Grizzly Bear Habitat Assessment of Quesnel Highlands (Penfold, Eastside and Wasko-Lynx Landscape Units), Central British Columbia

FINAL REPORT

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1. BACKGROUND

The mapping and evaluation of important grizzly bear habitats in the Quesnel Highlands Area is considered a priority under the Cariboo-Chilcotin Land Use Plan (Province of British Columbia 1995). To date, no formal grizzly bear habitat inventory has been conducted within the majority of the Quesnel Highlands. However, the area is considered to contain significant grizzly bear habitat. A variety of land uses occur around Quesnel Lake including forest harvesting, hunting, angling and a number of non-consumptive recreation activities. In order to support current forest management and future integrated resource management decisions grizzly bear habitat inventory and assessment is required.

Portions of the Quesnel Highlands (QUH) and adjacent Cariboo Mountains (CAM) Ecosections have received 1:50,000 scale Terrestrial Ecosystem Mapping (TEM) with associated grizzly bear habitat suitability ratings (Geowest 1998). In that project, grizzly bear habitat suitability rankings were developed based on the British Columbia system of provincial habitat evaluation, where habitat units are ranked against provincial "benchmark" areas of recognised habitat quality. While this approach provides a general landscape-level assessment of relative habitat quality between geographic areas, the approach does not incorporate place-specific, or "patch" habitat values. In order to provide a more accurate representation of grizzly bear habitat values within the Quesnel Highlands project area, place-specific habitat values require delineation, description and assessment.

This report describes the methods and results of a 1:20,000 scale grizzly bear habitat assessment and mapping project completed by Applied Ecosystem Management Ltd. (AEM) for three Landscape Units, Penfold, Eastside and Wasko-Lynx, within a portion of the Quesnel Highlands Ecosection in central British Columbia.

2. OBJECTIVES

The major objective of this project was to conduct an inventory and qualitative ranking of important grizzly bear habitats within three landscape units of the Quesnel Highlands Ecosection; Penfold, Eastside and Wasko-Lynx. Specific objectives included the following:

- Through field observation, data collection and literature review, provide information about grizzly bear habitat values and temporal patterns of use within the project area;
- Update existing 1:50,000 scale TEM mapping by delineating polygons of important spring, summer and fall grizzly bear habitat within the project area at a scale of 1:20,000;
- Develop a detailed, place-specific assessment of grizzly bear habitat values by incorporating habitat unit attributes such as inherent habitat quality and landscape position (adjacency to high value habitats, grizzly bear travel corridors, roads, forest harvest blocks and industrial camps);

- Identify forest areas, primarily second growth areas that would represent candidate locations for restorative forestry treatments that would improve current and future grizzly bear forage, primarily in relation to the modification of canopy closure and berry-feeding opportunities.

3. PROJECT AREA

The project area is located within the northeastern portion of the Cariboo Forest Region in central British Columbia (Figure 1). The 88,350 ha project area is adjacent to the North Arm of Quesnel Lake and is formed by three Landscape Units: Penfold, Eastside and Wasko-Lynx. The majority of the project area occurs within the Quesnel Highlands (QUH) Ecosection, with a small portion of the northern project area in the Cariboo Mountains (CAM). Five Biogeoclimatic subzones are found within the project area; vertical zonation is the most important ecological gradient. The lowest elevations around Quesnel Lake are ICHwk2, with the middle-forested slopes grading through the ESSFwk1 and ESSFwc3 and then into parkland ESSFwcp3. A significant portion of the project area contains non-forested alpine, ATp (Figure 1). This diverse ecological setting provides a variety of seasonally important habitats for grizzly bears, including valley bottom forests and wetlands, non-forested avalanche chutes, early successional burns, subalpine meadows and seeps and salmon spawning areas. The project area is bordered by the Cariboo Mountains Provincial Park to the north and east and bordered by Quesnel Lake to the west and south.

The West Fraser Mills Ltd. Penfold logging camp is located in the central portion of the Penfold Landscape Unit on the lower slopes above the lower Penfold River (Figure 1). No other permanent work camps or town sites are situated within the project area. Access to the Penfold Camp is possible only by boat, helicopter or small fixed-wing aircraft; a small airstrip lies adjacent to Penfold Camp. Forest harvesting on the lower and middle-elevation slopes of the ICHwk2 and ESSFwk1 has been the most significant human land use; a small but intensive network of permanent and non-permanent logging roads has been developed to support these activities.

TEM mapping at a scale of 1:50,000 for the entire project area (Geowest 1998) and 1:20,000 for the Penfold Landscape Unit (Bruhjell et al. 1998) was available with associated wildlife suitability rankings. Updates were made only to the 1:50,000 scale TEM. The primary reference for site series classification within the Cariboo Forest Region is Land Management Handbook 39 (Steen and Coupé 1997).

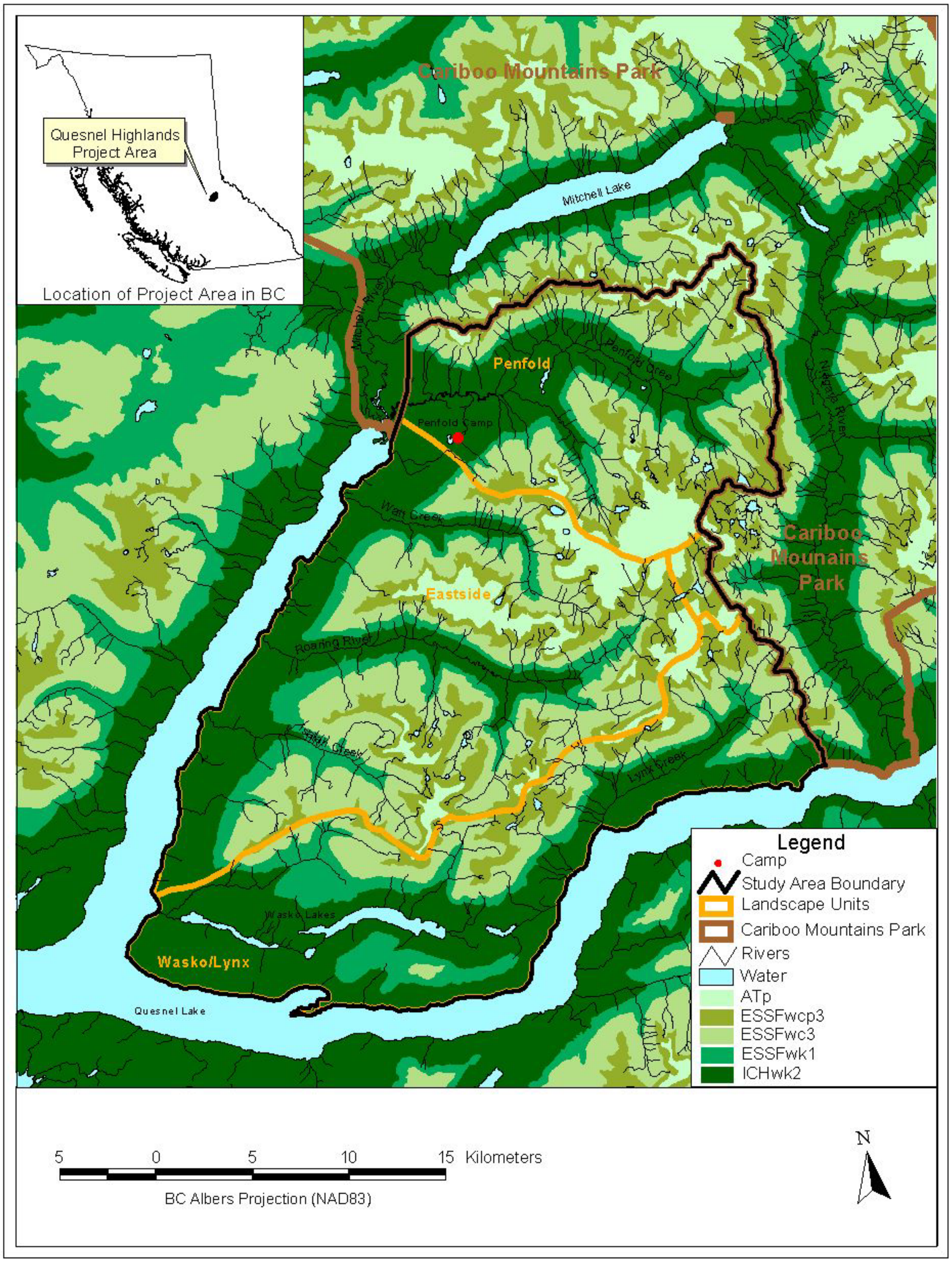

Figure 1. Location and Ecological Setting of Quesnel Highlands Project Area. Three Main Landscape Units, Penfold, Eastside and Wasko/Lynx, comprise the study area.

4. METHODS

Methods for this project involved three major phases, 1) pre-field planning, 2) field sampling and 3) post-field data analysis and mapping. The following sections provide a detailed description of all project methods.

4.1 PRE-FIELD PLANNING

4.1.1 LITERATURE REVIEW AND MODEL ASSUMPTIONS

Research studies of radio collared grizzly bears in the Wet Columbia Mountains were reviewed (Simpson et al. 1985; Munro 1999; Ramcharita 2000; Apps et al. in press) and grizzly bear food habits, habitat use patterns and seasons of use were interpreted. Data on habitat use and movements of grizzly bears within a salmon system were interpreted from data collected on radio collared grizzly bears in coastal British Columbia (Hamilton 1987; MacHutchon et al. 1993). Tables 1 - 3 summarize the seasonal food habits and habitat use patterns of grizzly bears in the Quesnel Highlands project area based on these literature sources. Grizzly bears may adopt one, or a combination of the three main strategies within the project area. These strategies can be characterized by the primary foods exploited during fall: 1) low elevation - fall salmon feeders, 2) elevational migrants - fall root and rodent feeders and 3) elevational migrants - fall berry feeders. Research in the Wet Columbia Mountains provides data on the variation in habitat use patterns of grizzly bears which allows for the delineation of two separate elevational migrant strategies: between early August and the end of September 1) some bears (most males and some females) show a strong selection towards early successional burns, 2) while others (mostly females) show a strong selection towards sub-alpine units (Munro 1999). Delineation of these three strategies aims to ensure that the diversity of grizzly bear habitat use patterns is considered in the delineation of critical grizzly bear habitat within the Quesnel Highlands project area. Seasons in the Quesnel Highlands project area are defined consistently across strategies as: Spring (late April – mid July); Summer (late July – late August) and Fall (early September – mid November). Bear seasons are uniquely defined within each strategy to reflect differences in estimated timing of phenology and grizzly bear food habits. In this project, the following definitions are employed:

Pre-green up refers to the period prior to vegetation growth (vegetative stage = 0, Land Management Handbook #25, Province of British Columbia, 1998) and extends at lower elevations (≤ 1500m) from den emergence to approximately late April.

