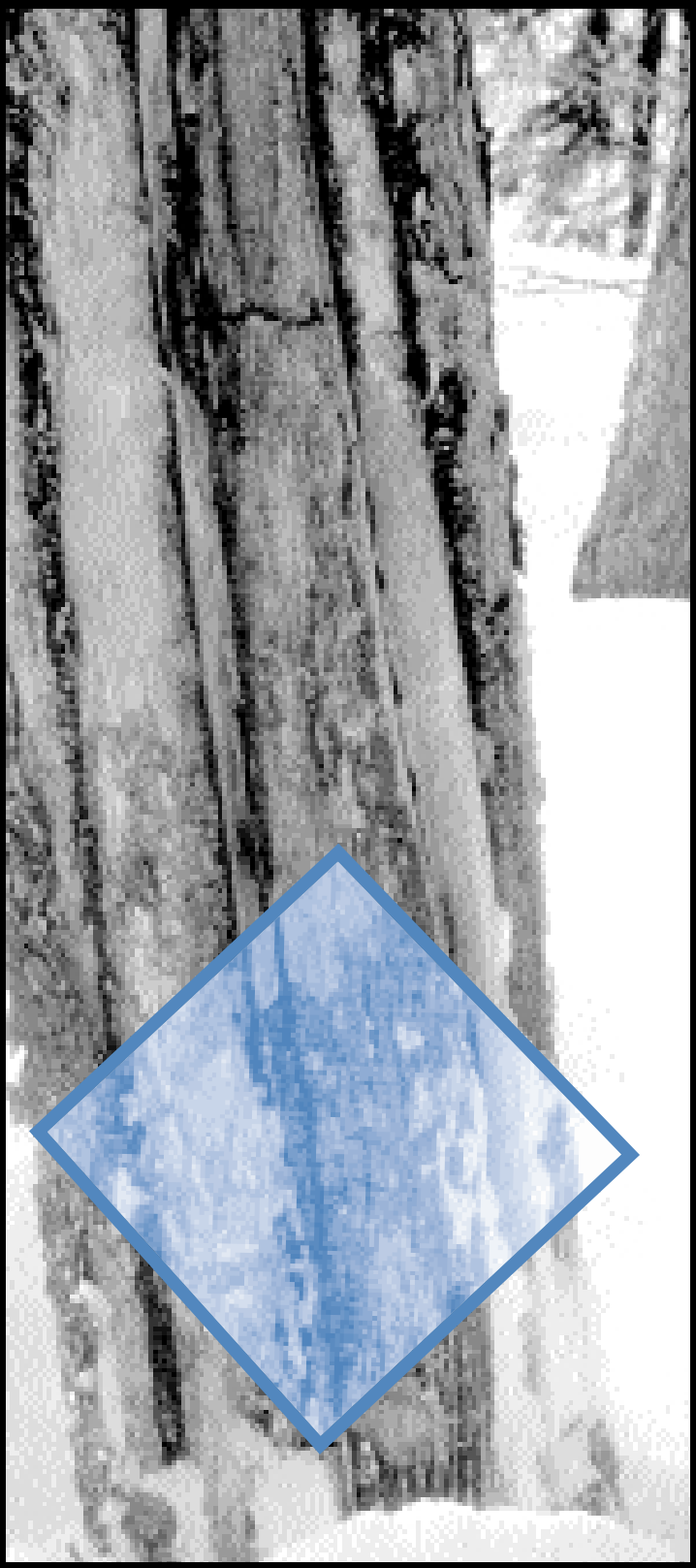
A R E V I E W

of Fire Management
on Forested Range
of the Beverly
and Qamanirjuaq
Herd of Caribou

the BEVERLY
and QAMANIRJUAQ
CARIBOU
MANAGEMENT
BOARD



TECHNICAL REPORT 1

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The opinions expressed in this report are those of the author and do not necessarily reflect the views of individual members of the Beverly Qamanirjua Caribou Management Board. All data contained herein is current to 1989.

s u m m a r y

This is a detailed technical report to support fire management recommendations of the Beverly and Qaminurjuaq Caribou Management Board (BQCMB). The brief management report (Beverly and Qamanirjuaq Caribou Management Board 1994a) is all that is needed to understand the system and implement it. The brief management plan, which contains seven recommendations and several maps, is intended for fire managers, caribou users, and managers.

The fire management system is based on the following criteria:

1) **Fire management zones** based on modified **community priority zones** within political boundaries and the limit of forest;

2) **Goals for productive caribou range** (>50 years since fire) within each fire management zone, based on **community priority level** (1-4) and **fire cycles** of three lengths (the natural fire-dependent ecosystem);

3) The need for fire management based on the ratio (%) of **present (P) occurrence of productive caribou range** to the **goals (G) for productive caribou range**. Suppression is indicated where P < G (< = less than).

A separate map (Beverly and Qamanirjuaq Caribou Management Board 1994b), generated by a Geographic Information System (GIS) also contains all the necessary information to make decisions on fire management within the **fire management zones.** This map will be updated periodically as new burns change the ratio of productive caribou habitat to the goal for such habitat. In addition, fire history was provided to communities on topographic maps at scales of 1:1 million and 1:250 000 (Beverly and Qamanirjuaq Caribou Management Board 1994c & 1994d).

The purpose of this report is to provide the detailed information that led to the fire management recommendations. It is technical and intended largely for scientists, technicians, and managers in the disciplines of fire, caribou, and forest ecology.

The range of the Beverly and Qamanirjuaq herds of barren-ground caribou (*Rangifer tarandus groenlandicus*) includes transitional and boreal forest in northern Manitoba, Saskatchewan, extreme northeastern Alberta, and the southern Northwest Territories (NWT). The southern and western limits of the herd changes annually and over decades. A trend over the past 35 years is for most of both herds to stay in the Northwest Territories during winter. Only in occasional winters (e.g., 1979-80 in Saskatchewan and 1992-93 in Manitoba) do the herds travel far into the provinces. In most winters, the hunters must travel long distances from settlements in Saskatchewan and Manitoba to obtain caribou.

The herds number 400-600 thousand caribou of which 8,000-20,000 are harvested annually and consumed by 12,000-15,000 residents in 19 settlements. An estimated 26,000-33,000 caribou would be used if the herds were fully accessible to all communities in any one year. The replacement value of meat is $12-15 million annually and potentially as high as $22-28 million. The **cultural and social values** are incalcuable. Furthermore, there are **intrinsic values** for all Canadians and others.

The Beverly and Qamanirjuaq caribou herds travel hundreds of miles south each winter to graze in forests.

The small amount of fire suppression on the forested ranges of the herds has been one of the primary concerns of traditional users. Such concerns were given more expression in 1982 with formation of the Beverly and Kaminuriak (subsequently Qamanirjuaq) Caribou Management Board. Several "action plans" of the Board addressed this issue including a major study of the effect of fire on the ecology of caribou. A major conclusion of the study was that sufficient winter range was present for the Beverly herd but burns affected the distribution of the herd. Nevertheless, priority areas were identified for fire management if necessary for herd conservation or management of the herds for high sustained yield (intensive management).

Data on the fire history and age distribution of the forest were mapped at scales of 1:250 000 and 1:1 000 000 and provided to the settlements and fire managers. Those data were entered in a Geographic Information System (GIS) in Yellowknife. The winter range of the two caribou herds was divided into three zones based on estimated number of years to complete a fire cycle (approximately the average interval between burns). Priority areas for hunting and fire management were mapped by each community on the forested range of the herds. The final step was to assign arbitrary goals for proportions of the community priority zones that should contain forests of sufficient age (>50-70 years) to support caribou. These data were also entered in the GIS and they can be revised at any time.

The goals for usable caribou range in community priority zones recognize that fire is a normal and essential component in the transitional forest ecosystem. Fire sets off successional sequences that creates diversity in the vegetation and the animals that live in the forest. Caribou are only one of many species that has adapted to the transitional forest. Priority must be placed on maintenance of the natural forest, as much as is possible, with various socio-economic developments.

Recommendations on suppression of fires in any fire management zone is based on the relative proportion of usable caribou range to the arbitrary goal established for that zone. The scheme of attempting to stabilize the proportion of forest in ages >50 years, within any given area, is somewhat analogous to ungulate managers stabilizing the population of moose (*Alces alces*), elk (*Cervis elaphus*), and deer (*Odocoileus spp.*). However, controlling fire is more difficult and expensive than preventing the "boom and bust" of ungulate populations.

These fire management recommendations incorporate the best of local knowledge and science to set goals for productive caribou habitat within the priority zones established by each community. Wider application of these guidelines depends on future rates of burning and goals associated with more intensive caribou management or their conservation. Greater coordination is needed among jurisdictions because residents of one jurisdiction often hunt in another and fires cross jurisdictional boundaries. Caribou users should be involved in all stages of fire management. Limitations of fire management in wilderness areas are also recognized.

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1 The Beverly and Qamanirjuaq Caribou Herds

In North America, there are eight major herds of caribou that winter in forested areas and summer on the tundra: The George River, Leaf River, Qamanirjuaq, Beverly, Bathurst, Bluenose, Porcupine, and Western Arctic. Parts of these herds may winter on the tundra and major subherds of the Qamanirjuaq herd often do so.

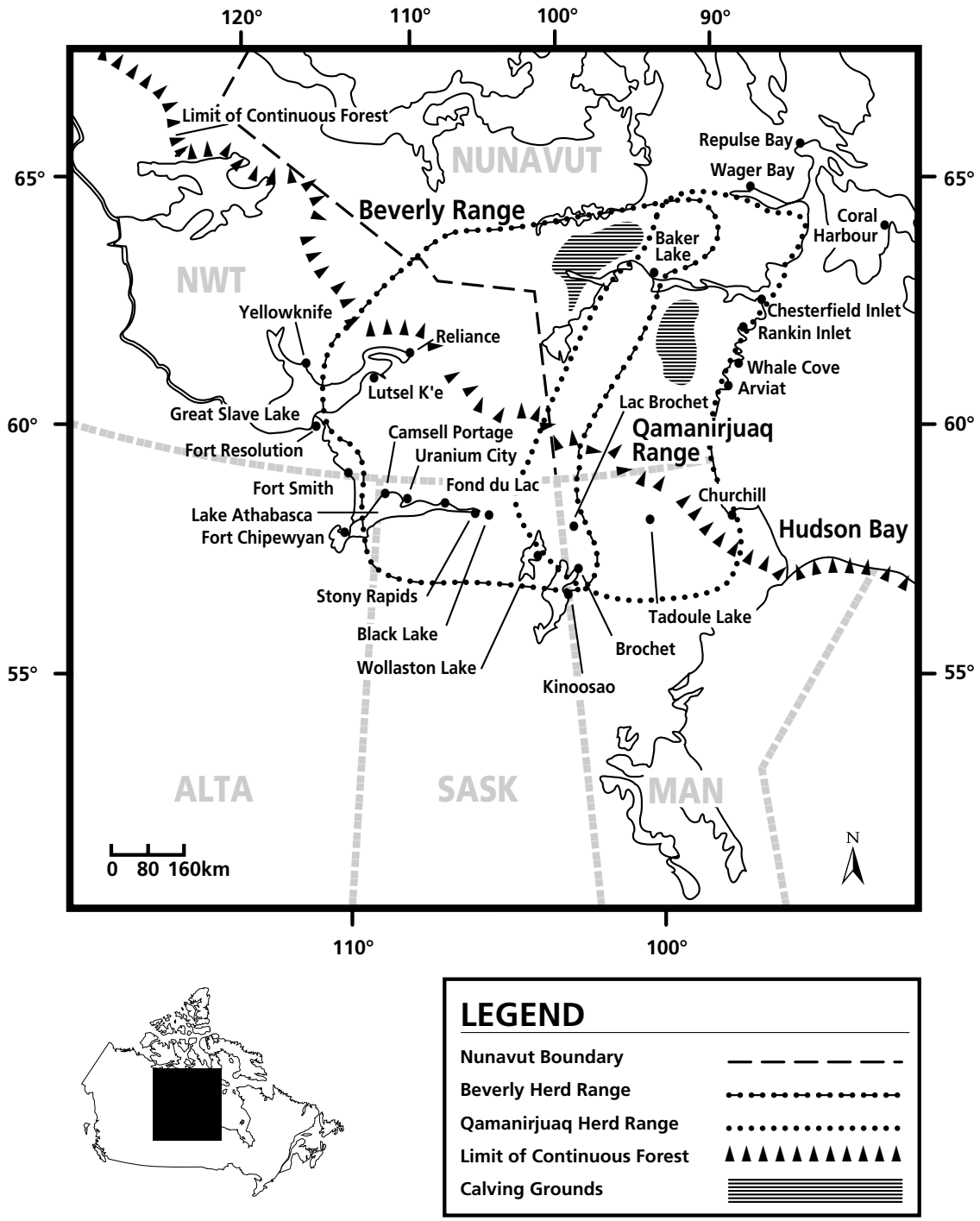
The Qamanirjuaq and Beverly herds cross two or three jurisdictional boundaries (Fig. 1) and this will increase by one in 1999 when the NWT is officially divided into two jurisdictions. The fact that political boundaries have no relationship to ecological or resource units, complicates the management of migratory species such as the caribou. Management can be achieved only through cooperation and coordination of people, managers, and politicians.

The estimated numbers of caribou in the two herds (Table 1) has changed because of actual fluctuations in numbers and also because of changes in the technique used to estimate their numbers. Photographic estimates of herd numbers commonly are about double concurrent visual estimates (Heard pers. comm.).

Table 1. Estimated size (thousands, excluding calves) of the Beverly and Qamanirjuaq herds of caribou, 1967 through 1988, based on visual and photographic, aerial, strip surveys on the calving grounds in June.

