Jumbo Glacier Resort Master Plan

Appendix 3-D

A Cartographic Model-Based Cumulative Effects Assessment of JGR on Grizzly Bears in the Central Purcell Mountains

Prepared by
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A CARTOGRAPHIC MODEL-BASED CUMULATIVE EFFECTS ASSESSMENT OF THE PROPOSED JUMBO GLACIER RESORT DEVELOPMENT ON GRIZZLY BEARS IN THE CENTRAL PURCELL MOUNTAINS, BRITISH COLUMBIA

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Prepared for

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ABSTRACT

I was contracted to conduct a GIS modeling-based cumulative effects assessment (CEA) of the proposed Jumbo Glacier Resort (JGR) development on grizzly bears within a 3,977 km^2 analysis area in the central Purcell Mountains. This involved the application of an existing model to evaluate the relative (%) reduction in habitat effectiveness and increase in mortality risk resulting from the JGR development. The modeling framework consisted of a habitat submodel comprised of an existing habitat suitability model developed and tested for the analysis area. A displacement submodel was built from existing human use data for the analysis area and features associated with the proposed JGR development, as provided by ENKON Environmental. Parameters for the displacement submodel were adopted from previous CEA model applications in the Canadian Rocky Mountains. The mortality risk submodel integrated habitat and human use data, and parameters were adopted from the latest CEA model iteration for the northern U.S. Rocky Mountains. Under the direction of ENKON Environmental and the provincial large carnivore specialist, my analysis was conducted under a stated set of assumptions representing expected minimum and maximum impact scenarios. Analysis results reflect these assumptions, the stated assumptions of the CEA model, and the availability and accuracy of data inputs. Model outputs suggest that the JGR development will decrease habitat effectiveness 1.7 – 3.1% over the 3,977 km^2 analysis area, resulting in an overall value of 74.9 – 73.5%, while the mortality risk index is projected to increase 2.6 – 3.8% over existing levels. Impacts are apparent within 4 of 14 drainages within the analysis area, with a habitat effectiveness reduction of 30 – 43, 3 – 7, 0 – 5, and 2%, and a mortality risk increase (relative to existing levels) of 41 – 55, 4 – 7, 0 – 3, and 3%, within the Jumbo, Toby, Glacier, and Horsethief drainages respectively. Upon considering mitigation options, the model suggests that the JGR development (1) cannot be mitigated within the Jumbo drainage itself, but (2) can theoretically be mitigated by implementing partial or total restrictions on motorized human access in all or sub-drainages of the Jumbo, Glacier, Howser, Toby, Horsethief, and Brewer/Dutch drainages. These conclusions assume that (1) all road networks are currently accessible to motorized vehicles, (2) non-motorized recreation will not increase as a result of decreased motorized access, and (3) mitigations will also compensate for any loss in population connectivity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS USED

AD	Activity Duration
BTM	Baseline Thematic Mapping
CEA	Cumulative Effects Assessment
CRA	Controlled Recreation Area
DC	Disturbance Coefficient
GIS	Geographic Information System
GVI	Green Vegetation Index
HC	Habitat Coefficient
HE	Habitat Effectiveness
HV	Habitat Value
JGR	Jumbo Glacier Resort
MR	Mortality Risk Index
MWLAP	Ministry of Water, Land and Air Protection
TM	Thematic Mapper
TRIM	Terrain Resource Information Management
USDA	U.S. Department of Agriculture
ZI	Zone of Influence

INTRODUCTION

Landscape quality for grizzly bears (*Ursus arctos*) can be characterized in terms of habitat "capability", "suitability" and "effectiveness". Habitat capability refers to a landscape's intrinsic potential to support a species under ideal conditions of vegetation composition and structure, while habitat suitability is the landscape's current capacity given existing vegetative conditions. Habitat effectiveness equates to the realized ability of a species to inhabit and persist within a landscape after accounting for human influence factors. The inherent assumption is that change in a habitat's provision of food and/or security, or a bear's ability to use or survive in that habitat, translates to a change in the bear population and the likelihood of long-term regional persistence. Cumulative effects analysis (CEA) is the process by which total human influence is modeled such that grizzly bear habitat effectiveness and mortality risk can be estimated. Unless the CEA model has been locally validated with field research, its parameters are based on expert-opinion of grizzly bear response to different types and levels of human activity. As derived from the CEA model, the relative (%) reduction in effective habitat can be compared (1) among human-use scenarios for a given landscape, (2) among landscapes for a given human use scenario, or (3) to a pre-determined management threshold for a given landscape or analysis area. Thus, CEA modeling can aid in the decision process pertaining to human activity and development (Winn and Barber 1986, Weaver et al. 1986).

I was contracted to conduct a GIS modeling-based cumulative effects assessment of the proposed Jumbo Glacier Resort (JGR) development on grizzly bears for a 3,977 km^2 analysis area in the central Purcell Mountains of southeastern British Columbia (Figure 1). The analysis was to be based on the eventual construction and operation of the resort at full "build out" (i.e., approximately 6,252 bed units) and was to assume maximum potential impact on grizzly bears. ENKON Environmental and Pheidias Project Management were to provide all human use data to be used in this analysis and all assumptions regarding development and human activity resulting from the JGR. I was instructed to apply the latest version of the USDA Forest Service grizzly bear cumulative effects assessment (CEA) model (USDA Forest Service 1990), the parameters of which were to be reviewed by the provincial large carnivore specialist. In this report, I describe the CEA modeling approach and the input data and assumptions used. I compare habitat effectiveness results among landscapes within the greater analysis area, between human use scenarios that do and do not include the JGR development, and for several mitigation options.

As a predictive, decision-support tool, output from CEA modeling is limited by several factors. These limitations include (1) our ability to account for inherent variation in grizzly bear habitat quality, (2) our assumptions about grizzly bear behavioural response to human activity and the lethality of human activities to grizzly bears, (3) our ability to accurately represent human activity types and levels in the model, and (4) our ability to project human use types, levels, and patterns resulting from the proposed JGR development and any other developments or trends that will influence habitat quality or human use within the analysis area. The effect of these factors on the accuracy of predictions should be acknowledged when considering CEA model output in decision analysis. Moreover, while model output can be displayed spatially such that the distribution and configuration of impacts can be qualitatively considered, the analysis itself does not explicitly account for implications to grizzly bear habitat or population connectivity within a given analysis area.

Due to limited time, I was not able to conduct a review of the literature or expert opinion to critically evaluate and possibly refine the parameters and assumptions of the grizzly bear CEA model. Also, I was not able to personally evaluate human-use data sources and forecasts for accuracy and completeness. The assumptions I have made are explicitly stated, and I cannot quantify the extent to which they may be wrong. Finally, mitigation options were restricted to those I could consider given the available data and the constraints of the CEA model.

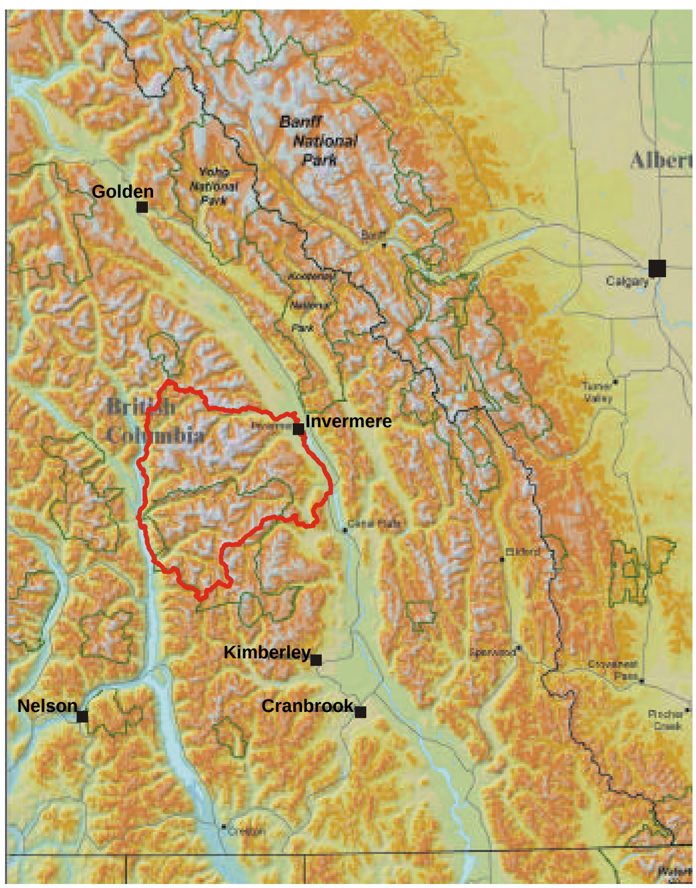

Figure 1. Central Purcell Mountains and the greater grizzly bear cumulative effects analysis area (red) in southeastern British Columbia.

OVERVIEW OF THE GRIZZLY BEAR CEA MODEL

As reviewed by Apps (1993), the Weaver et al. (1986) CEA modeling framework is comprised of 3 models pertaining to habitat, displacement, and mortality (Figure 2). Model coefficients are derived from expert opinion that is based on grizzly bear research (Mattson et al. 1986). The 2 main outputs are grizzly bear habitat-effectiveness value and mortality risk index.

