CARCROSS WOODLAND CARIBOU HERD WINTER RANGE CUMULATIVE EFFECTS ASSESSMENT

FINAL REPORT, VER. 1.0
April 23, 2004

Prepared for:

YTG DEPARTMENT OF COMMUNITY SERVICES
COMMUNITY DEVELOPMENT BRANCH

and

YTG DEPARTMENT OF ENVIRONMENT
FISH AND WILDLIFE BRANCH

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"Excellence in Natural Resource Management"

April 23, 2004

Attn: Brian Ritchie
George Stetkiewicz
Rob Florkiewicz

Re: Carcross Woodland Caribou Herd Winter Range Cumulative Effects Assessment – Final Report

Please find attached our final report of the Carcross Woodland Caribou Herd Winter Range Cumulative Effects Assessment Project. Many thanks for all your help with this project, particularly in the co-ordination of meetings of the technical committee, the provision of our many data sources and your comments and direction on the report.

The spatial database files listed below document and characterize the current footprint of human features within the Carcross Woodland Caribou Herd Winter Range. The accompanying report details the methodology employed and the findings of our summary GIS analyses. The results are discussed within the context of the overarching initiative of a thresholds approach to the assessment of cumulative effects in Yukon.

This final report presents an updated version to the draft report provided in October 2003 and incorporates the revisions discussed subsequent to and during the meeting of the technical committee on November 18, 2003. Specifically, revisions include clarification of the assumptions relating to study area selection and the capture of fuel wood harvesting within the project area and also includes an elaboration of how data collected as part of caribou collaring and monitoring efforts will be integrated into the habitat effectiveness approach to the assessment of cumulative effects on the Carcross winter range. No revisions have been made to the spatial database files that accompany this report.

A CD containing the following files and associated metadata will be dropped off at your offices accompanied by three hard copies of the final report:

ESRI Shapefiles (AEM 2003)

1) ***direct_hf_project_oct2003*** displays the direct footprint of all human features within the project area.

2) ***direct_hf_study_oct2003*** displays the direct footprint of all human features within the study area.

3) ***lowzoi_hf_study_oct2003*** displays the indirect footprint of all human features within the study area under the scenario of the low level of human influence i.e., extent of footprint determined using lower ZOI values.

4) ***midzoi_hf_study_oct2003*** displays the indirect footprint of all human features within the study area under the scenario of the moderate level of human influence i.e., extent of footprint determined using middle ZOI values.

5) ***uppzoi_hf_study_oct2003*** displays the indirect footprint of all human features within the study area under the scenario of the high level of human influence i.e., extent of footprint determined using upper ZOI values.

ESRI Shapefiles (YTG 2003)

6) ***carcross_outline_update2003*** displays the boundary of the Carcross Woodland Caribou Herd Winter Range (updated by Rob Florkiewicz in April 2003)

Word Documents

7) ***aem_ytg_metadata_Apr2003.doc*** documents the attributes of each of the shapefiles created by AEM (2003).

8) ***aem_ytg_final_report_ver1.0_april2004.doc*** presents the final report of the Carcross Woodland Caribou Herd Winter Range Cumulative Effects Assessment Project.

If you have any comments or questions regarding this report or accompanying data, please feel free to contact me at 633 6474 (ex 32) or through my personal email (mgallagher@gartnerlee.com). Sincere thanks for having Applied Ecosystem Management Ltd. involved in this very important initiative. We look forward to our continued involvement in this work, as Gartner Lee Ltd., and in seeing a thresholds approach to cumulative effects evolve and ultimately become established in Yukon.

Many thanks.

Sincerely, on behalf of the project team,

Marie Gallagher, M.Sc., R.P.Bio.
Sr. Biologist.

Project Team:

Marie Gallagher M.Sc., R.P.Bio., Senior Biologist / Project Manager
Robert Anderson M.Sc., R.P.Bio., P. Biol., Senior Biologist / Woodland Caribou Specialist
Crystal Lambert Adv. GIS Dipl, GIS Analyst / Applications Specialist

EXECUTIVE SUMMARY

The Carcross Woodland Caribou Herd Winter Range occurs within the most densely human populated area of Yukon; approximately 80% of the Yukon's population lives within the Southern Lakes region. While the level of industrial activity occurring within the Southern Lakes region is currently low, the incremental expansion of residential and country residential lot development, associated transportation infrastructure and recreational pressures within the Carcross caribou herd winter range has become a concern. In a situation like the Southern Lakes, where a caribou winter range directly overlaps with a large concentration of human development and activity, it is probable that the cumulative nature of all disturbances interact to negatively impact the herd at the population level. In this situation, the concept of a "development or activity threshold" beyond which additional development or activity leads to unacceptable impacts is therefore relevant. Managing the rate and pattern of development within the Southern Lakes region will therefore be an effective strategy for maintaining the Carcross caribou herd at sustainable levels. Understanding the current level and pattern of the human footprint within this area is therefore an important research requirement and is the focus of this project and report. The objective of this assessment is to document and characterize the current anthropogenic footprint within the winter range of the Carcross Woodland Caribou Herd. It is important to note that the results of this study do not extend to the determination of thresholds to human development and activities within the Carcross caribou herd winter range, but rather form the basis for the determination or application of thresholds in the future.

The general methodology employed in this project involves: 1) the development of a comprehensive map of all human features within the project area using Geographic Information Systems (GIS), 2) the establishment of zones of influence (ZOI) around each human feature based on existing data and expert / local knowledge, and 3) the calculation of the total amount of direct (i.e., physical extent of the development or activity) and indirect (i.e., extent of the influence of the development or activity) human footprint within the Carcross caribou herd winter range, i.e., the study area. Indirect footprint calculations were conducted under three scenarios of human influence: low, moderate and high determined by the extent of the zones of influence around each human feature. These steps required input and direction from a multi-stakeholder technical advisory committee and were based on the best available data sources from Yukon and neighboring jurisdictions. The methods developed within this project may also serve as a template to assess the diversity of cumulative human impacts that can occur on woodland caribou

throughout Yukon, i.e., from urban, transportation, agricultural and recreational, as well as industrial, development and activities. Spatial database files (shapefiles) created as part of this project can be used to visually display and query the direct and indirect footprint of human features within the study area and also form the basis of calculations of direct and indirect human footprint expressed as a proportion of the Carcross caribou herd winter range study area.

Much of the concentrated human development within the Carcross woodland caribou herd winter range occurs in association with the primary roads that connect the communities inside and outside the study area. These corridors often occur along valley bottoms and lake shores. There is also a significant amount of diffuse human development and use within the study area. Most obvious are the winter recreational areas found in alpine areas or on lakes. However, less obvious are the rough roads and recreational trails that occur throughout the study area. Between 16.7% and 21.3% of the Carcross woodland caribou herd winter range is influenced by human development and / or activities. This indirect footprint is derived from 3.3% direct human footprint within the study area. Transportation corridors (especially primary roads and rough roads) are the most significant contribution to the total human footprint in the study area under all three scenarios of human influence. Rural residences also consistently rank within the top three most significant contributors to the human footprint under all three scenarios of human influence. However, when all recreational trails are combined, trails exceed the contribution of both rural and urban residences by at least 0.13% of the study area under all three scenarios of human influence. Under the scenarios of moderate and high human influence, winter recreational areas are included in the estimation of human footprint within the study area and in these cases, the contribution of recreation to the entire footprint exceeds the footprint of all urban development and is second only to the footprint of transportation corridors. Furthermore, recreation can also occur in areas not classified within the recreation class, e.g., electrical utility corridors, survey cutlines and rough roads. The contribution of recreational features could therefore be as much as an additional 5% of the entire human footprint when these features are considered.

The documentation and characterization of the current anthropogenic footprint within the winter range of the Carcross Woodland Caribou Herd is set within the context of an overarching initiative that aims to develop a threshold approach to the assessment of cumulative effects on woodland caribou populations in Yukon. The spatial databases created as part of this project can be used in future work:

- To form the foundation of the landscape tracking system required of a thresholds approach to cumulative effects assessment within the Carcross caribou herd winter range;
- To explore the effects of new developments and the reclamation of old developments on the overall human footprint in scenario based planning exercises;
- To calculate and characterize the unplanned human footprint that can be associated with planned developments;
- To explore trade-offs in land and resource management decisions necessary to sustain caribou populations;
- To contribute to an increased understanding of the dose response of woodland caribou populations in Yukon to varying levels of human development and activities;
- To explore the use of a thresholds approach to the assessment and management of cumulative effects on other species, e.g., grizzly bears.

The continued development of a thresholds approach to the assessment and management of cumulative effects within the Carcross caribou herd winter range requires: 1) an assessment of the contribution of the effect of natural disturbance (especially fire) on the Carcross caribou herd winter range; 2) the incorporation of disturbance coefficients to the assessment of human footprint within the study area; 3) an increased understanding of the dose response of caribou populations to varying levels of human development and activities and 4) the incorporation of habitat effectiveness based on a concerted habitat mapping effort and an expanded collaring and monitoring program.

The success, and the strength, of a thresholds approach to cumulative effects assessment is the contribution of, and communication between, representatives of the various stakeholders that have a vested interest in land and resource management decisions. It is strongly recommended that an advisory committee be established to play an active role in the assessment and management of cumulative effects within the Carcross caribou herd winter range. Individuals could be drawn on from the technical advisory committee established as part of this project and also from those parties not previously represented, e.g., mining representatives and those First Nations not previously represented whose settlement lands and traditional territories lie within the winter range of the Carcross Caribou Herd.

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1.0 INTRODUCTION

Woodland caribou (*Rangifer tarandus caribou*) are a focus species in the boreal forests of northwest Canada and Alaska. Due to concern over the population status and trend of some herds, woodland caribou have been the object of substantial scientific research and monitoring. Woodland caribou, which are often identified as one of the Valued Ecosystem and Cultural Components (VECCs) in environmental impact assessment, are valued for a number of reasons: 1) in the northern reaches of their continental distribution, woodland caribou form an important component of both First Nation's harvest and regulated hunting, 2) caribou are seen as an umbrella species, the protection of which also benefits many other species that occupy caribou habitat, and 3) as animals with large home ranges, woodland caribou may serve the role of a "canary in the coal mine", with population declines signifying reductions in overall ecosystem health. There is much evidence that industrial development associated with oil and gas activity (both exploration and production), forest harvesting, and mining (both exploration and production) negatively impact woodland caribou (see Dyer 1999 and Anderson et al. 2002 for review). Reduction or alteration of important habitats through associated land uses such as urban residential or country residential development is also thought to have negative impacts on woodland caribou and other wildlife species (UNEP 2001). Experience from other areas of Canada suggests that a failure to address cumulative effects in the early stages of development lead to threatened and endangered woodland caribou populations (Dzus 2001).

The Southern Lakes region is the most densely populated area of Yukon; approximately 80% of the Yukon's population (30,256 as of June, 2002; Yukon Bureau of Statistics Information Sheet #58.19) lives within the Southern Lakes region, with the majority within and surrounding the City of Whitehorse. The Carcross woodland caribou herd winter range occurs within this area of high human development and intense land use (Figure 1). While the level of industrial activity occurring within the Southern Lakes region is currently low (modern and historical industrial activities were largely focused on mining and forestry), the incremental expansion of residential and country residential lot development, and associated transportation infrastructure, within the Carcross caribou herd winter range has become a concern. In this situation, the concept of a "development or activity threshold" beyond which additional development or activity leads to unacceptable impacts may therefore be relevant.