	Beverly herd		Qamanirjuaq herd	
Year	Mean	Confidence limits[a]	Mean	Confidence limits
A. Visual surveys				
1967[c]	159			
1971[d]	188		63	
1974	154 (157)[b]		54	
1978	126			
1980	114		39	
1982[e]	120	17-224	133	
1983[e]			126	69-182
1984[e]	132	77-187		
1985[e]			183	24-342
1985				
1987[e]	94	55-132		
1988[e]	51	17-84	95	32-158
B. Photographic survey				
1982[e]	164	20-309		
1983[e]			230	111-349
1984[e]	264	102-425	272	0-556
1987			>260[f]	
1988[e]	190	48-331	221	76-366

[a]Confidence limits of the estimate are approximately the estimate (mean value) ± (2 X SE) where SE = SD/sq. root (N-1), where SD is standard deviation and N is sample size. The true population size should lie in that range in 19 out of 20 cases. However, the estimate is more variable because technique of estimating herd size is based on other variables that are assumed to be average values (Thomas 1991).
[b]Different interpretations of the same survey.
[c]Survey of caribou in spring migration (Thomas 1969).
[d]Parker's (1972) surveys.
[e]Heard and Jackson (1990a, 1990b).
[f]Post-calving survey (Gates 1985, Heard and Calef 1986).



LEGEND

- Nunavut Boundary
- Beverly Herd Range
- Qamanirjuaq Herd Range
- Limit of Continuous Forest
- Calving Grounds

Figure 1. Generalized ranges, since about 1955, of the Beverly and Qamanirjuaq (formerly Kaminuriak) herds of caribou.

2 The Users of the Beverly and Qamanirjuaq Caribou Herds

About 12,000-15,000 people live in the 19 communities that have access to the two herds of caribou (Table 2, A1). Most of those are indigenous people whose ancestors have relied on the herds for food for thousands of years. Native people from communities to the south of the range occasionally access the herds by use of roads and snowmobiles. Examples are roads to Wollaston Lake and Points North, Key Lake, Cluff Lake, Fort Resolution, the Ingram Trail east of Yellowknife, and the winter road to Contwoyto Lake.

3 Value of the Caribou Herds

The replacement value of the meat is about $13.5 million annually at a harvest of 16,000 caribou from the Beverly and Qamanirjuaq herds (Beverly and Qamanirjuaq Caribou Management Plan, 1994, in prep.). The type of survey conducted for harvest statistics tends to underestimate the harvest by about 20% (Usher 1975, Interdisciplinary Systems Limited 1978). If the harvest of 16,000 caribou is adjusted for underreporting, the harvest is 19,269 caribou and the replacement value is $16.9 million annually.

An update and re-evaluation of the harvest for the period 1982-83 to 1990-91 (A1) indicates reported and adjusted harvests averaging 14,127 and 17,660 caribou, respectively (Table 2). Corresponding annual replacement values for meat are calculated as $11.9 million and $14.9 million, respectively. The second adjustment in Table 2 accounts for wounded and unretrieved caribou and is not used in calculating meat replacement costs.

The maximum harvest for each settlement in any year from 1982-83 through 1990-91 (Table 2) is an approximation of the *need* for caribou. The kill would be approximately 26,738 (reported) and 33,423 (adjusted) at replacement costs of $22.6 million and $28.2 million if caribou were readily available every year. The estimated minimum needs per person are about three caribou or 20 per family (Jingfors 1986).

In Manitoba, the average harvest is worth $2.0-2.5 million and the potential harvest (accessible caribou) is valued at $5.8-7.3 million. Corresponding numbers for Saskatchewan are $2.5-3.1 million and $6.5-8.1 million; for the NWT $7.5-9.3 million and $10.3-12.9 million.

The average reported harvest in Manitoba, Saskatchewan, and the NWT was 1.0, 0.8, and 1.8 per person per year. Corresponding adjusted values were 1.2, 0.9, and 2.2 per person. Maximum reported harvest in Manitoba, Saskatchewan, and the NWT equates to 2.8, 2.0, and 2.4 caribou per person and 3.5, 2.5, and 3.0 if adjusted values are used.

The cultural, social, and spiritual value of caribou is incalculable. Caribou also have intrinsic value to all Canadians and the human population.

4 The Beverly and Qamanirjuaq Caribou Management Board (BQCMB)

The Beverly and Kaminuriak Caribou Management Board (BKCMB) was established in June 1982. The 10-year agreement was among the governments of Canada, Manitoba, Saskatchewan, and the NWT. The agreement was renewed for an additional 10 years in 1993, retroactive to June 1992, and the Kaminuriak herd name was replaced by Qamanirjuaq (BQCMB). The name, after a lake in the calving area, was officially changed in 1989 by the Canadian Permanent Committee on Geographical Names.

Objectives within the agreement relating to habitat are (c) "...in order to ensure coordinated caribou conservation and caribou habitat protection..." and (d) "to discharge the collective responsibilities for the conservation and management of caribou and caribou habitat within the spirit of this Agreement." (Beverly-Kaminuriak Barren Ground Caribou Management Agreement 1982).

Table 2. Settlement populations and estimated average harvest of caribou from the Beverly and Qamanirjuaq herds, 1982-83 through 1990-91, by settlement.[a]

Jurisdiction/ Settlement	Approximate population[b]	Average harvest	Maximum harvest[c]
Manitoba			
Brochet	650	647	1475
Lac Brochet	695	1031	2758
Tadoule Lake	450	425	1125
South Indian Lake	1000	89	800
Resident hunt		163	750
Manitoba totals	2795	2355	6908
Adjusted total[d]		2944	8635
Saskatchewan			
Camsell Portage	61	68	205
Uranium City	209	94	600[g]
Fond du Lac	1026	1061	1761
Stony Rapids	276	117	244
Black Lake	1400	807	2300[g]
Wollaston Lake	900	694	2300[g]
Other		73	235
Saskatchewan totals	3872	2914	7645[g]
Adjusted total[d]		3643	9556[g]
Northwest Territories			
Fort Resolution[e]	515	E200	E500
Fort Smith[e]	2512	E400	E500
Snowdrift[e]	286	E1000	E1200
Fort Reliance[e]	11	E50	E100
Baker Lake[f]	1186 (854)[i]	E2816	3379
Chesterfield Inlet[h]	316 (79)[i]	E100	E300
Rankin Inlet	1706	1524	2737
Whale Cove	235	545	704
Arviat	1323	2223	2765
NWT totals	8090	8858	12185
Adjusted NWT total[d]	5009[i]	11073	15231
All Jurisdictions			
Grand total	14757	14127	26738[g]
Adjusted grand total	11673[i]	17660	33423[g]
Double adjusted grand total[j]		22075	41779[g]

[a]In annual reports of the Board and summarized in Thomas (1991).
[b]Maximum population in annual reports of the Board to 1993.
[c]Maximum harvest is highest kill by each settlement in any year.
[d]Adjusted by 20% (reported X 1.25) to account for underreporting.
[e]Estimate (E) based on population size and accessibility of caribou.
[f]Assumes 72% of caribou obtained from the Beverly and Qamanirjuaq herds (estimated ratio in 1982-83 and 1983-84).
[g]Includes data for 1991-92 (Trottier pers. comm.).
[h]Assumes 25% of caribou obtained from the Beverly and Qamanirjuaq herds (estimated ratio in 1983-84).
[i]Adjustment reflects omission of Fort Smith (few hunters), 72% of the Black Lake population and 25% of the Chesterfield Inlet population.
[j]Second adjustment of 20% to account for wounding and unretrieved losses.
Note: A few other caribou included in total for Sask. (Thomas 1991).

The goals, objectives, principles, and action plans of the BQCMB are set out in a management plan (1987, under revision in 1993-94). The fire management recommendations relate to two objectives of the plan: (4) "Access and availability: to ensure that caribou are accessible and available to traditional users"; and (5) "To cooperate with other northern wildlife management boards and to involve local individuals and organizations in management programs." (Beverly and Kaminuriak Caribou Management Plan 1987).

5 Purpose of this Technical Review and the Fire Management Recommendations

The main purposes of this technical review are:

1) To state the collective views of the BQCMB regarding fire management on the forested ranges of the Beverly and Qamanirjuaq herds;

2) To provide the jurisdictions with recommendations regarding fire BQCMB management; and

3) To provide background information to fire managers, caribou managers, the BQCMB, and others on caribou ecology and management, fire history, fire effects, fire ecology and management, and the socio-economic importance of the herds.

6 Objectives

1) To seek ways of modifying fire for the benefit of the Beverly and Qamanirjuaq herds of caribou, the uses of those herds, and boreal and transitional forest ecosystems;

2) To make general recommendations on fire management policy, options, and guidelines and specific recommendations for each jurisdiction; and

3) To seek ways of involving caribou users and their communities in fire management policy, in implementing that policy, and in fire suppression and management.

7 Goals

1) To maintain sufficient forested winter range in mature (51-150 yr), old (151-250 yr), and ancient (>250 yr) forests to sustain the two herds at minimum population sizes of 150,000 caribou older than one year;

2) To maintain sufficient amounts of mature and older forests in traditional caribou hunting areas of each community such that caribou may winter there, access to the herds is maintained, and hunting is a sustainable option;

3) To maintain adequate amounts or proportions of each forest successional stage such that the natural forest ecosystem is maintained, including all its components and the functional relationships among them; and

4) To draft the first recommendations in 1993, to review them in 1993-94, to seek their implementation beginning with the 1994 fire season, and to revise the recommendations at five-year intervals.

8 Principles

1) Natural fire is an essential process to maintain boreal forest and transitional forest ecosystems in their normal state;

2) Modification of the fire regime, as proposed in this plan, is within acceptable limits and will result in minor changes to the ecosystem and the natural fire regimes;

3) The extent of future burning cannot be predicted as the fire history statistics vary with the area selected and the time period. The natural fire cycle in any area can only be characterized by wide ranges of statistics;

4) Priorities for fire management will be based on social and cultural values as well as economic and environmental factors;

5) The highest priority in fire and caribou management is to provide traditional users with the option to maintain the traditional hunting of caribou;

6) Fire and caribou management recommendations must reflect the fact that traditional users of the caribou resource have first priority of use after conservation needs are met (Minutes of BKCMB, April 1987);

7) Traditional users must have a greater role in all aspects of fire management on the range of the Beverly and Qamanirjuaq herds, including planning, decision making, and implementation of policy and guidelines;

8) The development of fire management recommendations must combine the best local knowledge and science in the delineation of priority zones, the rating of priorities, fire policy, fire management guidelines, implementation of fire policy, and plan revisions;

9) The latest technology must be used as tools in fire management including satellite data, geographic information systems, geographic position systems, lightning detectors, remote weather stations, and computerized fire models and predictive systems; and

10) This plan relates to caribou and caribou hunters only and it should become part of a larger plan that includes all values within the range of the two herds. For example, prescribed fire to enhance populations of moose and bison (*Bison bison*) is an option in some areas on the periphery of the caribou range.

Board objectives are complementary to Federal and Territorial Government objectives and guidelines to improve the lives of residents in the Northwest Territories. Murphy et al. (1980) summarized some of these as follows:

1) Provide for a higher quality of life;

2) Increased employment opportunities for northern natives;

3) Development of the renewable resource sector;

4) Protecting the options of northerners to maintain traditional lifestyles; and

5) More involvement of native northerners in the decision-making process.

9 Historical Background

9a. Philosophy of Fire and Fire Management

The use of fire is one behavior that sets humans apart from other animals. Fire has been used to cook, as heat, and to modify the environment for thousands of years. Survival in northern areas was dependent on it. Aboriginal peoples had a good understanding of fire and its effects. Indians living in the Grasslands and Aspen Parklands used fire for many reasons (Lewis 1982), including vegetation management to attract animals. These tribes were mobile and moved to areas favorable for hunting.

The use of fire for vegetation management by people inhabiting the boreal and transitional forests is less clear. People that relied on moose, elk and bison probably set fires to improve the habitats of those species. Indians in northwestern Alberta apparently used fire to improve moose range (Lewis 1977).

Caribou hunters probably did not intentionally start forest fires because they understood the need for mature forests to sustain caribou in winter. Fire that escaped could destroy cabins in hunting and trapping areas.

The arrival of agrarian, immobile Europeans started a period of fire suppression. The mindset was that fire was bad and it must be prevented and suppressed. This attitude was extended throughout North America. Some negative consequences of fire suppression gradually were realized. Aspen and shrubs encroached on grasslands, insects killed large areas of mature and overmature forests, and very large fires burned large expanses of protected mature and old forests (e.g., 15% of Wood Buffalo Park in 1981 and 16% of Yellowstone National Park in 1989). Fire suppression was replaced by fire management, which included prescribed fire as an important component. However, prescribed fire was of such a small scale that the forest-aged distribution was abnormal with excessive amounts of mature and older stands in most commercial southern forests. One solution, eagerly embraced by forest companies in the commercial forest zone south of the Precambrian Shield, was to replace fire with logging.

Fire is a natural process that has shaped ecosystems and contributes to habitat and animal diversity. In fact, the boreal forest is termed a fire-dependent ecosystem. It may be difficult to duplicate the effects of natural fire either through prescribed fire or through logging. Whether fire is good or bad depends on its scale in space and time in relation to human objectives.

9b. Research on the Effects of Fire on Caribou Winter Range

Perceived declines in caribou numbers in the first half of this century led, in 1948-52, to a preliminary study of barren-ground caribou in Canada (Banfield 1954). The study identified high harvests and wolf (*Canis lupus*) predation as the main causes of declines in caribou. It also noted loss of winter range from fire, which led to a range study by Kelsall (1957).

Continued, apparent declines in the 1950s resulted in a second major study in 1957 and 1958 (Kelsall 1960, 1968). The only fire-related studies were photointerpretation to establish the amount of burned range in Manitoba (Beckel 1958) and Saskatchewan (Brown 1961), and aerial reconnaissance to determine the same for an area in Saskatchewan (Kuyt in Kelsall 1968). Range studies received a setback with the resignation of the researcher hired to conduct such studies. The conclusion at the end of the 1967/68 study was that a combination of hunting, wolf predation, and weather were considered the main causes of caribou declines (Kelsall 1968).

Studies designed to determine the effect of fire on caribou and caribou range started in 1964 in northern Saskatchewan and continued in 1965 in northern Manitoba. The results indicated a long recovery period (50-100 years) for "caribou" lichens after fire and avoidance of burns by caribou (Scotter 1964, 1965). Scotter (1964) concluded that:

> "... if the effect of fire ... are similar throughout the winter range, then there would be little doubt that forest fires have been one of the principal causes of the decline." (P. 80).

