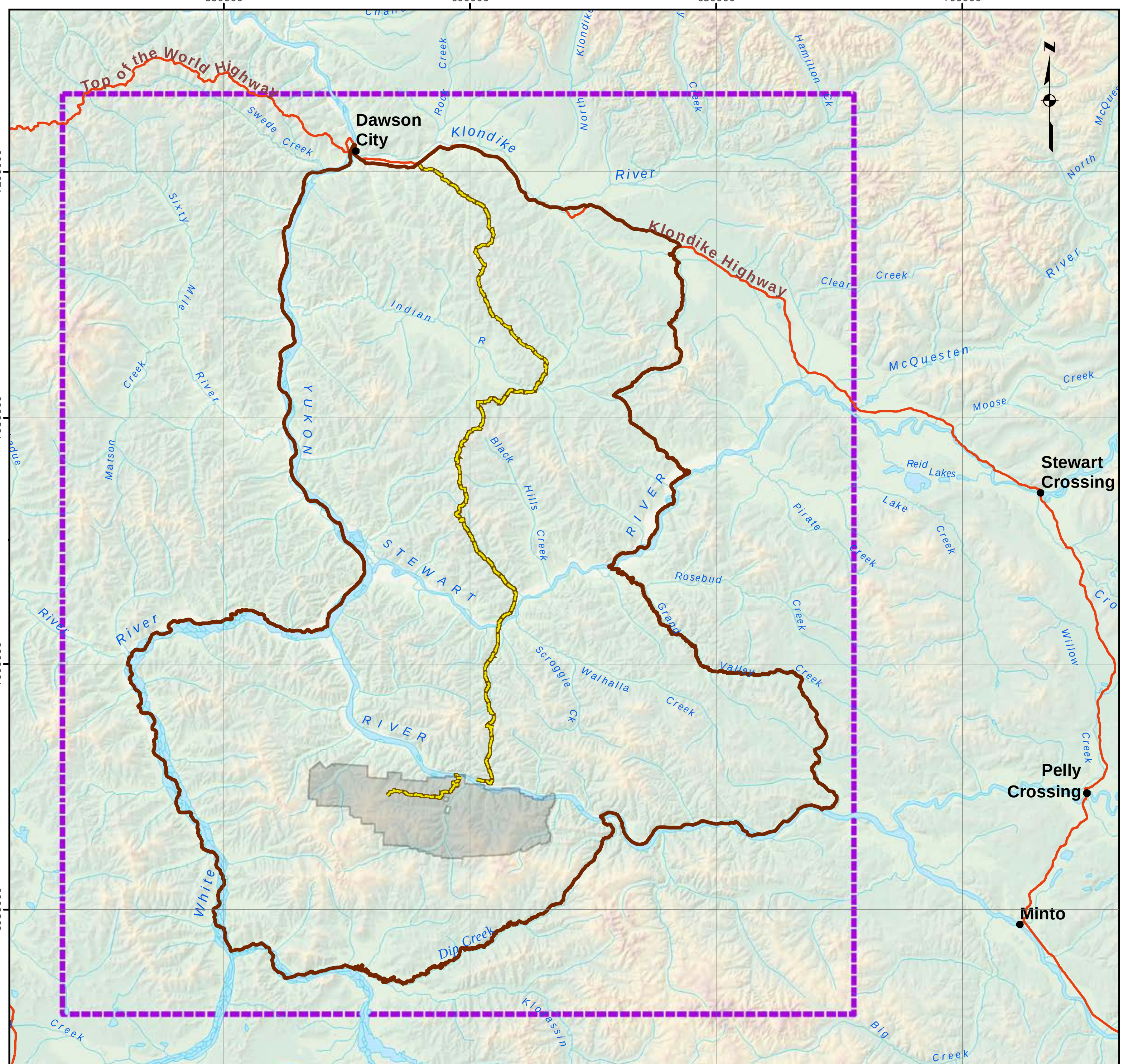
The RSA is characterized by smooth topped ridges bisected by deep, narrow, v-shaped valleys. Major landscape features in the RSA include the northern portion of the Dawson Range and the Yukon and Stewart rivers. The study area contains no notable lakes, though small waterbodies and wetlands are common along river valleys. The area hosts a range of vegetation communities and habitat types from low elevation boreal forests along river valleys to high elevation subalpine and alpine habitats on ridge crests. Below treeline, the vegetation pattern reflects the discontinuous distribution of permafrost with stunted black spruce woodlands on cold, north facing slopes with mixed forests or grasslands on warm south-facing slopes (YEWG 2004). Subalpine habitats are dominated by a dense shrub layer with an open canopy of coniferous trees, while alpine areas support a variety of dwarf shrubs, herbs, mosses and lichen.