Green-up refers to the period of vegetative growth (vegetative stages = 1 – 5 inclusive, Land Management Handbook #25, Province of British Columbia, 1998) and extends at lower elevations from roughly early May to mid July. The period of green-up continues at higher elevations into late July (≤ ~1800m) and into late August (> ~1800m).

Post-green up refers to the period of vegetative senescence (vegetative stages = 6 – 10 inclusive, Land Management Handbook #25, Province of British Columbia, 1998) and marks the end of the period bears will feed on green vegetation: this roughly corresponds to mid-July at lower elevations (< 1500m); to early August (< 1800m) and to early September (> ~1800m).

The **berry** season refers to the period when shrubs bear ripe or overripe fruit (generative stages = 11 – 12, Land Management Handbook #25, Province of British Columbia, 1998) and extends at lower elevations from roughly mid July to late August. At higher elevations the berry season extends from approximately early August to early October (≤ ~1800m) and to early November (> ~1800m).

The **salmon** season refers to the period when spawning salmon are within the project area and available to grizzly bears. This period extends from early September to den entry.

Denning refers to the period grizzly bears spend in hibernation. At lower elevations this period may extend from ~ mid November to ~ mid April. At higher elevations denning may extend from ~ mid October to ~ early May. There is variation in the timing of den entry and den emergence in grizzly bears; mostly between sex-age classes: adult males typically remaining active for longer periods (late den entry and early den emergence) and adult females and sub adults remaining in hibernation for longer (early den entry and late den emergence). These denning dates are therefore approximate and represent the times when the majority of bears enter and emerge from their dens.

4.1.1.1 Strategy 1: Low Elevation - Fall Salmon Feeders

Low elevation grizzly bears concentrate their activities throughout their active seasons within the valley bottoms and lower slopes below (Table 1). During pre-green up (i.e. from den emergence to ~ late April) some grizzly bears will feed on winter weakened moose in the willow dominated habitats of the valley bottoms. During green up (i.e. early May – mid July) grizzly bears feed on grasses, sedges, horsetails, forbs and roots in the avalanche chutes, wetlands, forested and non-forested seeps of the valley bottoms and lower slopes. During the berry season (i.e. mid July – late August) grizzly bears feed on the berries of a variety of species that can be found in the forested and non-forested receiving slopes and floodplain units of the lower elevations. Berry producing species include *Vaccinium spp.*, *Viburnum edule*, *Lonicera involucrata*, *Sambucus racemosa*, *Sorbus spp.*, *Amelanchier alnifolia*, *Rubus spp.*, *Oplopanax horridus*, *Ribes spp.*, *Cornus stolonifera*, *Prunus spp.*, *Shepherdia canadensis*, *Smilacina spp.* and *Streptopus spp.*. During the salmon season (early September to den entry) bears will fish for spawning salmon and feed on the carcasses of spawned out salmon. Sockeye salmon (*Oncorhynchus nerka*) is the most abundant salmon in the project area but kokanee (non-anadromous *Oncorhynchus nerka*), coho (*Oncorhynchus kisutch*) and chinook (*Oncorhynchus tshawytscha*) also spawn within the project area. The distribution of spawning locations of kokanee, coho and chinook occurs within the distribution of sockeye spawning locations (Tony Rathbone pers. comm.). The earliest salmon in to the system are the chinook and sockeye: these fish begin spawning within the project area in late August. The latest salmon to spawn in this system are the shore spawning kokanee and coho: these fish finish spawning in mid November. Although the majority of bears likely enter their dens by mid November, there has been an observation of a grizzly bear remaining active feeding on the carcasses of spawned out kokanee into late November (Rob Dolighan, pers. comm.). There has also been documentation of grizzly bears in other areas feeding on coho into December (Schoen et al. 1987; pers. obs.). The primary foods during these grizzly bears' hyperphagic period are therefore salmon and to a lesser extent, berries.

Table 1. Food habits and seasonal habitat use patterns of grizzly bears following Strategy 1 (Low elevation - fall salmon feeders).

Seasons	Months	Bear Seasons	Food Habits/Activity	Habitat Use
Spring	late April	Pre-green up	Ungulates	Willow dominated habitats of the valley bottoms
	early May	Green-up	Grasses, sedges, horsetails, forbs, shoots and roots	Avalanche chutes[1, 2, 4, 5, 7, 8,] wetlands, forested and non-forested seeps of the lower slopes and valley bottoms[4, 5, 8]
	late May	Green-up		
	early June	Green-up		
	late June	Green-up		
	early July	Green-up		
Summer	late July	Berry	Low elevation berries	Floodplain units and forested and non-forested receiving slopes of the lower slopes and valley bottoms[4, 5, 8]
	early Aug	Berry		
	late Aug	Berry		
Fall	early Sep	Salmon	Salmon and skunk cabbage	Valley bottoms and forested seeps of the lower slopes[4, 8]
	late Sep	Salmon		
	early Oct	Salmon		
	late Oct	Salmon		
	early Nov	Salmon		

[1]Munro 1999; [2]Ramcharita 2000; [3]Bruhjell et al. 1998; [4]MacHutchon et al. 1993; [5]Simpson et al. 1995; [6]Munro pers. comm.; [7]Apps et al. in press; [8]Hamilton 1987.

4.1.1.2 Strategy 2: Elevational Migrants - Fall Root and Rodent Feeders

Elevational migrant grizzly bears make significant elevational movements throughout their active year, exploiting habitats below 1500m and above 1800m (Table 2). During green-up (i.e. early May to late August) these grizzly bears feed on grasses, sedges, horsetails, forbs and roots (*Erythronium grandiflorum* and *Claytonia lanceolata*) in the avalanche chutes, tracking the changes in phenology of these food types with increasing elevation as the season progresses. Between early May and early July bears feed in the avalanche chutes of the lower elevation slopes (below ~1500m), while later in the season (late July to late August) they feed in the avalanche chutes, subalpine meadows and forested and non-forested seeps at higher elevations (above ~1500m). During post-green up (from early September to den entry) bears are believed to continue to feed on roots in sub-alpine meadows, forested and non-forested seeps and hunt for rodents (*Spermophilus columbianus* and *Marmota caligata*) in the sub-alpine meadows and talus slopes (above ~1500m) until they enter their den in approximately mid October. The primary foods during these grizzly bears' hyperphagic period are roots and rodents.

4.1.1.3 Strategy 3: Elevational Migrants - Fall Berry Feeders

These bears also make significant elevational movements throughout their active year and follow a similar pattern of movement from green-up to late July as the bears following Strategy 2; feeding on grasses, sedges, horsetails, forbs and roots in the avalanche chutes of the lower elevation slopes and of the higher elevation slopes below ~1800m (Table 3). Habitat use patterns of these two groups of bears diverge in early August when bears following Strategy 3 move to the early successional burns to feed on *Vaccinium spp.* and *Shepherdia canadensis* where it occurs. From mid October to den entry bears may continue to feed on other berry species (*Arctostaphylos uva-ursi* and *Empetrum nigrum*) at higher elevations in sub alpine and alpine meadows (> 1800m) and hunt for rodents (*Spermophilus columbianus* and *Marmota caligata*) in the sub-alpine meadows and talus slopes. The primary foods during these grizzly bears' hyperphagic period are berries.

4.1.2 FIELD SAMPLING STUDY DESIGN

Habitat types identified as being of high value to grizzly bears from the literature (Simpson et al. 1985; Hamilton 1987; MacHutchon et al. 1993; Munro 1999; Ramcharita 2000; Apps et al. in press) were translated into TEM ecosystem units by the project grizzly bear ecologist and plant ecologist. Field data collection aimed to refine and ground-truth the assumptions of grizzly bear food habits, habitat use patterns, timing of use, season definitions and habitat translations interpreted from the literature. Sampling therefore focused on the habitat types suspected from the literature to be of high value to grizzly bears. Examples of these units were identified during pre-field airphoto interpretation. Field sampling was distributed across Penfold, Eastside and Wasko-Lynx landscape units in an attempt to capture the ecological variation within the project area. A secondary goal of the field session was to sample a representative of all ecosystem units. Most cut blocks within the project area occur at lower elevations within the ICHwk2 and ESSFwk1 subzones. A small number of cut blocks were sampled within these subzones on both cool and warm aspects in order to ground truth assumptions of grizzly bear habitat value of the component ecosystem units.

Table 2. Food habits and seasonal habitat use patterns of grizzly bears following Strategy 2 (Elevational migrants - fall root and rodent feeders)

Seasons	Months	Bear Seasons	Food Habits/Activity	Habitat Use
Spring	Late April	Den	Hibernation	Timber adjacent to upper avalanche chutes[4] and sub-alpine shrub/krumholz[3]
	Early May	Green-up	Grasses, sedges, horsetails, forbs, roots and later rodents	Avalanche chutes[1, 2, 4, 5, 7, 8]
	Late May	Green-up		
	Early June	Green-up		
	Late June	Green-up		
	Early July	Green-up		
Summer	Late July	Green-up		Avalanche chutes[1, 2, 5, 7], sub-alpine meadows[1, 2], forested and non-forested seeps and sub-alpine meadows and talus slopes where rodents are found[6]
	Early Aug	Green-up		
	Late Aug	Green-up		
Fall	Early Sep	Post green-up	Roots (glacier lilies and spring beauty) and rodents	Sub-alpine meadows, forested and non-forested seeps[1, 2] where roots are found and sub-alpine meadows and talus slopes where rodents are found[6]
	Late Sep	Post green-up		
	Early Oct	Post green-up		
	Late Oct	Den	Hibernation	Timber adjacent to upper avalanche chutes[4] and sub-alpine shrub/krumholz[3]
	Early Nov	Den		

[1]Munro 1999; [2]Ramcharita 2000; [3]Bruhjell et al. 1998; [4]MacHutchon et al. 1993; [5]Simpson et al. 1995; [6]Munro pers. comm.; [7]Apps et al. in press; [8]Hamilton 1987.

Table 3. Food habits and seasonal habitat use patterns of grizzly bears following Strategy 3 (Elevational migrants - fall berry feeders).

Seasons	Months	Bear Seasons	Food Habits/Activity	Habitat Use
Spring	Late April	Den	Hibernation	Timber adjacent to upper avalanche chutes[4] and sub-alpine shrub/krumholz[3]
	Early May	Green-up	Grasses, sedges, horsetails, forbs and roots	Avalanche chutes[1, 2, 4, 5, 7, 8]
	Late May	Green-up		
	Early June	Green-up		
	Late June	Green-up		
	Early July	Green-up		
Summer	Late July	Green-up		
	Early Aug	Berry	High elevation berries, e.g., black huckleberry in burns	Early successional burns and shrubfields[1, 5, 7]
	Late Aug	Berry		
Fall	Early Sep	Berry		
	Late Sep	Berry		
	Early Oct	Berry		
	Late Oct	Post-berry	Rodents and berries, e.g., bearberries and crowberries	Sub-alpine meadows[6] and talus slopes where rodents are found and sub-alpine meadows where bearberries and crowberries are found
	Early Nov	Post-berry		

[1]Munro 1999; [2]Ramcharita 2000; [3]Bruhjell et al. 1998; [4]MacHutchon et al. 1993; [5]Simpson et al. 1995; [6]Munro pers. comm.; [7]Apps et al. in press; [8]Hamilton 1987.