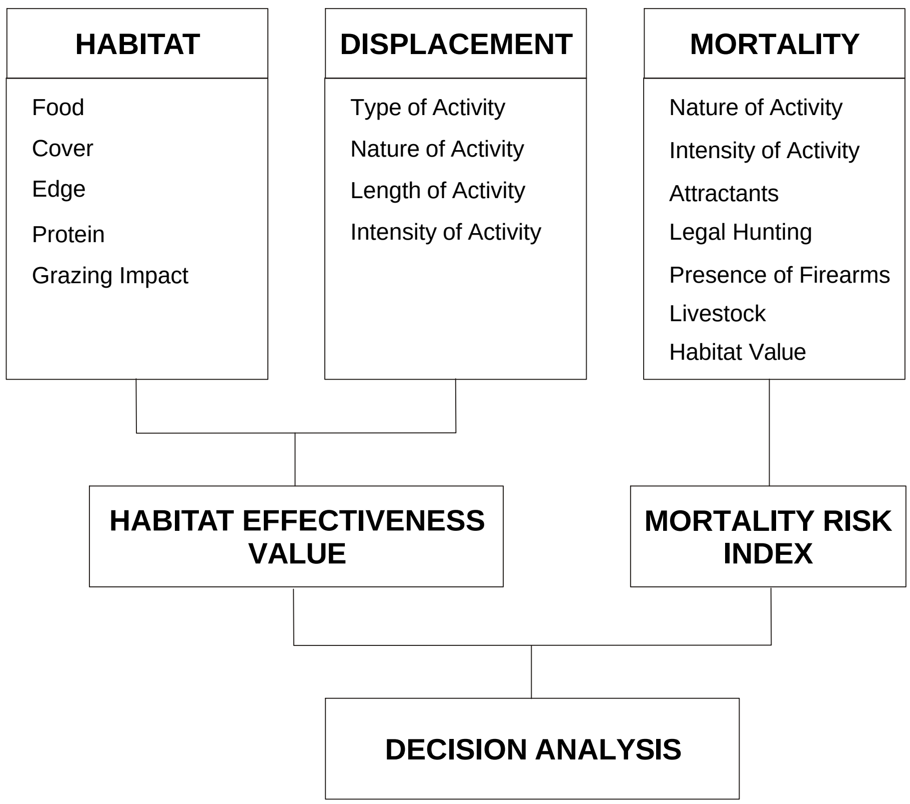

Figure 2. A framework for modeling the cumulative effects of human activity on grizzly bears (adapted from Weaver et al. 1986 and USDA Forest Service 1990).

The habitat submodel quantifies habitat value for a given area. This may reflect both existing and potential conditions. The following are typically considered: vegetative and animal food sources, availability of cover, presence of forest/nonforest edge, diversity of habitat, and seasonal availability of habitat. These variables carry weightings that reflect their relative importance as shown by research. Thus, values depicting habitat quality can be assigned to mapped habitat polygons in a given area. In its various applications, the habitat submodel has not been applied in any standardized way due to differences in biophysical inventory systems among jurisdictions. Rather, habitat models have been derived using independent approaches. In at least one case, the USDA Forest Service (1990) habitat submodel has been replaced by an empirically derived habitat suitability model (e.g., Mace et al. 1999). Canadian CEA modeling applications have used habitat models based on 1:50,000 ecological land classifications (Herrero and Herrero 1996, Gibeau 1998) or 1:20,000 forest cover classification (Miistakis Institute for the Rockies 2002).

The displacement submodel quantifies the effects of disturbance associated with human use or activity on the grizzly bear's ability to use a specific habitat. That is, the displacement submodel spatially accounts for the reduction of habitat use by grizzly bears attributed to cumulative human influence. Activities are based on their type (motorized, non-motorized, explosive), nature (point, linear, dispersed), duration (diurnal or 24 hour), and intensity (high or low). Each activity type has associated with it a zone of influence (ZI) that identifies the distance at which a grizzly bear would be affected by the activity. Since the area of disturbance often depends on the amount of cover available, separate values may be given to ZI in both cover and noncover situations. Values are assigned to each activity type, reflecting the degree to which habitat within the ZI may be effectively used by grizzly bears. Overlapping ZI from multiple, simultaneous activities create cumulative disturbance, and this is reflected in assigned disturbance values.

A combination of habitat and displacement submodels leads to a realized habitat value, and the proportion of potential habitat value that this represents is the *habitat effectiveness* value, one of 2 main outputs of the CEA model. Habitat effectiveness results from an analysis of human disturbance within ZI against habitat value for a given area. Habitat effectiveness is assumed to reflect the actual ability of a particular site to support grizzly bears. Overall reduction in habitat effectiveness can then be summarized for a given analysis unit (e.g., bear management unit, landscape unit, or watershed).

Given that human-caused grizzly bear mortality can take a considerable toll on a population's prospects for long-term survival, it is an important consideration in the CEA model. The mortality submodel quantifies the grizzly bear mortality risk associated with a given human activity. This results in the *Mortality Risk Index*, the second main output of the CEA model. Human activities contributing to grizzly bear mortality are classified similarly to those in the displacement submodel, with slight modification. Seven variables are incorporated: nature of the activity (point, linear, dispersed), intensity of disturbance, availability of attractants, legal hunting seasons, presence of firearms, and livestock. Habitat quality is also included as a variable, under the assumption that grizzly bears are more likely to occur in landscapes of higher inherent habitat value and are thus more susceptible to any existing mortality risk. Habituation has been identified as a significant factor in increasing grizzly bear mortality risk given that bears remaining in close proximity to humans face a higher chance of conflict or other situations leading to direct mortality (USDA Forest Service 1990). The mortality risk index is not currently incorporated into U.S. models due to a lack of sufficient data and difficulty in quantifying habituation (Ibid.), and it has not been applied in Canadian CEA modeling applications.

The establishment of thresholds for minimum habitat loss and mortality risk is the final step in relating model output to grizzly bear population and habitat objectives (Weaver et al. 1986). Such thresholds depict the minimum acceptable levels of habitat effectiveness and mortality risk needed to achieve or maintain population objectives and may vary according to ecosystem and area of analysis. Thresholds for habitat effectiveness should ideally maintain population objectives by providing for energetic needs under worst-case scenarios. Similarly, an acceptable number of cohort-specific mortalities under population objectives should determine mortality risk thresholds (Mattson and Knight 1991).

In application of the CEA model, the larger regional ecosystem is usually stratified into landscape units that typically follow watershed boundaries (Weaver et al. 1986). This subdivision of analysis is necessary in order to: (1) assess existing and proposed activities without having the diluting effect of an overly large area, (2) address unique habitat characteristics and bear activity/use patterns, (3) identify areas of contiguous habitat that provides for year-long needs of the grizzly bear, and (4) prioritize areas where management goals require CEA. Mattson and Knight (1991), however, stress the importance of an initial assessment of habitat and population prospects at a broad, population level, and with finer scales considered for analysis of impact distribution. The basic level of analysis for CEA model applications in the US has been the Bear Management Unit, which typically encompasses several watersheds (Weaver et al. 1986, USDA Forest Service 1990). Habitat and human use data used in the model has typically been of 1:24,000 map scale (K. Ake, USDA Forest Service, pers. comm.).

METHODS

Analysis Units

All input data used in this analysis were rasterized at a 50-m resolution, and model application was conducted using the geographic information system (GIS) Idrisi® (ver 14; Clark Labs 2003). Previous CEA model applications have been conducted over areas corresponding to landscape units (often Bear Management Units), which typically correspond to major watershed boundaries. This allows comparison of outputs among landscapes and controls the dilution of effects over excessively large areas. Thus, I stratified the central Purcells greater analysis area by watersheds, the boundaries for which I received from ENKON Environmental. I labeled these landscapes as analysis units, some of which represent groupings of several minor watersheds (Duncan, Kootenay, and Windermere Lakes) (Figure 3).

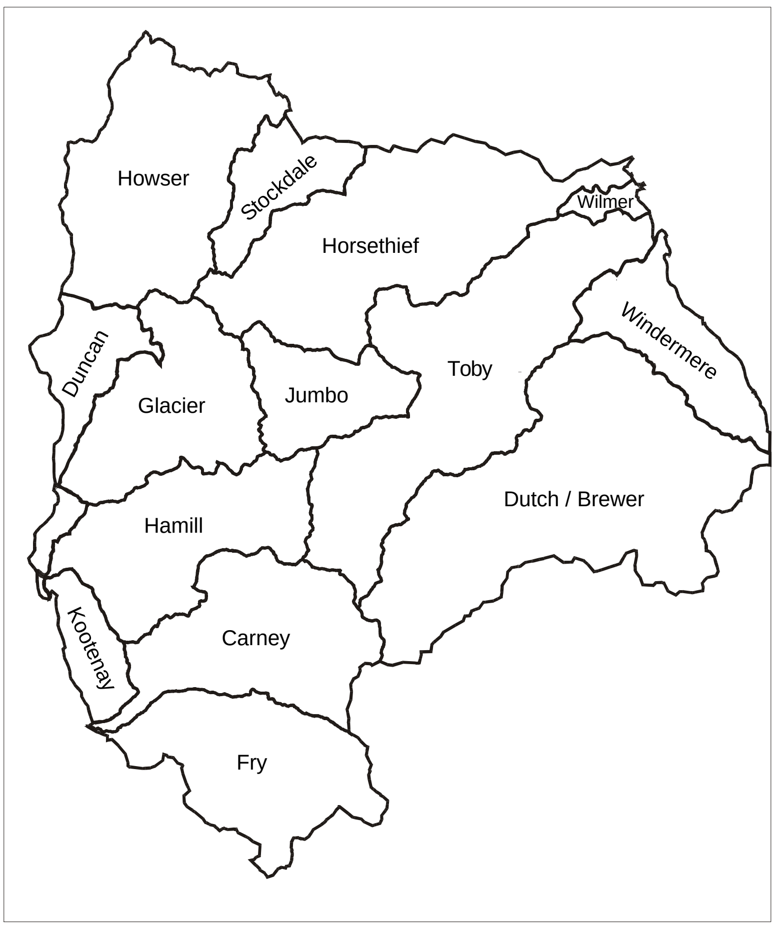

Figure 3. Landscape analysis units corresponding to watersheds in the central Purcells grizzly bear cumulative effects analysis area.

Habitat Submodel

<u>Model Assumptions</u>

The basic assumptions behind the habitat submodel of the CEA model are:

1. Habitat quality is a function of food and cover.
2. Where human presence is not a factor and/or cover is not limiting, food availability considerably outweighs cover in contributing to habitat quality.
3. Any research data on which coefficients are based are representative of the local population.
4. Vegetation classification systems used in the mapping are accurate predictors of food and cover for grizzly bears.
5. Habitat value is accurately predicted by the habitat component representation and presence of animal food sources.