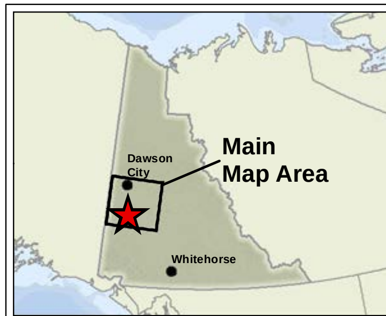
The study area used to assess wolverine denning is larger than the RSA due to data processing requirements. The geographic extent of the wolverine denning model is defined by an origin at 62.5 latitude and -140 longitude, and extends 187 km north and 161 km east. The wolverine denning habitat study area is approximately 30,100 km^2.

Both the RSA and the wolverine denning habitat study area are shown in Figure 1.

1.3.2 TEMPORAL BOUNDARY

The temporal extent of snow cover data used to create the wolverine model is 24 April to 15 May, consistent with Copeland *et al.* (2010). To reflect the variability in snow cover among years, we used ten years of snow cover data (2006–2015).





Legend

- Proposed Route
- Highway
- Regional Study Area
- Coffee Property
- Wolverine Denning Habitat Study Area

FIGURE: 1

Wolverine denning habitat study area for the Coffee Project

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

Project data displayed is site specific. Survey data collected by EDI Environmental Dynamics Inc. (2015).

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

0 10 20 30 40
KM

Map Reference Scale: 1:1,100,000 (Printed at 8.5 x 11)
Coordinate System: NAD 1983 UTM Zone 7N

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2 METHODS

We developed the wolverine denning habitat model based entirely on snow cover as described by Copeland *et al.* (2010). The method was shown to be predictive of known wolverine den locations; therefore, we replicated the analysis using ten years of daily snow cover data (2006–2015).

Snow cover data are produced by the National Snow and Ice Data Center (NSIDC; https://nsidc.org) and are freely available through NASA's Earth Observing System Data and Information System (EOSDIS). The ground snow cover estimates are developed from an algorithm that is primarily based on a normalized difference snow index (NDSI) with additional screening steps (Hall *et al.* 1995). The snow cover data were developed from remotely sensed data acquired from the moderate resolution imaging spectroradiometer (MODIS) onboard NASA's Terra satellite. The MODIS sensor provides data in 12-bit radiometric resolution for 36 spectral bands. The data have a temporal resolution of 1 to 2 days allowing almost daily snow cover estimates for the entire study area.

2.1 DATA ACQUISITION

We selected the dataset that provides the highest resolution and most frequent snow cover estimates. The selected dataset was 'MODIS/Terra Snow Cover Daily L3 Global 500 m Grid', which provides daily estimates of snow cover at a spatial resolution of 500 m (Hall *et al.* 2006). The following criteria were used to select the appropriate granules, or satellite scenes, using the EOSDIS (http://reverb.echo.nasa.gov):

- Spatial search: location N63 and W-139.
- Annual search: repeating date range: April 24–May 15 between 2006 and 2015.
- Search term: MOD10A1.

The search returned 635 granules. The granules were screened to those that covered the entire geographic extent of the study area. The selected data were in the h11v02 MODIS Sinusoidal Grid reference number, as all other granules that only partially covered the study area were excluded. The final selection identified 210 suitable granules for analysis.