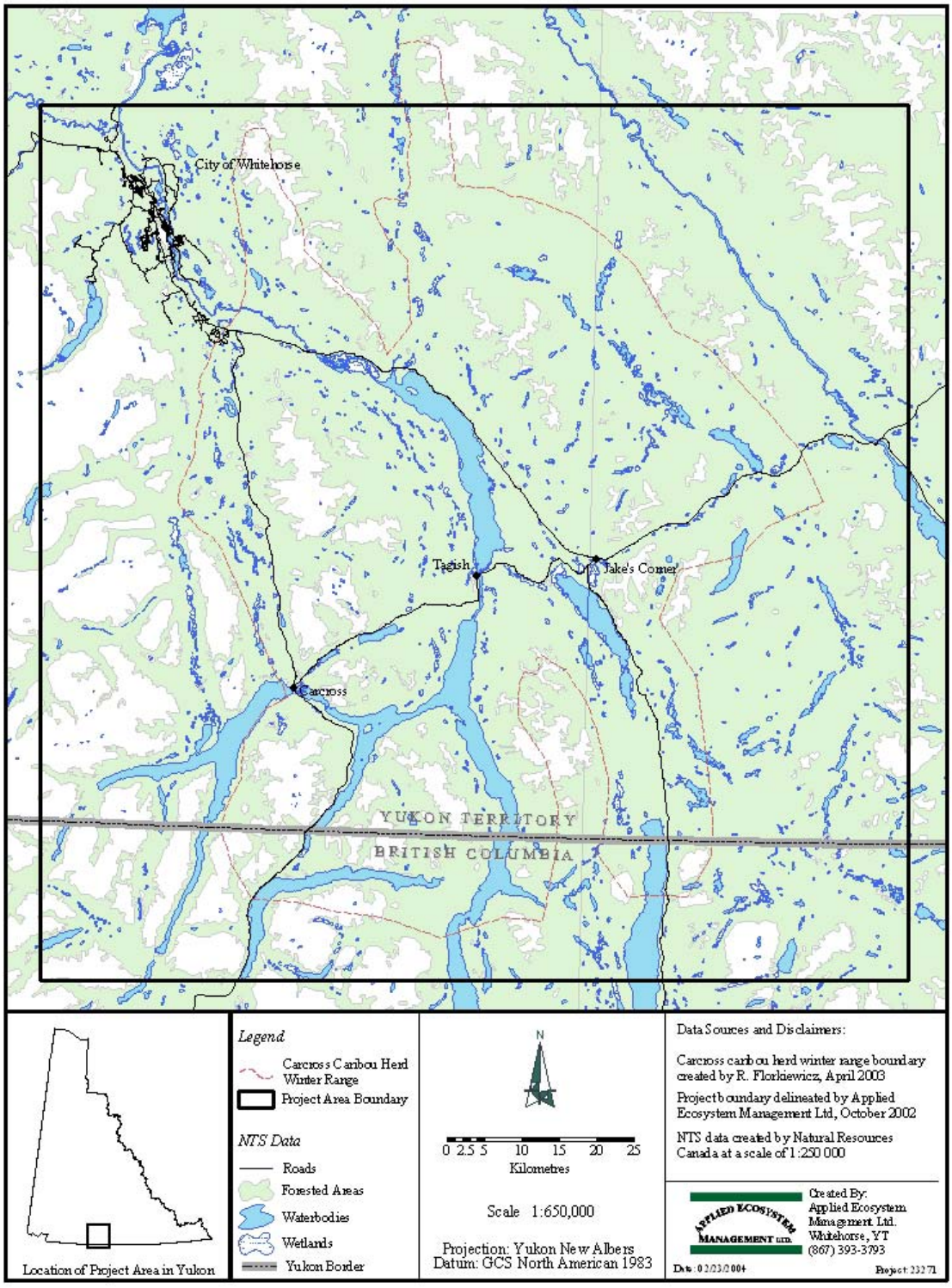

Figure 1. Carcross Woodland Caribou Herd Winter Range and Cumulative Effects Assessment Project Area.

The Southern Lakes Caribou Recovery Program was initiated in 1993 in response to the low population level of the Carcross woodland caribou herd observed between the late 1970s and early 1990s. During this time, the population level was thought to be as low as 100 – 150 animals. Furthermore, the observed mortality rates, in excess of 3% human caused mortality due to hunting, were considered unsustainable (YTG Department of Environment 1996). The Recovery Program has had much success; the results of the most recent census in March 2003 show that the Carcross herd continues to increase from an observed 450 in 1998 to 800 caribou in 2003. Key components of this recovery plan are a voluntary hunting ban by First Nations and a legislated ban by non-First Nation hunters (YTG Department of Environment 1996), an active game guardian program and committed work of the Southern Lakes Caribou Steering Committee (Rob Florkiewicz, pers. comm., 23rd September 2003). The ultimate goal of the Recovery Program is to reach 1200 – 1400 animals within the Carcross herd in the next 5 years (Rob Florkiewicz, pers. comm., 23rd September 2003). However the continued success of this program will depend upon effective land and resource management practices as well as the continued harvest ban (Rob Florkiewicz, pers. comm., 23rd September 2003). In the long term, the need for an effective joint management program among all partners is recognized to be the key to the long term survival of the Carcross caribou herd (Rob Florkiewicz, pers. comm., 23rd September 2003). Managing the rate and pattern of land development within the Southern Lakes region may therefore be an effective strategy for maintaining the Carcross caribou herd at acceptable levels. Understanding the current level and pattern of the human footprint within this area is therefore an important research requirement (Anderson et al. 2002), and forms the focus of this project and report.

1.1 BACKGROUND ON THRESHOLDS

In the context of cumulative environmental effects, a threshold may be defined as "the limit to which an important ecological resource can tolerate land-use impacts before experiencing an unacceptable adverse effect" (Hegmann et al. 1999). The use of development or associated thresholds as a mechanism to manage and mitigate potential cumulative effects of human activities on wildlife populations is a relatively new concept, and to date has not been effectively implemented in any jurisdiction in western Canada.

There is mounting evidence that the amount of range impacted by human development and activities may influence caribou herd population health. Figure 2 shows data from a number of woodland caribou herd ranges throughout Alberta, British Columbia and Yukon (Anderson et al.

2002). In this figure, the rate of caribou population change is plotted against the amount of habitat disturbed by human and natural disturbances. These data point to a potential threshold or "breaking point" related to cumulative range disturbance, after which caribou populations begin to decline rapidly. Due to the large geographic area the herd data was collected from, and the host of range-specific factors that may need to be considered, these data must be interpreted cautiously. However, such a population trend is consistent with published research from other species and may be related to a number of complex issues associated with habitat fragmentation (Komers 2000).

Over the past two years, the DIAND Environment Directorate has explored the use of thresholds to manage cumulative environmental effects in Yukon. A report entitled "*Thresholds for Addressing Cumulative Effects on Terrestrial and Avian Wildlife in the Yukon*" was prepared for DIAND Environment Directorate by AXYS Environmental Consulting Ltd. (AXYS 2001). A second report prepared by Applied Ecosystem Management Ltd. (Anderson et al. 2002) titled "*Development of Threshold Approach for Assessing Industrial Impacts on Woodland Caribou in Yukon*" expanded on the AXYS (2001) document. Anderson et al. (2002) recommended two major thresholds approaches for assessing and managing cumulative human impacts on woodland caribou in Yukon:

1. **Zone of Influence approach (ZOI).** The ZOI approach requires the characterizing of all human features on the landscape (i.e., anthropogenic or human footprint), and then within a GIS environment, assigning various zones of influence to the features based on either empirical or traditional / local knowledge. The ZOI approach provides quantitative information on the amount of habitat that has been influenced by human features and activities, resulting in either exclusion or reduced use of certain areas as a result of cumulative human activities. The ZOI approach does not relate directly to the ecology of caribou, instead it describes the cumulative amount of human activities and their associated zones of displacement (Anderson et al. 2002).

2. **Habitat Effectiveness approach (HE).** The HE approach expands upon the ZOI approach by incorporating the additional factor of habitat quality into the ZOI assessment. The HE approach requires that habitat mapping be factored into the ZOI assessment. The HE approach brings the added interpretation of habitat quality to the disturbance assessment, and

is therefore considered to relate directly to the ecology of caribou (Anderson et al. 2002), a potentially important consideration in the development of cumulative effects thresholds.

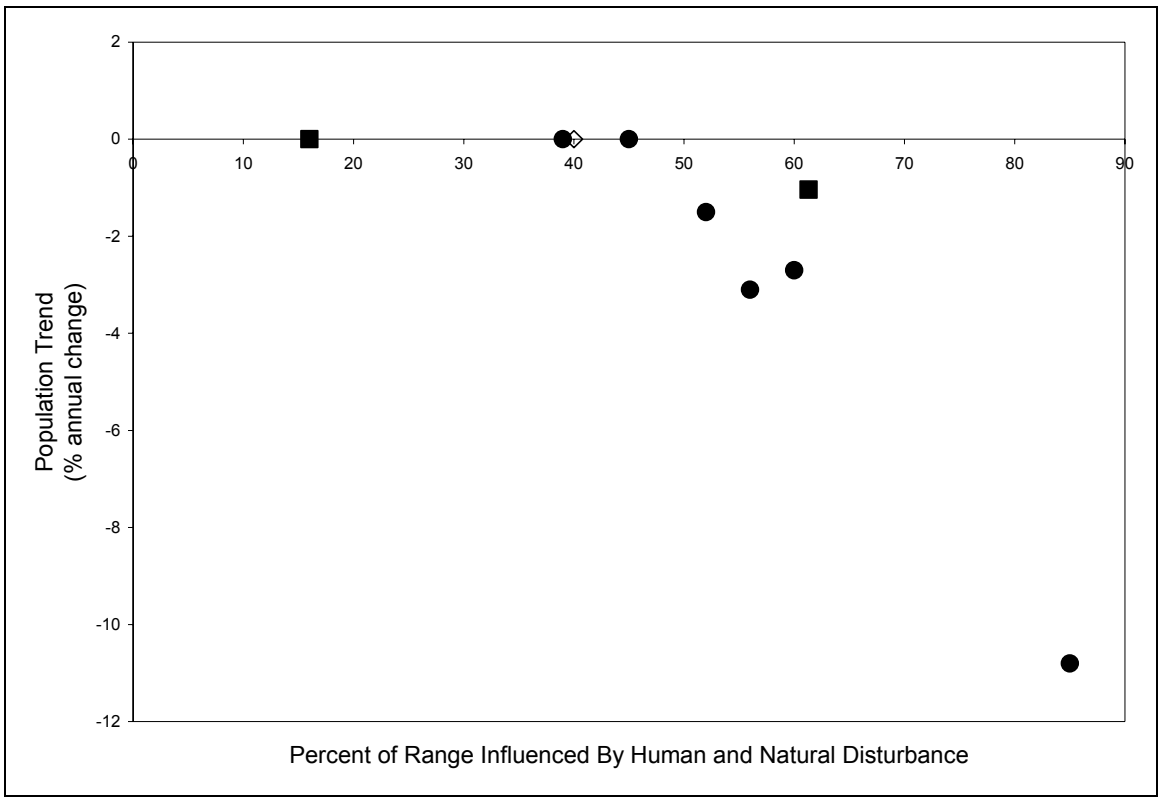

Figure 2. Approximation of Woodland Caribou Habitat Disturbance and Population Rates of Change for Several Herds in Western Canada. Data presented for boreal (●) and northern mountain (■) woodland caribou were derived from the Boreal Caribou Committee (2001), Dzus (2001), Florkiewicz et al. (2002), and T. Sorensen (pers. comm.). The datum presented for southern mountain (◊) woodland caribou represents a minimum suitable winter habitat threshold for occupation, as suggested by Simpson et al. (1997). Figure from Anderson et al. (2002).

While the HE thresholds approach has many benefits over the ZOI approach, the completion of a ZOI assessment is considered to be simpler and is also a necessary precursor to the development of a full HE assessment. Given the current state of regional habitat mapping and habitat use patterns of woodland caribou within the Southern Lakes area, the HE approach is not possible at this time without a concerted habitat mapping program and an expanded woodland caribou collaring and monitoring program. Therefore, this project presents a ZOI-based assessment of cumulative human development in the Carcross woodland caribou herd winter range of Yukon and northern British Columbia.

1.2 OBJECTIVES

The objective of this assessment is to document and characterize the current anthropogenic footprint within the winter range of the Carcross Woodland Caribou Herd. To date, most threshold-related approaches have been developed specifically for industrial activities; this project is therefore somewhat unique in Canada, as the major source of existing development pressure is currently occurring from residential and country residential lot development, associated transportation infrastructure and unplanned recreational development. The methods developed within this project can therefore serve as a template to assess the diversity of cumulative human impacts that can occur on woodland caribou throughout Yukon, i.e., from urban, transportation, agricultural, recreational, as well as industrial, development and activities.