4.2 FIELD SAMPLING

4.2.1 FIELD SAMPLING PROGRAM

All field work performed in support of this project was completed between August 21st and 31st, 2001. Due to the inaccessibility of the Quesnel Highlands project area, most field work was completed through helicopter assisted sampling using the West Fraser Penfold logging camp as a primary base. Watercraft-assisted sampling was also used along portions of Quesnel Lake in the ICHwk2. Vehicle-assisted sampling was also conducted in the ICHwk2 and lower ESSFwk1, where most logging roads occur. Marie Gallagher (grizzly bear ecologist) and Samuel Skinner (plant ecologist) completed all field work.

4.2.2 FIELD FORMS AND DATA COLLECTION

In order to fulfill the goals of this project, portions of four field forms were used. Two forms were used to collect information on vegetation and terrestrial ecosystems; Ground Inspection Form (GIF) and the Vegetation Ecosystem Field Form (FS882(3) HRE 98/5). Grizzly bear activity and habitat suitability information was collected with a custom-designed Grizzly Bear Activity field form based on a number of different sources, most notably a modification of previous forms used by Grant MacHutchon, and through modified use of the Wildlife Habitat Assessment Field Form (FS882(5) HRE 98/5). Examples of all field forms are contained in Appendix One.

Ground Inspection Forms were chosen due to the range of vegetation and terrain information that can be collected, plus the additional benefit of being able to assess habitat unit complexes within a single polygon. Ground Inspection Forms are well suited to the assessment of high value grizzly bear patch habitats within a single polygon, thereby facilitating improved interpretation of place-specific context for the habitat patches. Detailed vegetation information was recorded for a representative sub-set of high-value habitat patches on the Vegetation Ecosystem Field Form.

The Management section of the Wildlife Habitat Assessment Form was used to record information on human disturbed ecosystems (i.e. forest harvest blocks). The Grizzly Bear Activity Form contains a range of attributes relevant to the assessment of grizzly bear habitat suitability, such as forage potential, animal food potential and cover values (Appendix One). The Grizzly Bear Activity Form also provides more detailed information of grizzly bear use sites through documentation of sign. Grizzly Bear Activity Forms, as displayed in Appendix One, were therefore used instead of the Evidence of Use section in the Wildlife Habitat Assessment Form.

4.3 POST-FIELD ANALYSIS AND MAPPING

4.3.1 TERRESTRIAL ECOSYSTEM MAPPING – POLYGON REVISIONS

The existing ecosystem database of the 1:50,000 scale TEM coverage (Geowest 1998) was updated to incorporate grizzly bear habitat inclusions and corrections of errors in polygon classification. These errors were discovered during the AEM 2001 field season and post-field session airphoto interpretation. In some cases original TEM polygons were reclassified with new ecosystem units or updated with revised ecosystem unit proportions. In other cases, polygon revisions included the splitting of original polygons into 2 or more, smaller polygons. Changes to the TEM ecosystem database were tracked (field entitled *"updates"* in "*tem_gb_final.e00*" coverage). Habitat revisions were made at the 1:20,000 scale and focused only on those habitats identified as being of high value to grizzly bears. The goal of these revisions was to map high value grizzly bear habitat where it had been previously omitted in the ecosystem database due to smaller mapping scale (i.e. 1:50,000 scale compared with 1:20,000 scale). In most cases, grizzly bear habitat inclusions were incorporated into existing polygons as secondary or tertiary ecosystem units but when necessary, inclusions were mapped as either pure (i.e. polygons containing only one ecosystem unit) or complex polygons (i.e. polygons containing two or three ecosystem units). Every effort was made to follow provincial TEM guidelines (RIC 1998) regarding minimum polygon size (2 ha at 1:20,000 scale mapping) but in 13 situations small habitat inclusions of < 2 ha could not be incorporated into existing polygons and were instead mapped as new polygons. The smallest of these mapped polygons is 0.81 ha in size.

The extraction of the Quesnel Highlands project area from the original TEM coverage resulted in 96 slivers of < 2 ha along the boundary of the project area; this was due to the difference in mapping scale between the project area boundary and TEM. The splitting of TEM polygons within salmon, grizzly bear travel and displacement buffers (see Section 4.3.4) introduced many slivers and small polygons into the TEM coverage. These mapping artefacts were eliminated from the database using ArcInfo: polygons smaller than the smallest mapped polygon of 0.81 ha (except those containing water features) were merged with the neighbouring polygon which shared the longest common edge. A total of 940 polygons were merged in this way. When all polygon revisions and alterations were complete all polygons were assigned a new and unique number.

4.3.2 ECOSYSTEM UNIT RANKING - RATINGS TABLE 1

A preliminary list of ecosystem units was made based on the occurrence of all ecosystem units within the project area mapped during the 1:50,000 TEM (Geowest 1998). Ecosystem units mapped during the Penfold Landscape Unit 1:20,000 TEM (Bruhjell et al. 1998) were also incorporated into this list (i.e. ICHwk2: AS, SB, SR and ESSFwc3: AS). One additional ecosystem unit (ICHwk2: WD6) was identified during the AEM 2001 field season. Two ecosystem unit modifiers (w = warm; a = active floodplain) and one disturbance type (F = fire) were identified during the AEM 2001 field season as necessary to adequately classify the diversity of grizzly bear values within ecosystem units. For example, all ecosystem units classified with a warm modifier and a fire disturbance class were ranked higher during summer (and in most cases during fall) than the same ecosystem unit lacking any specific modifiers or disturbance types.

Wildlife ratings calculated during the 1:50,000 TEM (Geowest 1998) were not utilised during our rating process for the following reasons: 1) this study mapped grizzly bear habitat at a finer mapping scale (1:20,000 as opposed to 1:50,000); 2) this study derived wildlife ratings from habitat use data of radio-collared grizzly bears as opposed to predictions of use based on the abundance of grizzly bear plant foods; 3) this study rated ecosystem units for living during spring, summer and fall as opposed to only feeding; and 4) new field data have recently been collected on grizzly bear habitat use patterns and food habits within the Wet Columbia Mountains (Munro 1999; Ramcharita 2000; Apps et al. in press.). Consequently, the present study utilised these data to better predict habitat use patterns and food habits of bears within the Quesnel Highlands project area based on data from ecologically similar areas. In contrast, the Geowest (1998) wildlife ratings were based on grizzly bear studies from ecologically dissimilar areas in the Rocky Mountains, primarily the East Slopes and Yukon Northern Interior.

Tables 4 – 6 summarize the translation of habitat types identified from the literature as being of high value to grizzly bears into TEM ecosystem units for each of the three grizzly bear strategies. The tables list only those ecosystem units which rank 1 or 2 during spring, summer and fall. Ecosystem units were ranked to incorporate the value of mammalian prey when a strong association existed between the habitat use patterns of mammalian prey (notably moose, ground squirrel and marmot), timing of grizzly bear use of these prey, and evidence of use in the Quesnel Highlands project area. Field work conducted in the Quesnel Highlands (AEM 2001 field season; Bruhjell et al. 1998) indicated that ecosystem units ICHwk2: WW, ST, WD and WS and ESSFwk1: WS were strongly associated with the presence of moose during early spring when grizzly are most likely to be feeding on ungulate prey (McLellan and Hovey 1995; Riddell in prep.). Field work (AEM 2001 field season) also indicated that ecosystem units ESSFwcp3: HL and HV were associated with ground squirrel presence during fall when grizzly bears are most likely to be feeding on these rodents (Munro pers. comm.). Ecosystem unit ESSFwcp3: TA was likewise associated with marmots during fall.

Wildlife ratings for each ecosystem unit mapped within the project area are listed in Ratings Table 1 (Appendix Two). Ecosystem units were ranked according to the 6 class rating scheme (RIC 1999) and compared to examples of provincial benchmarks familiar to the project grizzly bear ecologist through field and research experience in those areas (i.e. Khutzeymateen Inlet; Taku River; Columbia River; Flathead River). Wildlife ratings assigned to each TEM ecosystem unit were derived from the density of grizzly bear radio locations (reflecting the amount of time spent) within the corresponding habitat type. Wildlife ratings therefore do not separate feeding value from other values the habitat type provides (e.g. thermal/security values) and better represent *living* values than *feeding* values alone (RIC 1999). These wildlife ratings consider the value of the ecosystem unit in isolation of its landscape context. This assessment is equivalent to the plot-type assessment outlined in the Wildlife Habitat Assessment Field Form (FS882(5) HRE 98/5).

Table 4. TEM ecosystem unit translations from habitat use patterns of grizzly bears following Strategy 1 (Low elevation - fall salmon feeders).

Season	Food Habits/Activity	Habitat Use	High Value TEM Ecosystem Units
Spring	Ungulates	Willow dominated habitats of the valley bottoms	ICHwk2: WWa3; WGa3; WD3,6 ESSFwk1: WS3; WC3
	Grasses, sedges, horsetails, forbs, shoots and roots	Avalanche chutes[1, 2, 4, 5, 7, 8,] wetlands, forested and non-forested seeps of the lower slopes and valley bottoms[4, 5, 8]	ICHwk2: AF2,3; PF2; AS3; AL2,3; RC2-7; WD2,3,6; ST2; SBa2,3; WGa2,3; WWa2,3 ESSFwk1: AF2,3; BV2,3; PF2; AL2; FH2; FT2; SM2; WC2,3; WS2,3
Summer	Low elevation berries	Floodplain units and forested and non-forested receiving slopes of the lower slopes and valley bottoms[4, 5, 8]	ICHwk2: AS3; WD3,6; AL3; RC2-7; RDa3; RJw3F; SO3,6,7; ST3,6,7 ESSFwk1: AL3; FD3; FT3,6,7
Fall	Salmon and skunk cabbage	Valley bottoms and forested seeps of the lower slopes[4, 8]	ICHwk2: AS3; RC2-7; WD3,6

[1]Munro 1999; [2]Ramcharita 2000; [3]Bruhjell et al. 1998; [4]MacHutchon et al. 1993; [5]Simpson et al. 1995; [6]Munro pers. comm.; [7]Apps et al. in press; [8]Hamilton 1987.

Table 5. TEM ecosystem unit translations from habitat use patterns of grizzly bears following Strategy 2 (Elevational migrants - fall root and rodent feeders).