Scotter (1964) may have been referring to declines from the estimated millions of caribou at the turn of the century (reviewed in Kelsall 1968). He also believed that the incidence of fire had increased during 1945-1971 relative to earlier periods, with a much reduced rate from 1840 through 1884. A possible cause was prospectors intentionally setting fire to expose bedrock for easy viewing of minerals (Scotter 1964).

Range studies were part of a major study of the apparent decline of the Kaminuriak herd from 1967 through 1969. The range studies continued into 1973 and included range in northern Saskatchewan. The major conclusions were that lichens favored by caribou returned after 40 years but other forages such as sedges were used in burned habitat; that caribou did not avoid burns but preferred them for travel; and that fire was necessary to create habitat diversity (Miller 1976a, 1976b, 1980).

From about 1970 through 1976, studies were conducted in the NWT of the causes of fire, the frequency of fire, the sizes and distributions of burns, and on fire ecology (Rowe

et al. 1975; Johnson and Rowe 1975; Johnson 1979, 1981a, 1981b). Major conclusions were that: (1) Fire was a natural consequence of the meeting of arctic and maritime air masses; (2) 99% of burned areas was caused by lightning fires; (3) Much of the area burned over a period of 20-50 years was caused by fires in a few years; (4) the fire frequency changed from west to east and in relation to the "tree line" and other factors; and (5) fire was necessary to maintain the fire-dependent ecosystem.

Analysis of fires, 1975-79 inclusive, in the NWT revealed that fires started by lightning accounted for 97% of the area burned (Murphy et al. 1980). Fire size isolines indicated a sharp transition in fire sizes from the Rutledge River to the upper Thoa River. The distinction was sharper in an earlier version of the isolines (Johnson and Rowe 1974).

Fire history in the boreal and transitional forests indicates that most of a specified area is burned by natural fires in only a few years over spans of 25-100 years (Alexander 1981, Murphy et al. 1980, Ferguson 1983, MacAuley 1983, Heathcott 1990, Bergeron 1991). In Wood Buffalo National Park, fires in 1953 and 1981 accounted for 60% of the area burned from 1950 through 1989 (Heathcott 1990). Addition of fires in 1971 and 1980 increased the percentage to 83. Fires in 1979 accounted for 40% of the "Caribou Range" burned from 1966 through 1982 (Ferguson 1983). The percentage would be higher with inclusion of range on the Shield to the west. Fires in 1971, 1973, and 1979 accounted for 47% of the area burned from 1950 through 1979 in the NWT (Murphy et al. 1980). Fires in eight years over 228 years accounted for 72% of lakeshore forests of one lake in the southern boreal forests of Quebec (Bergeron 1991). Fires in six years in a 40-year period accounted for 63% of the area burned in Alaska (Viereck and Schandelmeier 1980).

Fire dependency refers to the need for fire to renew certain species such as jack pine and to maintain a certain distribution of successional stages. The distribution of area burned in relation to time had the shape of the Weibull distribution (Rowe et al. 1975, Johnson and Rowe 1975, Johnson 1979) and the negative exponential (Van Wagner 1978).

From 1973 through 1976, further studies of the effects of fire were conducted at Carleton Lake between Abitau and Dunvegan lakes (Kershaw et al. 1975, Kershaw and Rouse 1976). Only one habitat type, the tops of drumlinoid ridges, was sampled because additional sampling was beyond the capabilities determined by time and funds. One conclusion, refuted by others (Strang and Johnson 1981, Thomas 1994c) was that fire was necessary to open the canopy that gradually closed and caused lichens to be replaced by moss (Kershaw and Rouse 1976).

9c. Fire Occurrence Terminology

(See A2 for more definitions)

The occurrence of fire and extent of burns has been expressed in several ways and some confusion has developed even among fire researchers and managers. Thus, the need to define terms.

Fire occurrence is the number of fires in a given area over a stated time. *Fire frequency* is equivalent to fire occurrence for some authors. It includes area of burns for others (Johnson and Van Wagner 1985, Bergeron 1991). *Rate of burn* (burning) is used to express the areal proportion (e.g., percent) of a given area that is burned over a stated time period. Fire scientists like to reserve the term "burn rate" to imply rate of spread of a particular fire. For comparative purposes, the *average annual rate of burning* is used. If it averages 1% per year, then over 100 years the cumulative area burned will equal the entire "study" area in size (the *fire cycle*) (Van Wagner 1978). Some areas will be burned twice and others not. *Mean fire return interval* is the average interval between fires at any one spot or collectively at many locations randomly or systematically distributed over a study area. It is measured by obtaining interval data from trees with two or more fire scars."Stand" is a term used to indicate forests arising from a single fire. Such interval data tend to underestimate the average fire interval unless the trees in all sampled sites have at least two

Plant life, seven years after this area at Porter Lake was burned. In forests, future burn patterns are influenced by previous fire history.

scars. *Age class distribution of burns* refers to the proportion of the range in arbitrary age classes at any given time.

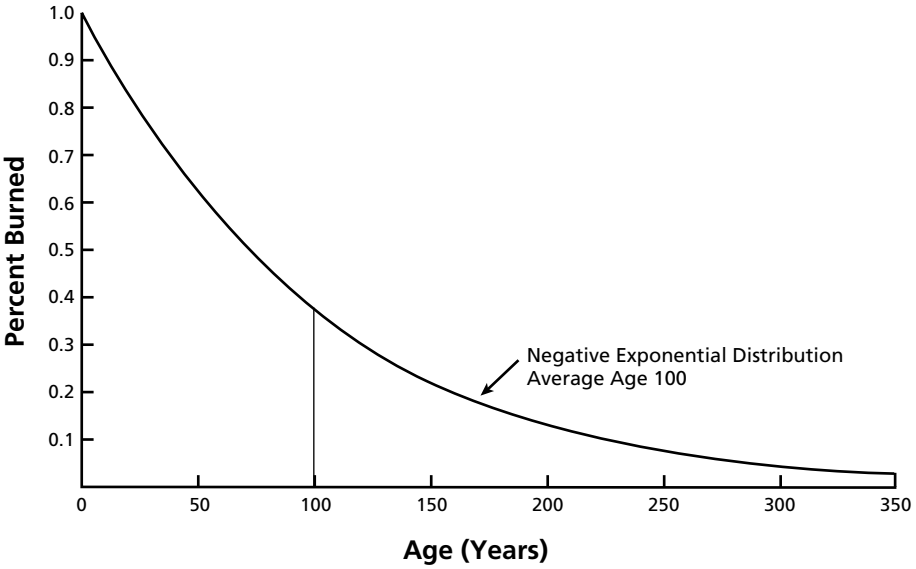
An understanding of the relationship among these fire occurrence estimators and the proportion of the forest in age classes that are used by caribou is fundamental to fire and caribou management (Thomas 1985, Couturier and St-Martin 1990).

9d. The Natural Fire Cycle?

Rowe et al. (1974, 1975), Johnson and Rowe (1975), and Johnson (1979, 1981a, 1981b) attempted to fit fire statistics to statistical distributions (Fig. 2). Their purpose was to detect the pattern of fire history and to predict future rates of burning. The Weibull distribution provided the best fit. The distribution was tested by systematically obtaining fire interval data at sites within four areas that had burned in the previous four or five years (Johnson and Rowe 1975, Johnson 1979). The data were biased by selection of sites that burned in the recent past (vs. areas not burned) and by the age of stands that had not as yet burned.

Van Wagner (1978) found that the negative exponential distribution fit burn history data for a study in Minnesota where stand origin was obtained for the entire area (Heinselman 1973). Assumptions of equal flammability with age of forest and random and constant burned area with time clearly were violated and yet the statistical fit was good. Van Wagner (1978) tested use of the negative exponential in the Hinton area of Alberta and found it was satisfactory.

A measure of the *past* fire cycle is long-term data on the fire history of the entire forested winter range (Heinselman 1973). A stand origin map is created. Most fires on the caribou range are crown fires that destroy the surface vegetation. Stand origin is the important temporal variable in terms of caribou food. The additional information that is needed is the mean fire-return interval or fire cycle. One method of estimating these statistics is to survey ages of the forest when it last burned. Because the fire-return interval varies greatly in relation to climatic and physiographic features, the range must be divided (stratified) into units with different fire-return intervals or fire cycles. The proportions of the



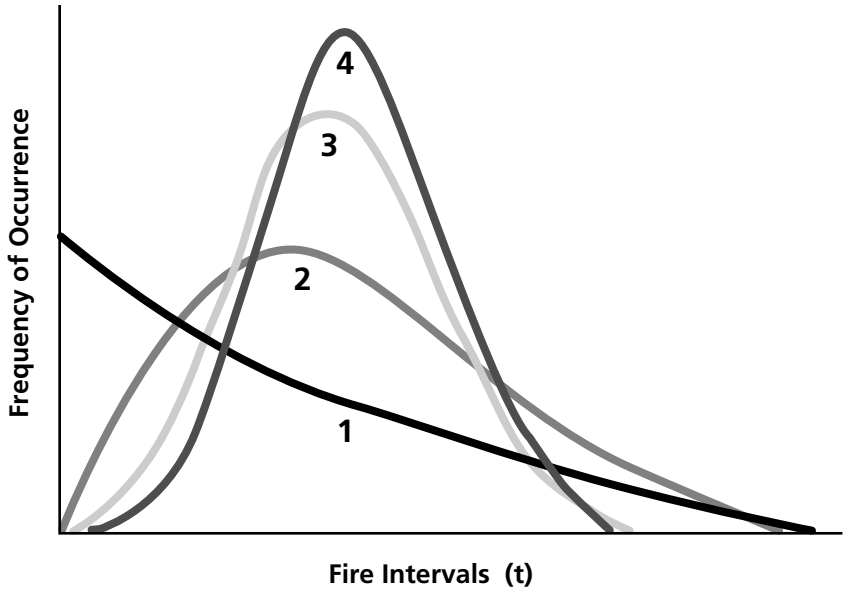


Figure 2. The negative exponential and Weibull distributions of the area burned with time and fire intervals: a. Negative exponential data for an average age of 100 years (Van Wagner 1978); b. Weibull shapes with various values of parameter C (Johnson 1979).

range in various age classes can be used for management of fire and caribou.

Variation in fire return interval is related to the isolines of fire sizes in Rowe et al. (1975) (Fig. 2). The exercise should now be repeated using the data in the GIS database of burns and ecoregional data. The stratification should be fit into ecoregional and ecodistrict classifications as much as possible because future land management probably will be related to those units. The burn statistics reflect climatic, vegetational, and surface characteristics to a large extent and those are the criteria for stratification of the landscape into ecological and ecoclimatic (= biogeoclimatic) units (Ecoregions Working Group 1989).

An important factor that influences the future burn pattern is the previous fire history. Ignition probability and flammability clearly increases with forest age, at least to some mature or older stage (A3). Pine (*Pinus banksiana)* forests are more prone to fire than spruce *(Picea* spp.*)* forests. Tree density also is imporatant. Tree density depends on soil characteristics, age of forest that burned, and fire intensity among other variables. Fires will burn into young pine stands and they will spread for several kilometres under extreme fire conditions (extremely dry with strong winds). However, examination of where fires occurred and age of burned forest reveals a preponderance of old stands that burned.

Data from Quebec (Payette et al. 1989) and Labrador (Foster 1983) indicate that the frequency of burn size classes also fits a negative exponential distribution but most of the area is burned by large fires.

The burn history is not difficult to "ground truth" if preliminary maps are made using LANDSAT scenes obtained in summer and winter. Ground checking can be incorporated with fire mapping and fire training exercises. Hunters and trappers could obtain tree disks needed for stand history. Training would be needed to obtain accurate information.

9e. Fire Management on Caribou Winter Range

In the 1950s, the fire managers were asking caribou biologists if fire suppression was needed to improve caribou ranges. The biologists of the day were uncertain. The studies of Scotter (1964, 1965), Kelsall (1968), and Ruttan (pers. comm.) tipped the scales in favor of suppression. Scotter (1964) said that fire may have been a factor in caribou declines and Ruttan thought that there were too many caribou for the range. That set the stage in 1965 for a five year experimental program of fire suppression on the winter range of the Beverly herd in the NWT. The experimental area, the "Caribou Range", was between 104°W and 112°W and between the border and "tree line". The western border between 60°N and 62°N was from 110°W to 112°W. Cabins were built at Porter and Sandy lakes in 1966, 1967, and 1968. Fire crews were positioned at the sites from 1967 through 1972.

Costs in 1966 through 1968 were 117K, 50K, and 42K, excluding salaries of permanent staff and overhead costs in Fort Smith (Naysmith pers. comm.). The crews were not able to suppress some large fires in 1970 and 1971. Subsequently, some fires were fought on caribou range in the NWT when they threatened cabins or fishing lodges. For example, in 1979 fire fighting on the Caribou Range amounted to 1.4% of the NWT fire management budget (Murphy et al. 1980). Increasingly, through the years, fires were fought on the "caribou range" if fire crews were not needed for fires with higher priority.

9f. Fire Management Policy

Fire management policy has several components (e.g., Murphy et al. 1980):

1) The criteria used for zone determination and delineation;

2) The fire management objectives for each zone;

3) The action guidelines for each zone (e.g., maximum expenditures per zone and per fire); and

4) Implementation of the policy and guidelines.

Highest priority in all jurisdictions is protection of human life. Next priority is always valuable structures and property.

Northwest Territories

Large fires in 1961, 1964, and 1966 (2 340 km^2 average per year) resulted in a policy formulated in 1967 to protect life, property, and specific resource values (Northwest Territories Department of Renewable Resources 1991). A new fire management plan with four priority zones was introduced in 1972 and 1973. Priority Zone 1 included communities; Zone 2 included public works, lodges, mines, commercial timber, and road and waterway corridors; Zone 3 contained specific wildlife habitat, trapping areas, recreational sites, some watersheds, and timber resources. Zone 4 was the remainder or the Unprotected Zone. Guidelines imposed spending limitations on fires in each zone.

The size of the protected zones was decreased in 1976 and Zone 3 was added to Zone 4 in 1977. "By this stage, the priority of the fire management objectives had been largely overtaken by the priorities of financial management" (Northwest Territories Department of Renewable Resources 1991).