2.2 DATA PREPARATION

Each granule comes as a hierarchical data format file that includes four estimates snow cover parameters as separate bands:

- Band 0: Snow Cover Daily Tile Field (8-bit)
- Band 1: Snow Spatial QA Field (8-bit)
- Band 2: Snow Albedo Daily Tile Field (8-bit)
- Band 3: Fractional Snow Cover Field (8-bit)

Daily snow cover is used as the estimate of snow cover. Data were prepared for analysis using the HDF-EOS To GeoTIFF Conversion Tool (HEG). Data were subset to xMin: -142.5, yMin: 62.0, xMax: -136.0, yMax: 65.0 to include all GMZs that intersect the Coffee Project infrastructure. The data were reprojected to the WGS84/UTM zone 7N coordinate reference system (EPSG: 32607) and resampled using nearest neighbour method because data are categorical.

2.3 DATA ANALYSIS

Daily snow cover layers were reclassified to Boolean data where a value of 1 indicates snow cover or data categories that were inconclusive (e.g., night, no decision), and a value of 0 for the data categories that indicated 'no snow' or water bodies. The approach is more conservative as it assumes all areas are snow covered until the data defines the area as not covered in snow. A summary of the reclassification and the rationale are provided in Table 1.

The reclassified daily snow cover datasets were combined using the minimum value within each year to create annual composite snow cover estimates. Using the minimum value infers that if an area was identified as snow free at any point during the spring, then the area was defined as snow free for the entire denning season.

Annual composites were combined by summation. The final snow cover layer, therefore, reflects the number of years that a location (pixel) was snow covered through the late spring period. Figure 2 shows a schematic of the wolverine denning habitat model concept.

Table 1: Description of snow cover estimates and Boolean reclassification with rationale.

Digital Number	Description	Boolean Value	Rationale for Reclassification
0	data missing	No Data	No data
1	no decision	1	Assumed potentially snow covered
11	night	1	Assumed potentially snow covered
25	no snow	0	Not denning habitat
37	lake	0	Not denning habitat
39	ocean	0	Not denning habitat
50	cloud	1	Assumed potentially snow covered
100	lake ice	0	Not denning habitat
200	snow	1	Snow covered
254	detector saturated	1	Assumed potentially snow covered
255	fill	No Data	No data, outside the study area

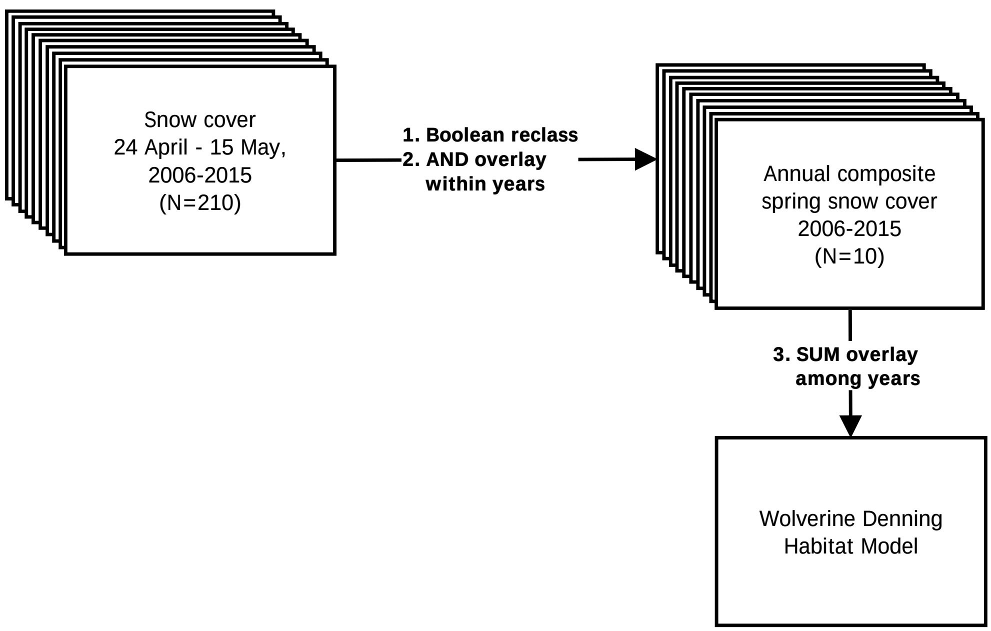


Figure 2: Schematic of wolverine denning habitat model concept.