Season	Food Habits/Activity	Habitat Use	High Value TEM Ecosystem Units
Spring	Hibernation	Timber adjacent to upper avalanche chutes[4] and sub-alpine shrub/krumholz[3]	-
	Grasses, sedges, horsetails, forbs, roots and later rodents	Avalanche chutes[1, 2, 4, 5, 7, 8]	ICHwk2: AF2,3; PF2 ESSFwk1: AF2,3; BV2,3; PF2
Summer		Avalanche chutes[1, 2, 5, 7], sub-alpine meadows[1, 2], forested and non-forested seeps and sub-alpine meadows and talus slopes where rodents are found[6]	ESSFwc3: AF2,3; BV2,3; VG2; VM2; SM2; VD2; FA2-7; FG2; WV2,3 ESSFwcp3: BV2; VG2; VM2; FV2; HV2; HL2; VD2; SG2
Fall	Roots (glacier lilies and spring beauty) and rodents	Sub-alpine meadows, forested and non-forested seeps[1, 2] where roots are found and sub-alpine meadows and talus slopes where rodents are found[6]	ESSFwc3: FA2-7; VD2 ESSFwcp3: HL2; HV2; VD2
	Hibernation	Timber adjacent to upper avalanche chutes[4] and sub-alpine shrub/krumholz[3]	-

[1]Munro 1999; [2]Ramcharita 2000; [3]Bruhjell et al. 1998; [4]MacHutchon et al. 1993; [5]Simpson et al. 1995; [6]Munro pers.comm.; [7]Apps et al. in press; [8]Hamilton 1987.

Table 6. TEM ecosystem unit translations from habitat use patterns of grizzly bears following Strategy 3 (Elevational migrants - fall berry feeders).

Season	Food Habits/Activity	Habitat Use	High Value TEM Ecosystem Units
Spring	Hibernation	Timber adjacent to upper avalanche chutes[4] and sub-alpine shrub/krumholz[3]	-
	Grasses, sedges, horsetails, forbs and roots	Avalanche chutes[1, 2, 4, 5, 7, 8]	ICHwk2: AF2,3; PF2 ESSFwk1: AF2,3; BV2,3; PF2 ESSFwc3: AF2,3; BV2,3; VG2; VM2
Summer	High elevation berries, e.g., black huckleberry in burns	Early successional burns and shrubfields[1, 5, 7]	ESSFwc3: FRw3bF; FQw3bF
Fall	Rodents and berries, e.g., bearberries and crowberries	Sub-alpine meadows[6] and talus slopes where rodents are found and sub-alpine meadows where bearberries and crowberries are found	ESSFwcp3: HL2; HV2; VD2

[1]Munro 1999; [2]Ramcharita 2000; [3]Bruhjell et al. 1998; [4]MacHutchon et al. 1993; [5]Simpson et al. 1995; [6]Munro pers.comm.; [7]Apps et al. in press; [8]Hamilton 1987.

4.3.3 POLYGON RANKING - HABITAT SUITABILITY

The habitat suitability value for each polygon was calculated based only on the wildlife ratings determined for living within each ecosystem unit (Ratings Table 1 in Appendix Two) using the following rationale. Ecosystem units valued at rank ≥ 3 are omitted and habitat suitability is calculated using only those ecosystem units ranked as either 1 or 2. Habitat suitability is then calculated based on the product of the rank value of the ecosystem units and their decile proportion within each polygon. For the purposes of GIS analysis, rank values were reversed to reflect the higher value of a rank of 1 when using addition and multiplication in algorithms. For example, an ecosystem unit valued to be 1 (≅ 2) which covers 50% (= 5 deciles) of a polygon will receive a habitat suitability value of 10 (Calculation: 2 * 5 = 10). If this polygon also contained an ecosystem unit ranked as 2 (≅ 1) and this unit comprised 30% (= 3 deciles) of the polygon the overall habitat suitability value for this polygon would be 13 (Calculation: (2*5) + (1*3) = 13). The habitat suitability value would remain unchanged unless the remaining 20% of the polygon was comprised of an ecosystem unit valued to be either 1 or 2 in the primary ratings table. Habitat suitability values range from 0 to 20.

Since habitat suitability is calculated using only high value ecosystem units (i.e. with wildlife ranks of either 1 or 2), all polygons with habitat suitability values greater than zero are of high value to grizzly bears. The resulting coverage therefore displays ecosystem units with wildlife ratings of 1 or 2 wherever they occur. The advantage of this approach is that the significance of high value ecosystem units (1 or 2) is not diluted during a weighted average calculation by the presence of lower value ecosystem units within the same polygon. The resulting evaluation is believed to more closely represent grizzly bears habitat values.

4.3.4 MODIFICATION OF ECOSYSTEM UNIT RANKS

While the evaluation of habitat suitability is a useful tool to delineate polygons containing ecosystem units of intrinsically high value to grizzly bears, it does not consider polygon value in a landscape context. Incorporating the influence of habitat and non-habitat features into the evaluation of ecosystem units is fundamental to the accurate portrayal of grizzly bear habitat values within the project area. The approach outlined below is based on quantitative habitat information and more closely approaches a cumulative environmental effects assessment through the incorporation of additional values and potential displacement factors.

Wildlife ratings for each ecosystem unit were modified based on the proximity of habitat and non-habitat features to reflect the landscape context of the unit. This assessment is most similar to the plot-in-context assessment outlined in the Wildlife Habitat Assessment Field Form (FS882(5) HRE 98/5). The proximity of the following habitat and non-habitat features influence grizzly bear use of an ecosystem unit: spawning salmon (Hamilton 1987; MacHutchon et al. 1993); roads (McLellan and Shackleton 1988; Aune and Kasworm 1989; Mace et al. 1996); logging activity (incorporated into the impacts of roads) and industrial camps (BIOS 1996). The influence of the proximity of ecosystem units to predicted grizzly bear travel routes and linkage areas was also incorporated in this analysis. Each ecosystem unit was modified from its original wildlife ratings value assigned in Ratings Table 1 (Appendix Two) according to: 1) proximity to spawning salmon (value increased to a rank value of 1 during fall and left unchanged during spring and summer); 2) proximity to a grizzly bear travel route or linkage area (value increased by a value of 1 during all three seasons); 3) proximity to a road corridor (value decreased by a value of 1 during all three seasons) and 4) proximity to an industrial camp (rank value decreased by a value of 1 during all three seasons). Since the value of an ecosystem unit is greater when the rank value is lower (i.e. rank 1 is higher than rank 2), the calculation of modified ranks requires that the addition of values becomes a subtraction. For example, an ecosystem unit with an original wildlife ratings value of 2 during spring which lies within a grizzly bear travel corridor will be assigned a modified rank value of 1 (Calculation: 2 - (+1) = 1). An ecosystem unit with an original wildlife ratings value of 2 during spring which lies within a road corridor will be assigned a modified rank value of 3 (Calculation: 2 - (-1) = 3). This methodology requires a complete departure from provincial TEM guidelines (RIC 1998); new polygons are created where buffers associated with adjacent habitat and non-habitat features are overlaid on existing polygons. Table 7 provides a summary of the modifications to ecosystem unit wildlife ratings used in this project.

Table 7. Summary of modifications to ecosystem unit wildlife ratings.

Feature	Buffer Width	Modification of Ecosystem Unit Value	Season
Salmon Spawning Stream	150m	=1	Fall
Grizzly Bear Travel Route	150m	+1	Spring, Summer and Fall
Linkage Area	0m*	+1	Spring, Summer and Fall
Spur Roads (<1 vehicle/day)	250m	-1	Spring, Summer and Fall
Mainline Road (>1 vehicle/day)	500m	-1	Spring, Summer and Fall
Penfold Logging Camp	1000m	-1	Spring, Summer and Fall

(* polygons digitized by hand)

4.3.4.1 Spawning Salmon

Spawning salmon are a vital fall food for grizzly bears in many areas in B.C. (Hamilton 1987; MacHutchon et al. 1993). In areas where bears rely on spawning salmon as the primary fall food, salmon constitute the most significant source of energy during the hyperphagic period (i.e. the period when bears deposit the fat which will sustain them through winter hibernation, and supplement their diet through the spring until berries and salmon again become available). Grizzly bears are known to feed on spawning sockeye in the Mitchell River, in the Lower Penfold River (Riddell in prep) and throughout the Quesnel Highlands project area (Tony Rathbone pers. comm.). Grizzly bears have also been observed in the project area feeding on the carcasses and eggs of spawned out kokanee (Rob Dolighan, pers. comm.). It is assumed that grizzly bears feed on all the salmon species found within the project area: sockeye; kokanee; chinook and coho.

Grizzly bears who feed on spawning salmon during fall have been documented to use areas close to Class I streams more than expected (MacHutchon et al. 1993). The majority of radio locations during their salmon feeding season are found < 150m from a Class I stream. These data were used to determine the buffer width around salmon spawning streams in the Quesnel Highlands project area. This buffer reflects the concentration of grizzly bear use around salmon streams.

Sockeye spawning locations within the project area were obtained through communications with Department of Fisheries and Oceans (DFO) personnel and also a review of the DFO Quesnel Lake Sockeye Enumeration Program 2001 (unpub. report). All sockeye spawning sites were then digitised in ArcView using 1:20,000 TRIM base mapping. Since the distribution of spawning locations of kokanee, coho and chinook occurs within the distribution of sockeye spawning locations (Tony Rathbone pers. comm.), it was assumed that the delineation of sockeye spawning areas would also include those of kokanee, chinook and coho.

The salmon buffer of 150m around sockeye spawning locations was overlaid onto the original TEM coverage and a new TEM coverage created. Where the buffer intersected a portion of an existing polygon, the polygon was automatically split. When all polygon revisions and alterations were complete all polygons were assigned a new and unique number. Due to the significance of spawning salmon to grizzly bears, all areas within the 150m buffer were assigned a rank of 1 during the fall season. For example, an ecosystem unit with an original wildlife ratings value of 3 during fall which lies within 150m of a salmon spawning stream would be assigned a revised rank of 1 during fall, but would remain unchanged during spring and summer. However, if this unit also lay within a road buffer (-1), a camp buffer (-1) and a grizzly bear travel buffer (+1), the final modified ecosystem unit rank would be 2 during fall (see Sections 4.3.4.2 – 4.3.4.4).

4.3.4.2 Grizzly Bear Travel Corridors and Linkage Areas

Travel is an integral part of grizzly bear daily and seasonal movement patterns but is notoriously difficult to quantify without continual radio or GPS location data. Telemetry studies show that grizzly bears often use river corridors to travel between activity sites, especially in mountainous terrain (Photo 1). Travel routes may be used for short distance daily movements between feeding and bedding sites or longer distance movements between seasonally important feeding areas and between den sites and feeding areas during spring and fall.

Photo 1. Grizzly bear trail with mark tree on bench above Lower Penfold River (ICHwk2: HM5).