2.0 METHODS

2.1 GENERAL APPROACH

Detailed methods for the assessment of cumulative human effects within the Carcross caribou herd winter range are based on Anderson et al. (2002). The general approach involves: 1) the development of a comprehensive map of all human features within the project area using Geographic Information Systems (GIS), 2) the establishment of zones of influence around each human feature based on existing data and expert / local knowledge, and 3) the calculation of the total amount of human footprint within the Carcross caribou herd winter range. These steps required input and direction from a multi-stakeholder technical advisory committee and were based on the best available information from Yukon and neighboring jurisdictions. Specific steps are outlined below:

2.2 ESTABLISHMENT OF A TECHNICAL COMMITTEE

The technical committee for the Carcross caribou herd winter range cumulative effects assessment was established to provide discipline specific information and expertise required for the creation and review of a human footprint map of the Carcross caribou herd winter range. Representatives from Federal, Territorial and First Nation Government departments were contacted and requested to attend a series of technical committee meetings. Appendix One provides the names of all the technical committee members who attended at least one meeting. Committee members contributed to the creation of the human footprint map in three critical ways:

- Committee members provided digital data and / or guidance that helped improve the accuracy of the human feature map;
- Committee members provided their expertise in their specific fields that allowed for the accurate representation of true widths of human features in the feature map, e.g., the average width of a primary road within the project area;
- Committee members played a critical role in the establishment of the size of zones of influence around human features necessary for the creation of the human footprint map.

2.3 STUDY AREA DELINEATION

The Carcross woodland caribou herd winter range, i.e., the **study area**, was delineated by R. Florkiewicz, Regional Caribou Biologist for the Southern Lakes Region. The delineation of the winter range involved the interpretation and integration of a number of data sources, including the key wildlife habitat database, 10 – 15 years of radio telemetry / GPS data, field observations, field habitat investigations and sighting data collected during interviews with locals. It should be noted that although the Carcross caribou herd winter range has been delineated based on the best available information, this winter range, as with the extent of any wildlife population, is dynamic and its delineation can only be considered a snap shot in time. It is anticipated that the winter range boundary will be refined as new data continues to become available, particularly as part of collaring and monitoring efforts within the Southern Lakes. Indeed the winter range originally delineated in November 2002 was modified during the course of this project when new data became available, i.e., caribou movement data collected during the winter of 2002 / 2003.

Human features were originally mapped within a **project area** that extended beyond the Carcross caribou herd winter range delineated in November 2002. Following revisions of the winter range boundary in April 2003, human features were also mapped in an area that extended beyond the original project area. All analyses were reported in the context of the revised Carcross caribou herd winter range, i.e., the **study area** displayed in Figure 1.

2.4 COLLATION AND REVIEW OF AVAILABLE DATA

The accuracy of the human feature map and resulting analyses is primarily based on the availability and accuracy of spatial digital data and the ability of these data to be integrated effectively.

2.4.1 DATA AVAILABILITY AND ACCURACY

Digital data were collated from a number of sources: YTG Community Services, YTG Environment, YTG Department of Infrastructure, YTG Department of Energy, Mines and Resources, Natural Resources Canada (NRCAN), City of Whitehorse Planning Department and local experts. Human feature data were also captured through interpretation of non-digital data sources, i.e., Whitehorse Trail Map, YTG and COW 1999 and DIAND Contaminants and Waste Management Division aerial photographs and topographic maps and through ground investigations conducted by AEM staff. Table 1 summarizes the extent of available digital data sources and Figure 3 displays the extent of available imagery within the project area.

In order to investigate the accuracy of available digital coverages for the capture of human features, digital coverages were compared against 1m orthophotos. Orthophotos of 1m pixel size represent the highest resolution imagery available within the project area.

Some digital coverages, notably those originally derived from YTG legal cadastral and NTDB data layers, do not provide the most accurate representation of human features within the study area for the following reasons:

- Issues of current vs. potential footprint: legal cadastral and NTDB data often do not represent the current human footprint. For example, a lot may be surveyed and set aside for development as a rural residential lot and therefore be represented as such on the legal cadastral while there may be no current development of the lot. In these situations it was necessary to exclude those lots not currently developed from inclusion in the human feature map to ensure the human footprint map represents the current anthropogenic footprint;
- Issues of suitability of data for spatial analyses: YTG legal cadastral often captures identical features multiple times within the same coverage. To avoid over estimating the human footprint within the project area, human features should be represented only once in the coverage;
- Many human features, such as recreational trails, rough roads, cut lines, cut blocks, mine sites / tailings, backcountry camps, private airstrips and excavation sites, are not represented on legal or NTDB coverages. The omission of these features could result in a significant underestimation of the current human footprint within the project area. This is

particularly true of the linear features (recreational trails, rough roads and survey cut lines) that can be found in high density in some areas within the project area;

- Issues of scale: digital data derived from 1:50,000 scale NTDB was available at a coarser scale than could be mapped using orthophotos of 1m resolution. Therefore coverage data often appeared "off" and could be more accurately represented through primary data capture using orthophotos. Issues of scale are even more significant when ZOI contribute to the determination of habitat effectiveness.

In summary, available data sources of the highest accuracy were selected and used preferentially to capture human features within the project area as follows (Table 1):

- Features could be captured and classified directly from interpretation of 1m orthophotos using heads-up digitizing. These data were considered to be of highest accuracy but could not be used throughout the project or study area. Orthophotos are available along the highway corridors between Whitehorse, Carcross, Tagish and Jake's Corner;

- Features could be directly incorporated into the human feature map from digital data layers that were based on ground locations. These data were considered to be of high accuracy and include:
  - Digital data produced by the federal and territorial governments for the purposes of resource planning (Agparcel.shp; Harvesting polygon; log_roads.shp and Cont & Waste Mngt DIAND 1983, 1993, 1999 or 2002). These data are available throughout the Yukon portion of the project area;
  - Digital data derived from the Updated Road Network (URN) data (Roads.shp). These data are available throughout the project area;
  - Snowmobile.shp and Ground Truthing are available for localized parts of the project area and are particularly useful where orthophotos are not available;

- Features could be directly incorporated into the human feature map from digital data layers based on expert or local knowledge, i.e., R.Florkiewicz; dave_byng_mnt_2003.shp and dave_michie_2003.shp. These data were considered to be of moderate accuracy; accuracy somewhat reduced due to coarse mapping scale (approximately 1:50,000 scale). These data sources were available for localized parts of the project area and were particularly useful where human activity could not be captured through the observation of any physical footprint, e.g., recreational areas and trails used only during winter;

- Features could be directly incorporated into the human feature map from non-digital data sources, i.e., Whitehorse Trail Map YTG & COW. These data were considered to be of moderate accuracy; accuracy somewhat reduced due to coarse mapping scale (1:40,000 scale). These data sources were available for localized parts of the project area and were particularly useful for the refined classification of recreational trails;

- In most cases, LANDSAT 7 could not be used alone to represent the majority of human features within the study area. The resolution of LANDSAT 7 imagery is too coarse to capture human features with the same accuracy and resolution as is possible using orthophotos; LANDSAT 7 imagery is comprised of 15m pixels while orthophoto pixel size is 1m. However, in a few situations a few larger features could be captured and classified directly from interpretation of 15m LANDSAT7 using heads-up digitizing. These data were considered to be of moderate accuracy. Landsat7 imagery is available throughout the project area at 15m pixel resolution;

- Features could be selected directly from data layers derived from YTG legal cadastral and NTDB and incorporated into the human feature map where the location and extent of features were observed on orthophotos to be accurate. Features mapped using these data sources were considered to be of high accuracy where orthophoto coverage existed (and therefore could be truthed against the orthophotos). However, in the absence of orthophoto coverage, these data were considered to be of low accuracy;

- Digital data derived from YTG legal cadastral is available throughout the Yukon portion of the project area at 1:5,000 scale and include: New_whse and Parcel.shp.

- Digital data derived from National Topographic Database (NTDB) data are available throughout the project area at 1:50,000 scale and include: Rail.shp; Roadtrail.shp and Trail.shp.

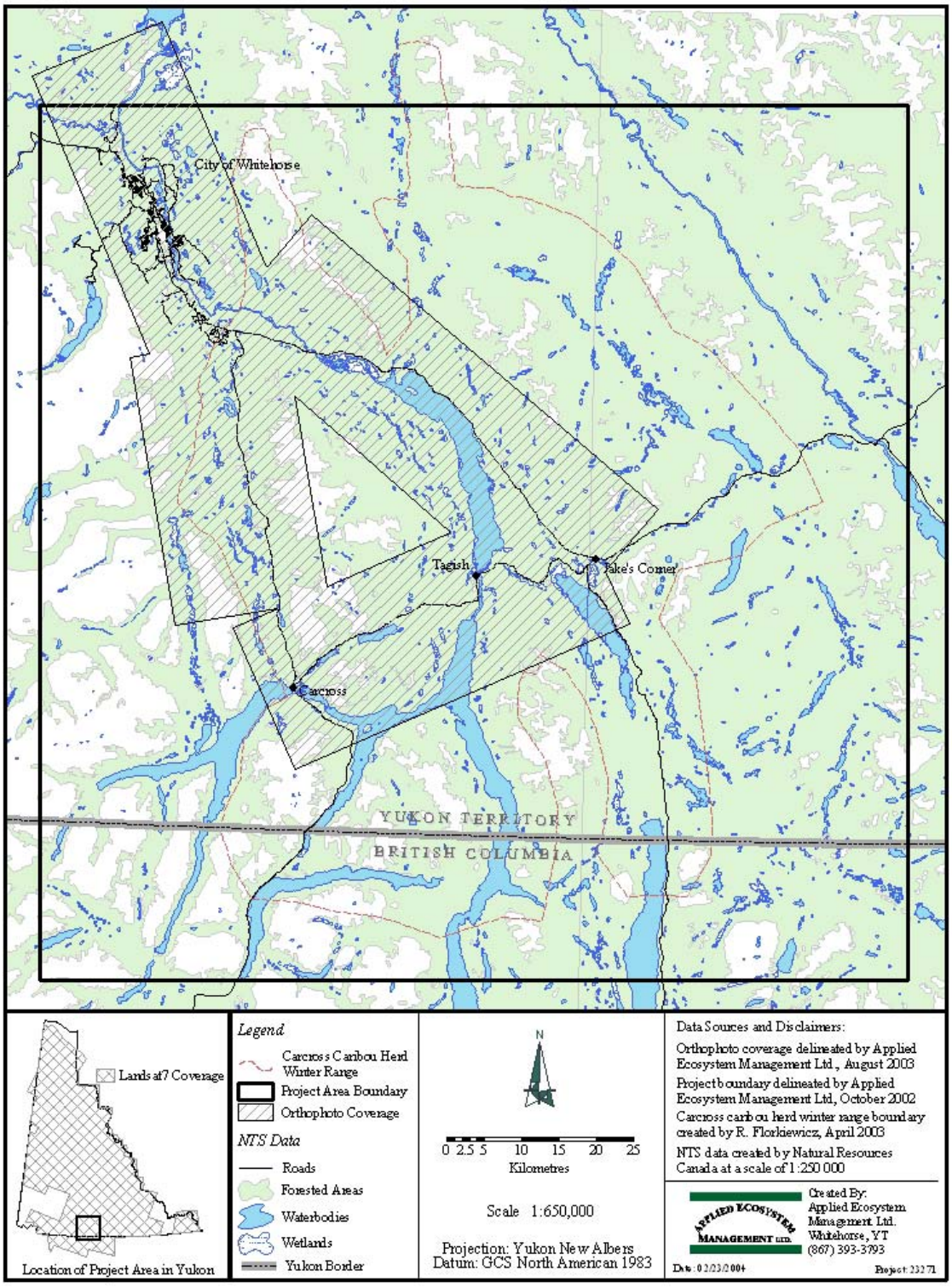

Figure 3. Extent of Available Orthophotography within the Carcross Woodland Caribou Herd Winter Range Cumulative Effects Assessment Project Area.