<u>Habitat Coefficients (HC)</u>

Habitat coefficients reflect the relative value of vegetative conditions in providing food and cover for grizzly bears. This layer is often derived independently for each CEA model application given that biophysical inventory systems often differ among analysis areas. For this analysis, the habitat submodel was represented by an existing grizzly bear habitat suitability model tested with grizzly bear occurrence data sampled in the central Purcells (Apps 2002). This model used values of the green vegetation index (GVI), derived from a Landsat TM satellite image, as a direct surrogate (not season-specific) of habitat suitability based on grizzly bear plant foods (Mace et al. 1999, K Ache, USDA Forest Service, pers. comm.). GVI values were transformed such that all values reflecting unvegetated sites were forced to 0, and the lowest GVI value on vegetated sites was 1. This was then re-scaled to a 0→1 index. The index was then adjusted using a step-down multiplier for slope condition, such that the maximum possible suitability index was limited by terrain conditions and bear movement potential. Specifically, slopes of 50 – 80% were downgraded by 0.5, and slopes >80% were forced to an index of 0. The model was derived at a spatial scale corresponding to the expected average daily foraging radius of a female grizzly bear. In evaluation against independent data of grizzly bear detection within the analysis area, this habitat model performed better than a competing model derived primarily from forest cover data. Based on the results of this evaluation, the GVI-based habitat model was judged to be appropriate for use in CEA modeling (Apps 2002).

Protein Coefficients (PC)

Protein coefficients are often applied to habitat values in areas designated as containing extensive concentrations of protein-rich foods such as ungulates and fish. Coefficients can be expected to vary among grizzly bear ecosystems according to species, season and type of range. In cases where 2 or more protein sources overlap, the coefficient with the highest value is applied. For the central Purcells analysis area, spatial data on ungulate distribution and relative densities were not available and so protein coefficients were not applied in CEA model application.

Habitat Value (HV)

Habitat value is determined using the above coefficients. This provides a relative index representing the inherent capacity of a site to support grizzly bears. Habitat value is normally calculated as:

$$HV = HC \times PC ,$$

where HC is the habitat coefficient, and PC is the protein coefficient.

Average Habitat Value (AHV)

For both the greater analysis area and individual watershed units, an average habitat value was determined as:

$$AHV = \frac{\sum_p HV}{n_p} ,$$

where p is the pixel, and HV is the habitat value.

Displacement Submodel

Model Assumptions

The displacement submodel quantifies the effects of disturbance associated with human activity on a grizzly bear's ability to use a given habitat. Interaction of the habitat submodel and the displacement submodel results in a measure of habitat effectiveness. The basic assumptions of the displacement submodel are:

1. Grizzly bears are sensitive to disturbance from human activities.

2. Grizzly bears respond to human activities by altering normal spatial and temporal patterns of habitat use to the extent reflected by disturbance coefficients.
3. Disturbance from human activities is greater in open areas than in areas with security cover.
4. Model coefficients are designed to reflect habituation and other factors that may influence normal grizzly bear response patterns for a particular population.
5. Disturbance effects from overlapping, simultaneous activities accumulate in a multiplicative manner.

Data

I applied the displacement submodel to human use data that were either provided to me or approved by ENKON Environmental. The controlled recreation area (CRA) is a polygon (59.6 km^2) that indicates the area to be directly affected by the Jumbo Glacier Resort development. Within the CRA, a dataset (impacts) was provided that spatially represents all infrastructure features associated with the proposed development, including trails, lifts, and lodges. These data matched features on map P2.1 "preliminary conceptual area map of summer trails" that was provided to me. The transmission corridor for the development was represented outside the CRA. Roads data (roads_code) were originally derived from the 1:20,000 forest roads inventory, and roads were classified according to a "best guess" of road type (M. McLorg, ENKON Environmental, pers. comm.). Roads attributes did not indicate whether roads were subject to total or seasonal closures and all roads were assumed to be open to motorized access. A provincial inventory was provided for point and linear recreation activity features (rcbrp & rcbra). This included some outfitter camps, trail heads, hut/shelters, a lodge, helicopter landing and fuel caches, and weather/communication stations. These recreational datasets may be incomplete, given my personal knowledge of the analysis area[2]. A foot-trail dataset was provided to me that included trails digitized from a Forest Service recreation map (Ministry of Forests 1995) and a commercially produced trail map (ITMB Publishing Ltd. 1992). Because trails are often poorly mapped and trail maps can be inaccurate, subjective judgment was used to determine if features on one map did or did not represent the same trails as on the other map (M. McLorg, ENKON Environmental, pers. comm.). A "gas distribution" polygon and line were also provided that appears to represent the gas line and distribution area for the Panorama Resort. Some buildings, mine sites, and Panorama ski resort infrastructure features were derived from 1:20,000 TRIM data (Surveys and Resource Mapping Branch 1992). More specific information on the above datasets can be provided by ENKON Environmental (Michael McLorg, GIS Specialist). I

[2] The implications of incomplete human use data are that existing habitat effectiveness will be overestimated and mortality risk will be underestimated. If missing recreational features (e.g., guide-outfitter trails, camps, helicopter hiking areas and associated landing sites) are expected to receive increased use as a result of the JGR development, then development impacts will be underestimated (see Analysis Assumptions, p 17).

independently acquired 1:250,000 Baseline Thematic Mapping data (BTM; Geographic Data BC 2001) for the analysis area specifically to delineate existing urban and recreational areas (e.g., Invermere and Panorama Resort) as well as agricultural lands. I did not have data pertaining to helicopter-assisted summer recreation. The following data sets provided by ENKON were not relevant for CEA modeling and were not used: mining (mining claims), helicopter ski runs, and water rights.

I was furnished with traffic volume projections for the Toby Creek and Jumbo Creek roads that will be paved and improved to provide access to the Jumbo Glacier Resort development (McElhanney Consulting Services 2003), and I was provided with assumptions from ENKON Environmental to calculate maximum summer daily traffic volume that can be expected. I was subsequently informed that the projected average daily traffic volume for the JGR development during summer is 400 (J. Pinto, McElhanney Consulting, pers. comm.). Research in Montana suggested that roads with >10 vehicles per day have a displacement effect on bears (Mace et al. 1996). Although I did not have access to current traffic volume estimates on any roads within the analysis area, according to the JGR development proponent, it is reasonable to expect that current summer vehicle traffic accessing the Jumbo Valley is 10 to 20 vehicles per day (O. Oberti, Pheidias Project Management Corp., pers. comm.). A significant difference in disturbance to grizzly bears can be expected between a volume of 10 and 400 vehicles per day as reflected in temporal use patterns and the ability of bears to habituate to disturbance within the zone of influence (M. Austin, MWLAP, pers. comm.). Thus, I assumed that the JGR access route beyond the Panorama Resort is currently of “low” use intensity but will be of “high” use intensity upon full build-out of the JGR development (disturbance classes described below).

<u>Variables</u>

Human activities and uses that occur within the analysis area were stratified into groups having similar displacement potential. Activity groups have been identified according to the following criteria (USDA Forest Service 1990):

1. Type of activity: motorized, nonmotorized or explosive
2. Nature of activity: point, linear, or dispersed
3. Duration of activity: percent of grizzly bear season in which activity occurs
4. Intensity of activity: high or low (subjective judgement)

I categorized the human use data I had available for this analysis into activity and intensity-use classes (Table 1). I assumed that mapped trails within the CRA would receive high intensity (>80 people per month) non-motorized use, and I also assumed that the CRA as a whole would receive non-motorized dispersed human use at low intensity.

Table 1. Activity type and use intensity classes assigned to features within human use datasets provided for grizzly bear CEA analysis of the Jumbo Glacier Resort development. Each feature type's expected association with a grizzly bear attractant (e.g., garbage) or firearms is relevant to the mortality risk submodel.

Data Source[1]	Feature	Feature Type	Activity Type	Use Intensity	Attractant	Firearm
BTM	Urban	Point/Polygon	Motorized	High	Yes	Yes
BTM	Agriculture/Range	Point/Polygon	Motorized	Low	No	Yes
BTM	Recreation	Point/Polygon	Motorized	High	Yes	No
ROADS	Paved 2-Lane	Linear	Motorized	High	No	No
ROADS	Gravel 2-Lane	Linear	Motorized	High	No	Yes
ROADS	Gravel 1-Lane	Linear	Motorized	Low	No	Yes
ROADS	Logging Road	Linear	Motorized	Low	No	Yes
IMPACTS	Lodges	Point/Polygon	Motorized	High	Yes	No
IMPACTS	Residential - Subdivision	Point/Polygon	Motorized	High	Yes	No
IMPACTS	Residential – Urban	Point/Polygon	Motorized	High	Yes	No
IMPACTS	Road – Urban	Linear	Motorized	High	No	No
IMPACTS	New trails	Linear	Non-motorized	High	No	No
IMPACTS	Summer Lifts	Linear	Motorized	Low	No	No
CRA	Controlled Recreation Area	Point/Polygon	Non-motorized	Low	No	No
TRIM	Buildings	Point/Polygon	Motorized	High	Yes	Yes
TRIM	Mine	Point/Polygon	Motorized	High	Yes	Yes
TRIM	Ski Resort	Point/Polygon	Motorized	High	Yes	No
RCBRP	Helicopter Fuel Cache	Point/Polygon	Motorized	Low	No	No
RCBRP	Helicopter Landing	Point/Polygon	Motorized	High	No	No
RCBRP	Hut/Shelter	Point/Polygon	Non-motorized	Low	Yes	Yes
RCBRP	Lodge	Point/Polygon	Non-motorized	High	Yes	Yes
RCBRP	Outfitter Camp	Point/Polygon	Non-motorized	High	Yes	Yes
RCBRP	Trail Head	Point/Polygon	Non-motorized	Low	No	No
RCBRP	Weather/Comm. Station	Point/Polygon	Non-motorized	Low	No	No
RCBRA	Access Roads	Linear	Motorized	Low	No	No
RCBRA	Trails – Riding	Linear	Non-motorized	Low	No	No
RCBRA	Trails - Snowmobile/ATV	Linear	Motorized	Low	No	No
TRAILS	Trails – hiking/biking	Linear	Non-motorized	Low	No	No
MISC	Transmission Corridor	Linear	Motorized	Low	No	No
MISC	Gas Line	Linear	Non-motorized	Low	No	No

1. With the exception of BTM, all human use data files were provided by ENKON Environmental.

Data/Analysis Assumptions

Under the direction of ENKON Environmental and the provincial large carnivore specialist, I applied 2 different sets of assumptions, corresponding to minimum and maximum impact scenarios:

Assumptions Common to both Scenarios:

1. The human-use data and attributes described above are representative of human activity within the analysis area.
2. The Toby/Jumbo access road to the JGR will be of "high" use-intensity during summer months upon full build-out of the development.
3. Other than the main JGR access road, no increased motorized or non-motorized human use of roads will occur anywhere within the analysis area as a result of the JGR development.
4. Summer recreational use within the analysis area is constrained to road and trail features.