2.4 VALIDATION

The snow cover data are a validated product with absolute accuracy assessed at 93% (Hall and Riggs 2007). There are no empirical data of wolverine denning observations within the study area for validating the models application as a wolverine denning habitat; however, spring snow cover as a proxy for wolverine denning habitat was validated by Copeland *et al.* (2010), who used late snow cover as an a partial explanation for the global extent of wolverine. Copeland *et al.* (2010) determined that spring snow coverage was an important predictor of wolverine denning — 98% (N=562) of dens were in areas that had spring snow cover for at least one of seven years and 69% (n=65) of North American dens were in areas that had spring snow cover for at least six of seven years.

3 RESULTS AND DISCUSSION

Deep snow has consistently been described as the most important parameter predicting wolverine den sites (e.g. May *et al.* 2012, Magoun and Copeland 2008). The snow cover model shows that there are few areas that contain consistent snow cover through the spring, suggesting there are likely also few locations of deep snow pack. The area contains approximately 22 km² of terrain that were consistently covered by snow during the study period, while 93% of the study area had snow cover through the spring during fewer than half of the years (Table 2). The lack of consistent snow cover indicates that the area contains limited wolverine denning potential.

Snow cover is strongly correlated with elevation (Figure 3) and latitude. The study area contains little high elevation habitat — the maximum elevation in the study area is approximately 1,630 m asl. A large portion of the study area (4,571 km^2) did not contain snow during the study period between 2006 and 2015 (Table 2). These areas are primarily the lowest elevation terrain adjacent to larger streams (Figure 3). The wolverine denning habitat model is shown in Figure 4. Areas with moderate and high denning habitat potential are limited, representing 1.9% and 0.2% of the wolverine denning habitat study area, respectively.

The model shows that the majority of the area had snow cover through the spring during at least one year (Figure 3; Table 2). The late snow cover for at least one year is attributed to an unusually late spring in 2013. The snow cover model for 2013 indicates that 84% of the study area remained snow covered through the spring.

The areas where late snow persisted through the majority of the annual study period are those areas where wolverine denning is most likely. Potential denning habitat seems distributed throughout the study area (Figure 4), but concentrated within the higher elevation habitats. The larger patches of wolverine denning habitat exist within the northern portion of the Dawson Range, including a portion of the Coffee Project and a number of small mountains within the Dawson Gold Fields.

The limited availability of wolverine denning habitat is predictable given that the study area is within the Dawson Range and Dawson Goldfields within the Klondike Plateau ecoregion. The Klondike Plateau ecoregion is a relatively dry area of Yukon, with most precipitation deposited during summers and little snowfall during winters (YEWG 2004).