In an attempt to quantify significant grizzly bear travel routes, the main river corridors and major tributaries within the project area were captured using 1:50,000 Watershed Atlas data (B.C. Ministry of Environment, Lands and Parks). These rivers were then surrounded with a 150m buffer to reflect potential grizzly bear travel routes. Data collected on grizzly bear movements in an area of similarly mountainous terrain in the Khutzeymateen Valley in coastal British Columbia (MacHutchon et al. 1993) were used to determine this corridor width. The results of the Khutzeymateen study showed that the majority of grizzly bear radio locations were < 150m from a Class I stream at all times of the bears' active year. This buffer reflects the concentration of grizzly bear use of travel corridors.

The travel corridor buffer was overlaid onto the revised TEM coverage (original TEM + salmon) and a new TEM coverage created. Where the buffer intersected a portion of an existing polygon, the polygon was automatically split. When all polygon revisions and alterations were complete all polygons were assigned a new and unique number. All areas within the 150m travel buffer were increased in rank by 1 during all seasons. For example, an ecosystem unit with an original wildlife rating value of 3 would be increased to a modified rank value of 2 (which would result in this unit being included in the calculation of the habitat effectiveness of the polygon). In comparison, an ecosystem unit with an original wildlife rating value of 5 would be increased to a modified rank value of 4 (this ecosystem unit would remain omitted from the calculation of habitat effectiveness. This approach aims to reflect grizzly bear travel between and within seasonally important ecosystem units.

Longer range movements of grizzly bears can involve traversing drainages. Linkage areas between major drainages were identified during field work and from interpretation of airphotos. The criteria for selection were: 1) that the route be either a mountain pass or a relatively shallow slope linking two major drainages and 2) that it contain useable habitat throughout (e.g. not comprised of rock or ice). Beyond the immediate vicinity of the mountain pass the delineation of grizzly bear travel routes becomes more subjective. The delineation of linkage polygons was therefore restricted to the pass itself, defined by the location of the same contour interval on either side of the pass and the contour interval immediately (20m) above (reflecting the width of the pass). Eleven major linkage areas were identified and digitised as polygons on ArcView with the aid of 1:20,000 TRIM contours.

Linkage polygons were overlaid onto the revised TEM coverage (original TEM + salmon + travel) and a new TEM coverage created. Where the linkage polygons intersected a portion of an existing TEM polygon, the TEM polygon was automatically split. When all polygon revisions and alterations were complete all polygons were assigned a new and unique number. All areas within the linkage polygons were increased in rank by 1 during all seasons.

4.3.4.3 Roads

All existing roads within the project area were classified as either mainline or spur roads. It is assumed that mainline roads generally receive >1 vehicle/day and spur roads receive <1 vehicle/day. Road coverage was obtained from two sources: 1) TRIM transportation layer (B.C. Ministry of Environment, Lands and Parks) and 2) Forest Development Plan (West Fraser Mills Ltd.). Mainline roads were identified as "gravel, undivided" in the TRIM transportation layer and were selected visually from 2 different feature classes in the FDP layer (colour = 0, layer = 8; colour = 0, layer = 16). Spur roads were identified as "road, unimproved"; "trail" and "unclassified" (DA25150100 - representing a trail network) in the TRIM transportation layer and were again selected visually from 2 different feature classes in the FDP layer (colour = 0, layer = 8; colour = 0, layer = 16).

There is a complex relationship between grizzly bear movements and areas of human use. Factors which influence this relationship include: intensity of human use, timing of human use, proximity of high value habitats, amount of available cover and the overall density and intensity of human use throughout the bears' home range. Grizzly bears also vary in their response to the same human activity depending upon their sex, age and learned behaviour. Non-habituated adult female grizzly bears are the focus of management guidelines so whenever possible data collected from this cohort will be used. Data of all sex-age classes are often combined for analysis in studies while habituated bears are most often identified and separated. The aim of the following sections is to summarise the available data on grizzly bear responses to human activities pertinent to this study, thereby presenting the reasoning behind the use and size of buffers in the determination of habitat quality for the Quesnel Project.

Grizzly bears tend to use cut blocks less than expected based on data of radio collared grizzly bears (McLellan and Hovey 2001a; Apps et al. in press). However, the influence of cut blocks on grizzly bear movements and habitat use have not been separated from the displacement impacts of roads in these data. Since all cut blocks within this project area contain roads, for the purposes of this analysis, the influence of cut blocks is incorporated into the displacement impacts of roads.

Grizzly bear displacement from industrial and recreational road corridors in areas of relatively low overall human density is most relevant to this study. Although a study was conducted in the Wet Columbia Mountains (Munro 1999), this study investigated the effects of the Trans-Canada highway and the Canadian Pacific Railway on grizzly bear habitat use patterns and is therefore less pertinent to the Quesnel Project. In Munro (1999) non-habituated adult female grizzly bears used areas < 10km from the road-rail corridor less than expected. In this situation grizzly bears were likely responding to both the presence of the highway and railway and may have also been influenced by the presence of front country facilities adjacent to the road-rail corridor. In Yellowstone, front country facilities are documented to displace grizzly bears more than roads, trails and back country campsites (Mattson 1990).

4.3.4.3.1 Roads (>1 vehicle/day)

Studies conducted in the north fork of the Flathead (McLellan and Shackleton 1988), the East Slopes of the Rockies (Aune and Kasworm 1989) and in the south fork of the Flathead (Mace et al. 1996) are considered a more relevant source of data since these studies investigate the effect of industrial, commercial, recreational and minor roads on grizzly bear movements and habitat use in areas with similar levels of human use to the Quesnel Highlands project area. The displacement of grizzly bears from these types of roads varies from 250m (McLellan and Shackleton 1988) to 300m (Aune and Kasworm 1989) and to >500m (Mace et al. 1996). In the studies conducted by McLellan and Shackleton (1988) and Aune and Kasworm (1989), the impact of roads >1 vehicle/day and <1 vehicle/day were not distinguished in the analyses. As a result, the zones of displacement calculated in these studies could tend to underestimate the displacement zone width around roads receiving >1 vehicle/day. Mace et al. (1996), showed that grizzly bears were displaced by at least 500m from roads bearing >1 vehicle/day. For the purposes of our analysis, the mainlines within the Quesnel Highlands project area are assumed to receive average traffic volumes of >1 vehicle/day. These roads were surrounded by a 500m buffer to reflect the distance grizzly bear movements are altered in response to the presence of mainline roads.

Displacement from valuable habitat in response to the presence of roads reduces the effective value of that habitat; grizzly bears use the area much less or not at all. Also, the probability of grizzly bear mortality increases with the presence of roads by increasing access for legal and illegal hunting (McLellan and Shackleton 1988). To reflect the reduction in habitat value due to the displacement of grizzly bears from roads and the potential for grizzly bear mortality associated with roads, areas within the 500m buffer around mainline roads were decreased in rank value by 1. Using this approach, an ecosystem unit with an original wildlife rating of 1 would be decreased to a modified rank value of 2 (which would result in this unit remaining within the calculation of habitat effectiveness for the polygon). An ecosystem unit with an original wildlife rating of 2 would be decreased to a modified rank value of 3. This would result in the unit being omitted from the calculation of habitat effectiveness for the polygon. This method aims to reflect a cost-benefit approach to habitat use: ecosystem units of highest value (i.e. wildlife ratings of 1) will remain incorporated into the calculation of habitat effectiveness despite the proximity of roads (modified rank value of 2), while units of less high value (i.e. wildlife rating of 2) will be omitted (modified rank value of 3).

The road buffers were overlaid onto the revised TEM coverage (original TEM + salmon + travel + linkage) and a new TEM coverage created to incorporate the effect of mainline roads on grizzly bear movements and habitat use. Where the buffer intersected a portion of an existing polygon, the polygon was automatically split. When all polygon revisions and alterations were complete all polygons were assigned a new and unique number. All areas within the 500m buffer around mainline roads were decreased in rank by 1 during all seasons.

4.3.4.3.2 Roads (<1 vehicle/day)

Studies conducted in the north fork of the Flathead (McLellan and Shackleton 1988), the East Slopes of the Rockies (Aune and Kasworm 1989) and in the south fork of the Flathead (Mace et al. 1996) are considered a relevant source of data for this road type within the Quesnel Highlands project area. The displacement of grizzly bears from industrial, commercial, recreational and minor roads varies from 250m (McLellan and Shackleton 1988) to 300m (Aune and Kasworm 1989). In the study of Mace et al. (1996) grizzly bears did not show a clearly negative nor positive response to a buffer area of 500m adjacent to a road with <1 vehicle/day. In the studies conducted by McLellan and Shackleton (1988) and Aune and Kasworm (1989), the impact of roads >1 vehicle/day and <1 vehicle/day were not distinguished in the analyses and as a result, the zones of displacement calculated in these studies could tend to overestimate the displacement zone width around roads receiving <1 vehicle/day. For the purposes of our analysis, spur roads within the Quesnel Highlands project area are assumed to receive average traffic volumes of <1 vehicle/day. These roads were buffered 250m to reflect the distance grizzly bear movements are altered in response to the presence of spur roads.

To reflect the reduction in habitat value due to the displacement of grizzly bears from roads and the potential for grizzly bear mortality associated with roads, areas within the 250m buffer around spur roads were decreased in rank value by 1. Methods employed for the determination of modified ecosystem unit ranks for polygons within this 250m buffer are the same as those outlined above for mainline roads in Section 4.3.4.4.1.

Displacement of grizzly bears from cut blocks is incorporated into the displacement impacts of spur roads. This approach aims to reflect the variation in the value of different cut blocks to grizzly bears depending upon the ecosystem units the cut block is comprised of. For example, ICHwk2: SO3 has an original seasonal wildlife rating of 2 during summer. This same unit within a cut block would have a modified ecosystem unit rank of 3 since the cut block would be contained within the 250m buffer created by the roads within it. ICHwk2: HO3 has an original seasonal wildlife rating of 3 during summer. This same unit within a cut block would have a modified ecosystem unit rank of 4. Again, this methods aims to reflect a cost-benefit approach to habitat use.

4.3.4.4 Industrial Camps

Unfortunately there is no data available on the level of displacement from industrial facilities and camps in areas with similar levels of human use to the Quesnel Highlands project area. In Yellowstone grizzly bears were displaced from back country campsites from between 1km (Gunther 1990) and 2.5km (Mattson 1990) and from between 3km and 5km from front country facilities (Mattson et al. 1987). However these study areas differ markedly from the Quesnel Highlands project area in terms of the overall intensity of human use and as a result these data are likely less applicable. For the purposes of this project a buffer of 1000m is proposed around Penfold Camp. This is concurrent with the 1000m buffer established around an industrial camp (a mine site) in the Cheviot Mine in Alberta for the purposes of a cumulative effects project (BIOS 1996). A 1000m circular buffer was created around Penfold Camp and overlaid onto the revised TEM coverage (original TEM + salmon + travel + linkage + roads). A new TEM coverage was created to include the impact of the Penfold Camp on grizzly bear movements and habitat use. Where the buffer intersected a portion of an existing polygon, the polygon was automatically split. When all polygon revisions and alterations were complete all polygons were assigned a new and unique number. All areas within the 1000m camp buffer were decreased in rank by 1 during all seasons. As with the displacement from roads, this method aims to reflect a cost-benefit approach to habitat use.