Minimum Impact Scenario:

5. Human activity resulting from the development will not emanate beyond the CRA and the access road leading directly to it (O. Oberti, Pheidias Project Management, pers. comm.).
6. Hiking parties originating from the JGR will be constrained to the CRA.
7. There will be no "spin-off" development or increased recreational demand in the analysis area resulting from the Jumbo Glacier Resort (G. Stewart, ENKON Environmental, pers. comm.). This includes guided hiking, trail riding, and other non-motorized or motorized recreational activities.
8. High-intensity human activity within the CRA will be restricted to the infrastructural features (e.g., roads, trails, buildings) represented by the data provided.
9. Summer helicopter access to the CRA will be rare and for emergency only, and will not influence grizzly bears.
10. There will be no increase in helicopter-assisted summer recreation in the analysis area due to the JGR development.

Maximum Impact Scenario:

5. No new hiking trails will be constructed outside of the CRA, and decommissioned roads will receive only low-intensity non-motorized use.
6. All trail systems that are directly accessible from the paved JGR access road will increase from low to high intensity non-motorized use to the point beyond which overnight stay outside of an existing public or commercial shelter would be expected.

This includes: (1) all mapped trails within the Jumbo drainage[3], (2) trails within the north and south forks of the upper Glacier Creek drainage, and (3) the main fork of Toby Creek within the Purcell Wilderness Conservancy[4], and (4) the Coppercrown and Delphine subdrainages of Toby Creek. The Farnham subdrainage and the trail to Lake of the Hanging Glacier within the Horsethief drainage will not be easily accessed from the CRA (O. Oberti, Pheidias Project Management, pers. comm.) and will remain at low intensity use.

7. There will be no increased use of non-mapped guide-outfitter trails (e.g., trail riding).
8. The effect of any "spin-off" development within the analysis area will be only to shift the intensity of non-motorized use of the above-listed hiking trails from low to high.
9. Grizzly bears will be influenced within a 5 km zone surrounding the specific localized resort area as defined by "residential" features associated with the JGR development. However, this influence will be blocked by major ridgelines (i.e., the zone extends for 5 km or until a ridgeline is hit). Within this zone, the effect of human influence will equate to that of high intensity non-motorized use with no attractants or firearms. This assumption is supported by Mattson et al. (1998).
10. A helicopter landing site will be situated and used within the CRA (as indicated on map P2.1), but will not service helicopter-assisted summer recreation (e.g., hiking) within the analysis area.
11. There will be no increase in helicopter-assisted summer recreation in the analysis area due to the JGR development.

Zones of Influence (ZI)

Zones of influence (ZI) identify the distance at which grizzly bears are expected to be affected by a particular activity class. They are expressed as "buffer zones" around mapped human activity features. A ZI is not generated for "dispersed" activities, as the entire area of the dispersed activity polygon is considered the ZI.

Based on the assumption that bears are sensitive to disturbance from multiple activities, effects from overlapping ZI are considered multiplicative.

As per previous applications of the grizzly bear CEA model in the Canadian Rocky Mountains (Gibeau 1998, Miistakis Institute for the Rockies 2002), I applied an 800-m ZI to features deemed to facilitate motorized activity and a 400 m ZI to those that facilitate only non-motorized human activity.

[3] Average monthly (April – November) use of the Jumbo Pass cabin, 1994 – 1998, was 35 people (statistics provided by the Columbia Valley Hut Society).
[4] Current annual use estimates (A. Green, WLAP, pers. comm.): 400-600 people hike 5 km into the park to Earl Grey cabin; 50-80 people traverse the park on the Earl Grey trail, and approximately 50 -60 people access the park with commercial operators in the Toby drainage.

Disturbance Coefficients (DC)

I assigned disturbance coefficients (DC) to activity groups indicating the degree to which habitat within ZI remains effectively usable by bears. A greater degree of disturbance is expected when security cover is not available, and so different DCs were applied in habitats with security cover vs. noncover. I defined security cover as forest stands with >30% canopy cover and >3 m height, as would be expected to hide 90% of a bear from sight at a distance of 60-m (Apps 1997).

DCs from 0.0 to 1.0 are based on how grizzly bears are expected to respond to a given activity within a 24 hr period. I adopted ZI and DC values from the most recent CEA application in the Canadian Rocky Mountains (Gibeau 1998, Miistakis Institute for the Rockies 2002; Table 2). A DC of 0.0 implies total displacement, while a DC of 1.0 indicates no disturbance. A DC of 0.5 indicates that the area's ability to support grizzly bears is 50% of potential. The DC may describe the proportion of bears totally displaced from the ZI, the change in activity patterns as a result of an activity, or a combination of the two (USDA Forest Service 1990). Displacement within overlapping ZI is cumulative, and I used the product of displacement caused by multiple activities in this situation. Polygons of dispersed human use (e.g., the CRA) are not buffered.

Activity Duration (AD)

The activity duration (AD) coefficient reflects how long an activity occurs in the assessment period, and it is applied in determining both habitat effectiveness and mortality risk. AD is simply the proportion (0-1) of an activity's duration relative to the assessment period (i.e., grizzly bear active season). For all human activities considered in this analysis, AD was assumed to be 1.

Habitat Effectiveness (HE)

Habitat effectiveness (HE) is one of the two outputs of the CEA model. It combines the habitat value for an area with the cumulative disturbance to estimate the ability of a given area to support grizzly bears. HE takes the habitat value (HV) and adjusts it by the bear's ability to use the habitat after accounting for human influence as measured by disturbance coefficients (DC). Habitat effectiveness is typically expressed per unit of area. The zone of influence (ZI) was used to determine where disturbance coefficients were applied. For a given analysis unit:

$$HE = \frac{\sum_p \{HV \times (DC_c \times AD)\}}{n_p},$$

where p is the pixel, HV is habitat value, DC_c is the cumulative disturbance coefficient, and AD is the activity duration coefficient.

Table 2. Disturbance coefficients (DC) and zones of influence (ZI) used in cumulative effects model application for grizzly bears in the central Purcell Mountains, British Columbia. Parameters are adopted from Gibeau (1998) and Miistakis Institute for the Rockies (2002).

Activity Type	Zone of Influence (m)	Use Intensity	Security Class	Disturbance Coefficient
Linear Motorized	800	High	Cover	0.37
			Non-cover	0.16
		Low	Cover	0.73
			Non-cover	0.64
Point Motorized	800	High	Cover	0.37
			Non-cover	0.16
		Low	Cover	0.73
			Non-cover	0.64
Dispersed Motorized	N/A	High	Cover	0.37
			Non-cover	0.16
		Low	Cover	0.73
			Non-cover	0.64
Linear Non-motorized	400	High	Cover	0.65
			Non-cover	0.56
		Low	Cover	0.88
			Non-cover	0.83
Point Non-motorized	400	High	Cover	0.50
			Non-cover	0.33
		Low	Cover	0.88
			Non-cover	0.83
Dispersed Non-motorized	N/A	High	Cover	0.50
			Non-cover	0.33
		Low	Cover	0.88
			Non-cover	0.83

Mortality Submodel

The mortality submodel quantifies the risk of mortality associated with human activities within grizzly bear habitat. This submodel is tied to both the habitat and displacement submodels. Habitat quality is assumed to determine a bear's vulnerability, and the type of human activity determines the risk to individual bears in the ecosystem. The mortality risk index is a relative numeric evaluation of grizzly bear mortality risk for a given analysis area. The general assumptions are that:

1. The risk of bear mortality associated with human activities is cumulative and can be expressed as an index to mortality risk.
2. The risk of bear mortality associated with multiple human activities accumulates in an additive manner.
3. The risk of bear mortality associated with each activity classification type remains constant.
4. The risk of a bear mortality increases with increased human activity or association.
5. The availability of food attractants associated with human activities increases the risk of bear mortality.
6. The presence of firearms associated with human activities increases the risk of bear mortality.
7. Increased mortality risk attributed to bear habituation is reflected in mortality coefficients.

The variables used to determine mortality risk coefficients for this analysis are:

1. Nature of activity: point, linear, or dispersed
2. Intensity of activity
3. Presence of firearms
4. Presence of attractants

I categorized the human-use data I had available for this analysis as to whether they were potentially associated with grizzly bear attractants and/or firearms (Table 1). Application of the mortality risk submodel was governed by the same data/analysis assumptions outlined above for the displacement submodel.

Mortality Risk Coefficients (MR)

Mortality risk coefficients (MR) assigned to each category of human activity depicts their relative risk of causing grizzly bear mortality (Table 3).

Table 3. Mortality risk coefficients (MR) used in CEA model application for grizzly bears in the central Purcell Mountains, British Columbia (adopted from USDA Forest Service 1990).

Feature Type	Use Intensity	Attractant?	Firearm?	Mortality Risk Coefficient
Point/Polygon	High	Yes	Yes	1.00
			No	0.50
		No	Yes	0.30
			No	0.10
	Low	Yes	Yes	0.80
			No	0.00
		No	Yes	0.20
			No	0.00
Linear - Road	High		Yes	0.50
			No	0.10
	Low		Yes	0.30
			No	0.00
Linear - Trail	High		Yes	0.50
			No	0.10
	Low		Yes	0.30
			No	0.00
Dispersed	High		Yes	0.50
			No	0.10
	Low		Yes	0.30
			No	0.00

For a given analysis unit:

$$MR = \frac{\sum_p \{HV + MC_c\}}{n_p},$$

where p is the pixel, HV is habitat value, and MC_c is the cumulative disturbance coefficient.