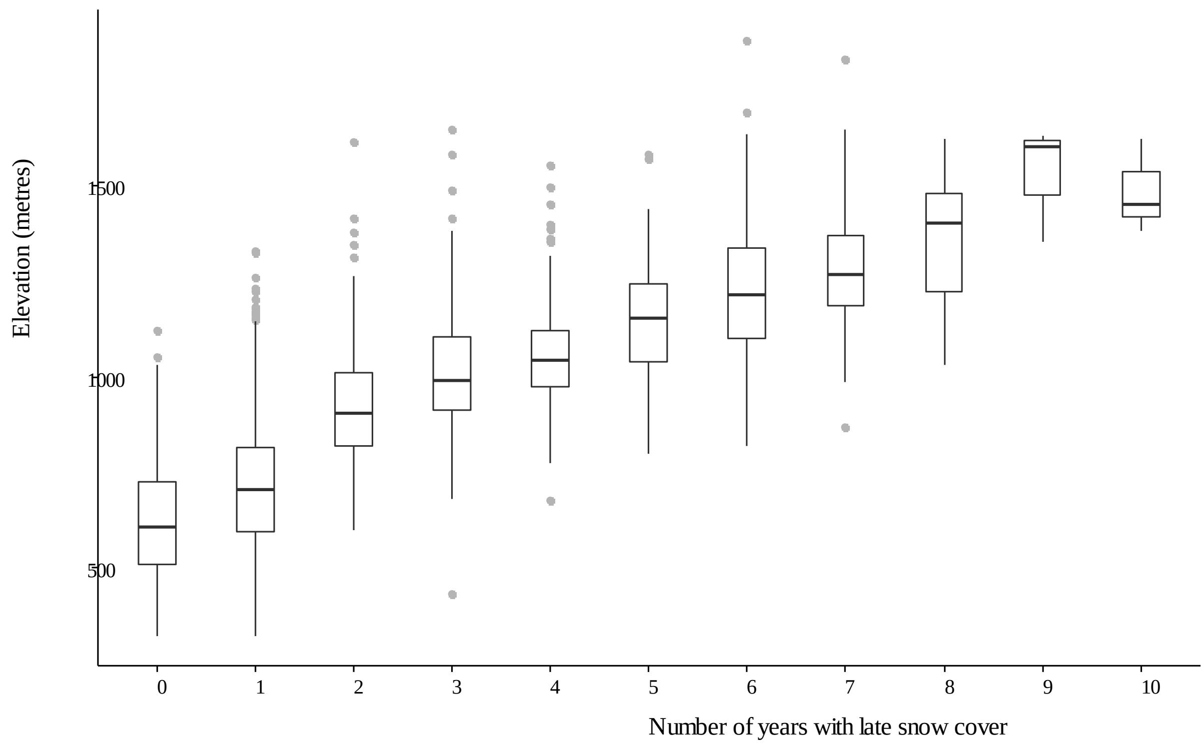
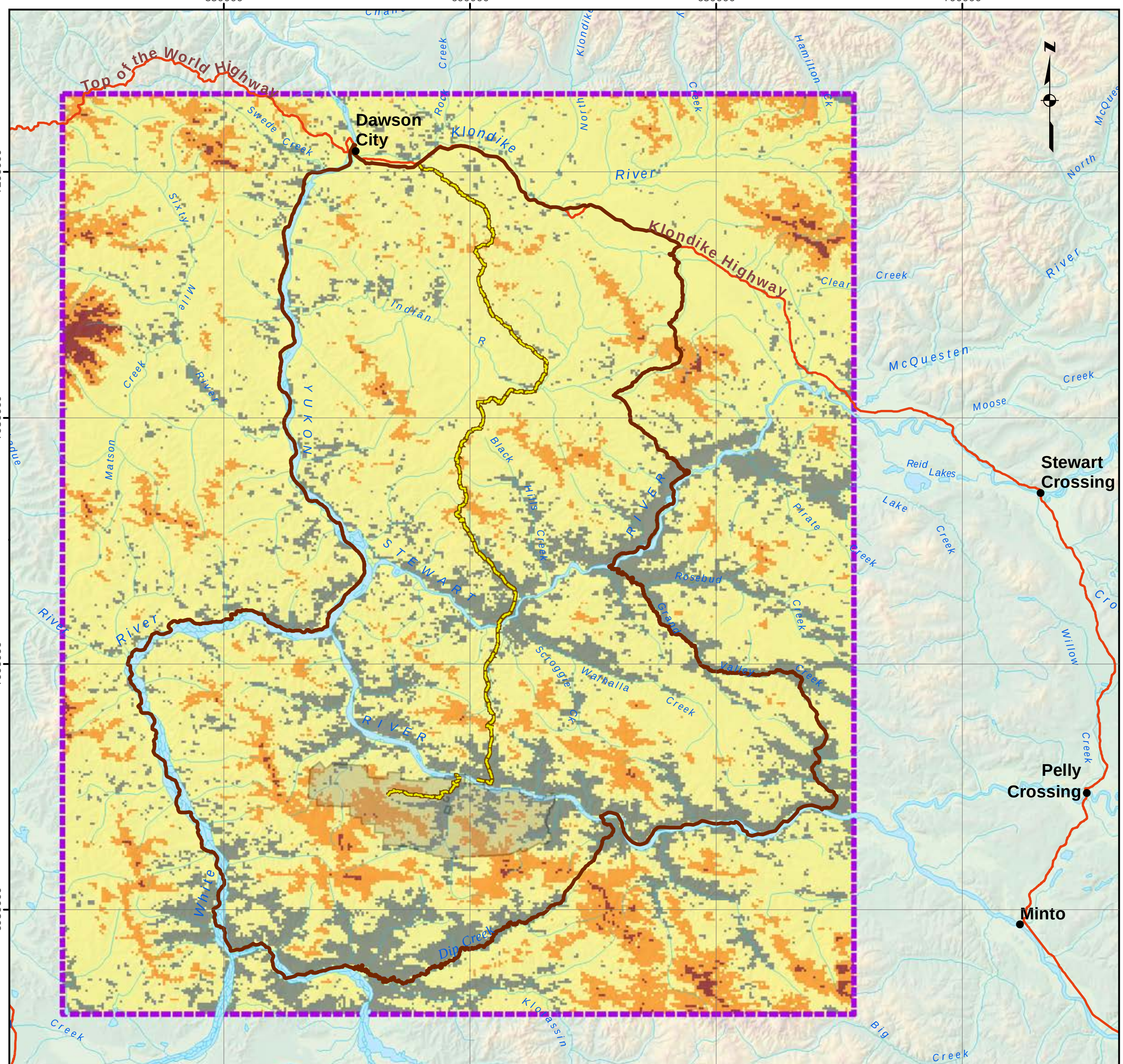
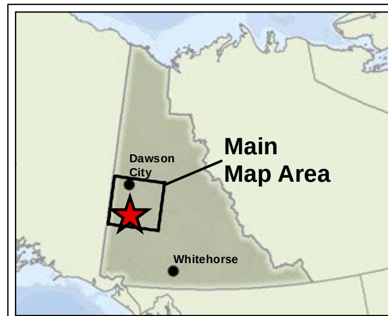