4.3.5 POLYGON RANKING - HABITAT EFFECTIVENESS

The habitat effectiveness value for each polygon was calculated based on the modified ecosystem unit ranks calculated for living within each component ecosystem unit. The same numerical procedures as those described for the calculation of Habitat Suitability (Section 4.3.3) were used in the calculation of Habitat Effectiveness. Ecosystem units which have a modified rank value of ≥ 3 are omitted and habitat effectiveness is calculated using only those units with modified ranks of 1 or 2. Habitat effectiveness is then calculated based on the product of the modified rank value of the ecosystem units and their decile proportion within each polygon. For the purposes of GIS analysis rank values were reversed to reflect the higher value of a rank of 1 when using addition and multiplication in algorithms. For example, an ecosystem unit having a modified rank value of 1 (≅ 2) which covers 50% (= 5 deciles) of a polygon will receive a habitat effectiveness value of 10 (Calculation: 2 * 5 = 10). If this polygon also contained an ecosystem unit with a modified rank value of 2 (≅ 1) and this unit comprised 30% (= 3 deciles) of the polygon the overall habitat effectiveness value for that polygon would be 13 (Calculation: (2*5) + (1*3) = 13). The habitat effectiveness value would remain unchanged unless the remaining 20% of the polygon was comprised of an ecosystem unit with a modified rank value of either 1 or 2. Habitat effectiveness values range from 0 to 20.

Similarly to the calculation of habitat suitability, habitat effectiveness is calculated using only high value ecosystem units (i.e. with modified ranks of either 1 or 2). Therefore all polygons with habitat effectiveness values greater than zero are of high value to grizzly bears and all ecosystem units with modified ranks of 1 or 2 are displayed wherever they occur. In contrast to the calculation of habitat suitability, habitat effectiveness calculations consider polygons in a landscape context. The resulting coverage is believed to more closely represent grizzly bear habitat values and patterns of use across the landscape and is expected to be a more precise tool for operational level management.

4.3.6 ENHANCEMENT OF GRIZZLY BEAR FORAGE AND BERRY PRODUCTION

Restorative forestry practices (see Section 6.1) can enhance the productivity of grizzly bear forage and berry species. To identify sites that would benefit from restorative forestry practices, Ratings Table 1 (Appendix Two) was queried. The occurrence of all forested ecosystem units within the ICHwk2 and ESSFwk1 identified to have wildlife ratings of 1 or 2 during spring and summer were collated. The TEM database (*"tem_gb_final.e00"*) was then queried for the occurrence and location of these ecosystem units in pole sapling or young forest stage.

Research on the influence of harvesting methods on grizzly bear forage abundance and berry productivity was reviewed and general guidelines presented for the Quesnel Highlands project area, based on the findings and recommendations of these studies: Zager et al. 1983; Mattson 1990; Knight 1999; MELP 2001; McLellan and Hovey 2001a; Symbios Research and Restoration unpublished report.

5.0 RESULTS

5.1 FIELD WORK SUMMARY

All field work performed in support of this project was completed between August 21st and 31st, 2001. During the 11 day field sampling program, a total of 142 formal field observations of 112 polygons were recorded (Appendix Three). During each observation the following field data were documented: landscape unit; biogeoclimatic zone, subzone and variant; ecosystem unit (to site series and structural stage); aspect; a description of any grizzly bear sign observed, grizzly bear foods and habitat values and a brief description of the site and it's location in the project area. Sites photos also document representative or significant findings. Site location was marked on airphotos and the associated airphoto number and TRIM mapsheet number noted. Nineteen observations were accompanied by full TEM plots. Tables 8 and 9 provide a summary of sampling effort by Landscape Unit and Biogeoclimatic subzone.

Table 8. Summary of field observations by Landscape Unit.

Landscape Unit	Observations (n = 142)
Penfold	71
Eastside	55
Wasko/Lynx	16

Table 9. Summary of polygons sampled by Biogeoclimatic Subzone.

Biogeoclimatic Subzone	Polygons Sampled (n = 112)
ICH wk2	44
ESSF wk1	13
ESSF wc3	41
ESSF wcp3	14
AT p	0

5.2 ECOSYSTEM UNIT RANKING - RATINGS TABLE 1

Ratings Table 1 is presented by season in Appendix Two. This table lists the wildlife ratings value of each ecosystem unit occurring within the Quesnel Highlands project area for each season of use using the provincial 6-class rating scheme (RIC 1999). Seasons in the Quesnel Highlands project area are defined as: Spring (late April – mid July); Summer (late July – late August) and Fall (early September – mid November).

Within the *"tem_gb_final.e00"* coverage, MURAR_LIP1 represents the wildlife rating for living in the primary ecosystem unit during spring, MURAR_LIP2 represents this rating for the secondary ecosystem unit and MURAR_LIP3 for the tertiary ecosystem unit. MURAR_LIS1 represents the wildlife rating for living in the primary ecosystem unit during summer, MURAR_LIS2 represents this rating for the secondary ecosystem unit and MURAR_LIS3 for the tertiary ecosystem unit. MURAR_LIF1 represents the wildlife rating for living in the primary ecosystem unit during fall, MURAR_LIF2 represents this rating for the secondary ecosystem unit and MURAR_LIF3 for the tertiary ecosystem unit.

5.3 POLYGON RANKING - HABITAT SUITABILITY

Within the *"tem_gb_final.e00"* coverage, HS_LIP, HS_LIS and HS_LIF represent the seasonal habitat suitability values for living during spring, summer and fall respectively for each polygon. These fields can be used to theme a seasonal grizzly bear habitat suitability map of the Quesnel Highlands project area.

5.4 MODIFICATION OF ECOSYSTEM UNIT RANKS

Within the *"tem_gb_final.e00"* coverage, UPDATE_LIP1 represents the modified ecosystem unit ranks for living in the primary ecosystem unit during spring. UPDATE_LIP2 represents this rating for the secondary ecosystem unit and UPDATE_LIP3 for the tertiary ecosystem unit. UPDATE _LIS1 represents the modified ecosystem unit ranks for living in the primary ecosystem unit during summer. UPDATE _LIS2 represents this rating for the secondary ecosystem unit and UPDATE _LIS3 for the tertiary ecosystem unit. UPDATE _LIF1 represents the modified ecosystem unit ranks for living in the primary ecosystem unit during fall. UPDATE _LIF2 represents this rating for the secondary ecosystem unit and UPDATE _LIF3 for the tertiary ecosystem unit.

5.5 POLYGON RANKING - HABITAT EFFECTIVENESS

Within the *"tem_gb_final.e00"* coverage, HE_LIP, HE_LIS and HE_LIF represent the seasonal habitat effectiveness values for living during spring, summer and fall respectively for each polygon. These fields could be used to theme a seasonal grizzly bear habitat effectiveness map of the Quesnel Highlands project area. Metadata document *"Tem_GB_Final_README.doc"* accompanies the *"tem_gb_final.e00"* coverage and provides a description of all new attribute fields contained within the database.

Figure 2 shows the distribution of all polygons of high spring value within the Quesnel Highlands project area. High value spring habitats are found within the floodplain forests (Photo 2), valley bottom wetlands and within the lower reaches of avalanche chutes within all major watersheds; Penfold and its tributaries, Watt, Roaring and its tributaries, Isaiah, Wasko and its tributaries and Lynx as well as the floodplain communities along the shores of Quesnel Lake (e.g. Bowling Point).

Figure 3 shows the distribution of all polygons of high summer value within the Quesnel Highlands project area. High value summer habitats are found within the higher reaches of avalanche chutes and within subalpine meadows and seeps. Valley bottom forests and wetlands remain significant to bears who feed on low elevation berries. The few early successional burns within the project area become significant, particularly Isaiah Burn within Eastside landscape unit (Photo 3). There is a greater number of high value polygons identified during summer than any other season; grizzly bear strategies diverge the most in terms of food habits and habitat use patterns during this season (i.e. low elevation berry feeders, elevational migrant foragers and berry feeders).

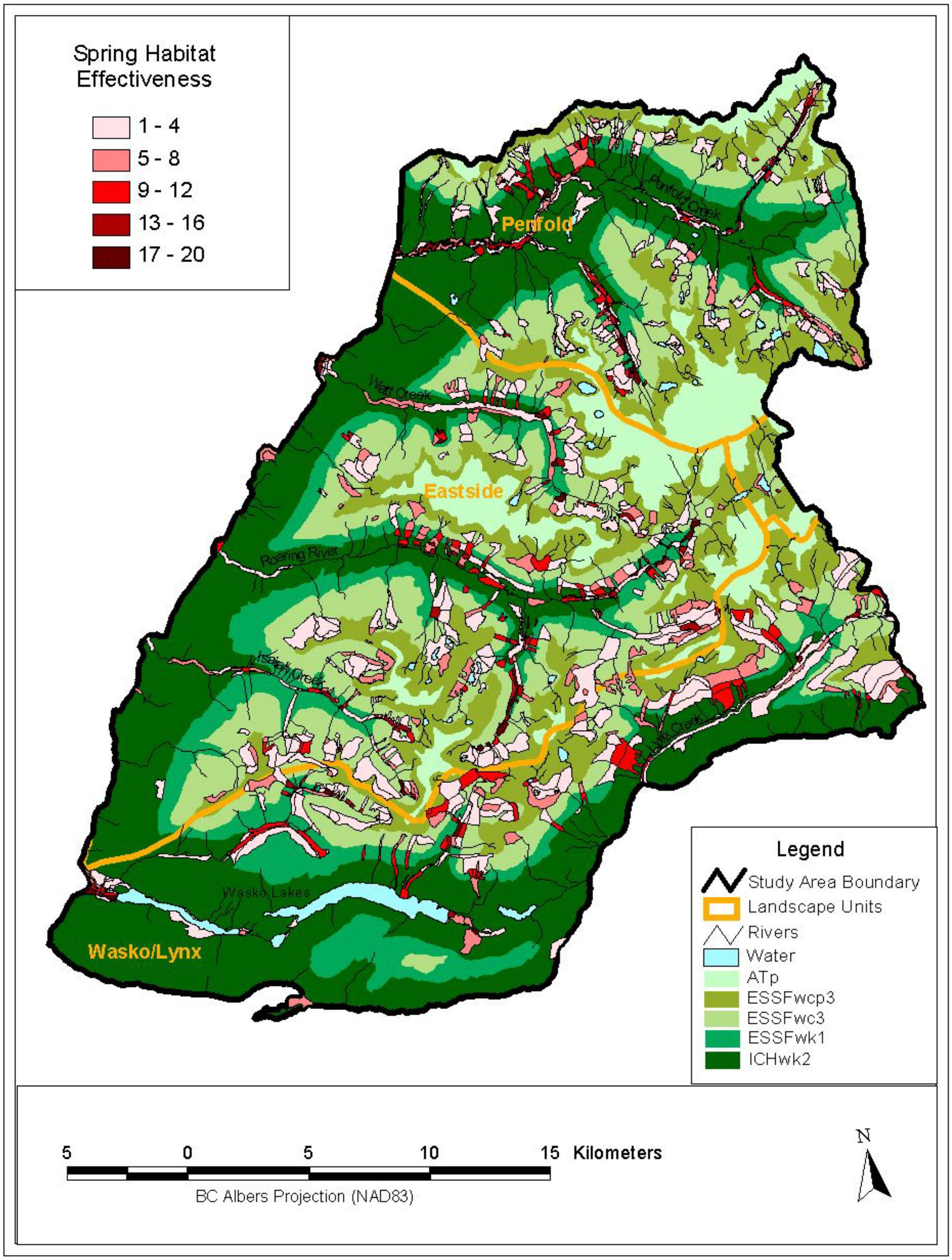

Figure 2. High Value Spring Grizzly Bear Habitat within the Quesnel Highlands Project Area.