Table 1. Summary and Extent of Digital Data Sources Used to Capture and Classify Human Features within Carcross Caribou Herd Cumulative Effects Assessment Project Area

Source Information	Data Source	Extent	Accuracy	Details
Agparcel.shp YTG 2003	Ground Locations	Yukon portion of project area	High	Coverage produced by YTG by digitizing sketches from hard copy maps. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth January 2003.
Cont & Waste Mngt DIAND 1983, 1993, 1999 or 2002	Ground Locations	Yukon portion of project area	High	Location and extent of mine sites digitized in July 2003 from sketches on air photos and 1:250,000 scale topographic maps housed at DIAND. Contact: Crystal Lambert, Gartner Lee Ltd. Contact at DIAND: Brett Hartshorne, DIAND Contaminants and Waste Management Division.
dave_byng_mnt_2003.shp 2003	Local Knowledge	Localized	Moderate	Coverage produced by Dave Byng. Contact: Rob Florkiewicz, YTG Department of Environment. Obtained from Rob Florkiewicz in March 2003.
dave_michie_2003.shp 2003	Local Knowledge	Localized	Moderate	Coverage produced by Dave Michie. Contact: Rob Florkiewicz, YTG Department of Environment. Obtained from Rob Florkiewicz in March 2003.
Ground Truthing AEM 2003	Ground Locations	Localized	High	Ground based survey by AEM staff in May and June 2003. Contact: Marie Gallagher, Gartner Lee Ltd.
Harvesting polygon YTG 2003	Ground Locations	Yukon portion of project area	High	Coverage of all harvesting post 1990 produced by Jesse Devost, Forest Planning and Development. Obtained from Jesse Devost in July 2003.Contact: Jesse Devost, YTG Energy, Mines and Resources.
Landsat7 15m YTG 1999	Imagery	Project Area	Moderate	Mosaic created by Geomatics Yukon, YTG Department of Infrastructure. Images 59-18 and 57-18 used for this study created in August 1999. Contact: Lauren Crooks, YTG Highways and Public Works. In house.
log_roads.shp YTG 2003	Ground Locations	Yukon portion of project area	High	Coverage produced by Jesse Devost, Forest Planning and Development. Contact: Jesse Devost, YTG Energy, Mines and Resources. Obtained from Jesse Devost in July 2003.
New_whse YTG 2003	YTG Legal Cadastral	Yukon portion of project area	High / Low*	Coverage created as part of YTG Legal Cadastral at 1:5,000 scale. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in March 2003.
Ortho 1m COW 2001	Imagery	Localized	High	Sht1_1m_rotate.ecw, Sht2_1m_rotate.ecw, Sht3_1m_rotate.ecw and Sht4_1m_rotate.ecw Orthophotos of the City of Whitehorse taken in 2001. Contact: City of Whitehorse. In house.
Ortho 1m YTG 2001	Imagery	Localized	High	1_ne.tif, 1_sw.tif, 2_ne.tif, 2_sw.tif, 3_ne.tif, 3_sw.tif, 4_ne.tif, 4_sw.tif, 5_ne.tif and 5_sw.tif. Orthophotos taken along the highway corridor between Whitehorse and Jakes Corner in 2001. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in January 2003.

Ortho 1m YTG 2001	Imagery	Localized	High	Sheet6_north.tif, Sheet6_south.tif, Sheet7_north.tif, Sheet7_south.tif, Sheet8_north.tif, Sheet8_south.tif, Sheet9_north.tif and Sheet9_south.tif. Orthophotos taken along the highway corridor between Carcross and Tagish in 2001. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in January 2003.
Ortho 1m YTG 1997	Imagery	Localized	High	Sheet10_east.tif, Sheet10_west.tif, Sheet11_east.tif, Sheet11_west.tif, Sheet12_east.tif and Sheet12_west.tif. Orthophotos taken along the highway corridor between Whitehorse and Carcross in 1997. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in March 2003.
Parcel.shp YTG 2003	YTG Legal Cadastral	Yukon portion of project area	High / Low*	Coverage created from YTG Legal Cadastral at 1:5,000 scale. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in January 2003.
Rail.shp YTG 2003	NTDB	Project Area	High / Low*	Coverage produced by YTG in 2003 based on 1:50,000 scale NTDB. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in January 2003.
R.Florkiewicz 2003	Expert Knowledge	Localized	Moderate	Data digitized on screen and as Playareas_spatial_edit.shp at approximately 1:50,000 scale using heads up digitizing by Rob Florkiewicz in March 2003. Contact: Rob Florkiewicz, YTG Department of Environment. Obtained from Rob Florkiewicz in March 2003.
Roads.shp NRCAN 2001	Ground Locations	Project Area	High	Coverage selected from Updated Road Network (URN) produced by NRCAN in 2001. URN created from ground GPS locations captured by Center for Topographic Information in Sherbrooke in 2001. Contact: Rolande LeBlanc, NRCAN Legal Surveys Division. Obtained from Laurie Butterworth in January 2003.
Roadtrail.shp YTG 2003	NTDB	Project Area	High / Low*	Coverage produced by YTG in 2003 based on 1:50,000 scale NTDB. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in January 2003.
Snowmobile.shp YTG 2003	Ground Locations	Localized	High	Coverage produced by Klondike Snowmobile Association in 2003 based on ground GPS locations. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in March 2003.
Trail.shp YTG 2003	NTDB	Project Area	High / Low*	Coverage produced by YTG in 2003 based on 1:50,000 scale NTDB. Contact: Laurie Butterworth, YTG Community Services. Obtained from Laurie Butterworth in March 2003.
Whitehorse Trail Map YTG & COW 1999	Whitehorse Trail Map	Localized	Moderate	Location and extent of human features displayed at 1:33,000 scale on Whitehorse Trail Map (YTG and COW 1999) originally captured from 1:40,000 scale airphotos. Contact: Crystal Lambert, Gartner Lee Ltd.

** Accuracy high within orthophoto coverage and low outside of orthophoto coverage.*

2.5 CAPTURE AND CLASSIFICATION OF HUMAN FEATURES

All human features were captured in ArcGIS and stored in two separate working shapefiles: one containing all linear features and one containing all polygon features within the project area. All human features digitized were classified into one of 25 feature types (Table 2) and one of 5 feature classes (Table 3). Classification by feature type allowed for distinct zones of influence to be assigned to different feature types. Classification by feature class allowed the footprint of different classes to be separated for the purpose of analysis and interpretation.

Classification of feature classes and types were reviewed during meetings of the technical committee. Methods of classification attempted to reflect the type and relative intensity of human activity that would typically occur on each human feature type.

2.5.1 TRANSPORTATION

2.5.1.1 Primary Roads

Primary roads are considered to receive the highest level of domestic and industrial traffic within the project area and include all highways and major roads that connect Carcross, Tagish, Jake's Corner and Atlin.

2.5.1.2 Secondary Roads

Secondary roads are roads that typically connect primary roads to branches of subdivision, rural and / or rough roads. Secondary roads are considered to receive high levels of domestic and industrial use.

2.5.1.3 Subdivision Roads

Subdivision roads are roads that lead to or lie within residential subdivisions. Subdivision roads may branch from primary or secondary roads. Subdivision roads are considered to receive moderate levels of primarily domestic traffic.

2.5.1.4 Rural Roads

Rural roads are roads that access rural residences. Rural roads may branch directly from a primary, secondary or rough road. Rural roads are considered to receive low levels of domestic traffic.

Table 2. Human Feature Type Codes and Descriptions

Feature Class Code	Feature Type Code	Feature Type	Description
AG	AGL	Agricultural Land	Areas partially or completely cleared for agricultural use, i.e., planting and harvesting of crops and housing of livestock and horses.
AG	GRL	Grazing Lease	Areas used only for housing of livestock and horses.
IN	CUT	Cut Blocks	Forest harvest blocks and areas of cut forest, e.g., fire guards.
IN	EUC	Electrical Utility Corridor	Cut line with associated above ground structures, i.e., pylons and powerlines.
IN	EXS	Excavation Sites	Any areas where vegetation and top soil have been removed, e.g., gravel, topsoil or rock extraction sites, borrow pits, observable placer mining activity and exploration ditches.
IN	MST	Mine Site / Tailings	Areas developed as part of hard rock and coal mining operations.
IN	SCL	Survey Cut Line	Line cut for purposes of surveying, e.g., pipeline right of way and seismic lines.
RE	BAC	Backcountry Camp	Permanent backcountry camp assumed to be used seasonally and intermittently.
RE	HUT	High Use Trail	Trails receiving high intensity recreational use (see methods for definition).
RE	LUT	Low Use Trail	Trails receiving low intensity recreational use (see methods for definition).
RE	MUT	Moderate Use Trail	Trails receiving moderate intensity recreational use (see methods for definition).
RE	WRA	Winter Recreational Areas	Areas receiving high intensity winter recreation use, usually related to snow mobile and dog mushing activities.
TR	AIR	Airstrip	Cleared area of airstrip used by fixed wing and helicopter.
TR	PRI	Primary Road	Highways, e.g., Alaska and Klondike highways, Tagish and Atlin roads and associated right of ways.
TR	RAI	Railroad (disused)	Railroad tracks and associated right of way.
TR	ROU	Rough Road	All other roads (and associated right of ways), e.g., roads leading to agricultural parcels, grazing leases, mine sites / tailings, excavation sites and recreational areas.
TR	RUR	Rural Road	Roads leading to rural residences and associated right of ways.
TR	SEC	Secondary Road	All major high use paved and gravel roads and associated right of ways.
TR	SUB	Subdivision Road	Roads leading to or within subdivisions and associated right of ways.
UR	CIN	Commercial / Industrial	Commercial properties, e.g., service industry, retail and light industry.
UR	CIT	City of Whitehorse	Polygon delineating Whitehorse city limits.
UR	PUR	Public Recreation	Recreation facilities e.g., golf courses, front country campgrounds and cemeteries.
UR	PUS	Public Service	Constructed infrastructure e.g., schools, communications, hospitals, fire halls, recreational centers and town halls.
UR	RRE	Rural Residences	Diffuse residential properties within a matrix of open space.
UR	URR	Urban Residences	Dense urban residential developments / subdivisions.

Table 3. Human Feature Class Codes and Descriptions

Feature Class Code	Feature Class	Description
AG	Agricultural	Features developed and used primarily for the purposes of agricultural development.
IN	Industrial	Features developed and used primarily for industrial use, exception may be cut lines and electrical utility corridors that could also be used for recreation.
RE	Recreation	Features constructed and used primarily for recreational use.
TR	Transportation	Features constructed and used primarily as transportation corridors, exception may be railroads. Parts of the White Pass Railroad are no longer active and are used primarily for recreation.
UR	Urban	Features constructed and used primarily for public residence and utility. Exception may be where sections of large rural lots are used primarily for the housing of horses.

2.5.1.5 Rough Roads

Rough roads are roads that access industrial, recreational or agricultural areas, e.g., roads leading to agricultural parcels, grazing leases, mine sites / tailings, excavation sites and recreational areas. Rough roads may branch from primary or secondary roads and are considered to receive moderate levels of domestic, recreational and industrial traffic.

2.5.1.6 Railroad

The only railroad within the project area is for the most part disused. A short stretch of railroad of approximately 3.5km operates south from Bennett during the summer months. During winter, the railroad is considered to receive moderate levels of recreational use, e.g., snow mobile use.

2.5.1.7 Airstrips

Airstrips are classified as those areas used by fixed wing and helicopter to take off and land. Airstrips are delineated by the extent of the cleared area immediately beyond the runway or pad. There are two airstrips within the project area (outside of the City of Whitehorse); the airstrips within the communities of Carcross and Teslin.

2.5.2 RECREATION

2.5.2.1 Trails

When capturing and classifying trails from orthophotos, trails can be distinguished from roads by width with the assumption that linear features narrower than a threshold width cannot normally support vehicles such as trucks and cars; trails are assumed to be <3m and roads >3m wide.

Trails may support all terrain vehicles such as quads and snowmobiles as well as non-motorized recreational activities such as hiking, biking, skiing and dog mushing. The intensity of recreational use on trails is first assessed by calculation of trail distance from a built up area, i.e., Carcross, Annie Lake, Tagish, Jake's Corner and the City of Whitehorse. Trail classification is refined where local knowledge indicates that intensity of trail use may be higher than would be anticipated based on the distance from a built up area.

2.5.2.2 Low Use Trails

Low use trails are all trails that lie >5km from a built up area such as Carcross, Annie Lake, Tagish, Jake's Corner and the City of Whitehorse. Where local knowledge indicates that these trails may receive high or moderate intensity recreational use, trail classification is modified accordingly.

2.5.2.3 Moderate Use Trails

Moderate use trails are all trails that lie between 3km – 5km from a built up area. Where local knowledge indicates that these trails may receive high intensity recreational use, trail classification is modified accordingly.

2.5.2.4 High Use Trails

High use trails are all trails that lie <3km of a built up area and trails >3km from a built up area that have been identified through local knowledge to receive high intensity recreational use.