A severe fire year in 1979 (19 891 km^2 burned) and action by the Fort Smith Hunters and Trappers Association led to the appointment of a Fire Review Panel (Murphy et al. 1980). The panel suggested that reasonable goals for average annual rates of burning should be 0.75-1.0% in the south and perhaps 0.5% in the north of the Fort Smith District. The 90 recommendations resulted in a new policy that was formulated after public consultation. There were only two zones, a Fire Attack Zone (FAZ for initial attack suppression) and an Observation Zone (OBS or natural fire area). The FAZ was subdivided into two areas based on values at risk. The policy objective was to maintain an average annual burn rate of 1%. There was a protective zone around Snowdrift that bordered on the Snowdrift River east of Siltaza Lake.

In April 1987, forest management was transferred from the Federal Government to the Territorial Government. A Forestry Working Group was established to make recommendations on a NWT fire policy. The draft policy contained provisions for management decisions based on values at risk, logistics, and weather. Financial constraints are unstated but paramount.

The current policy (NWT Dep. of Renewable Resources 1990) has no priority zones except settlements, towns, and cities. Rather, all detected and reported fires require a response (decision) based on: (a) values at risk; (b) land and resource management objectives; (c) availability of personnel and equipment; (d) weather; (e) fire risk in higher valued areas; and (f) the relative value of property and resources. The policy has provision for protection of areas around settlements of two sizes: 25-500 people = a 10-mile radius or 314 mi^2; >500 people = a 20-mile radius or 1 256 mi^2.

Values-at-risk priorities in decreasing order are: (1) human life; (2) property; (3) renewable resources (action discretionary depending on relative values); and (d) cultural resources (historic/archaeological sites or culturally-significant areas). Protection of renewable and cultural resources is withdrawn when expenditures after the first attack period equals the perceived value of the resource in the estimation of the fire manager.

The policy is guided by principles pertaining to the natural role of fire, fire management priorities, consultation, use of local knowledge, and government policies regarding renewable natural resources and the betterment of NWT residents.

The policy is highly flexible but it requires great knowledge of the relative values of property, renewable resources, and culture. Decision makers must subjectively weigh a number of variables.

Saskatchewan

Priority of values are: (1) life; (2) public and private property where values at risk justify the efforts and costs of likely suppression; (3) commercial forest; and (4) non-commercial forest. There are four priority zones with three priority subzones in Zone 1:

1) *Primary protection* — gets initial attack but further action is guided by three priority subzones.

2) *Secondary* — all forests north of Zone 1 (Fig. 6). Initial action is taken if suppression possible in first two burning periods. Large declining fires suppressed if extinction possible in two burning periods.

3) *Green space* — Areas with maximum radius of 24 km centered on all communities and large mines.

4) *Non-protected* — lands outside burning permit area. Generally south of the commercial forest.

An escape fire analysis procedure is used to decide on further action after the first burning period (generally the first day).

Manitoba

Fire protection zones in the forest region consist of an Observation Zone and a Primary Protection Zone. Within the Observation Zone an initial response is taken only if life is at risk and/or property values warrant a suppression response. The fire priority map for Manitoba (1992 season) indicates no general protection for lands north of 57°N in the west and north of 56°N and 54° 45′N in central regions. There are four priority levels within the protection zone.

The worst fire year in recorded history was in 1989 when about 10% of the boreal forest south of 58°N burned. The gap north of about 58°N represents lack of mapping rather than the absence of burns.

Alberta

Prime protection priorities are ranked: (1) population centres; (2) major industrial and commercial developments; and (3) areas requiring special protection. These are weighed against resource priorities ranked on a numerical rating where maximum values are 10 for timber; 5 for recreation; 2 for watershed; and 1 each for wildlife, soil sensitivity, and minor developments (Foley and Johnson 1990). A fire suppression priority map was generated using the above criteria.

9g. User Views of Fire Management

Most traditional users on the caribou range view fire as a destructive force. The views of users in the Fort Smith area were recorded in a review of fire management practices after the large fires of 1979 (Murphy 1980). Other viewpoints were recorded in tapes and text coordinated by Snowden (1981), in issues of Caribou News, in Board meetings, and in personal conversations outside meetings. Noting that some burns went to the border of one map and were not on the adjacent map, former Board president Jim Schaefer observed that all that was needed to reduce fire was to have more maps at a larger scale!

Caribou users are aware that caribou feed little in burns for several decades. They also know that caribou will travel through burned areas provided that there is good habitat around them. Some believe that "green" (mature or older forest) corridors and mature forest "peninsulas" that project into mostly burned areas should be protected. The hope is that caribou will continue to use these green corridors and peninsulas to travel

Native students Miranda Haupt and Trinity Macdonald of Fort Smith help with habitat studies.

to areas of good winter habitat. A mosaic of young and old forests increases moose abundance but caribou are preferred by most traditional users.

Protection of caribou range is not the only concern. Trappers fear that their cabins will burn and that the numbers of furbearers will decline in burned areas. Marten (*Martes americana*) are associated with mature forests. However, they will feed in young forests adjacent to old forests and even remain in burns or recolonize them (Latour pers. comm.). Wolves (*Canis lupus*) and foxes (*Vulpes vulpes*, *Alopex lagopus*) follow the caribou.

10 Elements Of Fire Management For People And Caribou

10a. Caribou Ecology

Gaining a good grasp of the relationship of caribou to their environment (caribou ecology) is a necessary first step in development of fire management recommendations. A study of the effects of fire on the Beverly herd and its range was started in 1980, expanded in 1982, and phased out in 1987-88. The study was designed to answer several ecological questions.

Major conclusions of the fire study:

1) The quantity and quality of the winter range was adequate for the number of caribou in the Beverly herd. Photographic-based estimates of the size of the herd (excluding calves) in the 1980s, in thousands, were 164, 264, and 190 (Table 1).

2) Caribou in the main herd travelled through burns of all sizes and ages but they did little feeding in burned areas until 50-70 years after the fire. There was some feeding in unburned patches within burns but caribou quickly moved to large expanses of mature and older forest. Travel through burns was on a few parallel trails. Several thousand caribou could travel on one trail and in one set of footprints. Small groups of caribou can spend the winter in patches of unburned forest and along waterways within the boundaries of burns.

3) Ground lichens constituted 80-95% of the winter diet of caribou. The lichens preferred by caribou were not abundant until 40-60 years after fire. One lichen species, *Cladina rangiferina*, was most abundant at 150-250 years after fire. At 40-60 years after fire, the lichens were in small patches but the lichens were relatively long and growing rapidly. By 80-100 years post fire, the lichens covered more of the forest floor. In old forests the lichens covered most of the forest floor but they were relatively short because of drier microclimate and perhaps other factors.

4) Caribou fed more in old (>150 yr) forests than in mature (51-150 yr) forests (Fig. 3). Recent burns and young forests were little used for feeding. The reasons for highest use of old forests is not clear. Visibility is good in old forests and caribou are likely to encounter lichens when they crater.

5) In most winters, snow was relatively deep on the eastern half of the winter range. The caribou appeared to have a movement pattern that took advantage of these differences in snow depth. In most winters, the main herd of caribou that contained cows, calves, yearlings, and young bulls (to three years) used eastern parts of the range in the early winter when snow was shallow and of similar depth across the range. Then they moved to western parts of the range in December and January where the snow was shallower.

6) Differences in fatness (physical condition) of caribou was due mainly to the spring and summer periods. Caribou maintained their fat or gained fat in most winters.

Summary of knowledge

Fire-caribou relationships were discussed in Couturier and St-Martin 1990; Ferguson 1982; Kelsall 1968; Kelsall et al. 1977; Klein 1982; Miller 1976a, 1976b, 1980; Scotter 1964, 1965, 1967, 1971a, 1971b; Thomas et al 1994). Current knowledge is summarized in reviews of the circumpolar literature on the effects of fire on caribou (Klein 1982) and the role of range in limiting caribou (Klein 1991).

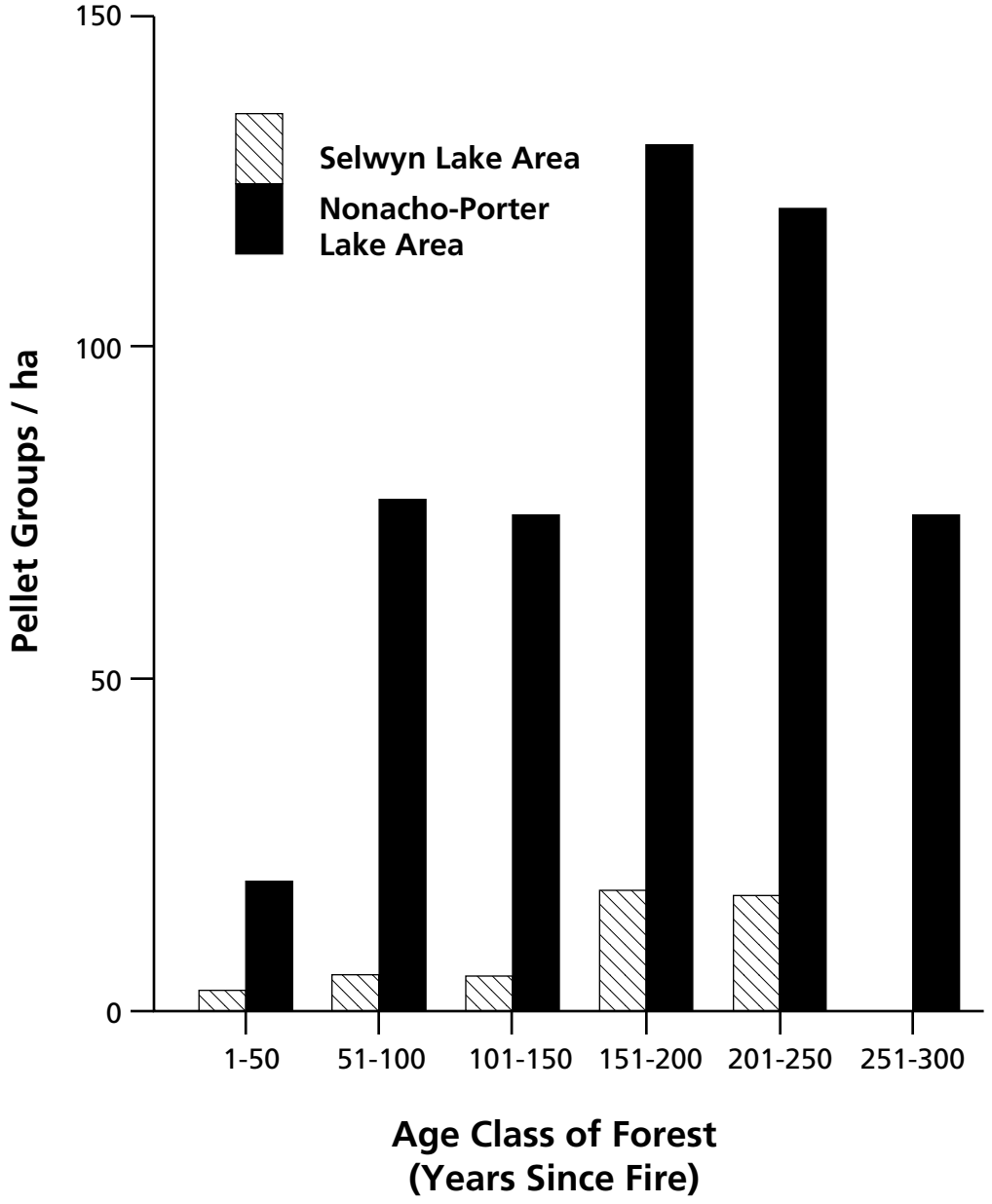


Figure 3. Relative use by caribou of forests in 50-year age classes west (Nonacho-Porter lakes region) and east (Selwyn Lake region) of 108°W in the NWT as indexed by densities of fecal groups.

Data needs

The preferences of caribou for plant species under snow is poorly understood. If the preferred species were overgrazed, could the caribou persist on other plant species? In the 1980s, the Beverly herd appeared to be exploring for additional range to the east and west. Is this normal behavior or a consequence of large population size and a need for space (winter habitat) proportional to herd size? Is this behavior related to depletion of forage along the winter travel routes?

Habitat preferences, other than those related to food, are poorly understood. Do caribou prefer open forests because of greater visibility or because lichens are more likely to be encountered?

More data are needed on the relative use of forest of various ages and canopy types (pine, pine/spruce, spruce/pine, and spruce) by caribou. The sites examined in the fire study were selected for other reasons and the results could be biased by the sampling technique, e.g., edge effects.

10b. Fire History

Fire history mapping

The earliest recorded accounts of fires are in journals of early explorers. Additional information is available in records of trading posts and the Royal Canadian Mounted Police. A large effort would be needed to assemble those data. A large amount of additional information could be obtained from elders. Approximate dates of major fires could be obtained from all those sources but few burn borders could be drawn. Burn distributions must be mapped using satellite imagery or aerial reconnaissance.

The maps of burns on the winter range of the Beverly herd in the NWT, located in the fire office in Fort Smith, date back to 1969 burns. Earlier burns must have been mapped because burn areas are given for some burns in the 1960s, shown as spot locations on some maps. The periphery of burns were mapped at a scale of 1:250 000 from circling aircraft. Their accuracy varies but generally they were adequate for fire management. The quality of the maps for fires in Saskatchewan and Manitoba were more variable.

All the burn boundaries were checked against ERTS and LANDSAT images. ERTS imagery was used by Rowe et al. (1975) to map burns west and north of Yellowknife. It was used by Murphy et al. (1980) to document the extent of 1979 fires east and northeast of Fort Smith. Moore (no date but probably 1982) mapped much of the forested areas of the NWT using LANDSAT imagery. LANDSAT was used to check burn boundaries mapped from aircraft and to measure the area of non-burned patches within burns (Mycasiw 1983).