Analysis Scenarios

I initially applied the grizzly bear CEA model under 4 scenarios. First, I considered current habitat effectiveness under the assumption of no existing human influence. This equates to the maximum habitat effectiveness that could be achieved given existing vegetation conditions and was used as a benchmark for determining habitat effectiveness reductions under current and future projections of human use. I then considered current habitat effectiveness and mortality risk given existing human influence but without the JGR development. Next, I modeled both habitat effectiveness and mortality risk given existing human influence and with the JGR development at full build-out, and this was conducted separately for scenarios of both minimum and maximum impact assumptions as described (p 17). For each watershed and for the greater analysis area, I then summarized both the minimum and maximum impacts of the JGR development that can be expected in terms of reduced habitat effectiveness and increased mortality risk for grizzly bears. Finally, under the direction of ENKON Environmental and the provincial large carnivore specialist, I modeled the effect of mitigation actions consisting of motorized access closures within the greater analysis area. This involved changing road networks within individual subdrainages into low intensity non-motorized trails and calculating the net re-gain of habitat effectiveness and reduction of mortality risk over the greater analysis area.

RESULTS

Habitat Effectiveness

In considering cumulative human influence associated with both existing activity and that of the proposed JGR development, grizzly bear habitat effectiveness varied among watersheds within the greater CEA analysis area. CEA model output suggests that the JGR development will result in a reduction of habitat effectiveness within 4 drainages (range shown indicates minimum and maximum impact scenarios): Jumbo (29.5 – 43.1%), Toby (3.0 – 6.9%), Glacier (0 – 5.2%), and Horsethief (1.7%). Over the greater 3,977 km^2 CEA analysis area, the JGR development is projected to decrease grizzly bear habitat effectiveness 1.7 – 3.1% resulting in an overall value of 74.9 – 73.5% (Table 4, Figures 4, 5 & 6).

Table 4. Grizzly bear habitat effectiveness by watershed in the central Purcell Mountains given (1) existing human influence, and (2) existing human influence with the JGR development (range is between minimum and maximum impact scenarios). Drainages where impacts of the JGR development are apparent are denoted by an asterisk.

		Habitat Effectiveness		
Landscape	**Area (km^2)**	**Existing Disturbance**	**Existing & JGR Disturbance[a]**	**Difference[a]**
Howser	408	0.862	0.862	0.000
Stockdale	116	0.956	0.956	0.000
Horsethief*	490	0.585	0.567 – 0.567	0.017 – 0.017
Wilmer	23	0.272	0.272	0.000
Toby*	533	0.715	0.686 – 0.647	0.030 – 0.069
Windermere	171	0.404	0.404	0.000
Glacier*	276	0.791	0.791 – 0.739	0.000 – 0.052
Duncan	129	0.647	0.647	0.000
Jumbo*	149	0.752	0.457 – 0.321	0.295 – 0.431
Dutch/Brewer	685	0.771	0.771	0.000
Hamill	299	0.963	0.963	0.000
Carney	318	0.963	0.963	0.000
Kootenay	80	0.681	0.681	0.000
Fry	300	0.993	0.993	0.000
ANALYSIS AREA	3,977	0.765	0.749 – 0.735	0.017 – 0.031

[a] ranges shown reflect minimum and maximum JGR development impact assumptions (see pg 17).

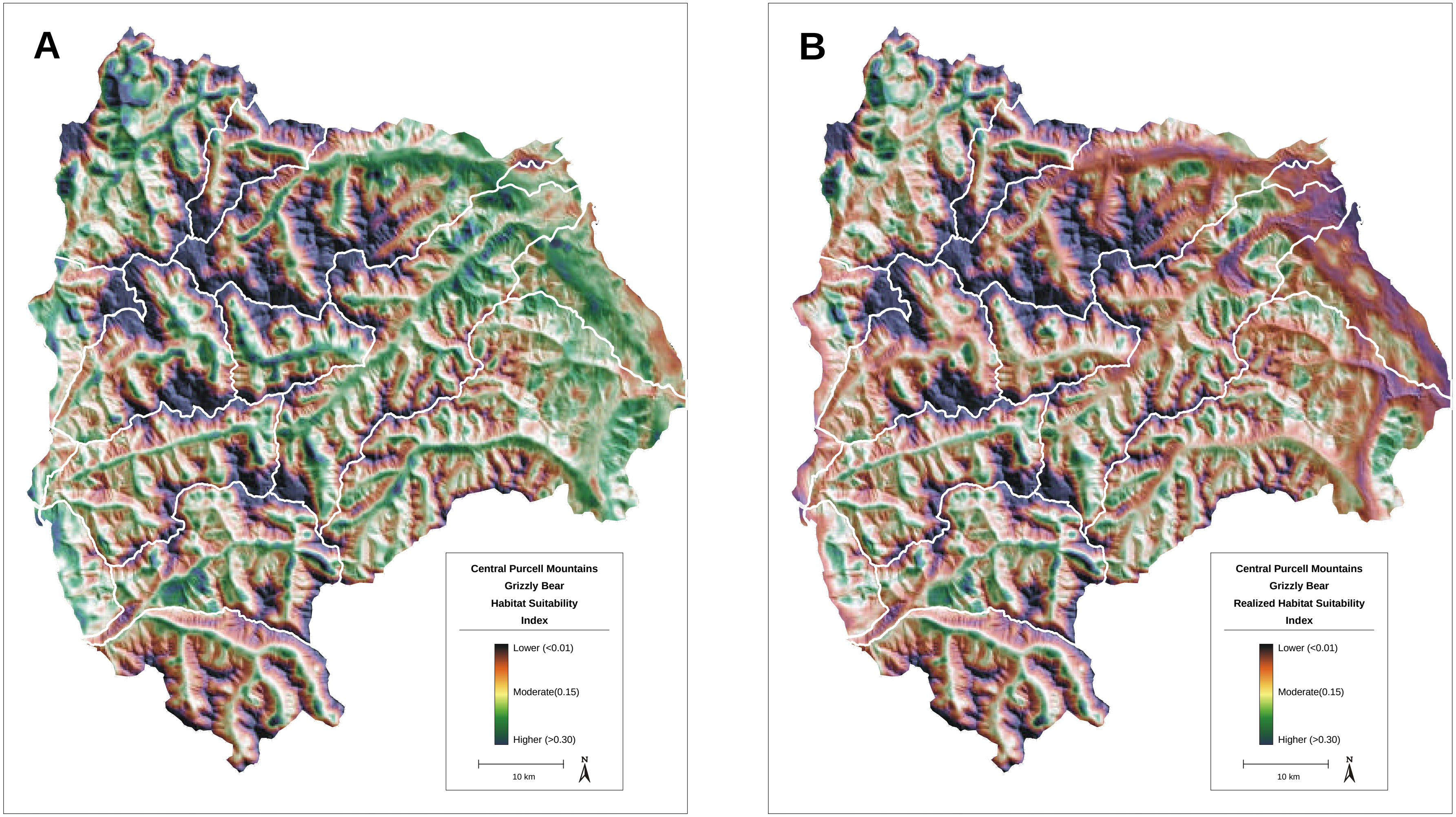

Figure 4. Habitat suitability and realized habitat effectiveness for grizzly bears in the central Purcell Mountains given (A) existing vegetation conditions but no human influence, and (B) the current base-case of human influence. Model outputs are dependent on stated data and assumptions.

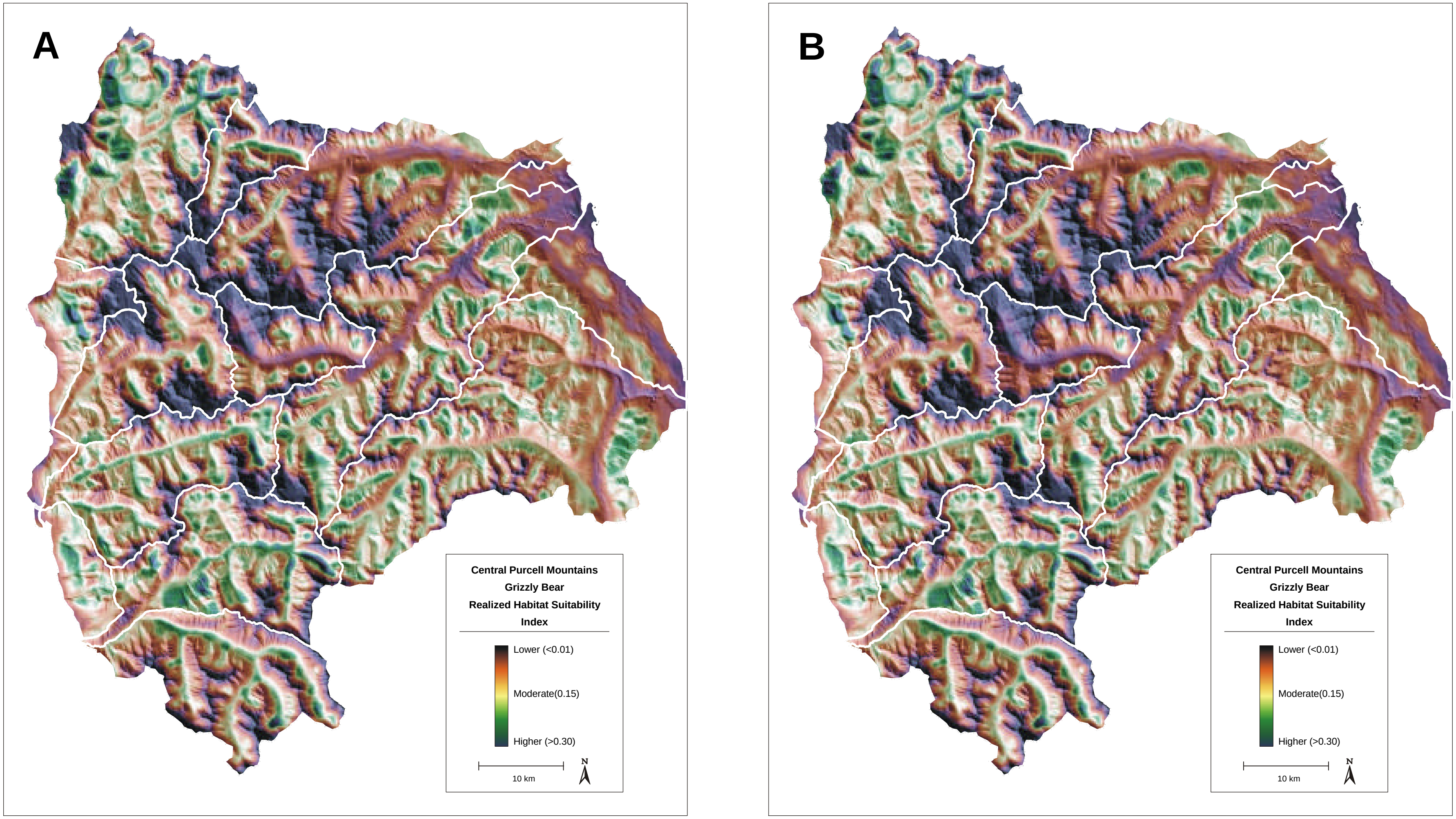

Figure 5. Realized habitat effectiveness for grizzly bears in the central Purcell Mountains given current human influence and with the JGR development at full build-out. Scenarios assume (A) minimum impacts, and (B) maximum impacts within the analysis area (see p 17). Model outputs are dependent on stated data and assumptions.