2.5.2.5 Backcountry Camps

Backcountry camps are identified on orthophotos to contain basic shelters such as wall tents or small cabins. These camps are not recorded on legal cadastral and are often accessible only by trail or water. In a few cases, backcountry camps are accessible from a rough road.

2.5.2.6 Winter Recreational Areas

Winter recreational areas are areas, typically in the alpine, that show no observable physical footprint on orthophotos due to the diffuse nature of winter recreational activities. Winter recreational areas are considered to receive moderate to high levels of recreational use by snowmobiles and also non-motorized activities such as dog mushing and skiing. These areas were delineated by Rob Florkiewicz, Regional Caribou Biologist, YTG Department of Environment.

2.5.3 INDUSTRIAL

2.5.3.1 Survey Cutlines

Survey cutlines include pipeline right of way and seismic lines. These features are observable on orthophotos as straight lines roughly 2m in width and appear in a grid pattern or as single lines. Lines can appear disconnected from other human features, i.e., where lines are partially revegetated. Survey cutlines can be associated with developed areas but can also be found in more remote areas. Survey cutlines are considered to receive variable levels of industrial and recreational use.

2.5.3.2 Electrical Utility Corridors

Electrical utility corridors are often found within the direct footprint of other human features, e.g., roads, residences. Electrical utility corridors are therefore digitized separately only where they diverge from other human features or where they parallel other features at a distance greater than the feature footprint. Electrical utility corridors are considered to receive moderate levels of industrial and recreational use.

2.5.3.3 Cut Blocks

Cut blocks refer to forest harvest blocks and areas of cut forest, e.g., fire guards. Cut blocks are considered to receive variable levels of industrial use.

It has been estimated that fuel wood harvesting within the Greater Whitehorse area could constitute the removal of as many as 20,000 cubic metres of wood per year and that this may correspond to a cumulative harvested area of roughly 200 hectares per year (C. Burgess email dated 18th November 2003). However, the location of fuel wood harvesting activities cannot be captured as either an observable footprint with available imagery or within any digital data coverages due to the diffuse nature of this activity and its locally small footprint. It may however be reasonable to assume that the majority of fuel wood harvesting occurs in association with a road or a trail. For the purposes of this assessment, it will therefore be assumed that the footprint of fuel wood harvesting is captured within the ZOI of an existing road or trail, e.g., within 250 m of a low use trail or 500m of a rough road.

2.5.3.4 Mine Site / Tailings

In this project mine sites / tailings are classified as areas developed as part of hard rock and coal mining operations. They are distinguished from excavation sites by the presence of mine tailings.

All mine sites / tailings within the project area are either inactive during winter or legally abandoned. Mine sites / tailings are considered to receive low levels of industrial use. Table 4 summarizes all legally active and abandoned mine sites that are documented to occur within the project area. These data were obtained from interpretation of aerial photographs and 1:250,000 scale topographic maps stored at DIAND Contaminants and Waste Management Division.

Table 4. Mine Sites Identified within the Project Area

Name	General Location
Union Mine	On west slopes above Annie Lake below Pugh Peak
Whitehorse Coalmine	On west of Coal Ridge and Coal Lake
Unnamed	At southern extent of city limits at south end of Copper Haul Rd
Gold Hill Mine	On Gold Hill, north of Wheaton River
Tally Ho Mine	On Tally Ho Mtn., south of Wheaton River
Becker Cochran Mine	On west slopes of Becker Creek (tributary of Wheaton River)
Arctic Gold / Silver Mine	South of Carcross towards Montana Mtn.
Big Thing Mine	Montana Mtn.
Venus Mine	On western shore of Windy Arm
Evelyn Creek Mine	At headwaters of Evelyn Creek, west of Canol Road.

The occurrence of mine sites / tailings within the British Columbia portion of the project area was determined through querying the minfile status at the BC Province website: http://webmap.em.gov.bc.ca/mapplace/maps/minpot/bcgs.MWF?LayersViewWidth=200&toolbar=small. It was determined that there were no documented mine sites within the British Columbia portion of the project area.

2.5.3.5 Excavation Sites

Excavation sites are classified as any areas where vegetation and top soil have been removed, e.g., gravel, topsoil or rock extraction sites, borrow pits, observable placer mining activity and exploration ditches. Excavation sites are visible on orthophotos as areas of cleared land where the topsoil has also been removed. Excavation sites may be currently or historically active and are considered to receive variable levels of industrial use.

2.5.4 URBAN

2.5.4.1 Urban Residences

Urban residences are characterized as dense residential developments and subdivisions. There is typically little undeveloped land on these properties and urban lots lie in close proximity. Lot lines were used to represent the footprint of the residence. Linear features, such as subdivision roads, trails and electrical utility corridors, were not digitized within the boundary of residential

polygons. Urban residences can be found within the project area within the communities of Carcross and Tagish. Urban residences are considered to receive high levels of domestic use.

2.5.4.2 Rural Residential

Rural residences are characterized as diffuse residential properties within a matrix of open space. Most rural residence lots are approximately 2.2 acres in size although the footprint of developed areas within the lots is usually more localized. Where lots are approximately 2.2 acres in size, lot lines are used to represent the footprint. Where rural residence lots are greater than 2.2 acres, an area of approximately 2.2 acres is digitized around the concentration of residences to represent the footprint unless there is development throughout the lot (in which case, lot lines are used to represent footprint). Linear features, such as rural roads, trails and electrical utility corridors, are not digitized within the boundary of residential polygons. Rural residences are considered to receive high levels of domestic use.

2.5.4.3 Commercial / Industrial Sites

Commercial / industrial sites are associated with the service, retail and light industry, e.g., gas stations, highway cafes and lumber yards. These sites are typically cleared areas with building complexes on site. It is recognized that there may be overlap in the classification of these sites and Public Service Sites; in particular when human activities can only by classified through orthophoto interpretation. Commercial / industrial sites are considered to receive high levels of domestic and moderate levels of industrial use.

2.5.4.4 Public Service Sites

Public service sites are sites of constructed infrastructure often associated with areas of urban development, e.g., schools, communications, hospitals, fire halls, recreational centers and town halls. These sites are typically cleared areas with building complexes on site. Public service sites are considered to receive high levels of domestic use.

2.5.4.5 Public Recreation Sites

Public recreation sites are public recreational facilities that are characterized by little construction but where human use can remain high, e.g., golf courses, front country campgrounds and cemeteries. These sites can be associated with urban development but can also be in more remote areas, e.g., Snafu Lake Campground along the Atlin Road. Public recreation sites are considered to receive moderate levels of recreational use.

2.5.4.6 City of Whitehorse

A small portion of the southern extent of the City of Whitehorse lies within the Carcross caribou herd winter range. It was decided that human features within the City of Whitehorse would not be digitized separately unless their associated ZOI were expected to extend beyond the city limits. Human features lying within 1km of the city limit boundary were therefore digitized separately. For the purposes of analyses, human features within the city limits were classified as "City of Whitehorse" while ZOI buffers extended beyond the city limits were classified as separate human features, e.g., rural residence, rural road. The advantage of this approach was that the focus of data capture was not directed away from within the Carcross caribou herd winter range; digitizing human features within the entire city would be very time consuming and for the most part not relevant to the analysis of the amount of human footprint within the Carcross caribou herd winter range.

2.5.5 AGRICULTURAL

2.5.5.1 Agricultural Lands

Agricultural lands include agricultural parcels as defined by YTG legal cadastral and areas within rural lots that have been cleared for small scale agricultural development. The boundary of the agricultural parcel was used to delineate the extent of the agricultural land unless the footprint within the parcel was less than 70% of the total lot area. In these situations the visible footprint of the agricultural activity (i.e., the extent of the cleared land) was digitized. Within rural residential lots, agricultural lands were delineated by the footprint of the cleared land within the rural lot. The footprint of the residence was captured and classified separately.

2.5.5.2 Grazing Leases

Grazing leases were identified during meetings of the technical committee. Fenced grazing leases were distinguished from those that were unfenced. Fenced leases were included in the human feature map since the fence could impede movements of caribou and in many cases could act as a barrier to movement (R. Florkiewicz, pers. comm., 12th March 2003). Unfenced leases identified during technical committee meetings were omitted from the coverage since these sites no longer constitute a human footprint, i.e., L. Blais; S. Holly; A. John's Atlin lease; W. Rhein's and an unnamed lease on the west slopes of Tagish Lake, approximately 2.5km north of Ten Mile. Table 5 summarizes fenced grazing leases within the Carcross Caribou Herd Project Area.

Table 5. Grazing Leases Identified within the Project Area

Name	General Location	Comments
Blackstone Safaris	On west slopes above Marsh Lake, ~6km north of Tagish.	Lease contains some drift fencing.
Gabb, K.	On south side of Tagish Rd., ~2km from Little Atlin Lake.	Lease fenced.
Johns, A.	Tagish Creek mouth on north side, immediately north of Tagish.	Lease terminated and now settlement land but remains fenced along one boundary.
Macdonald, R.	On Watson River on northwest side of Annie Lake Rd.	Lease fenced.
Rhein, W.	Near confluence of Bear Creek and Watson River, on west side of Thomson, W. lease.	Lease fenced.
Thomson, W.	Near confluence of Bear Creek and Watson River	Lease fenced.

2.6 DETERMINATION OF DIRECT HUMAN FOOTPRINT

2.6.1 CALCULATION OF AREA OF LINEAR FEATURES

Linear features have an inherent width that is not represented in a vector-based GIS system. Linear features were therefore assigned widths in order to more accurately represent their true physical footprint. For example, a 100m length of rough road that is 10m wide actually represents a true footprint of 1000m^2, i.e., 100m length * 10m width. Representative widths were determined for each linear feature during meetings of the technical committee. Committee members provided expertise in their specific fields to estimate the average width of linear feature (Table 6). Linear features were translated into polygons by assigning the appropriate feature width as a buffer to each feature type in ArcGIS (Table 6). This results in the creation of a third working shapefile that represents the direct footprint of all originally linear features, i.e., roads, railroads, trails, cut lines and electrical utility corridors.

Table 6. Linear Features Widths

Feature Type	Feature Width (m)
Primary Road	60
Secondary Road	25
Subdivision Road	25
Rural Road	10
Rough Road	10
Railroad (disused)	15
High Use Trail	2
Moderate Use Trail	2
Low Use Trail	2
Survey Cut Line	2
Electrical Utility Corridor	30

2.6.2 CREATION OF DIRECT HUMAN FOOTPRINT COVERAGES

All human features captured within the project area were combined into one shapefile in ArcGIS. The resulting coverage (*direct_hf_project_Oct2003*) displays the direct footprint of all human features within the project area. This coverage was clipped to the study area using ArcGIS. The resulting coverage (*direct_hf_study_Oct2003*) displays the direct footprint of all human features within the study area. See *aem_ytg_metadata_Oct2003* for attribute descriptions.

2.6.3 CALCULATION OF DIRECT HUMAN FOOTPRINT

There is a certain degree of overlap within the direct human footprint coverage due to the overlap of linear features, e.g., roads and trails that have been assigned representative widths. To account for this overlap, all features are dissolved to create a new coverage. The dissolved footprint can then be used to back calculate the contribution of each feature type to the dissolved human footprint. All calculations were conducted in Microsoft Excel and steps are outlined in Appendix Two.

2.7 DETERMINATION OF INDIRECT HUMAN FOOTPRINT

2.7.1 DETERMINATION OF ZONES OF INFLUENCE

The width of the zones of influence (ZOI) around each feature type was determined through interpretation of the available scientific literature and professional judgment. Two particularly valuable sources of information came from United Nation Environment Programme GLOBIO report (2001) and the work of the West Central Alberta Caribou Standing Committee (WSACSC). WSACSC buffers were developed using a Delphi process and research results from the WSACSC and Boreal Caribou Committee research programs.

Technical committee members played a critical role in the establishment of ZOI values. All ZOI values were reviewed, and when necessary revised, during meetings of the technical committee (Table 7). The committee recognized the value in assigning lower, middle and upper ZOI values to each feature type. This approach aimed to capture the variation in the extent of human influence that may be observed under different conditions within the same feature type. For example, within the category of *survey cutline* variation in the width and amount of human activity on the line may be expected to affect the extent of human influence (i.e., ZOI buffer width). Narrow hand-cut lines with little or no human activity might be expected to have little impact on caribou behavior while wide and open survey lines that are used recreationally would

have a greater impact. The use of lower, middle and upper ZOI therefore reflected three scenarios of human influence: low, moderate and high.