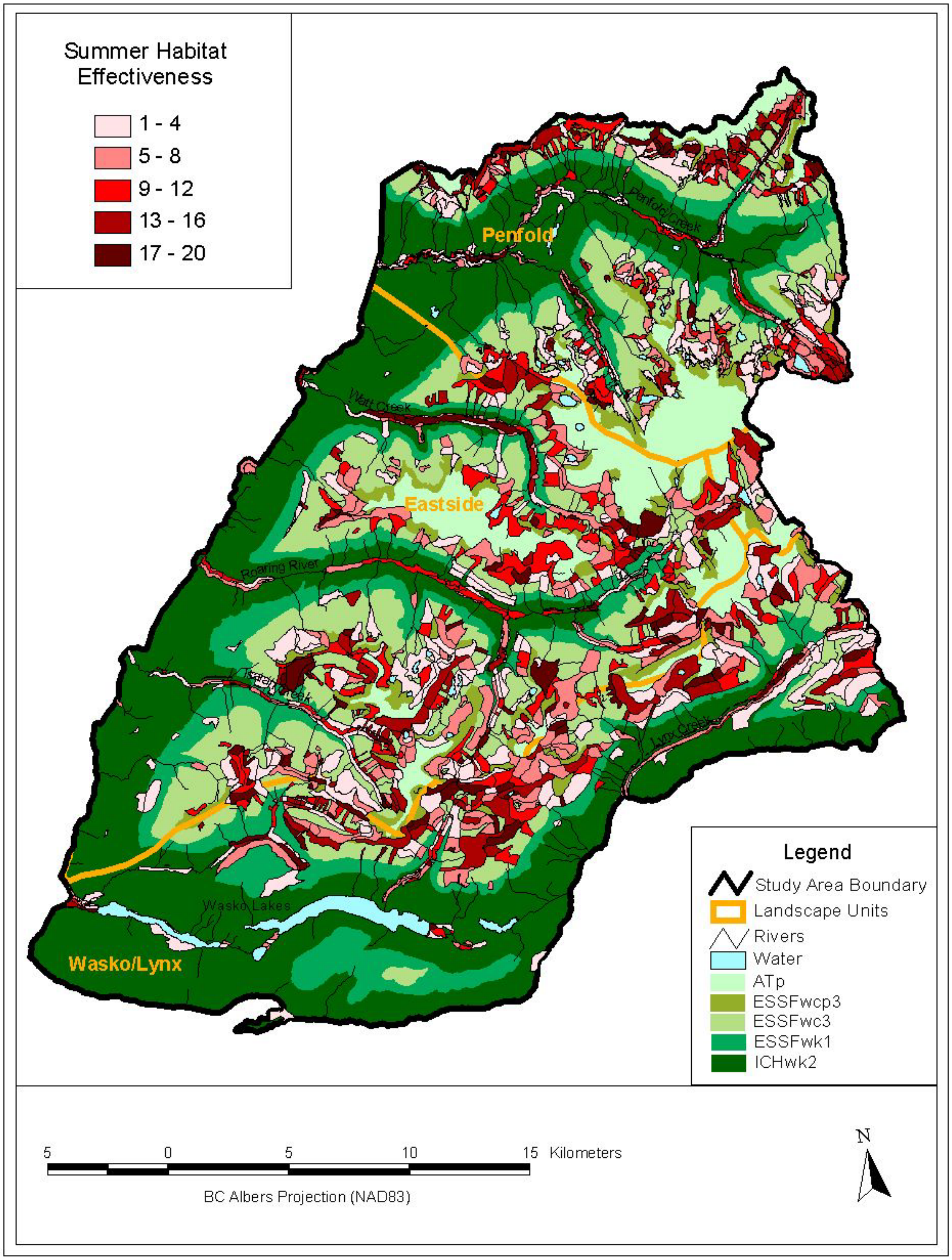

Figure 3. High Value Summer Grizzly Bear Habitat within the Quesnel Highlands Project Area.

Photo 2. Skunk cabbage swamp under an open white spruce canopy (ICHwk2: RC7).

Photo 3. Abundant black huckleberries in Isaiah Burn (ESSF wc3: FRw3b).

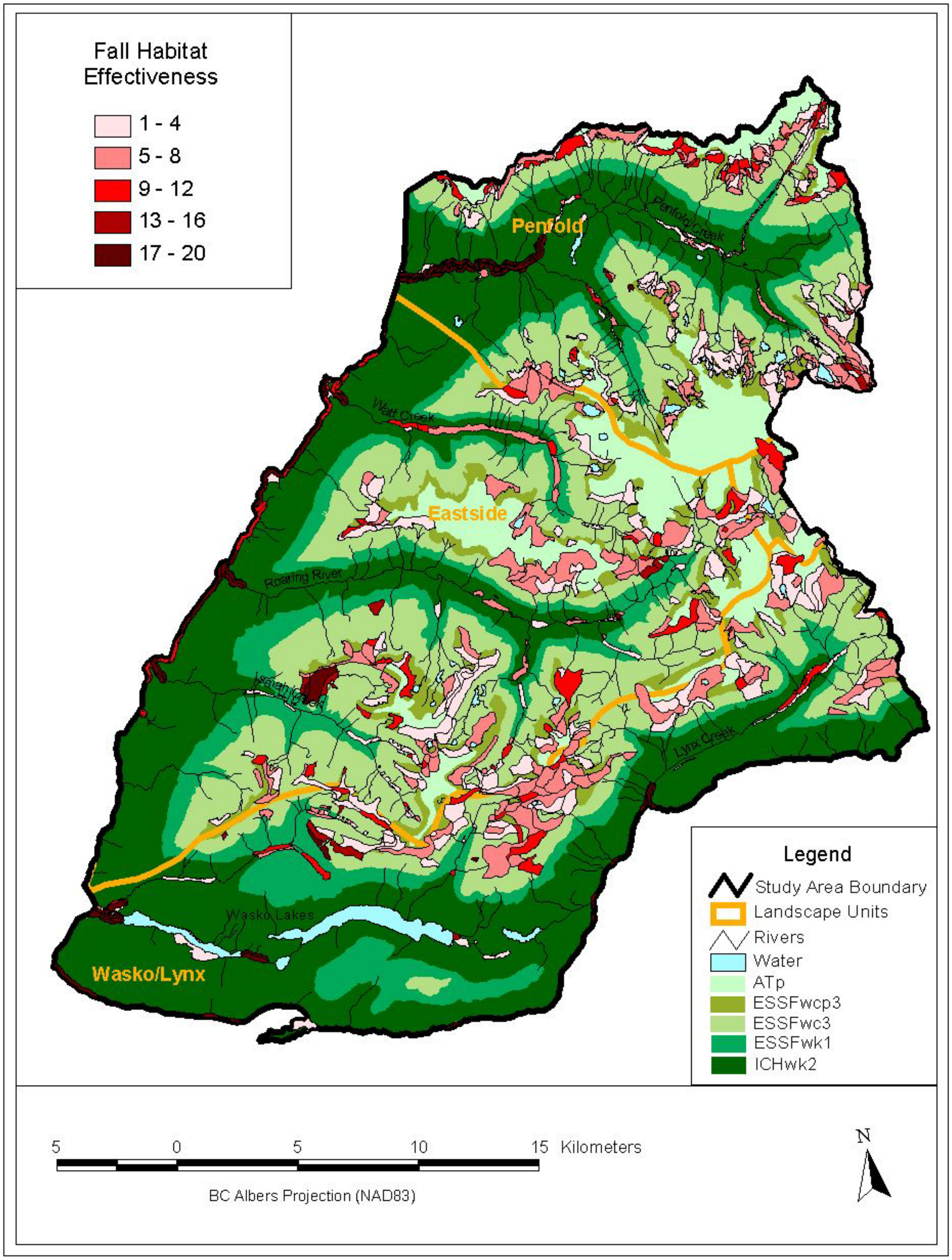

Figure 4. High Value Fall Grizzly Bear Habitat within the Quesnel Highlands Project Area.

Figure 4 shows the distribution of all polygons of high fall value within the Quesnel Highlands project area. High value fall habitats are associated with salmon spawning areas (Photo 4): Penfold River, the lower reaches of Watt, Roaring, Isaiah and Wasko Rivers and the shores of Quesnel Lake where salmon spawn (most notably between the mouths of Watt and Isaiah Creeks). High elevation burns and subalpine meadows remain significant during fall.

Photo 4. Salmon spawning channel of Watt Creek (ICH wk2: WD3b).

With the exception of the salmon spawning areas, most high value polygons lie adjacent to other valuable polygons when seasonal values and different feeding strategies are considered simultaneously. For example, the same avalanche chutes which are significant to bears during spring at the lower reaches remain significant during summer at higher elevations. The upper reaches of these chutes lead into subalpine meadows and seeps which are significant during fall. Valley bottoms of major river systems within the project area (especially Penfold River and it's tributaries, Watt, Roaring and it's tributaries, Isaiah, Wasko and it's tributaries and Lynx) are significant to bears throughout the year as both feeding areas and travel routes.

The contiguous forested slopes above the shores of Quesnel Lake within Eastside and Penfold landscape units generally contain fewer areas of high value grizzly bear habitat than elsewhere in the project area. This is not only the result of the reduction in habitat value due to the presence or roads and cut blocks but also due to the generally lower value of the ecosystem units found on these slopes. The contiguous forest slopes above Quesnel Lake within Wasko/Lynx support this conclusion; these areas are unroaded and yet do not appear to provide high value habitat for bears. There are, however, valuable areas which have been impacted by the presence of roads within the project area. For example, the continuity of grizzly bear travel routes along river corridors (notably Roaring and Watt Rivers) has been broken by the presence of roads. In some areas valuable habitats remain significant to bears, although reduced, despite the presence of roads (e.g. valley bottoms and the lower reaches of avalanche chutes of Roaring River).