Figure 3: Relationship between number of years with late snow cover and elevation within the wolverine denning habitat study area.

Table 2: Estimate of the wolverine denning habitat as a function of the number of years containing late snow cover.

Number of years snow covered	Pixel Count	Percent (%)	Area (km²)
0	21,293	15	4,571
1	80,956	58	17,378
2	13,574	10	2,914
3	8,424	6	1,808
4	6,480	5	1,391
5	4,187	3	899
6	2,416	2	519
7	1,803	1	387
8	796	1	171
9	155	0	33
10	104	0	22
Total	140,188	100	30,093





Legend

- Proposed Route
- Highway
- Regional Study Area
- Coffee Property
- Wolverine Denning Habitat Study Area

Wolverine Denning Habitat Potential (years with late snow)

- Very Low (0)
- Low (1-3)
- Moderate (4-7)
- High (8-10)

FIGURE: 4

Wolverine denning habitat for the Coffee Project

Data Sources
Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Models (30 m and 90 m) provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

Project data displayed is site specific. Survey data collected by EDI Environmental Dynamics Inc. (2015).

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

0 10 20 30 40
KM

Map Reference Scale: 1:1,100,000 (Printed at 8.5 x 11)
Coordinate System: NAD 1983 UTM Zone 7N

Drawn: MP	Checked: AM/LP	Date: 04/04/2016

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3.1 LIMITATIONS

The spatial resolution of the snow cover data is 500 m; therefore small snow patches would not be detected by the MODIS sensor and, consequently, would not be represented in the data. Snow cover data was selected over other Landsat derived products because we were required to balance precision and accuracy. The advantage of the snow cover data derived from the MODIS sensor is the data are more accurate as they have been validated and provide daily estimates for the entire study period. The Landsat derived snow cover data provides more precise data as it has a spatial resolution of 30 m; however, the accuracy of the snow cover estimate using Landsat has the potential to be considerably lower compared to the MODIS derived snow cover data because of the lower temporal resolution (approximately 16 days) and lack validation. A visual comparison of the two products was completed and generally showed consistency.

The regional wolverine population could be limited by denning habitat; however, female wolverines are likely able to establish dens in suitable locations that are too small to be remotely sensed (i.e., microsite snow cover is not detectable at the scale of the satellite imagery). Consequently, wolverine could be finding locations within the study area that have suitable snow depth for establishment of natal dens. In addition wolverines may select maternal den locations based on features within the habitat, such as under fallen trees and within boulder fields. Habitat features are not remotely detectable or easily mapped at the landscape scale; consequently, landscape models of wolverine denning habitat need to rely on coarser data.

4 CONCLUSION

The wolverine denning habitat model provides an indication where wolverine denning is most likely to occur, and suggests that the area contains limited wolverine denning habitat. The habitat model provides a useful tool for Project planning and assessment as it clearly shows a pattern of potential wolverine denning habitat.

5 REFERENCES

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5.1 SPATIAL DATA

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