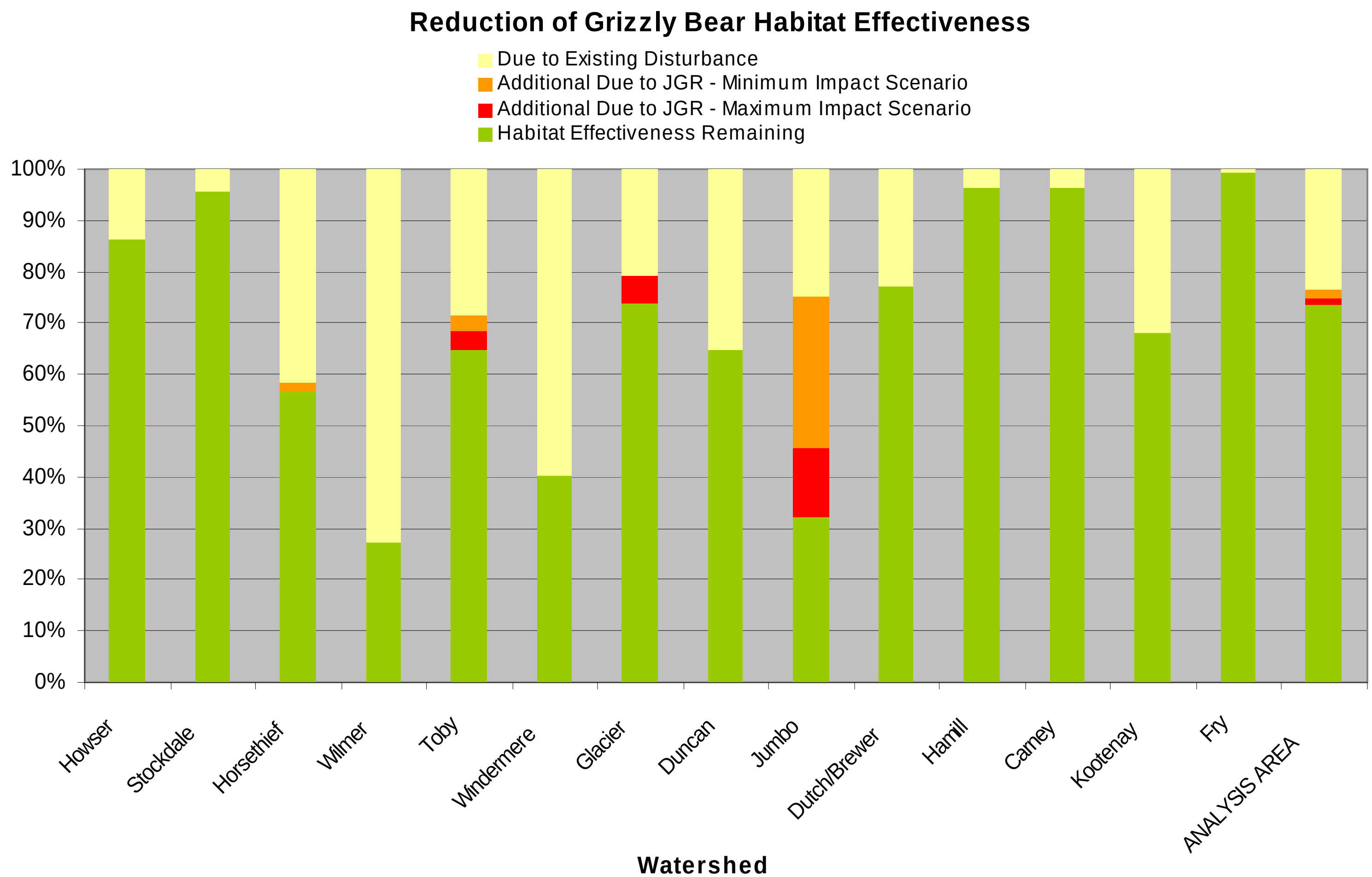

Figure 6. Cumulative reduction in grizzly bear habitat effectiveness in the central Purcell Mountains analysis area by watershed according to existing human disturbance and that resulting from the Jumbo Glacier Resort (JGR) development at full build-out. The potential effect of the JGR development is shown under assumptions of both minimum and maximum impacts (p 17).

Mortality Risk

In considering cumulative human influence associated with both existing activity and that of the JGR development, grizzly bear mortality risk varied among watersheds within the greater CEA analysis area (Table 6, Figures 6 - 9). Relative to existing human influence, CEA model output suggests that the JGR development will increase the grizzly bear mortality risk index within 4 drainages (range shown indicates minimum and maximum impact scenarios): Jumbo (0.184 – 0.250), Toby (0.029 – 0.048), Horsethief (0.015), and Glacier (0.0 – 0.012). Over the greater 3,977 km^2 CEA analysis area, the JGR development is projected to increase the grizzly bear mortality risk index 0.013 – 0.019, or 2.6 – 3.8% over existing levels (Table 5, Figures 7, 8 & 9).

Table 5. Average grizzly bear mortality risk index by watershed in the central Purcell Mountains given (1) existing human influence, and (2) existing human influence with the JGR development (range is between minimum and maximum impact scenarios). Drainages where impacts of the JGR development are apparent are denoted by an asterisk.

		Mortality Risk Index		
Landscape	Area (km^2)	Existing Disturbance	Existing & JGR Disturbance[a]	Increase[a]
Howser	408	0.412	0.412	0.0
Stockdale	116	0.188	0.188	0.0
Horsethief*	490	0.507	0.522 – 0.522	0.015
Wilmer	23	1.289	1.289	0.0
Toby*	533	0.668	0.697 – 0.716	0.029 – 0.048
Windermere	171	1.116	1.116	0.0
Glacier*	276	0.375	0.375 – 0.388	0.0 – 0.012
Duncan	129	0.603	0.603	0.0
Jumbo*	149	0.451	0.635 – 0.701	0.184 – 0.250
Dutch/Brewer	685	0.588	0.588	0.0
Hamill	299	0.302	0.302	0.0
Carney	318	0.314	0.314	0.0
Kootenay	80	0.770	0.770	0.0
Fry	300	0.215	0.215	0.0
ANALYSIS AREA	3,977	0.498	0.511 – 0.517	0.013 – 0.019

[a] ranges shown reflect minimum and maximum JGR development impact assumptions (see p 17).

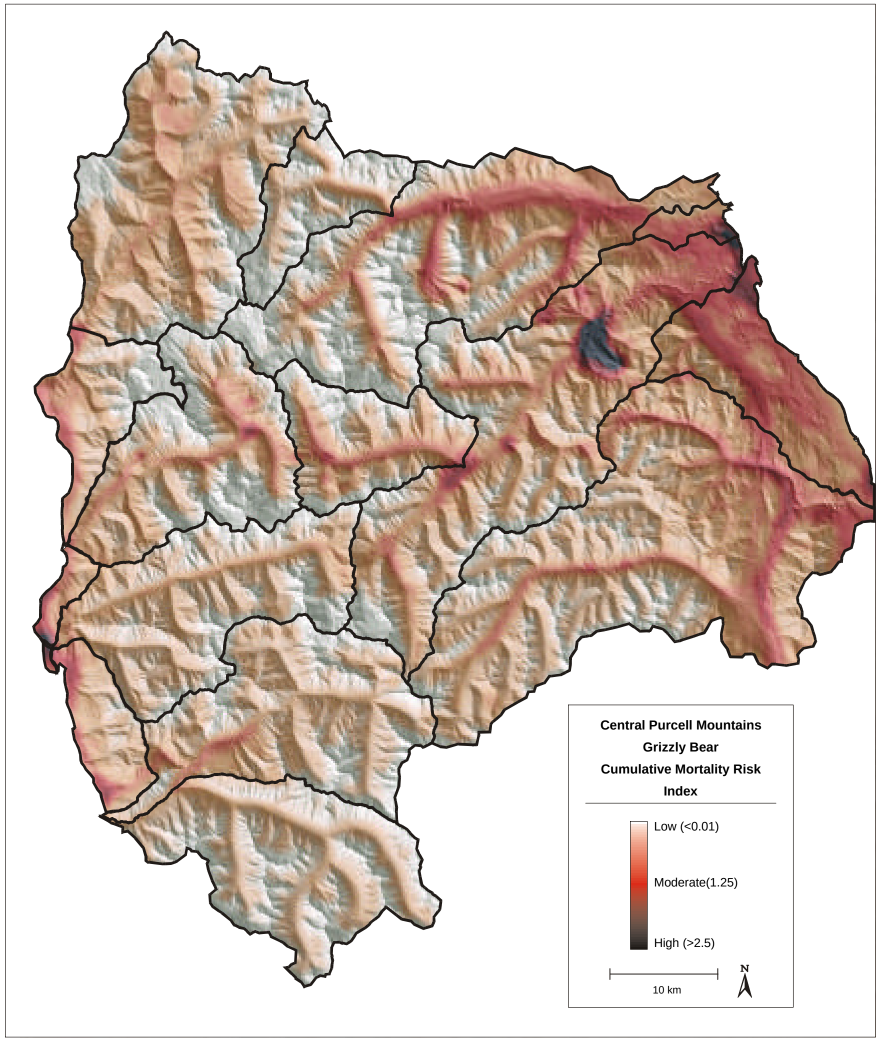

Figure 7. Cumulative morality risk index for grizzly bears in the central Purcell Mountains given the current base-case of human influence. Model outputs are dependent on stated data and assumptions.