Tables 10 presents the current distribution of high value grizzly bear habitat within the Quesnel Highlands project area. Polygons of high value to grizzly bears (i.e. those with habitat effectiveness values ≥ 1) comprise approximately 31% of the total project area (Table 10). Eastside contains the majority of high value grizzly bear habitat, accounting for almost half (46%) of all identified high value polygons (Table 10). The distribution of high value polygons across the project area is roughly proportional to landscape unit area; Eastside contains only slightly more high value polygons (46%) than would be predicted based on area (43%), Table 10.

Table 11 presents the current distribution of high value grizzly bear habitat within the Quesnel Highlands project area by season. Eastside contains the largest amount of high value spring (6.39%), summer (13.15%) and fall (7.13%) habitat within the project area (Table 11). The amount of high value habitat can be expressed as a percentage of the landscape unit area. Table 11 shows that the concentration of high value habitats within landscape units varies little between landscape units during spring and fall. The concentration of high value summer habitat is slightly greater in Eastside (30%) than in Penfold (27%) and Wasko/Lynx (25%).

Table 10. Percent distribution of all high value grizzly bear polygons within the Quesnel Highlands Project Area by Landscape Unit.

Landscape Unit	Landscape Unit Area (ha)	Landscape Unit Area (% of project area)	High Value Polygons (ha)	High Value Polygons (% of all high value polygons)	High Value Polygons (% of project area)
Penfold	21413.3	24.24	6564.2	23.94	7.43
Eastside	38354.4	43.42	12686.1	46.26	14.36
Wasko/Lynx	28575.4	32.34	8171.0	29.80	9.25
Totals	88343.1	100.00	27421.3	100.00	31.04

Table 11. Percent distribution of all high value grizzly bear polygons within the Quesnel Highlands Project Area by Landscape Unit and Season.

Landscape Unit	Season	High Value Polygons (% of project area)*	High Value Polygons (% of landscape unit)
Penfold	Spring	2.99	12.34
	Summer	6.46	26.65
	Fall	4.14	17.07
Eastside	Spring	6.39	14.71
	Summer	13.15	30.30
	Fall	7.13	16.42
Wasko/Lynx	Spring	5.07	15.67
	Summer	8.10	25.04
	Fall	4.61	14.24

* The percentages of high value polygons for each season do not sum to the percentage of high value polygons for all seasons combined (Table 10); some polygons are ranked high value during more than one season.

5.6 ENHANCEMENT OF GRIZZLY BEAR FORAGE AND BERRY PRODUCTION

No potential sites for immediate restorative forestry treatment were identified within the Quesnel Highlands project area. For future use, guidelines are presented which aim to assist managers in the selection of potential sites for restorative forestry treatment. Table 12 provides a summary of ecosystem units within the ICHwk2 and ESSFwk1 identified for potential restorative forestry treatment. Post-harvest restoration of these units at the pole sapling (structural stage 4) or young forest stage (structural stage 5) will enhance the abundance of grizzly bear forage and berry production.

Table 12. Ecosystem units within the ICHwk2 and ESSFwk1 identified for potential restorative forestry treatment.

Food Type of Value	BEC unit	Ecosystem Units
Forage	ICHwk2	RC4,5
Berry	ICHwk2	RC4,5
Berry	ICHwk2	SO4,5
Berry	ICHwk2	ST4,5
Berry	ESSFwk1	FT4,5

Additional site selection could focus where units shown in Table 12 are: 1) part of a contiguous stretch of similar aged cut blocks (MELP 2001); 2) within areas where the least amount of valuable spring and summer grizzly bear habitat exists, reflecting fewer alternative foraging areas for grizzly bears, (MELP 2001) and 3) areas that have undergone the most extensive history of harvesting (MELP 2001). Within the Quesnel Highlands project area, there is no one landscape unit that contains a significantly lower concentration of high value grizzly bear habitat, although Eastside contains a slightly higher concentration of high value summer habitat (Table 11). At present, the majority of logging activity has occurred within Eastside, however there is a slightly larger proportion of harvested land within Penfold. This would suggest that identifying sites for restorative forestry treatment within Penfold would potentially be most effective; grizzly bear feeding opportunities would be enhanced where they had been reduced due to timber harvesting.

6.0 RECOMMENDATIONS

6.1 SILVICULTURE PRACTICES IN AREAS WHERE VALUABLE GRIZZLY BEAR HABITAT HAS BEEN HARVESTED

Silviculture recommendations include the following:

- In situations where ecosystem units ICHwk2: RC; SO; ST and ESSFwk1: FT have been harvested, stocking standards be reduced (MELP 2001).
- Where ICHwk2: RC; SO; ST and ESSFwk1: FT have been harvested, cluster planting, spacing/thinning and pruning are preferred to standard planting practices (MELP 2001). These practices aim to ultimately increase the amount of light reaching herb and shrub layers and thereby promoting grizzly bear forage and berry production at the pole sapling and young forest stage of growth. Variable stocking density will provide higher levels of internal stand diversity.
- Where ICHwk2: RC; SO; ST and ESSFwk1: FT have been harvested, herbicide treatment should be avoided (Mattson 1990), whenever possible. Exceptions may be: 1) in cluster planted blocks, herbicide treatment could be administered within clusters but avoided in areas between clusters to promote shrub growth (MELP 2001); and 2) in an attempt to increase the abundance of berry producing shrubs (notably *Vaccinium spp*. and *Ribes spp.*), herbicides may be administered selectively to competing species (Symbios Research and Restoration, unpub. report).
- Effective enhancement of grizzly bear forage and berry producing shrubs in cut blocks is less effective in the absence of access management. Grizzly bears are displaced from areas of human activity and are exposed to higher risks of mortality through hunting, defense of life, control actions and poaching in these areas. This is also the case with valuable polygons which are at present within the zones of displacement from roads and camps. Grizzly bear habitat value can be greatly enhanced by access management. In particular, through the deactivation of roads and the control of human access on these deactivated roads. The project team recognizes that while the study area is not directly accessible from the public road system, access management would still provide a valuable tool to grizzly bear management within the Quesnel Highlands. For these reasons, it is recommended that, whenever possible, roads within valuable grizzly bear habitat are deactivated.
- In an attempt to enhance grizzly bear habitat value over the landscape, it has been suggested that conifer growth in medium-aged burns be reduced by mechanical thinning (McLellan and Hovey 2001a). Within this project area burns at the pole sapling and young forest stage within the warm aspect ESSFwc3 fir-rhododendron site series (FRw) would be suitable sites for this treatment. A specific example of a suitable treatment area would be the Wasko/Lynx burn.
- In an attempt to enhance grizzly bear habitat value over the landscape, it has been suggested that wildfires of suitable size and intensity be permitted to burn (McLellan and Hovey 2001a). Due to issues associated with wildfire effects on public safety, timber supply, visual quality, air quality and wildlife values, it is recognised that the use of uncontrolled wildfire to achieve habitat management objectives is a contentious issue. However, wildfires will undoubtedly occur within the ICH and ESSF zones of the Quesnel Highlands at some time in

the future. Under the proper burning conditions on specific locations, fire management planning should therefore consider using naturally occurring fires to achieve habitat management objectives. Allowing wildfires within the warm aspect ESSFwc3 fir-rhododendron site series (FRw) would greatly enhance grizzly bear habitat values within this project area. Prescribed fire may also achieve similar objectives under appropriate conditions and may in some cases be a more acceptable option.

6.2 FOREST HARVESTING PRACTICES IN AREAS WITH VALUABLE GRIZZLY BEAR HABITAT

Forest harvesting recommendations include the following:

- Avoid timber harvesting within an identified high value polygon and within 250m of that polygon. Shapefile "*Gb_high_250m.shp"* shows the extent of the 250m buffer around all high value polygons.
- Avoid the construction of mainline roads within an identified high value polygon and within 500m of that polygon. Shapefile "*Gb_high_500m.shp"* shows the extent of the 500m buffer around all high value polygons.
- Avoid the construction of spur roads within an identified high value polygon and within 250m of that polygon. Shapefile "*Gb_high_250m.shp"* shows the extent of the 250m buffer around all high value polygons.
- Avoid the construction of industrial camps within an identified high value polygon and within 1000m of that polygon.
- Avoid exceeding 1km of mainline roads / km^2 of land area and 2km of spur roads / km^2 of land area within high value polygons.

When avoidance is not feasible or possible, the following practices are recommended:

- Avoid all industrial activities within high value polygons and within the distance buffers identified for the specific activity (Table 7) during the seasons of grizzly bear use. Shapefile "*Gb_high_lip_250m.shp"* shows the extent of the 250m buffer around polygons of high spring value; shapefile "*Gb_high_lis_250m.shp"* shows the extent of the 250m buffer around polygons of high summer value; shapefile "*Gb_high_lif_250m.shp"* shows the extent of the 250m buffer around polygons of high fall value; shapefile "*Gb_high_lip_500m.shp"* shows the extent of the 500m buffer around polygons of high spring value; shapefile "*Gb_high_lis_500m.shp"* shows the extent of the 500m buffer around polygons of high summer value; shapefile "*Gb_high_lif_500m.shp"* shows the extent of the 500m buffer around polygons of high fall value.

- Forest harvesting adjacent to high value polygons should consider conifer retention through the use of partial-cut or shelterwood harvesting methods to maintain security cover (McLellan and Hovey 2001a).

- Leave strips should be maintained in areas within valuable grizzly bear habitats. Leave areas may be most effective when established along seepage areas. The establishment of these leave areas will improve forage and berry feeding opportunities and also provide bears with potential travel routes across areas that have been harvested. This aims to reduce the fragmentation effect of timber harvesting on grizzly bear habitat and movements.

- The creation and burning of large slash piles should be avoided as it has been well documented that lethal heating temperatures kill rhizomes and root crowns of berry producing shrubs (Zager et al. 1983). When fuel loading is an issue, broadcast burning is considered to be a better option (Zager et al. 1983).
- Mechanical scarification techniques and the use of heavy equipment should be minimised whenever possible. These methods destroy rhizomes and root crowns of berry producing shrubs (Zager et al. 1983; Knight 1999; Symbios Research and Restoration unpub. report) and will delay the amount of time an area becomes berry producing. The use of heavy equipment should be concentrated as much as possible to landings and roads to minimise surface disturbances across entire harvest blocks.
- Whenever possible, harvest valuable summer berry feeding habitat during winter (Symbios Research and Restoration unpub. report) to avoid the destruction of rhizomes and root crowns of berry producing shrubs through soil compaction, mechanical destruction and scarification.

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