2.7.2 CREATION OF INDIRECT HUMAN FOOTPRINT COVERAGES

The direct human footprint coverage *(direct_hf_study_Oc-2003)* was used as the basis for the creation of three separate shapefiles representing the indirect human footprint within the study area under three scenarios of human influence: low, moderate and high. Under each scenario, human features were buffered in ArcGIS with the appropriate ZOI value (Table 7) and clipped to the study area using ArcGIS. The resulting coverages display a complex of overlapping polygons that can be individually queried for feature type, class and area (in hectares):

- *lowZOI_hf_study_Oct2003* represents the indirect human footprint within the study area under the scenario of the low level of human influence i.e., extent of footprint determined using lower ZOI values. For example, a primary road such as the Alaska Highway was assigned a buffer width of 500m;
- *midZOI_hf_study_Oct2003* represents the indirect human footprint within the study area under the scenario of the moderate level of human influence i.e., extent of footprint determined using middle ZOI values. For example, a primary road such as the Alaska Highway was assigned a buffer width of 900m;
- *uppZOI_hf_study_Oct2003* represents the indirect human footprint within the study area under the scenario of the high level of human influence i.e., extent of footprint determined using upper ZOI values. For example, a primary road such as the Alaska Highway was assigned a buffer width of 1000m.

2.7.3 CALCULATION OF INDIRECT HUMAN FOOTPRINT

There is a certain degree of overlap within each indirect human footprint coverage due to the overlap of ZOI buffers. To account for this overlap, all features are dissolved to create new coverages. The dissolved footprints can then be used to back calculate the contribution of each feature type to the dissolved human footprints under the three scenarios of human influence. All calculations were conducted in Microsoft Excel and steps are outlined in Appendix Two.

Table 7. Lower, Middle and Upper Zones of Influence (ZOI) Values for each Feature Type

Feature Class Code	Feature Type Code	Feature Type	Lower ZOI Value (m)	Middle ZOI Value (m)	Upper ZOI Value (m)	Original Source
AG	AGL	Agricultural Land	250	500	500	Professional Opinion
AG	GRL	Grazing Lease	0	250	500	Profession Opinion
IN	CUT	Cut Blocks	250	500	900	WCACSC*
IN	EUC	Electrical Utility Corridor	500	500	500	UNEP (2001)**
IN	EXS	Excavation Sites	250	500	900	Professional Opinion
IN	MST	Mine Site / Tailings (inactive)	250	250	250	Professional Opinion
IN	SCL	Survey Cut Line	0	250	500	WCACSC
RE	BAC	Backcountry Camp	900	900	900	Professional Opinion
RE	HUT	High Use Trail	500	500	500	WCACSC
RE	LUT	Low Use Trail	250	250	250	WCACSC
RE	MUT	Moderate Use Trail	500	500	500	WCACSC
RE	WRA	Winter Recreational Areas	Exclude polygon	Include polygon	Include polygon	Professional Opinion
TR	AIR	Airstrip	500	900	1000	UNEP (2001)
TR	PRI	Primary Road	500	900	1000	UNEP (2001)
TR	RAI	Railroad (disused)	500	500	500	Professional opinion
TR	ROU	Rough Road	500	500	500	WCACSC
TR	RUR	Rural Road	250	250	250	WCACSC
TR	SEC	Secondary Road	500	900	1000	UNEP (2001)
TR	SUB	Subdivision Road	250	500	500	WCACSC
UR	CIN	Commercial / Industrial	900	900	900	UNEP (2001)
UR	CIT	City of Whitehorse	0	0	0	Professional Opinion
UR	PUR	Public Recreation	500	500	500	Professional Opinion
UR	PUS	Public Service	900	900	900	UNEP (2001)
UR	RRE	Rural Residences	900	900	900	UNEP (2001)
UR	URR	Urban Residences	900	900	900	UNEP (2001)

** WCACSC – West Central Alberta Caribou Standing Committee*

*** UNEP – United Nations Environment Programme (GLOBIO project)*

3.0 RESULTS

3.1 HUMAN FOOTPRINT MAP

The attached map (Map 1) displays the distribution of the direct and indirect human footprint within the Carcross woodland caribou herd winter range under three scenarios of human influence: low, moderate and high.

Much of the concentrated human development within the Carcross woodland caribou herd winter range occurs in association with the primary roads that connect the communities within the study area, i.e., City of Whitehorse, Carcross, Tagish and Jake's Corner and the primary roads that connect these communities to those outside the study area, i.e., Atlin, Teslin and Skagway. These corridors often occur along valley bottoms and lake shores (Map 1). There is also a significant amount of diffuse human development and use within the study area. Most obvious are the winter recreational areas found in alpine areas or on lakes. However, less obvious are the rough roads and recreational trails that occur throughout the study area. Rough roads, often originally constructed during the exploration and production phases of mineral resource extraction or forest harvesting, can be found, often in association with recreational trails, in locally extensive networks, e.g., Montana Mountain and McClintock River.

3.2 HUMAN FOOTPRINT SHAPEFILES

The shapefiles created as part of this project can be used to visually display and query the direct and indirect footprint of human features within the study area. Metadata associated with all shapefiles can be found in *aem_ytg_metadata_Feb2004.doc*

Shapefiles displaying the direct footprint of human features can be queried for: feature type, class, area (in hectares), and data source:

- The shapefile *direct_hf_project_Oct2003* displays the direct footprint of all human features within the project area.
- The shapefile *direct_hf_study_Oct2003* displays the direct footprint of all human features within the study area.

Shapefiles displaying the indirect footprint of human features can be queried for: feature type, class and area (in hectares):

- The shapefile *lowZOI_hf_study_Oct2003* displays the indirect footprint of all human features within the study area under the scenario of the low level of human influence i.e., extent of footprint determined using lower ZOI values;
- The shapefile *midZOI_hf_study_Oct2003* displays the indirect footprint of all human features within the study area under the scenario of the moderate level of human influence i.e., extent of footprint determined using middle ZOI values;
- The shapefile *uppZOI_hf_study_Oct2003* displays the indirect footprint of all human features within the study area under the scenario of the high level of human influence i.e., extent of footprint determined using upper ZOI values.

3.3 HUMAN FOOTPRINT CALCULATIONS

All footprint analyses were conducted within the Carcross caribou herd winter range, i.e., the study area. The entire study area (584,613.77 ha) was included in the analyses. There was no pre-stratification of the landscape, e.g., lakes were not excluded from analyses, no consideration of caribou habitat quality and no consideration of the amount of natural disturbance within the study area for these analyses.

Tables 8 and 9 summarize the contribution of each of the 25 feature types and each of the 5 feature classes to the total human footprint within the study area, expressed as a proportion of the study area. Appendix Two presents the raw and derived data used to determine these values.

Between 16.7% and 21.3% of the Carcross woodland caribou herd winter range is influenced by human development and / or activities. This extended footprint is derived from 3.3% direct human footprint within the study area (Table 8). Transportation corridors are the most significant contribution to the total human footprint in the study area under all three scenarios of human influence (Table 9). In particular, primary roads and rough roads consistently rank within the top three most significant contributors to the human footprint under all three scenarios of human influence (Table 8).

Rural residences also consistently rank within the top three most significant contributors to the human footprint under all three scenarios of human influence (Table 8). However, when all

recreational trails (high, moderate and low use trails) are combined, trails exceed the contribution of both rural and urban residences by at least 0.13% of the study area under all three scenarios of human influence (Table 8). Under the scenarios of moderate and high human influence, winter recreational areas are also included in the estimation of human footprint within the study area. In these cases, the contribution of recreation to the entire footprint exceeds the footprint of all urban development and is second only to the footprint of transportation corridors (Table 9).

Recreation can also occur in areas not classified within the recreation class, i.e., electrical utility corridors and survey cutlines (industrial class), rail and rough roads (transportation class) and public recreational sites (urban class). The contribution of recreational features could therefore be as much as an additional 5.2%, 5.3% and 5.4% to the entire human footprint when these features are considered under the low, moderate and high human influence scenarios respectively. The most significant contribution is from rough roads.

Table 8. Contribution of Feature Types to the Total Human Footprint within the Carcross Caribou Herd Winter Range Expressed as a Proportion of the Entire Study Area

Feature Label	Feature Type Description	Contribution of each feature type to total human footprint within study area (% of study area)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AGAGL	Agricultural Land	0.42	0.56	0.93	0.91
AGGRL	Grazing Lease	0.06	0.03	0.14	0.14
INCUT	Cut Block	0.05	0.17	0.74	0.72
INEUC	Electrical Utility Corridor	0.09	0.88	0.85	0.83
INEXS	Excavation Site	0.04	0.19	0.49	1.18
INMST	Mine Site / Tailings	0.07	0.08	0.08	0.08
INSCL	Survey Cut Line	0.00	0.00	0.61	0.60
REBAC	Backcountry Camp	0.00	0.23	0.22	0.22
REHUT	High Use Trail	0.01	1.22	1.17	1.14
RELUT	Low Use Trail	0.03	1.62	1.56	1.52
REMUT	Moderate Use Trail	0.00	0.32	0.31	0.30
REWRA	Winter Recreational Area	1.36	0.00	0.66	0.64
TRAIR	Airstrip	0.00	0.01	0.04	0.04
TRPRI	Primary Road	0.57	2.66	4.79	4.66
TRRAI	Railroad	0.03	0.48	0.47	0.45
TRROU	Rough Road	0.13	3.60	3.47	3.37
TRRUR	Rural Road	0.04	0.54	0.52	0.51
TRSEC	Secondary Road	0.01	0.11	0.23	0.22
TRSUB	Subdivision Road	0.01	0.05	0.10	0.09
URCIN	Commercial / Industrial Sites	0.02	0.36	0.34	0.33
URCIT	City of Whitehorse	0.05	0.02	0.02	0.02
URPUR	Public Recreation Sites	0.03	0.19	0.18	0.18
URPUS	Public Service Sites	0.01	0.32	0.31	0.30
URRRE	Rural Residences	0.29	2.92	2.82	2.74
URURR	Urban Residences	0.00	0.09	0.09	0.08
Total		**3.32**	**16.66**	**21.14**	**21.28**

Table 9. Contribution of Feature Classes to the Total Human Footprint within the Carcross Caribou Herd Winter Range Expressed as a Proportion of the Entire Study Area

Feature Class	Feature Class Description	Contribution of each feature class to total human footprint within study area (% of study area)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AG	Agricultural	0.48	0.59	1.08	1.05
IN	Industrial	0.25	1.33	2.78	3.41
RE	Recreation	1.40	3.39	3.92	3.82
TR	Transportation	0.79	7.46	9.62	9.35
UR	Urban	0.40	3.89	3.75	3.65
Total		**3.32**	**16.66**	**21.14**	**21.28**

4.0 DISCUSSION

The objective of this assessment is to document and characterize the current anthropogenic footprint within the winter range of the Carcross Woodland Caribou Herd. This exercise is set within the context of an overarching initiative that aims to develop a thresholds approach to the assessment of cumulative effects on woodland caribou populations in Yukon (Anderson et al. 2002; AXYS 2002). Two threshold approach options have been recommended for assessing and managing cumulative human impacts on woodland caribou in Yukon (Anderson et al. 2002): the zone of influence approach (ZOI) and the habitat effectiveness approach (HE). These two approaches are closely related as the ZOI calculations form the initial steps required in the calculation of habitat effectiveness. This project presents a ZOI-based approach to the assessment of cumulative human effects in the Carcross woodland caribou herd winter range of Yukon and northern British Columbia.

4.1 LANDSCAPE TRACKING

The spatial databases created as part of this project can be used to visually display and query the current human footprint within the Carcross caribou herd winter range. These files also form the foundation of the landscape tracking system required of a thresholds approach to cumulative effects assessment within the Carcross caribou herd winter range (Anderson et al. 2002). As new developments occur and old footprints are reclaimed, spatial databases can be updated and new indirect footprints calculated. Spatial databases can also be updated if need be, e.g., if more detailed or more recent imagery becomes available (allowing more human features to be captured), if new winter recreational areas are defined, if the boundary of the Carcross caribou herd winter range is modified or if a cumulative effects assessment is conducted on another species, e.g., grizzly bears.