The proportion of non-burned forest ("inclusions") often is lumped with lakes, meadows, and streams. The water and wet areas were found to comprise 20-28% of the landscape in the four map sheets examined by Mycasiw (1983). Percentage of the total non-burned area within burn peripheries were listed as up to 50% (Bradley et al. 1982), 15% on the caribou range in 1979 (Kourtz 1980 in Murphy et al. 1980), and 24% for a large burn (SM2) of mostly 68-year forest (Murphy et al. 1980). Mycasiw (1983) found that non-burned areas averaged 36% of large 1979 burns on the caribou range. Subtraction of 22% water and wet areas leaves 14% for non-burned forest (inclusions). Much of that is lowland forest. Qualitative observations of hundreds of burns indicated that most of them had 5-15% unburned inclusions. Inclusions are found in the lea of lakes, on islands, in lowland wet areas (bogs, meadows, and streams), and where convection tunnels were associated with strong surface winds partly generated by the fire.

The borders of burns on the Taiga Shield (transitional forest = lichen woodland) are easily detected for 30-60 years after the burn and some boundaries of older burns are visible on LANDSAT images. Boundaries in bogs are difficult to detect a few years after fire because the graminoid (grasses and sedges) and shrub vegetation is quickly re-established. Burn boundaries are poorly defined on the large Athabasca Sandstone Formation south of Lake Athabasca and the Fond du Lac River. These sparse pine forests burn

when young or in early maturity and burn edges tend to be ragged.

Transparencies of multispectral (bands 4, 6, and 7 or bands 5-7 of LANDSAT 1-3) were best to delineate burn boundaries in summer scenes. Single band 5 was preferred for winter scenes (November, February, and March). The tone of the monochrome images is an index of forest age and canopy type.

Size classes of burns vary with authors and jurisdictions. In Manitoba, Class 1 burns are >40 470 ha, Class 2 are 20 235-40 470 ha, Class 3 are 4047-20 235 ha, and Class 4 are <4047 ha (Manitoba Wildlife Branch 1983). Thomas (1994c) adopted eight metric size classes ranging from 1- >1 000 000 ha (A4).

Computerization of data (GIS)

In 1991 and 1992, existing burn maps for the NWT were digitized into a SPANS Geographic Information System (GIS). In 1991 and 1992, the mapping was extended to the historical range of the Beverly herd north of 58°N in Alberta, Saskatchewan, and Manitoba. Burn mapping in most of northwestern Manitoba ceased in 1981.

The mapped burns, placed in decade or multiple decade age classes, show a high prevalence of burns on the western and southern portions of the range of the Beverly herd. Burn maps at scales of 1:250 000 and 1:1 million contain actual or estimated year of each burn (Beverly and Qamanirjuaq Caribou Management Board 1994c, 1994d). Community priority zones, fire cycle zones, and the composite fire management zones were added to the GIS in summer 1993. The calculation of productive forest for caribou within the fire management zones was slowed by the lack of digital data for all but the largest lakes and incomplete fire history in Manitoba. A "Fire Suppression Action Zone Map" guided fire managers in summer 1994. It simplified fire management priorities into three levels of concern.

The GIS will permit rapid analysis of burn data and should provide the stimulus to update the files after each fire season or periodically by use of LANDSAT and other remotely sensed data. Priority for fire management can be updated periodically by comparing proportion of usable caribou range to goals for usable range within each fire management zone.

Areal Rate of burning

Rate of burning refers to the average annual percent of specified areas burned in a specified time period. Ideally, it should be based on the amount of an area burned in 100 or 200 years. In terms of caribou range, an important statistic is what percentage of a given area has forests old enough to produce sufficient food to support caribou. We use 50 years as a general average but there is not much use of forests by caribou until 60 or 70 years post fire. The proportion of forests older than 50, 70, 100, 150, and 200 years rapidly decreases as the rate of burning increases (Table 3). There is considerable variation among habitats in the recovery of caribou lichens after fire and a recovery range of 40-60 years or more should be understood when a mean recovery time is stated.

Scotter (1964) contracted Brown (1961) to estimate the age distribution of forest on the Black Lake map sheet. Scotter (1964) concluded there was an increase in the rate of burning in the 20th century compared with the 19th century. However, an opposite conclusion is reached if Scotter's (1964) data are adjusted by the reburn statistics of Rowe et al. (1975) for the Rutledge Lake area (A5). The adjustment probably overcompensates and a "middle ground" is suggested.

The rates of burning for forests in Saskatchewan, the NWT and Manitoba for certain time periods (Table 4) indicate highly variable rates over short periods.

Table 3. Relationship among average annual rate of burn, the fire cycle, and productive caribou range (>50 years) at several rates of burning, assuming that the distribution of ages of the areas burned fits a negative exponential distribution.[#]

A=Ave. ann. rate of burn (%)	*B* = Fire cycle		*C* = Percentage of range with forests older than:				
	(yr)[#]	Term[*]	50 yr	70 yr	100 yr	150 yr	200 yr
0.1	1000	"long"	95	93	90	86	82
0.2	500	"long"	90	87	82	74	67
0.3	333	"long"	86	81	74	64	55
0.4	250	"long"	82	76	67	55	45
0.5	200	"long"	78	70	61	47	37
0.6	166	"long"	74	66	55	41	30
0.7	143	"long"	70	61	50	35	25
0.8	125	"medium"	67	57	45	30	20
0.9	111	"medium"	64	53	41	26	17
1.0	100	"medium"	61	50	37	22	14
1.1	91	"medium"	58	46	33	19	11
1.2	83	"medium"	55	43	30	17	9
1.3	77	"short"	52	40	27	14	7
1.4	71	"short"	50	38	25	12	6
1.5	67	"short"	47	35	22	11	5
1.6	63	"short"	45	33	20	9	4
1.7	59	"short"	43	30	18	8	3
1.8	56	"short"	41	28	17	7	3
1.9	53	"short"	39	26	15	6	2
2.0	50	"short"	37	25	14	5	2
2.1	48	"short"	35	23	12	4	1
2.2	45	"short"	33	21	11	4	1
2.3	43	"short"	32	20	10	3	1
2.4	42	"short"	30	19	9	3	1
2.5	40	"short"	29	17	8	2	1
5.0	20	"short"	8	3	1	0	0

A = (Area burned/total area)/number of years.

B = 100/A.

C = Proportion older than x years: $C = e^{[A/100\text{-}x]}$. Proportion older than X years, where e = 2.7183.

[#]The assumptions of the negative exponential distribution (Rowe et al. 1975, Johnson 1979, 1981b) are not met (App.3) but these calculations provide an approximation of proportions in each category. At the next revision of the fire suppression model, values in this Table at fire cycles of 67,100, and 166 years and proportions of forests >50 years old will be used to revise the goals in Table 7. The goals in Table 7 were based on data for rotational age of commercial forests and proportions of productive caribou range (>50 years) of 25%, 50%, and 75% for the short (fire cycle = 67 years), medium (fire cycle = 100 years), and long (fire cycle = 200 years) fire cycles.

[*]Terminology used in Fig. 6 and this report.

Table 4. Average annual percentage of caribou range that burned (areal rate of burning) in given periods for areas in the Northwest Territories, Saskatchewan, and Manitoba.

Territory/ Province	Location	Study area (km^2)	Inclusive Period (years)	Number years	Ave. ann. rate of burn	Fire cycle (yr)	Source[a]
NWT	All	116 778	1966-82	17	0.96	104	1
(Caribou	West	58 498	1966-82	17	1.51	66	1
range)	East	58 280	1966-82	17	0.40	250	1
	Most	105 627	1966-73	8	0.91	110	2
NWT	East of Yellowknife	43 706	1968-73	6	0.89	112	2
Saskatchewan	Black Lake	12 727	1910-59	50	0.46	217	3
		7 202	1956-71	16	0.55	182	4
	N of 58°N	113 964[b]	1973-82	10	1.10	91	5
		88 194			1.42[c]	70[c]	5
	Composite		1910-82[e]	73	0.56	179	3-5
	of above				0.61[c]	164[c]	3-5
Manitoba	Northwest	12 107	1956-67	12	0.13	769	4
		42 899	1973-76	4	2.67	37	6
		76 438	1972-81	10	0.97	103	7
					1.41[d]	71[d]	7
	Composite		1956-81[f]	26	0.71	141	4,7

[a]Sources: 1 = Ferguson 1983; 2 = Rowe et al. 1975; 3 = Scotter 1964; 4 = Miller 1976b; 5 = MacAuley 1983; 6 = Robertson 1977; 7 = Manitoba Wildlife Branch 1983.
[b]North of 58°N and province wide (102°W-110°W).
[c]Recalculated based on 101 816 km^2 total area less 13 622 km^2 for large (>10 km^2) lakes.
[d]Excluding water and tundra.
[e]Overlap in 1956-59 and omission of 1972.
[f]Excluding 1968-71 inclusive (1970 was an above average fire year in Sask.).

Rates of burning for forests in Saskatchewan, the NWT and Manitoba vary widely over the short term.

Table 5. The average fire return interval calculated for various locations on the caribou range and fire statistics for other locations in the boreal forest.

Location	Area (km^2)	Period	No. of years	Ave. ann. rate of burning	Fire cycle	Mean return interval	Data Source
NWT Caribou	116 778	1966-73	6-8	0.90	110-112		1
range		1966-82	17	0.4-1.0	66-125	104	2
Manitoba	variable	1956-81	26	0.71	141		3
Saskatchewan	variable	1910-82	73	0.61	164		3
Athabasca				2.2		45	4
Labrador				0.2		500	5
N. Quebec				1.0		100	6
N. Ontario	5 078	1920-79	59	0.43	233		7
N. Ontario		(1940-59)	20	0.10	1053		
N. Ontario		(1960-79)	20	0.84	120		
N. Ontario		(1970-79)	10	0.86	116		
N. Ontario		(1824-1984)	160	5.0		20[a]	8

Sources: 1 = Rowe et al. 1975; 2 = Ferguson 1983; 3 = this report, Table 4; 4 = Carroll and Bliss 1982; 5 = Foster 1983; 6 = Payette et al. 1989; 7 = Alexander 1981; 8 = Lynham and Stocks 1989.

[a]Numerous or extensive burns occurred in 1870, 1923, 1950, 1955, 1960, and 1967.

Fire interval data from fire scars (Table 5) appears to yield intervals that are not representative of the forest as a whole. The data could be biased for several reasons. Scar data often are obtained at burn peripheries where fire may have burned out in younger stands. Trees with two or more scars are selected whereas locations with one or no scars are not sampled or are undersampled. Some scars are not from fires.

The data for Ontario (Table 5) illustrate the pronounced differences in rates of burn in successive 20-year periods. The rate for 1970-79 is similar to some of the concurrent rates on the range of the Beverly and Qamanirjuaq herds of caribou whereas the long-term rate is much lower.

Reduced rate of burning after 1870 was indicated for a site in Quebec (Bergeron 1991). A reduction in rate of burning after 1730 was proposed for the southern Canadian Rockies (Johnson and Larsen 1991).

Estimated lengths of fire cycles across the range of the two herds (Fig. 4) is based on current age of forest or its age when last burned as estimated from surviving trees in the burn and at the periphery.

Data needs

Burns from 1990-94 should be added to the burn maps and entered in the GIS. Some burns were not mapped in Manitoba since 1980. The 1989 burns should be checked in all areas. The burn history should be improved through site verification of forest ages particularly in Alberta, Saskatchewan, and Manitoba. The fire history should be extended back in time through field surveys. Minimum forest ages should be obtained where no fire scars exist. A select few hunters and trappers on the caribou range should be trained to provide tree disks to improve the fire history database. Additional data should be obtained by fire and wildlife personnel at every opportunity. Caribou distribution in winter could then be interpreted in terms of forest age, forest type, and other characteristics. The age distribution of forest that burned should be indicated within all large burns, e.g., dashed lines with age of forest in parentheses.

The GIS project should be extended to include historical range of the two herds between 57°N and 58°N. Additionally, ground

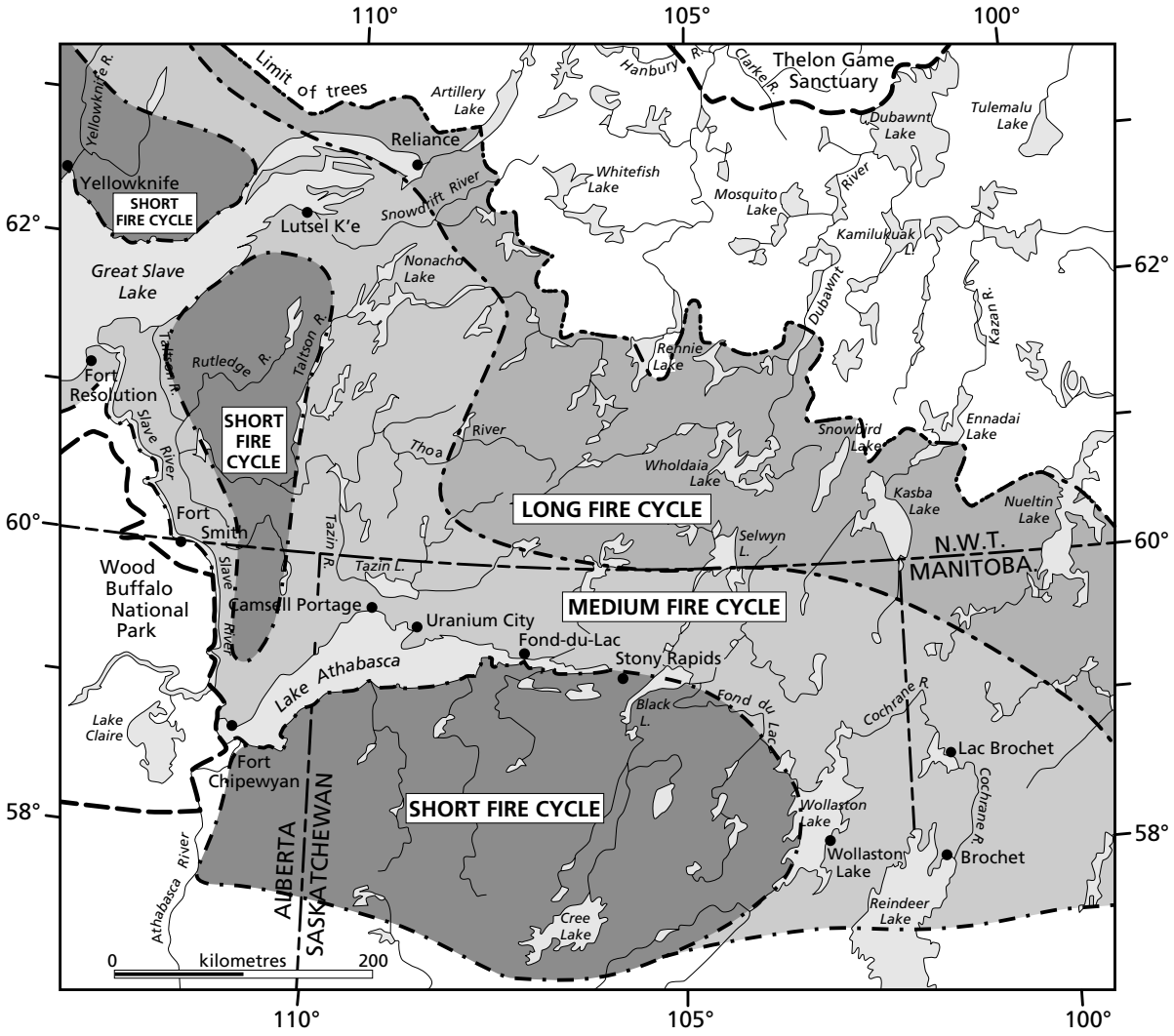


Figure 4. Estimated fire cycle lengths on the forested winter range of the Beverly and Qamanirjuaq herds of caribou: short = <81 years; medium = 81-140 years; and long = >140 years.

verification of burn ages is needed in all three provinces.