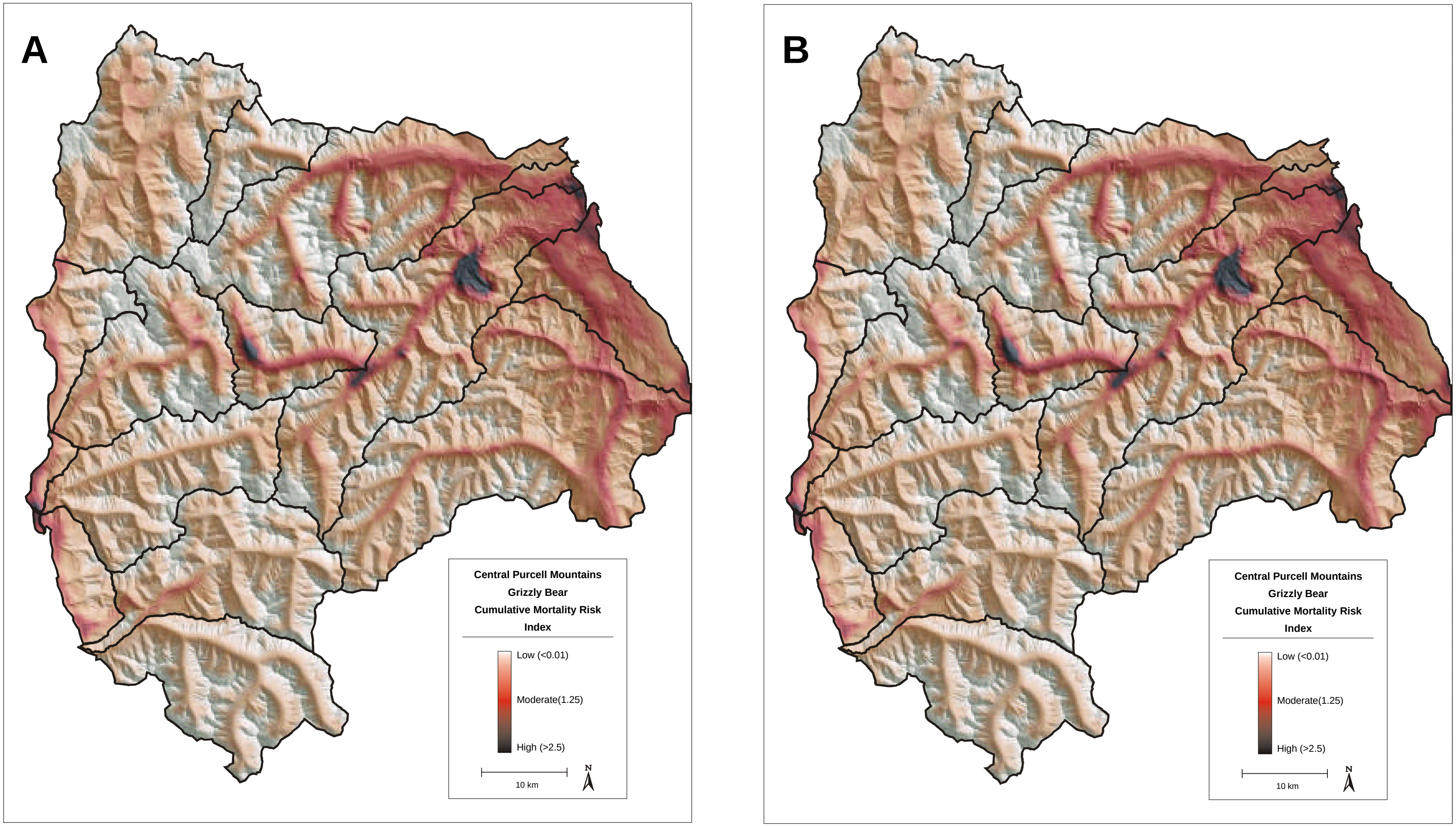

Figure 8. Cumulative morality risk index for grizzly bears in the central Purcell Mountains given current human influence and with the JGR development at full build-out. Scenarios assume (A) minimum impacts, and (B) maximum impacts within the analysis area (see p 17). Model outputs are dependent on stated data and assumptions.

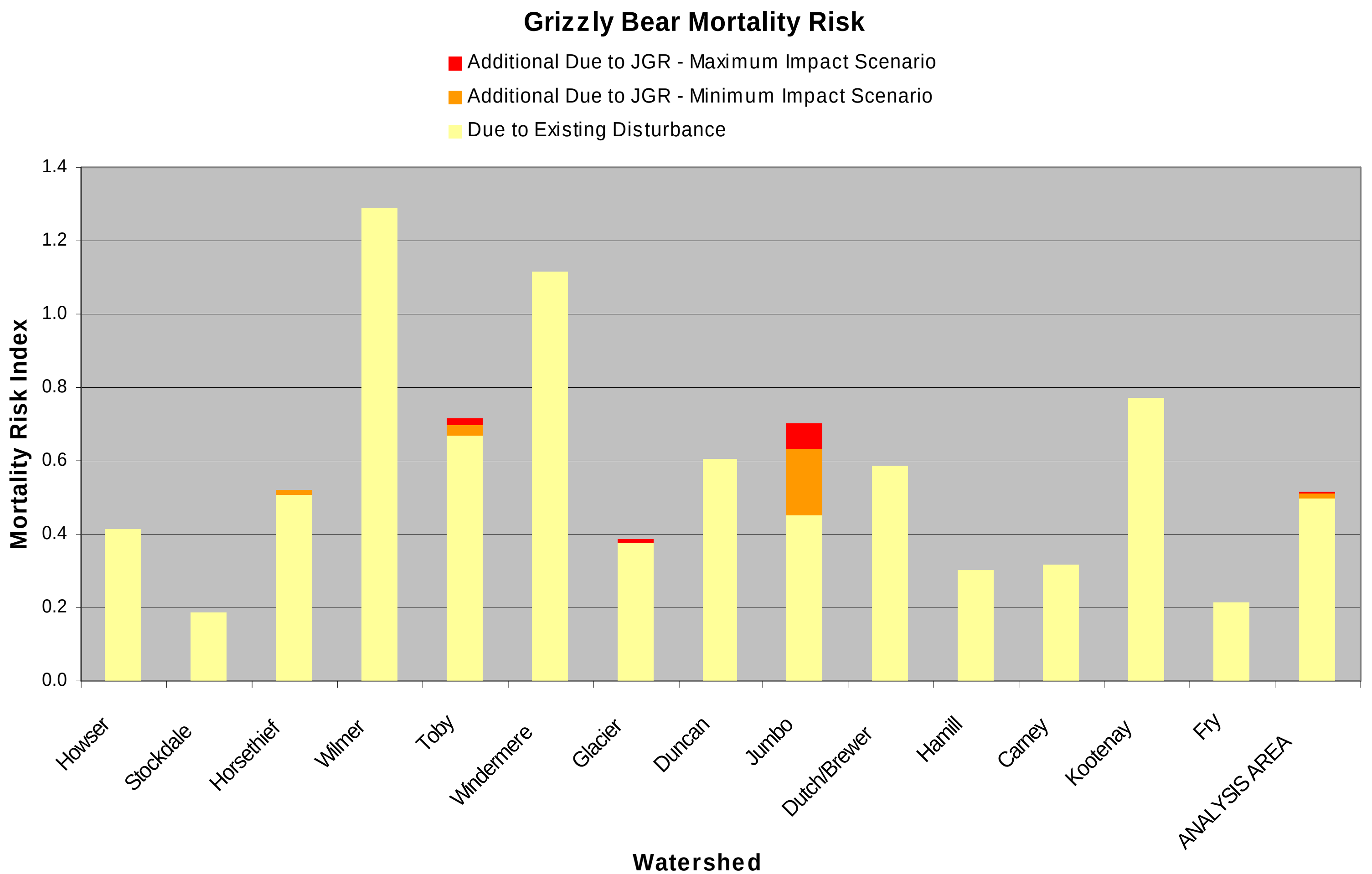

Figure 9. Cumulative increase in grizzly bear mortality risk in the central Purcell Mountains analysis area by watershed according to existing human disturbance and that resulting from the Jumbo Glacier Resort (JGR) development at full build-out. The potential effect of the JGR development is shown under assumptions of both minimum and maximum impacts (p 17).

Mitigation Options

Given the projected reductions in grizzly bear habitat effectiveness and increases in mortality risk, the CEA model would predict a net re-gain of habitat effectiveness and reduction of mortality risk through mitigation involving the localized closure of motorized human access within the greater analysis area (Table 6).

Table 6. Predicted habitat effectiveness re-gained and mortality risk reduced as a result of motorized access closures to mitigate the effects of the JGR development in the central Purcell Mountains. The effect of each scenario is calculated at the scale of the greater CEA analysis area, and should be compared to the 1.7 – 3.1% reduction in habitat effectiveness and 0.013 – 0.019 (2.6 – 3.8%) increase in the mortality risk index resulting from the JGR development.

Motorized Access Closure Mitigation Scenario[a]	Habitat Effectiveness Re-gained (%)	Mortality Risk Index Reduced
Jumbo Drainage		
All pre-existing roads within Jumbo except main access road	0.17%	0.0046
Glacier Drainage		
North fork of Glacier Creek (leading to Starbird Pass)	0.11%	0.0012
South fork of upper Glacier (leading to Jumbo Pass)	0.05%	0.0010
All roads downstream of Jumbo/Starbird junction	0.31%	0.0039
Howser Drainage		
Rory Creek sub-drainage	0.40%	0.0026
Tea Creek sub-drainage	0.19%	0.0018
Upper Howser (past Rory Creek junction)	0.21%	0.0017
Lower Howser (below Rory Creek junction)	0.37%	0.0033
Toby Drainage		
Upper Toby beyond Jumbo Creek	0.14%	0.0017
Delphine sub-drainage	0.11%	0.0018
Springs sub-drainage	0.09%	0.0013
Horsethief Drainage		
Farnham Creek sub-drainage	0.08%	0.0014
McDonald Creek sub-drainage	0.39%	0.0036
Bruce and Law creeks sub-drainage	0.39%	0.0050
Brewer/Dutch Drainage		
Upper Brewer (upstream of Thorald Creek) & roads both west of lower Dutch and south of Brewer Creek	0.60%	0.0081
All Closures	3.63%	0.0431

[a] Some options may be irrelevant if motorized access is already restricted.