4.2 SCENARIO BASED PLANNING EXERCISES

The spatial databases produced as part of this project can be used to investigate the effect of various planning scenarios on the overall human footprint within the Carcross caribou herd winter range. For example, the increase in human footprint associated with various planning options could be investigated. Likewise, the decrease in the overall human footprint as a result of the reclamation of particular human features could also be predicted, e.g., the reclamation of abandoned grazing leases following the removal of relict fencing or the reclamation of areas following the deactivation of selected rough roads. These exercises could be conducted with

some data preparation using ALCES (A Landscape Cumulative Effects Simulator, Forem Technologies 2002) or directly within ArcGIS using a customized GIS application.

These spatial databases can also be used to calculate and characterize the unplanned human footprint that can be associated with planned developments. For example, planned urban development can often be associated with the development of unplanned recreational trails. The characterization of these associated developments and activities can provide a more accurate representation of the predicted footprint associated with planned developments.

A ZOI or HE based approach to thresholds can show trade-offs potentially necessary to sustain caribou populations. An additional aspect of wildlife management that has significant impact on population viability is the level of direct mortality through hunting. Therefore the trade-offs are not only land management decisions but also resource management decisions. This is most apparent today when we observe the dramatic, and ongoing, recovery of the Carcross caribou herd, for the most part, in response to the voluntary and legislated hunting ban this herd has experienced in the last 10 years. This also demonstrates the inter-relatedness of all land and resource management decisions and illustrates the need for an integrated approach. Cumulative effects assessment in the context of development thresholds provides a key component of such an integrated approach.

4.3 CONTINUED DEVELOPMENT OF A THRESHOLDS APPROACH

A ZOI-based approach provides quantitative information on the amount of area within the Carcross caribou winter range that has been influenced by human features and activities that result in either exclusion or reduced use of certain areas as a result of cumulative human activities. ZOI does not relate directly to the ecology of caribou, instead it describes the cumulative amount of human activities and their associated zones of displacement (Anderson et al. 2002). Between 16.7% and 21.3% of the Carcross woodland caribou herd winter range is influenced by human development and / or activities. This extended footprint is derived from 3.3% direct human footprint within the study area (Table 7). While these data can be used to help determine or apply thresholds to human development and activities in the future, it should be noted that a number of steps are required before these goals can be achieved:

4.3.1 INCORPORATION OF NATURAL DISTURBANCE

The estimate of between 16.7% and 21.3% does not consider the contribution of natural disturbance to the amount of habitat disturbed within the winter range and therefore is likely somewhat underestimated. Habitat mapping can be used to determine the amount of disturbance related to natural events, most significantly fire, within the study area.

4.3.2 INCORPORATION OF DISTURBANCE COEFFICIENTS

It has been suggested that the degree of avoidance (or disturbance coefficient) be determined for each ZOI to explore both ZOI and HE thresholds (Anderson et al. 2002). The incorporation of disturbance coefficients would be better within the context of a habitat effectiveness model; coefficients can act upon habitat quality indices.

4.3.3 INCREASED UNDERSTANDING OF DOSE RESPONSE RELATIONSHIPS

Caribou demographic information is required to explore ZOI and / or HE thresholds by plotting total ZOI / HE against selected caribou population parameters. It has been suggested that the use of different parameters be examined to determine which gives the most defensible threshold value. The actual threshold values need to be set by examining the data and coming to a consensus on the appropriate values (Anderson et al. 2002).

Existing data suggest that the amount of range impacted by human development and activities may influence caribou herd population health (Anderson et al. 2002; Figure 2). First steps have been taken to determine the application of these data to Yukon woodland caribou herds. Data from the Little Rancheria woodland caribou herd was incorporated into Figure 2 and appears to be in accordance. However, the situation may be more complex, especially under varying wildlife management regimes. In the case of the Carcross caribou herd, the observed rate of population change is likely influenced by many factors additional to the level of human development within the winter range, most significantly the control of direct human caused caribou mortality through the voluntary First Nations and legislated non-First Nation hunting ban. The Carcross woodland caribou herd is currently increasing from an observed 450 in 1998 to 800 caribou in 2003. Work aiming to elucidate cumulative effects dose response in wildlife populations is currently ongoing (Anderson et al. in prep.).

The methodology provided in this report can be used as a template to assess the diversity of cumulative human impacts that can occur on woodland caribou throughout Yukon, i.e., from

urban, transportation, agricultural and recreational, as well as industrial, development and activities. This approach could be applicable to other areas, where caribou demographic information is available, to assist in the elucidation of cumulative effects dose response in woodland caribou populations in Yukon. The following key points were particularly relevant to the success of this assessment:

- Establishment of a multi-stakeholder technical advisory committee;
- Integration of spatial data of highest accuracy, currency and resolution;
- Standard approach to the capture and classification of human features;
- Establishment of a standard set of ZOI values for a wide diversity of human features;
- Standard approach to the calculation of cumulative human footprint within a defined study area;
- Design and creation of spatial databases that can be used as a tool for scenario based planning exercises.

4.3.4 INCORPORATION OF THE HABITAT EFFECTIVENESS APPROACH

The habitat effectiveness (HE) approach brings the added interpretation of habitat quality to the disturbance assessment and therefore requires that habitat quality mapping be combined with the ZOI assessment (Anderson et al. 2002). A concerted habitat mapping effort is therefore required in conjunction with an expanded caribou collaring and monitoring program to produce a habitat quality map that can be used as the basis of a habitat effectiveness model. A habitat quality map is created through assigning mapped habitat types with woodland caribou seasonal habitat values. At present there are insufficient data available to establish a clear understanding of caribou habitat quality within the Carcross caribou herd winter range (R. Florkiewicz, pers. comm., 27th November 2003). An expanded GPS collaring and monitoring program has therefore been initiated by YTG Department of Environment, with financial support from YTG Department of Community Services. This program aims to monitor up to twenty GPS collared caribou over a three year period with the objective of providing the data required to create a habitat quality map of the Carcross caribou herd range (R. Florkiewicz pers. comm., 18th November 2003).

Once habitat values are assigned to habitat units within the habitat map, the total habitat value for the winter range (assuming no footprint) can be determined by multiplying the habitat value of each unit by the area and summing across all habitat units. The ZOI are then used to calculate the reduction in habitat effectiveness as a result of the human footprint. The remaining habitat

effectiveness can be expressed as a proportion of the maximum potential habitat effectiveness (assuming no footprint) and can then be plotted against population parameters to identify thresholds. Consensus will be required to determine threshold values but must be based on demonstrable population responses (Anderson et al. 2002). The incorporation of habitat effectiveness to the assessment of cumulative effects could change the significance of the contribution of different human feature types and classes to the overall reduction in habitat effectiveness, e.g., human features that appear to be significant contributors to the overall human footprint may have less significance when the quality of the habitat under the influence of these features is considered.

4.3.5 ESTABLISHMENT AND MAINTENANCE OF ADVISORY COMMITTEE

The success, and the strength, of a thresholds approach to cumulative effects assessment is the contribution of, and communication between, representatives of the various stakeholders that have a vested interest in land and resource management decisions. It is strongly recommended that an advisory committee be established to play an active role in the assessment and management of cumulative effects within the Carcross caribou herd winter range. Individuals could be drawn on from the technical advisory committee established as part of this project (Appendix One) and also from those parties not previously represented, e.g., mining representatives and those First Nations not previously represented whose settlement lands and traditional territories lie within the winter range of the Carcross Caribou Herd.

5.0 REFERENCES

Anderson, R.B., Dyer, S.J., Francis, S.R. and Anderson, E.M. 2002. Development of a Threshold Approach for Assessing Industrial Impacts on Woodland Caribou in Yukon. Report prepared for Environment Directorate, Northern Affairs Program, Whitehorse, Yukon. Version 2.0, September 2002

Anderson, R.B. et al. in prep. Development of a Threshold Approach for Assessing Industrial Impacts on Woodland Caribou in Yukon: Document Revisions and Expansion.

AXYS Environmental Consulting Ltd. 2001. Thresholds for addressing cumulative effects on terrestrial and avian wildlife in the Yukon. Report prepared for Department of Indian and Northern Affairs, Environmental Directorate and Environment Canada, Whitehorse, YT.
AXYS Environmental Consulting Ltd. 2002. Options for Implementation of a Yukon Wildlife Thresholds Pilot Program: A Scoping Level Review. Report prepared for Department of Indian and Northern Affairs, Environment Directorate, Whitehorse, YT.

Boreal Caribou Committee (BCC). 2001. Strategic plan and industrial guidelines for boreal caribou ranges in northern Alberta. Report prepared by the Boreal Caribou Committee, Edmonton, AB. Available online at http://www.deer.rr.ualberta.ca/caribou/BCRP.htm.

Dzus, E. 2001. Status of Woodland Caribou (*Rangifer tarandus caribou*) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 30, Edmonton, AB.

Florkiewicz, R.F., Flynn, N., MacLean, N., Francis, S.R., Adamczewski, J.Z., and Loewen, V. 2002. Assessment of winter habitat, movement and distribution of the Little Rancheria caribou herd in Yukon. Department of Renewable Resources, Government of Yukon, Whitehorse, YT.

Forem Technologies 2002. A Landscape Cumulative Effects Simulator (ALCES). Forem Technologies, Bragg Creek, Alberta. http://www.foremtech.com.

James, A.R.C. and Stuart-Smith, A.K. 2000. Distribution of caribou and wolves in relation to linear corridors. J. Wildl. Manage. 64: 154-159.

Komers, P.W. 2000. Non-linear responses of ecosystem components to provide threshold values for cumulative effects management. In *Cumulative Environmental Effects Management: Tools and Approaches*. Alberta Society of Professional Biologists, Symposium Papers. Kennedy, A.J. (Ed.). Calgary, Alberta, Canada, November 2000.

YTG Department of Environment. 1996. Southern Lakes Caribou Recovery Program: Progress Report 1992 – 1996 (24p booklet). YTG Department of Environment, Box 2703, Whitehorse, YT, Y1A 2C6. Digital copies can be obtained on website: http://www.yfwmb.yk.ca/comanagement/mgmtplans/slcrp/index.html

United Nations Environment Programme (UNEP) 2001. C. Nelleman, L. Kullerud, I. Vistnes, B.C. Forbes, E. Husby, G.P. Kofinas, B.P. Kaltenborn, J. Rouaud, M. Magomedova, R. Bobiwash, C. Lambrechts, P.J. Schei, S. Tveitdal, O. Grøn, and T.S. Larsen. GLOBIO: Global methodology for mapping human impacts on the biosphere. UNEP/DEWA/TR. 01-3.

Appendix One

Carcross Caribou Herd Winter Range Cumulative Effects Assessment Technical Committee

Anderson, Robert - Gartner Lee Limited
Borotsik, Peter - Ta'an Kwach'an Council
Butterworth, Laurie - YTG Community Services
Dinn, Lyle - DIAND Forest Resources
Florkiewicz, Rob - YTG Environment.
Francis, Shawn - Yukon Land Use Planning Council
Gallagher, Corrine - YTG Community Services
Gallagher, Marie - Gartner Lee Limited
George, Morris - YTG Environment
Lamb, Randy - YTG Environment
Lambert, Crystal - Gartner Lee Limited
Loewen, Val - YTG Environment
McIntyre, Jerome - YTG Community Services
Mueller, Fritz - DIAND Environment
Murray, David - YTG Energy Mines & Resources, Agriculture Branch
Paish, Cathryn - YTG Business, Tourism & Culture
Perrier, Gerry - YTG Environment
Peter, Denise - YTG Business, Tourism & Culture
Pope, Geraldine - Ta'an Kwach'an Council
Ritchie, Brian - YTG Community Services
Sawyer, Chris - YTG Community Services
Sembsmoen, Dave - YTG Environment
Stetkiewicz, George - YTG Community Services
Vedress, Florian - YTG Transportation Division

Appendix Two

Calculation of Direct and Indirect Human Footprint

Calculations follow the same steps regardless of whether accounting for overlap between ZOI buffers or direct footprint polygons.