The burn history data in the GIS should be analyzed for areas of burns by year and decade. The relationship of the burns to geographic location (limit of forest, Hudson Bay, etc.), topography, surface materials, physiography (bedrock and till expression), and abundance of lakes, bogs, meadows, etc.

Data for each large (>10 000 ha) burn should include cause of fire; percentage of uplands and lowlands that burned; percentage of unburned inclusions, stratified into upland and lowland classes; a burn intensity rating (e.g., Alexander 1982), age of forest that burned as mapped from surviving trees or snags within the burn; characteristics of the ignition point; direction of burn indicated by arrows; type of forest that burned and tree density ratings; and fuel types and amounts.

10c. Priority for Fire Management, Exclusive of Community Priorities

Fire management recommendations now relate only to priority zones identified by each community. These priorities are based on access to the herds being highest priority *at the present time*. Priorities for fire management additional to those expressed by users in the communities may be necessary if winter range is identified as one of the major limiting factors of the herds or if there is intensive management of the herds. A limiting factor is one that lowers reproduction from potential (maximum) values or increases mortality above physiological minima (old caribou die!).

The priority zones for each jurisdiction are based on several criteria:

1) **Historical use by caribou** with priority declining in the order: core, usual, and occasionally-used range;

2) **Migration routes and corridors**, i.e., areas between summer range and core, usual, and occasionally-used winter range;

3) **Lichen productivity**: the ability of various landscape units to produce forages preferred by caribou, in particular the *Cladina* spp. and *Cetraria* spp. of lichens;

4) **The pattern of snow characteristics across the winter range** with preference given to areas with the least snow in late winter and the rare occurrence of hard layers;

Lichen is the primary nourishment for caribou during the long winter months.

5) **An estimate of the natural fire cycle** with priority given to areas with moderately long cycles and decreasing priority to those with progressively shorter and longer cycles. Areas with low proportions have no priority. Note that ideally this priority would be based on the fire cycle with highest priority in the 100-200 year range and declining at shorter and longer cycles;

6) **Surface materials** with priority given to areas of moderate and deep till and decreasing priority to areas of thin till and increasing amounts of exposed bedrock. (High priority *would* be given to areas with sandy soils if fire suppression was effective at lengthening the fire cycle or the climate changed towards less fire);

7) **Topography** with priority declining with fewer lakes and water courses because caribou use these elements for resting and travelling.

Each criterion was rated subjectively and all the criteria are combined in a subjective manner (Thomas 1985, 1994c). Numeric ratings were a possibility but they still would have been subjective and not enough was known about the importance of each factor in order to weigh their relative importance.

A key decision was whether to set priorities for each herd across its forested winter range or to rank priorities for fire management within each jurisdiction. The herd approach would be preferred if fire protection was needed to preserve a dwindling caribou resource. The jurisdiction approach was taken because it was directed towards maintaining the caribou resource in each jurisdiction for the benefit of the people. This humanistic and diversity emphasis was accepted by the Board in 1993 but it must be reassessed if preservation of the herds becomes an issue. A combination of factors including weather, hunting, predation and extensive burns throughout the winter range could trigger a herd approach to priority setting. The community priorities ignore jurisdictional boundaries.

Priorities for Fire Management in the Northwest Territories

Excluding community priorities, fire management priority zones for caribou (Flg. 5) are based on multiple criteria outlined above. These zones are adapted to ecological zones based on vegetation, climate, landform, and soils. Priority ranking by ecoregion and ecodistrict (Bradley et al. 1982) are: (1) Low Subarctic, (2) High Subarctic FT 5 & 6, (3) High Boreal 1, (4) High Boreal 2, and (5) Mid Boreal 1.

Special Priority Zone. This rating is top priority and is given to areas of special significance. The Snowdrift River and adjacent lowlands above Siltaza Lake receives this status because the river is used as a highway to and from the tundra and lichens are abundant in the open white spruce that grow on the sandy levees along the river margins.

Priorities for Fire Management in Saskatchewan

Excluding community priorities, fire management priority zones for caribou are based on multiple criteria outlined on pages 22 & 23. These zones are adapted to ecological zones based on vegetation, climate, landform, and soils. Generalized priority by ecoregion are (1) Subarctic Boreal Ecoregion; and (2) Northern Boreal Ecoregion. Generalized priority by ecodistrict are (1) Northern Transition Ecodistrict; (2) Northern Coniferous Ecodistrict; and (3) Athabasca South Ecodistrict.

The Athabasca South Ecodistrict produces excellent caribou range if the forest attains ages over 40-60 years. With a medium-length fire cycle (e.g., 80-140 years) this zone would produce the most productive winter habitat. However, major constraints are the short fire cycle estimated to be 50-70 years (scar interval data indicated 42 years— Carroll and Bliss 1982); the difficulty of suppressing fires because of the lack of firebreaks (large lakes, bogs, wide rivers); and the tendancy of the surface to dry quickly because of the sandy soils, low tree density, and scarcity of moss.

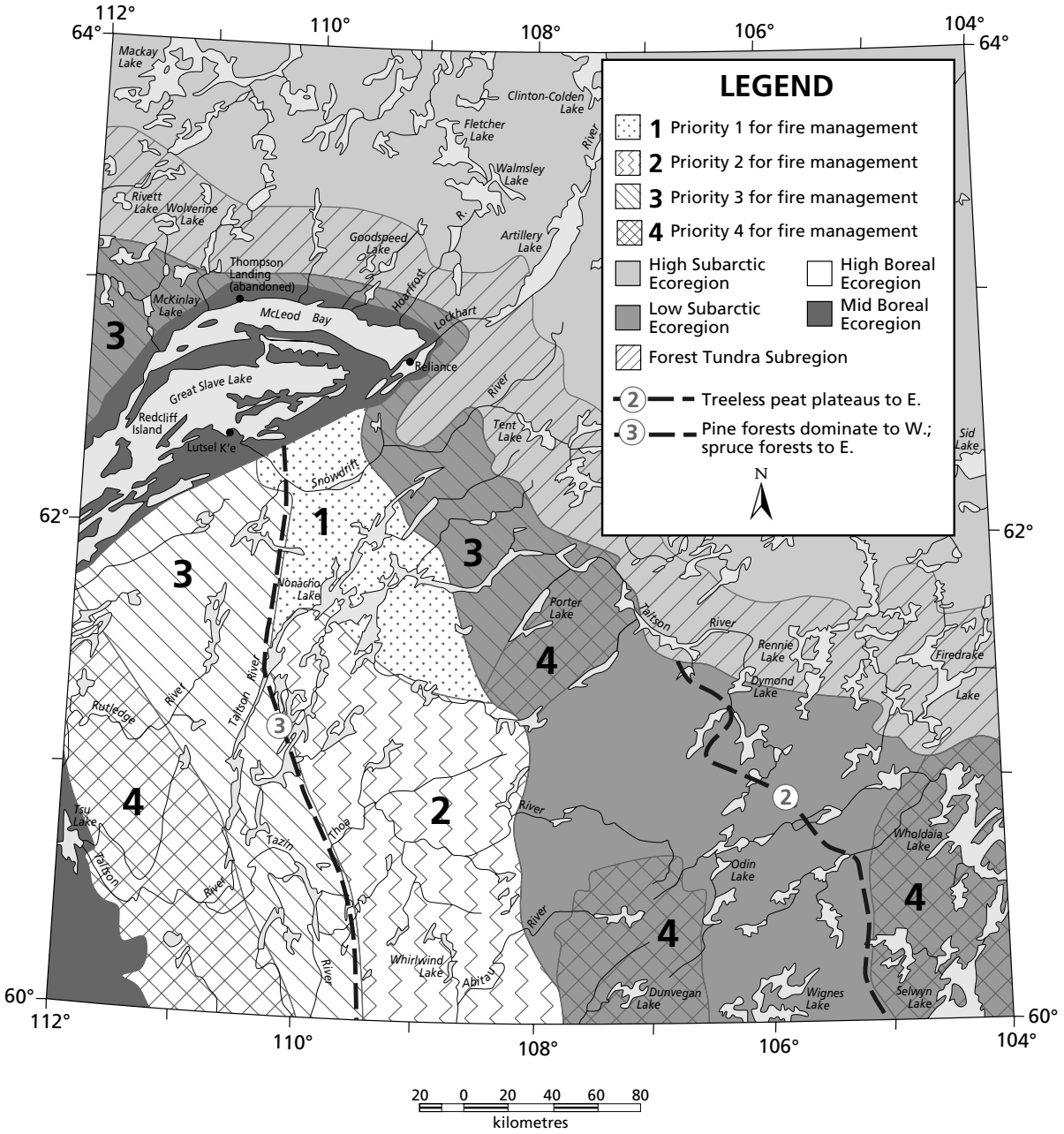


Figure 5. Priorities for fire management in the Northwest Territories, separate from community priorities, assuming a future need to manage caribou at a high sustained yield (harvest) and an indication that winter range limits the population. The priorities are adapted to the Ecological Land Classification (Bradley et al. 1982).

The ecodistricts (Harris et al. 1983, Kabzems et al. 1986) were subdivided for fire management based mainly on past use by caribou. The priority for fire management for caribou exclusive of community priorities is: (1) Northern Transition Ecodistrict; (2) Northern Coniferous Ecodistrict north of Lake Athabasca and the Fond du Lac River; (3) portions of the Athabasca South and North Coniferous ecodistricts that lie north of a line from 58°N on the west border of the province to 57°N on the east side; (4) portions of those ecodistricts south of the line described above (Fig. 6).

Priorities for Fire Management in Manitoba

Excluding community priorities, fire management priority zones for caribou are based on multiple criteria outlined on pages 22 & 23. These zones are adapted to ecological zones based on vegetation, climate, landform, and soils. Priorities are different in each jurisdiction and therefore priority zones are not continuous with those of other jurisdictions (Fig. 7). For example, relative numbers of caribou may be severalfold greater in the NWT than in the provinces. However, the caribou that enter the provinces are critical to the livelihood of users there.

Priorities for Fire Management in Alberta

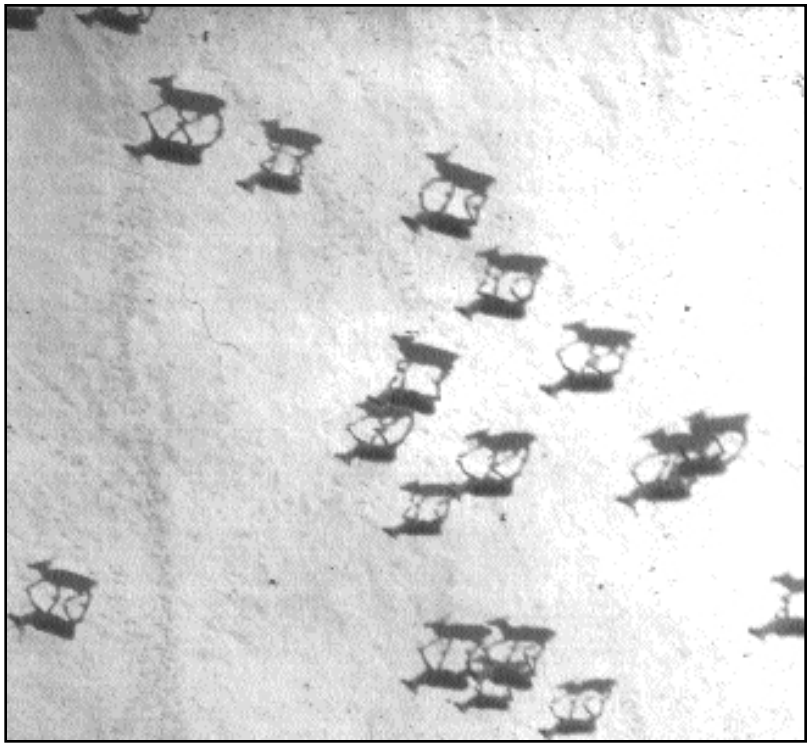
People in Fort Chipewyan were not surveyed for their priorities for fire management. Most of their hunting is by aircraft and into areas identified by other communities. In 1985-86, the council sought and received approval from the BQCMB for the hunting of 400 caribou in the NWT (BKCMB Minutes 1985).

Ecoregional priorities for fire management, exclusive of community priorities, as an aid to caribou management if it is deemed to be necessary, are: (1) Kazan Uplands and (2) Athabasca Sandstone Formation south of Lake Athabasca. More specific priorities are: (1) the northeastern Kazan uplands; (2) the remainder of the Kazan Uplands east of 111°W; and (3) the Athabasca Sandstone immediately south of Lake Athabasca; and (4) Athabasca Sandstone areas shown in Figure 8.

10d. Traditional-User Priorities for Fire Management

Priority areas for fire management were obtained from each community on the winter range of the two caribou herds. The mapped data were obtained by John Dantouze who interviewed hunters and band council members in each settlement of Saskatchewan and Manitoba (Dantouze 1991) and in the NWT (Dantouze 1992). This mapping exercise, funded by the BQCMB, was essential to development of fire management recommendations.