DISCUSSION

The cartographic model-based grizzly bear CEA described in this report allows predicted changes in habitat effectiveness and mortality risk to be compared among landscapes and/or development and mitigation scenarios. In summary, over the greater 3,977 km^2 CEA analysis area, the JGR development is projected to decrease grizzly bear habitat effectiveness by 1.7 – 3.1% resulting in an overall value of 74.9 – 73.5%, while the mortality risk index is projected to increase by 2.6 – 3.8% over existing levels. The significance of existing or projected reductions in habitat effectiveness and increases in mortality risk cannot be evaluated within the greater analysis area or individual watersheds without existing management thresholds for cumulative human impacts. However, previous grizzly bear CEA modeling applications in the Canadian Rocky Mountains have treated reductions in habitat effectiveness values below 70-80% as representing significant impacts on grizzly bears (Herrero and Herrero 1996, Gibeau 1998). In the United States, it has been suggested that bear management units, typically defined according to watershed boundaries, should maintain a minimum of 80% habitat effectiveness (USDA Forest Service 1990). Presumably, there is a threshold of reduced habitat effectiveness and/or increased mortality risk beyond which neither resident nor transient grizzly bears will occur or persist. This threshold is not known, although, it is insightful to consider model outputs for the Windermere and Wilmer landscapes where grizzly bears are expected to have occurred historically but at present are extremely uncommon.

One important component of human use in the analysis area for which I did not have data is helicopter-assisted summer recreation. This may have resulted in an underestimate of both existing and total projected human impacts. However, I was directed to assume that the JGR development would not result in an increase in helicopter-assisted recreation within the analysis area. Hence, the fact that helicopter-assisted recreation was not included in any scenario will have had no bearing on the basis for this evaluation which is the net differences in impacts among scenarios and mitigation options.

The CEA model output of this analysis should be interpreted in light of (1) the underlying assumptions about grizzly bear behavioural and survival response to habitat and human influence, (2) the existing and projected human-use assumptions applied in this analysis, and (3) the availability and quality of human use and habitat suitability data inputs. Given stated data and assumptions, outputs suggest that impacts of the JGR development (1) cannot be mitigated within the Jumbo drainage itself, but (2) can be mitigated by restricting human access elsewhere in the greater analysis area. Through partial or total motorized access closures throughout the analysis area, a “no net impact” standard can theoretically be attained. However, this conclusion relies on the assumption that all road networks represented by the available data are currently accessible to and used by motorized vehicles throughout the grizzly bear active season. If there are already legal or *de facto* motorized access restrictions, my analysis will have overestimated habitat effectiveness re-gained and mortality risk reduced through mitigation. This conclusion also assumes that decommissioned road networks will receive only "low intensity" non-motorized recreational use and that recreational use of existing trails will also not increase as a result of area closures to motorized vehicles.

Although motorized access closure is the only mitigation option I was able to consider in my quantitative evaluation (as reflected in my terms of reference), there may be other mitigation opportunities. These may include habitat enhancement and hunting restrictions. Because forage value to grizzly bears can be improved after fire disturbance (Hamer and Herrero 1987, McLellan and Hovey 2001), carefully planned prescribed burning could enhance local habitat quality. I cannot comment on the feasibility of prescribed burning for mitigation within the greater analysis area, given that it would need to be considered in the context of other resource management objectives and existing seral-stage distributions within specific landscapes. If prescribed burning can be applied for mitigation, careful consideration should be given to specific habitats and burning options that are most likely to result in benefits to the abundance, distribution, and nutritional quality of grizzly bear plant foods. The location of such enhancements would need to be considered together with human access management to ensure that habitat benefits are maximized and that increased mortality risk does not result. In addition to the motorized access restrictions that I have evaluated, increased mortality risk attributed to the JGR development could be further mitigated through hunting restrictions. Such actions could include any or a combination of (1) additional closures to motorized access specifically for the purpose of hunting, (2) closure of specific areas to grizzly bear hunting, (3) further restriction to local harvest quotas, and (4) local restrictions to all big-game hunting given that a significant proportion of grizzly bear deaths result from hunter self-defense (McLellan et al. 1999). With respect to item 3, there is currently a system in place to compensate for reported and estimated unreported grizzly bear mortality in harvest allocation (M. Austin, MWLAP, pers. comm.).

The JGR proponent has stated a commitment to ensuring that "no net impact" of the development to the local grizzly bear population is achieved, and a bear management plan has been developed outlining actions for which the proponent will be directly responsible (ENKON Environmental Ltd 2000). These include measures for managing any recreational use that occurs outside of the Jumbo Creek Valley but which originates directly from the resort, and the reduction of bear-human conflict potential in the Jumbo and surrounding drainages through public education and infrastructure. Management and mitigation actions outlined in this plan are intended to be adaptive to feedback from a local grizzly bear monitoring program.

LITERATURE CITED

Apps, C. 1993. Cumulative effects assessment for large carnivores: a literature review and development strategy for the Canadian Rockies. Canadian Parks Service, Western Region, Calgary, Alberta.

Apps, C. D. 1997. Identification of grizzly bear linkage zones along the Highway 3 corridor of southeast British Columbia and southwest Alberta. Prepared for BC Ministry of Environment, Lands and Parks, and World Wildlife Fund Canada. Aspen Wildlife Research, Calgary, Alberta.

Apps, C. D. 2002. Grizzly bear habitat suitability modeling in the central Purcell Mountains, British Columbia. Prepared for Ministry of Water, Land and Air Protection, Victoria. Aspen Wildlife Research, Calgary, Alberta.

Clark Labs for Cartographic Technology and Geographic Analysis. 2003. Idrisi 14.01 GIS & image processing. Clark University, Worcester, Massachusetts.

ENKON Environmental Limited. 2000. Grizzly bear management plan Jumbo Glacier Alpine Resort development. Prepared for Glacier Resorts Ltd. by ENKON Environmental Ltd., Surrey, British Columbia.

Geographic Data BC. 2001. Baseline thematic mapping; present land use mapping at 1:250,000. British Columbia specifications and guidelines for geomatics, content series volume 6, part 1, release 2.1. Ministry of Sustainable Resource Management, Victoria, BC.

Gibeau, M. L. 1998. Grizzly bear habitat effectiveness model for Banff, Kootenay, and Yoho National Parks, Canada. Ursus 10:235–241.

Hamer, D., and S. Herrero. 1987. Wildfire's influence on grizzly bear feeding ecology in Banff National Park, Alberta. International Conference on Bear Research and Management 7:179–186.

Herrero, S., and J. Herrero. 1996. Cheviot Mine project: specific and cumulative environmental effects analysis for mammalian carnivores. Prepared for Cardinal River Coals, Hinton, AB.

ITMB Publishing Ltd. 1992. Invermere and Columbia Valley - 349, 1:100,000, 1st edition. ITMB Publishing Ltd, World Wide Books and Maps, Vancouver, British Columbia.

Mace, R. D., J. S. Waller, T. L. Manley, L. J. Lyon, and H. Zuuring. 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395-1404.

Mace, R. D., J. S. Waller, T. L. Manley, K. Ake, and W. T. Wittinger. 1999. Landscape evaluation of grizzly bear habitat in western Montana. Conservation Biology 13:367-377.

Mattson, D. J., and R. R. Knight. 1991. Application of cumulative effects analysis to the Yellowstone grizzly bear population. USDI National Parks Service Interagency Grizzly Bear Study Team Report 1991C.

Mattson, D. J., R. R. Knight, and B. M. Blanchard. 1986. Derivation of habitat component values for the Yellowstone grizzly bear. Pages 222-229 *in* G. P. Conteras and K. E. Evans, Compilers. Proceedings - Grizzly Bear Habitat Symposium. USDA Forest Service Intermountain Research Station, Ogden, Utah.

Mattson, D. J., R. R. Knight, and B. M. Blanchard. 1988. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference on Bear Research and Management 7:259-273.

McElhanney Consulting Services. 2002. Route study report for Jumbo Glacier Alpine Resort access roads. McElhanney Consulting Services Ltd., Surrey, British Columbia.

McLellan, B. N., and F. W. Hovey. 2001a. Habitats selected by grizzly bears in multiple use landscapes. Journal of Wildlife Management 65:92–99.

McLellan, B. N., F. W. Hovey, R. D. Mace, J. G. Woods, D. W. Carney, M. L. Gibeau, W. L. Wakkinen, and W. F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management 63:911–920.

Miistakis Institute for the Rockies. 2002. Transboundary cumulative effects analysis for the grizzly bear. Miistakis Institute for the Rockies, Calgary, Alberta.

Ministry of Forests. 1995. Inveremere Forest District recreational map, 1:250,000. Province of British Columbia, Victoria, British Columbia.

Surveys and Resource Mapping Branch. 1992. Digital baseline mapping at 1:20,000. British Columbia specifications and guidelines for geomatics, content series volume 3, release 2.0. British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Surveys and Resource Mapping Branch. 1995. Baseline thematic mapping present land use mapping at 1:250,000. British Columbia specifications and guidelines for geomatics, content series volume 6, part 1, release 1.0. British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

USDA Forest Service. 1990. CEM - a model for assessing effects on grizzly bears. USDA Forest Service, Missoula, Montana.

Weaver, J., R. Escano, and D. S. Winn. 1986. A framework for assessing cumulative effects on grizzly bears. Transactions of the North American Wildlife and Natural Resource Conference 52:364-375.

Winn, D. S., and K. R. Barber. 1986. Cartographic modeling: a methods of cumulative effects appraisal. Pages 247-252 *in* G. P. Conteras and K. E. Evans. Proceedings - Grizzly Bear Habitat Symposium. USDA Forest Service Intermountain Research Station, Ogden, Utah.

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Oberti, Oberto. Pheidias Project Management Corporation, Vancouver, British Columbia. (1) Letter to G. Stewart, ENKON Environmental, dated October 31, 2003. (2) Letter to M. Glassman, BC Environmental Assessment Office, dated November 6, 2003.

Parkinson, Rob. McElhanney Consulting Services Ltd., Surrey, British Columbia.

Pinto, Jose. McElhanney Consulting Services Ltd., Surrey, British Columbia.

Stewart, Glenn. ENKON Environmental Ltd., Surrey, British Columbia.