First calculate the contribution of each feature type to the undissolved human footprint in percent (Table 3) based on the undissolved footprint determined using ArcGIS (Table 1). For example, to calculate the contribution of rural roads to the undissolved human footprint:

$$\text{Area of rural roads (\% Human Footprint)} = \frac{\text{(Undissolved area (ha) of rural roads * 100)}}{\text{Total undissolved area}}$$

Then use this value (Table 3) to calculate the contribution of rural roads to the dissolved human footprint in hectares (Table 5). For example, to calculate the contribution of rural roads to the dissolved human footprint:

$$\text{Corrected area of rural roads (ha)} = \frac{\text{(Total dissolved area (ha) * Area of rural roads (\% human footprint)}}{100}$$

The area of rural roads (Table 5) can then be used to calculate the footprint of each feature type as a proportion of the entire study area (Table 7). For example, to calculate the footprint of all rural roads as a proportion of the study area:

$$\text{Area of rural roads (\% Study area)} = \frac{\text{(Area of rural roads (ha) * 100)}}{\text{Area of study area (ha)}}$$

Finally, to calculate the footprint of each feature class as a proportion of the entire study area simply sum the contribution of all feature types of the same feature class, e.g., sum agricultural lands and grazing leases (Table 7) to determine footprint of agriculture as a proportion of the study area (Table 8).

Table 1. Contribution of Feature Type to Total Human Footprint within Carcross Caribou Herd Winter Range in Hectares (combined sum of all overlapping individual polygons)

Feature Label	Feature Type Description	Contribution of each feature type to total human footprint within study area (ha)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AGAGL	Agricultural Land	2518.172	6674.895	11612.389	11612.389
AGGRL	Grazing Lease	379.003	378.996	1763.108	1763.108
INCUT	Cut Block	284.963	2029.297	9263.869	9263.869
INEUC	Electrical Utility Corridor	528.955	10555.792	10555.792	10555.792
INEXS	Excavation Site	229.139	2289.422	6055.713	15133.140
INMST	Mine Site / Tailings	416.284	1014.986	1014.986	1014.986
INSCL	Survey Cut Line	22.891	22.479	7646.488	7646.488
REBAC	Backcountry Camp	6.805	2771.965	2771.965	2771.965
REHUT	High Use Trail	70.522	14568.390	14568.390	14568.390
RELUT	Low Use Trail	165.504	19390.911	19390.911	19390.911
REMUT	Moderate Use Trail	14.612	3873.901	3873.901	3873.901
REWRA	Winter Recreational Area	8168.771	0.000	8168.771	8168.771
TRAIR	Airstrip	4.638	179.046	510.107	510.107
TRPRI	Primary Road	3438.888	31884.311	59538.427	59538.427
TRRAI	Railroad	172.978	5813.795	5813.795	5813.795
TRROU	Rough Road	803.257	43135.023	43135.023	43135.023
TRRUR	Rural Road	256.581	6519.264	6519.264	6519.264
TRSEC	Secondary Road	54.112	1332.535	2872.597	2872.597
TRSUB	Subdivision Road	57.706	605.368	1205.426	1205.426
URCIN	Commercial / Industrial Sites	136.657	4256.381	4256.381	4256.381
URCIT	City of Whitehorse	299.439	299.439	299.439	299.439
URPUR	Public Recreation Sites	174.921	2245.019	2245.019	2245.019
URPUS	Public Service Sites	53.849	3795.190	3795.190	3795.190
URRRE	Rural Residences	1720.914	35017.976	35017.976	35017.976
URURR	Urban Residences	28.665	1066.592	1066.592	1066.592
Total		**20008.224**	**199720.973**	**262961.518**	**272038.945**

Table 2. Contribution of Feature Class to Total Human Footprint within Carcross Caribou Herd Winter Range in Hectares (combined sum of all overlapping individual polygons)

Feature Class	Feature Class Description	Contribution of each feature class to total human footprint within study area (ha)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AG	Agricultural	2897.175	7053.891	13375.496	13375.496
IN	Industrial	1482.230	15911.976	34536.847	43614.274
RE	Recreation	8426.213	40605.167	48773.938	48773.938
TR	Transportation	4788.161	89469.342	119594.639	119594.639
UR	Urban	2414.445	46680.597	46680.597	46680.597
Total		**20008.224**	**199720.973**	**262961.518**	**272038.945**

Table 3. Contribution of Feature Type to Total Human Footprint within Carcross Caribou Herd Winter Range Expressed as a Proportion of the Total Human Footprint

Feature Label	Feature Type Description	Contribution of each feature type to total human footprint within study area (% of total human footprint)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AGAGL	Agricultural Land	12.59	3.34	4.42	4.27
AGGRL	Grazing Lease	1.89	0.19	0.67	0.65
INCUT	Cut Block	1.42	1.02	3.52	3.41
INEUC	Electrical Utility Corridor	2.64	5.29	4.01	3.88
INEXS	Excavation Site	1.15	1.15	2.30	5.56
INMST	Mine Site / Tailings	2.08	0.51	0.39	0.37
INSCL	Survey Cut Line	0.11	0.01	2.91	2.81
REBAC	Backcountry Camp	0.03	1.39	1.05	1.02
REHUT	High Use Trail	0.35	7.29	5.54	5.36
RELUT	Low Use Trail	0.83	9.71	7.37	7.13
REMUT	Moderate Use Trail	0.07	1.94	1.47	1.42
REWRA	Winter Recreational Area	40.83	0.00	3.11	3.00
TRAIR	Airstrip	0.02	0.09	0.19	0.19
TRPRI	Primary Road	17.19	15.96	22.64	21.89
TRRAI	Railroad	0.86	2.91	2.21	2.14
TRROU	Rough Road	4.01	21.60	16.40	15.86
TRRUR	Rural Road	1.28	3.26	2.48	2.40
TRSEC	Secondary Road	0.27	0.67	1.09	1.06
TRSUB	Subdivision Road	0.29	0.30	0.46	0.44
URCIN	Commercial / Industrial Sites	0.68	2.13	1.62	1.56
URCIT	City of Whitehorse	1.50	0.15	0.11	0.11
URPUR	Public Recreation Sites	0.87	1.12	0.85	0.83
URPUS	Public Service Sites	0.27	1.90	1.44	1.40
URRRE	Rural Residences	8.60	17.53	13.32	12.87
URURR	Urban Residences	0.14	0.53	0.41	0.39
Total		**100.00**	**100.00**	**100.00**	**100.00**

Table 4. Contribution of Feature Class to Total Human Footprint within Carcross Caribou Herd Winter Range Expressed as a Proportion of the Total Human Footprint

Feature Class	Feature Class Description	Contribution of each feature class to total human footprint within study area (% of total human footprint)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AG	Agricultural	14.48	3.53	5.09	4.92
IN	Industrial	7.41	7.97	13.13	16.03
RE	Recreation	42.11	20.33	18.55	17.93
TR	Transportation	23.93	44.80	45.48	43.96
UR	Urban	12.07	23.37	17.75	17.16
Total		**100.00**	**100.00**	**100.00**	**100.00**

Table 5. Contribution of Feature Type to Total Human Footprint within Carcross Caribou Herd Winter Range in Hectares (sum of all dissolved cumulative polygons)

Feature Label	Feature Type Description	Contribution of each feature type to total human footprint within study area (ha)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AGAGL	Agricultural Land	2443.704	3254.923	5458.562	5310.096
AGGRL	Grazing Lease	367.795	184.812	828.773	806.231
INCUT	Cut Block	276.536	989.560	4354.608	4236.169
INEUC	Electrical Utility Corridor	513.312	5147.390	4961.895	4826.937
INEXS	Excavation Site	222.363	1116.406	2846.571	6920.060
INMST	Mine Site / Tailings	403.973	494.944	477.108	464.131
INSCL	Survey Cut Line	22.214	10.962	3594.336	3496.575
REBAC	Backcountry Camp	6.604	1351.712	1303.000	1267.560
REHUT	High Use Trail	68.436	7104.080	6848.071	6661.812
RELUT	Low Use Trail	160.610	9455.718	9114.964	8867.048
REMUT	Moderate Use Trail	14.179	1889.056	1820.980	1771.452
REWRA	Winter Recreational Area	7927.204	0.000	3839.843	3735.404
TRAIR	Airstrip	4.501	87.309	239.783	233.261
TRPRI	Primary Road	3337.194	15547.956	27986.854	27225.646
TRRAI	Railroad	167.863	2835.019	2732.854	2658.524
TRROU	Rough Road	779.503	21034.215	20276.209	19724.721
TRRUR	Rural Road	248.994	3179.032	3064.470	2981.120
TRSEC	Secondary Road	52.512	649.793	1350.304	1313.577
TRSUB	Subdivision Road	56.000	295.200	566.627	551.215
URCIN	Commercial / Industrial Sites	132.616	2075.567	2000.770	1946.352
URCIT	City of Whitehorse	290.584	146.017	140.755	136.927
URPUR	Public Recreation Sites	169.748	1094.753	1055.302	1026.599
URPUS	Public Service Sites	52.257	1850.673	1783.981	1735.459
URRRE	Rural Residences	1670.024	17076.046	16460.680	16012.970
URURR	Urban Residences	27.817	520.109	501.366	487.729
Total		**19416.542**	**97391.252**	**123608.666**	**124397.575**

Table 6. Contribution of Feature Class to Total Human Footprint within Carcross Caribou Herd Winter Range in Hectares (sum of all dissolved cumulative polygons)

Feature Class	Feature Class Description	Contribution of each feature class to total human footprint within study area (ha)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AG	Agricultural	2811.500	3439.735	6287.335	6116.328
IN	Industrial	1438.398	7759.262	16234.519	19943.872
RE	Recreation	8177.033	19800.565	22926.858	22303.276
TR	Transportation	4646.566	43628.524	56217.100	54688.064
UR	Urban	2343.045	22763.166	21942.854	21346.036
Total		**19416.542**	**97391.252**	**123608.666**	**124397.575**

Table 7. Contribution of Feature Type to Total Human Footprint within Carcross Caribou Herd Winter Range Expressed as a Proportion of the Entire Study Area

Feature Label	Feature Type Description	Contribution of each feature type to total human footprint within study area (% of study area)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AGAGL	Agricultural Land	0.42	0.56	0.93	0.91
AGGRL	Grazing Lease	0.06	0.03	0.14	0.14
INCUT	Cut Block	0.05	0.17	0.74	0.72
INEUC	Electrical Utility Corridor	0.09	0.88	0.85	0.83
INEXS	Excavation Site	0.04	0.19	0.49	1.18
INMST	Mine Site / Tailings	0.07	0.08	0.08	0.08
INSCL	Survey Cut Line	0.00	0.00	0.61	0.60
REBAC	Backcountry Camp	0.00	0.23	0.22	0.22
REHUT	High Use Trail	0.01	1.22	1.17	1.14
RELUT	Low Use Trail	0.03	1.62	1.56	1.52
REMUT	Moderate Use Trail	0.00	0.32	0.31	0.30
REWRA	Winter Recreational Area	1.36	0.00	0.66	0.64
TRAIR	Airstrip	0.00	0.01	0.04	0.04
TRPRI	Primary Road	0.57	2.66	4.79	4.66
TRRAI	Railroad	0.03	0.48	0.47	0.45
TRROU	Rough Road	0.13	3.60	3.47	3.37
TRRUR	Rural Road	0.04	0.54	0.52	0.51
TRSEC	Secondary Road	0.01	0.11	0.23	0.22
TRSUB	Subdivision Road	0.01	0.05	0.10	0.09
URCIN	Commercial / Industrial Sites	0.02	0.36	0.34	0.33
URCIT	City of Whitehorse	0.05	0.02	0.02	0.02
URPUR	Public Recreation Sites	0.03	0.19	0.18	0.18
URPUS	Public Service Sites	0.01	0.32	0.31	0.30
URRRE	Rural Residences	0.29	2.92	2.82	2.74
URURR	Urban Residences	0.00	0.09	0.09	0.08
Total		**3.32**	**16.66**	**21.14**	**21.28**

Table 8. Contribution of Feature Class to Total Human Footprint within Carcross Caribou Herd Winter Range Expressed as a Proportion of the Entire Study Area

Feature Class	Feature Class Description	Contribution of each feature class to total human footprint within study area (% of study area)			
		Direct	Indirect – Low	Indirect – Moderate	Indirect – High
AG	Agricultural	0.48	0.59	1.08	1.05
IN	Industrial	0.25	1.33	2.78	3.41
RE	Recreation	1.40	3.39	3.92	3.82
TR	Transportation	0.79	7.46	9.62	9.35
UR	Urban	0.40	3.89	3.75	3.65
Total		**3.32**	**16.66**	**21.14**	**21.28**