Just the Zone 1 priority areas include much of the winter range of the Beverly herd in the NWT.



Always on the move: here, Beverly caribou herd in spring migration at Mosquito Lake, NWT, 1959.

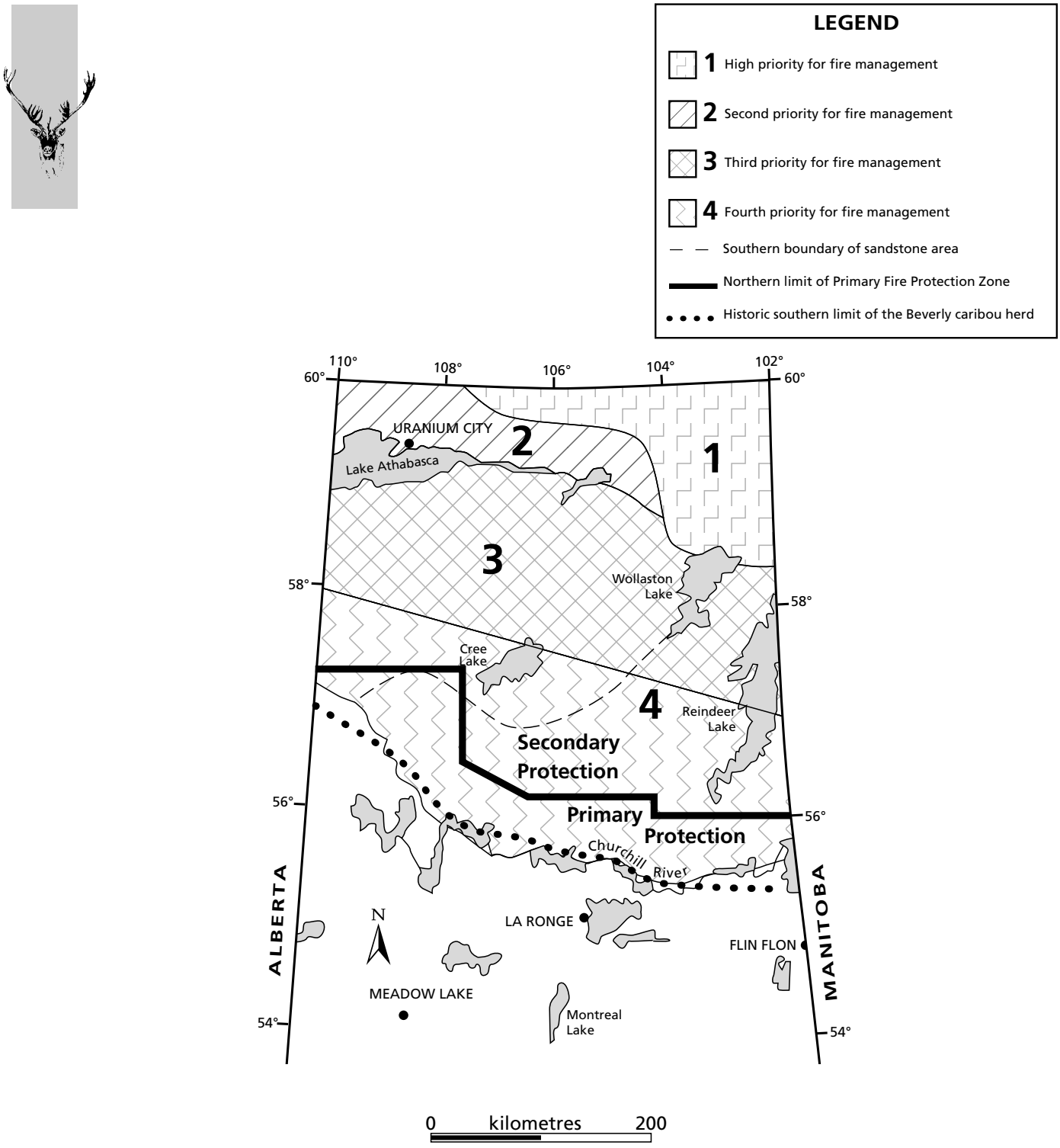


Figure 6. Priorities for fire management in Saskatchewan, separate from community priorities, assuming a future need to manage carbou at a high sustained yield, in relation to primary and secondary fire protection zones and the historic southern limit of the Beverly herd of caribou.

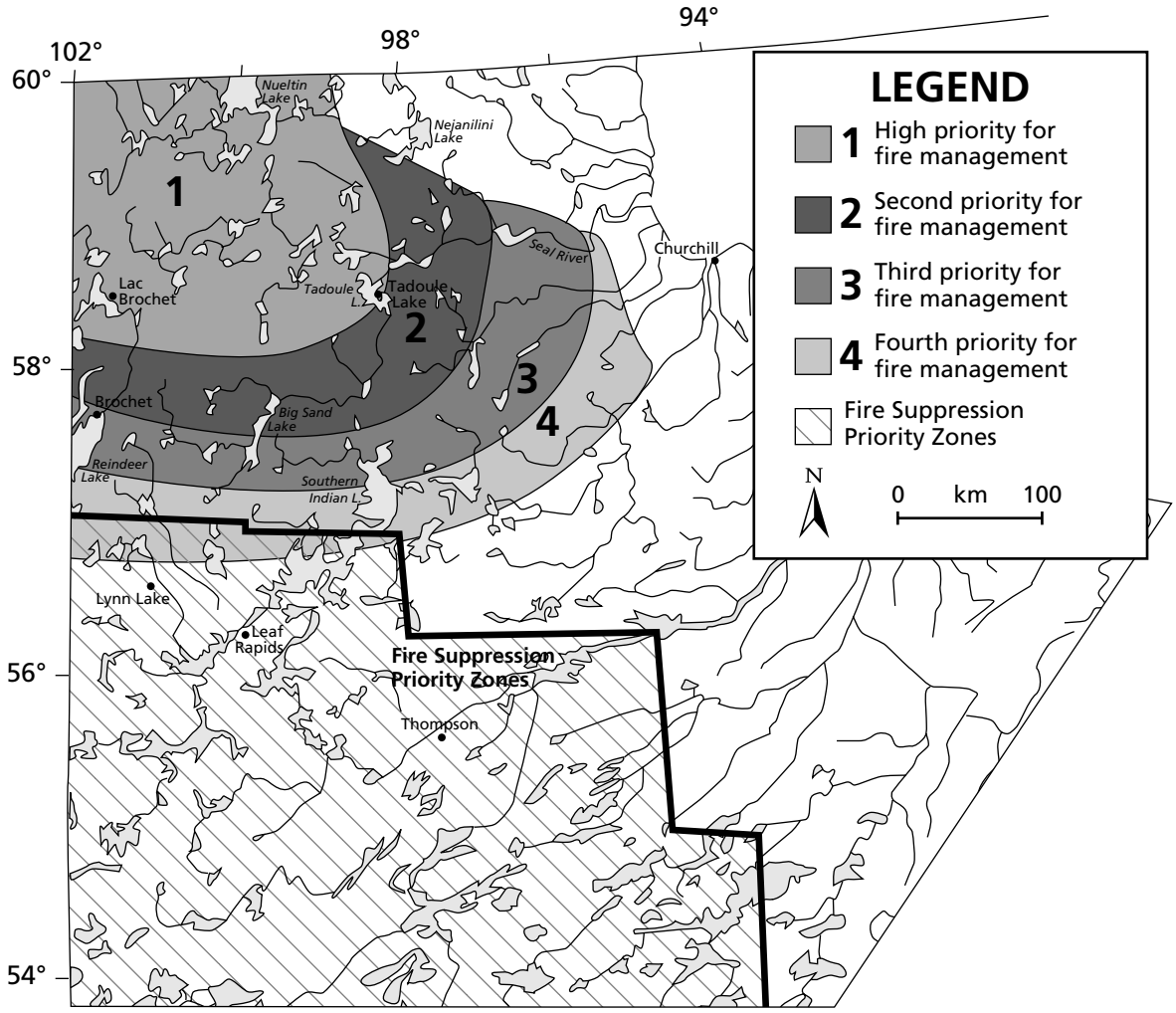


Figure 7. Priorities for fire management in northern Manitoba, separate from community priorities, assuming a future need to manage caribou at a high sustained yield and an indication that winter range limits the population. Fire management priority zones for commercial forest border on fire management zones for caribou.

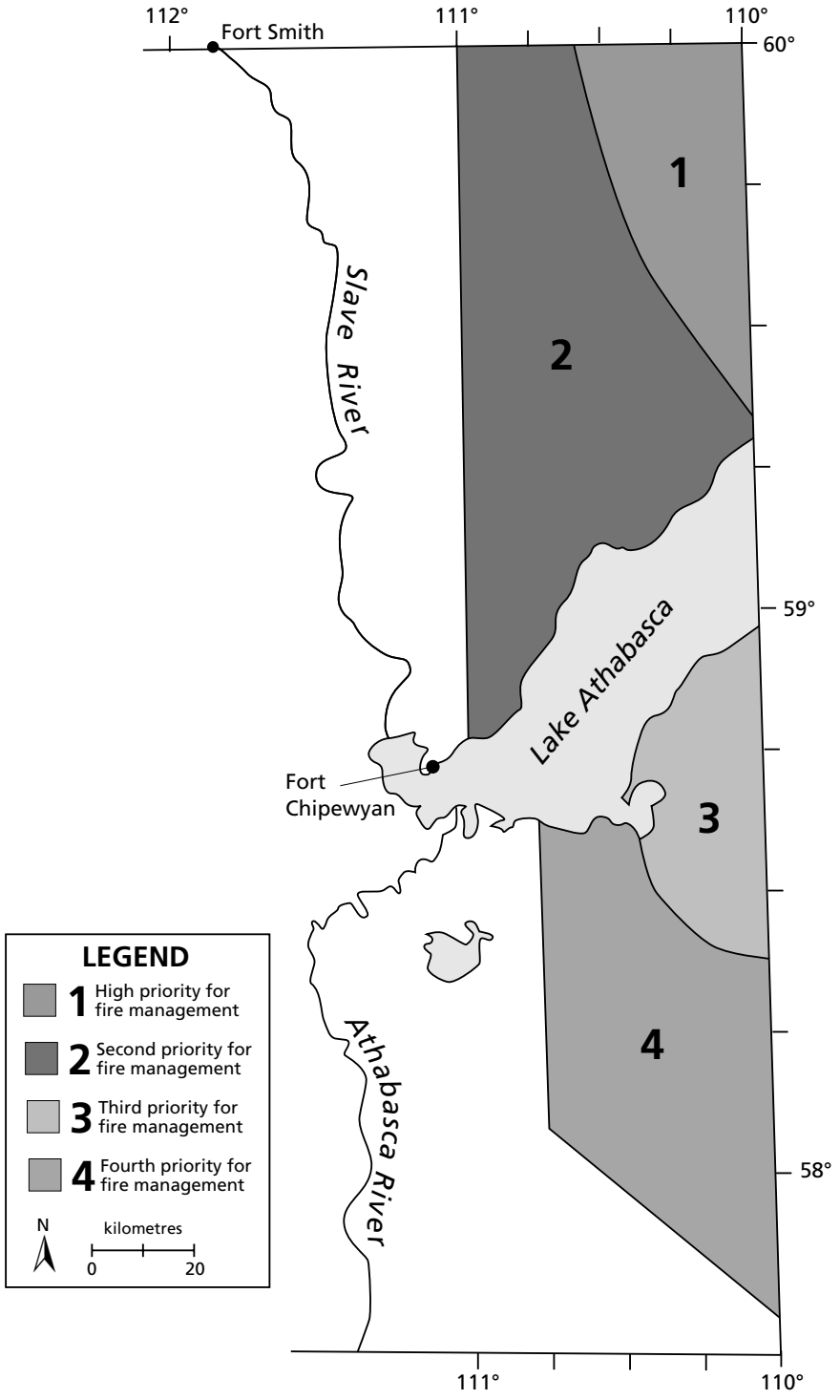


Figure 8. Priorities for fire management in Alberta, separate from community priorities, assuming a future need to manage caribou at a high sustained yield and an indication that winter range limits the population.

General priority map for all communities

A composite priority map (Fig. 9) was produced by including only the highest priority ranking for overlapping zones and dropping all A, B, and C designations and including them as their numeric (1, 2, 3, and 4 designation). The limit of trees or "tree line" forms the northern boundary.

Simplified priority map with jurisdictional boundaries and forest limit

The priority map was simplified and made more manageable (Fig. 10) by grouping small units into larger ones and averaging the priority ranking. In addition, one large unit was subdivided into two units. Jurisdictional boundaries were added and the northern boundary was retracted to the limit of forest from the limit of trees.

Proportions of areas in each priority zone in the NWT, Saskatchewan, and Manitoba are in Table 6.

10e. Goals for Productive Caribou Habitat in Each Priority Zone

The goals for the proportion of forests older than 50 years by priority zone are stratified according to the generalized length of the fire cycle (Table 7) as mapped in Fig. 4.

Table 6. Areas (km^2) and proportions (%) of forested winter range of caribou in the Northwest Territories, Saskatchewan, and Manitoba within community priority zones 1-4.

Priority zone	Northwest Territories[a]		Saskatchewan[b]		Manitoba[b]	
	Area	Proportion	Area	Proportion	Area	Proportion
1	77 185	63.8	24 703	30.2	31 384	38.7
2	23 164	19.1	27 618	33.7	20 450	25.2
3	12 189	10.1	11 096	13.6	15 469	19.1
4			1 134	1.4		
None	8 464	7.0	17 292	21.1	13 728	17.0
Large Lakes[c]	21 098		11 784		7 978	

[a]Defined here as forested range (less large lakes) from 60°N to the limit of forest and from Hudson Bay to 112°W except to western limit of range south of Great Slave Lake.
[b]Defined here as range north of 58°N.
[c]Areas of large lakes not included in proportions.

Table 7. Goals for the proportion of the forest in ages older than 50 years by priority zone for caribou hunting and by length of the fire cycle.

Priority rank	Proportion in forests >50 years (%)		
	Short fire cycle (<81 years)	Medium fire cycle (81-140 years)	Long fire cycle[a] (>140 years)
1	35	60	85
2	30	55	80
3[b]	25	50	75

[a]Note: based on total area within burn peripheries, including small lakes but excluding large (ca. >10 km^2) ones.
[b]The proportions in this row are the estimated long-term average values with no fire suppression.

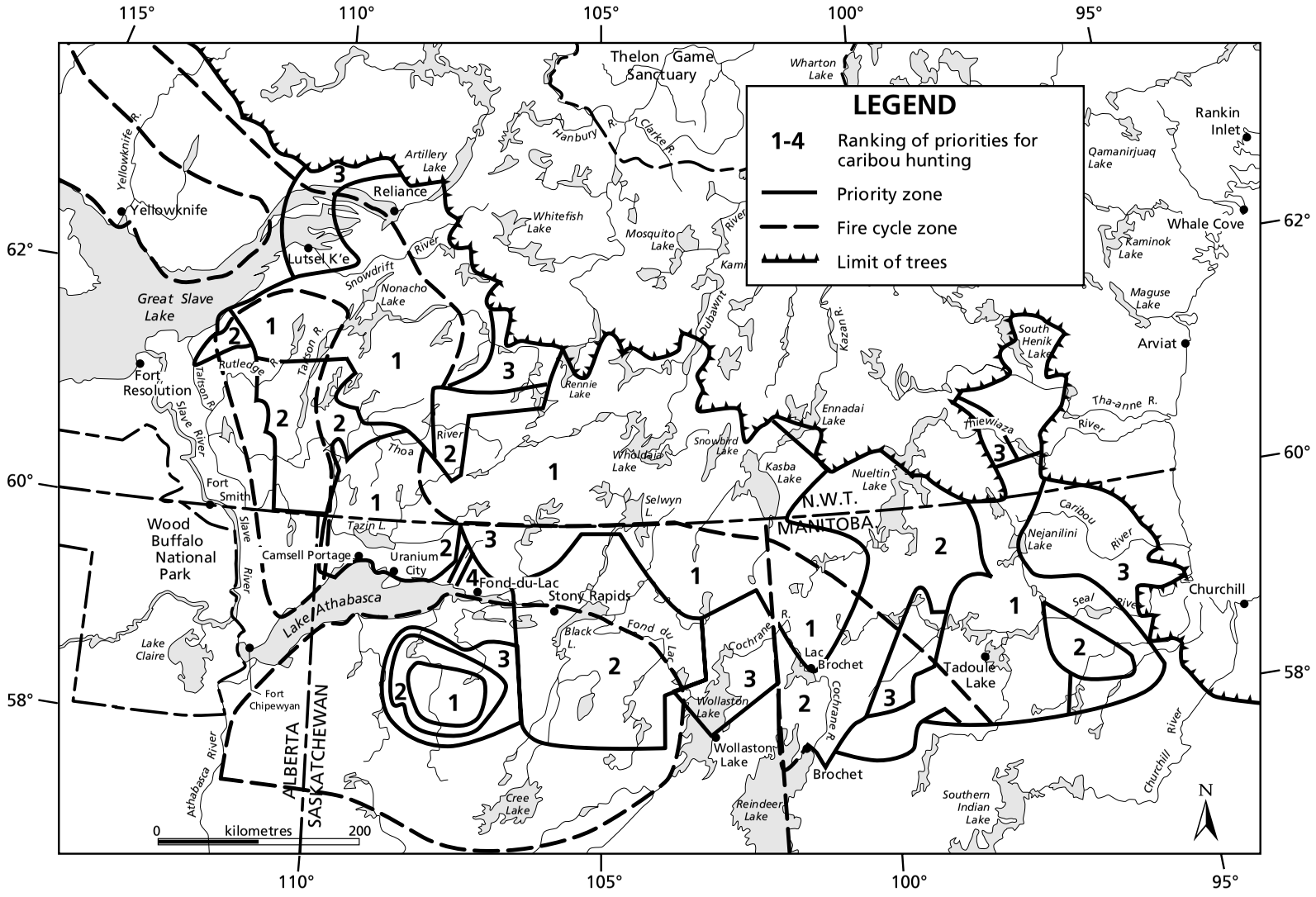


Figure 9. A composite of community priority zones for hunting caribou. The highest rating was accepted where zones overlapped.

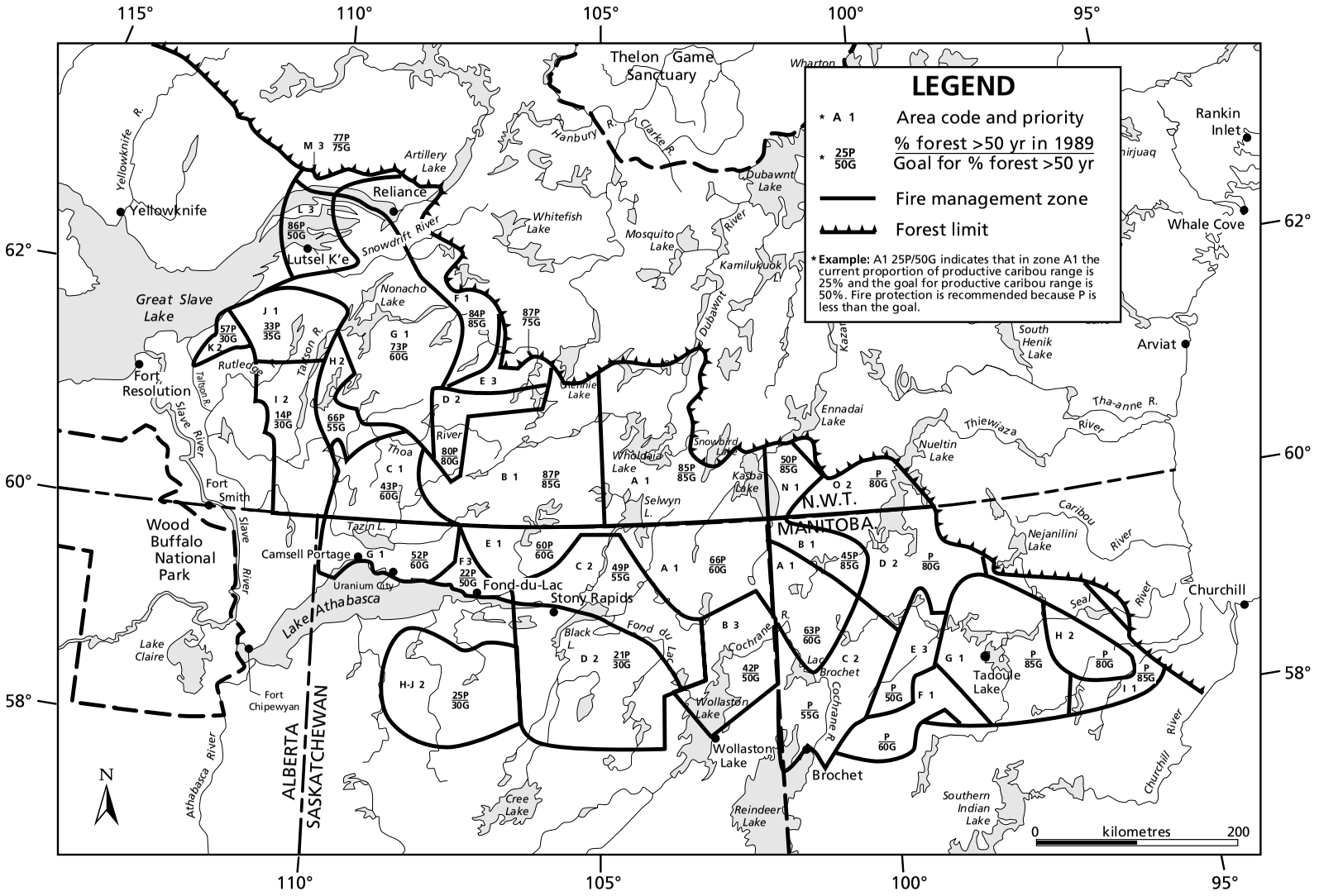


Figure 10. The present (P) (in 1989) proportions of productive caribou range and the goals (G) for each fire management zone, which were delineated from grouped community priority zones, fire cycle boundaries, jurisdictional boundaries, and forest limits, then simplified.

10f. Decisions on the Need for Fire Management

Fire suppression is indicated unless habitat goals in each priority zone are met. The present (P) proportion (in 1989) of habitat older than 50 years was calculated for each zone (Table 8). This proportion is compared to the goal (G). These numbers appear in each zone as e.g., 50P/70G (Fig. 10). Fire suppression is indicated until the first number is as large as the second.

10g. Caribou Management Goals

Fire management goals should be linked to caribou management goals if:

1) the high rate of area burned, as seen in the 1970s and 1980s, continues in the next two or three decades;

2) the populations of the Beverly and Qamanirjuaq herds are allowed to increase to large sizes, say 500, 000 to 1, 000, 000 each; and

3) winter range proves to be increasingly limiting as populations of caribou build.

On the first point, it is not possible to predict future rate of burning. If global warming continues, there is a distinct possibility that high burn rates will continue. The warming is predicted to be relatively pronounced over the ranges of the two herds (Stocks 1993, Zoltai et al. 1992). The effect is predicted to be drier summers and more snow in winter with higher occurrences of hard or icy layers in the snow.

On the second point, there is no consensus that the herds can be intensively managed to produce a higher annual yield of meat in the future. Current management is non-interventionist: the harvest is fairly constant among years and is superimposed on natural fluctuations in herd numbers caused by variations in recruitment and mortality.

On the third point, spring and summer range may prove to limit the growth of caribou populations before winter range becomes a major factor. Summer range overuse is believed to have caused the George River herd to stop growing and, perhaps, to decline in numbers (Messier et al. 1988, Couturier et al. 1990). However, the size of the summer range of the George River herd is comparatively small compared with that of the Beverly and Qamanirjuaq herds. An indicator of overuse of the winter range would be loss of fat reserves from December to March with about average snow conditions. Another indicator would be losses of weight greater than recorded in the studies of the Kaminuriak (Dauphine 1976) and Beverly (Thomas and Kiliaan 1994a) herds. A less reliable indicator, in the absence of data on wolf numbers, would be low recruitment for several years. Inadequate spring and summer range will be reflected in lower pregnancy rates, particularly in females one and a half to five years old.

Current management

The current management of the two caribou herds does not depend on regulation of harvest. There are no guidelines regarding hunting for most of the traditional users. The kill by non-aboriginal residents of the jurisdictions is low. There is no active predator management. There are land use regulations that restrict certain uses of land for mining and other industrial activities. A decline in caribou recruitment because of weather extremes or increased harvest because of changes in the winter distribution of the herds could reduce the herds.

Intensive management to population goals for each herd

In theory, as human populations increase and the need for caribou increases, the caribou populations can be managed at or near the optimum sustained yield level. That is a level where high productivity (e.g., recruitment of calves to age one year) is maintained, mortality from undernutrition is absent, and the range is maintained in a highly productive state. Intensive management of wild reindeer in the Taimir region of Siberia has resulted in harvests of about 16% of the herd annually (Klein and Kolpashchikov 1991). Such high harvest rates are possible only with low predation and favorable foraging conditions.

Table 8. Preliminary estimates of areas (km²) of large lakes and forests younger and older than 50-60 years (in 1989) and the proportion of productive caribou range within grouped community priority zones.

Zone code/ Priority	FCL[a]	General location (map sheet)	Area (km²) Large lakes	burns <50 yr	forests >50 years[b]	Proportion (%) >50 yr[c] Total	Present	Goal
NWT A (1)	L	Whold/Kasba[d]	4 027	1 680	9 480	15 187	85	85
NWT B (1)	L	Abitau/Rennie[d]	1 920	2 013	13 187	17 120	87	85
NWT C (1)	M	Hill Island[d]	387	3 253	2 440	6 080	43	60
NWT D (2)	L	Hill/McCann	467	600	2 400	3 467	80	80
NWT E (3)	L	McCann/Rennie	373	413	2 827	3 613	87	75
NWT F (1)	L	McCann/Reliance	1 107	960	5 160	7 227	84	85
NWT G (1)	M	Nonacho[d]	2 173	4 133	11 347	17 653	73	60
NWT H (2)	M	Hill Island	187	920	1 760	2 867	66	55
NWT I (2)	S	Fort Smith	667	4 667	760	6 093	14	30
NWT J (1)	S	Taltson Lake	680	3 307	1 627	5 614	33	35
NWT K (2)	S	Resolution	187	400	533	1 120	57	30
NWT L (3)	M	Snowdrift	1 680	307	1 853	3 840	86	50
NWT M (3)	L	Walmsley	133	240	800	1 173	77	75
NWT N (1)	L	Ennadai Lake	387	1 067	1 067	2 520	50	85
NWT O (2)	L	Ennadai/Nueltin	Incomplete burn data					
Sask A (1)	M	Phelps Lake	1 160	2 667	5 187	9 013	66	60
Sask B (3)	M	Wollaston Lake	1 840	2 827	2 080	6 747	42	50
Sask C (2)	M	Stony Rapids	1 280	4 080	3 853	9 213	49	55
Sask D (2)	S	Pasfield Lake	1 280	11 880	3 093	16 307	21	30
Sask E (1)	M	Fond du Lac	693	1 493	2 280	4 467	60	60
Sask F (3)	M	Fond du Lac[e]	40	1 293	360	1 693	22	50
Sask G (1)	M	Tazin Lake	733	2 267	2 467	5 467	52	60
Sask H (2)	S	Livingstone[f]	253	6 987	2 280	9 520	25	30
Man A (1)	M	South Kasmere Lake	427	1 600	2 773	4 800	63	60
Man B (1)	L	North Kasmere Lake	347	1 387	1 173	2 907	46	85
Man C (2)	M	Whiskey Jack Lake	Incomplete burn data					55
Man D (2)	L	Munroe Lake	ditto					80
Man E (3)	M	Tadoule Lake	ditto					50
Man F (1)	M	Tadoule Lake	ditto					60
Man G (1)	L	Tadoule Lake	ditto					85
Man H (2)	L	Nejanilini Lake	ditto					80
Man I (2)	L	Shethanei Lake	ditto					85

[a]FCL = fire cycle length: L = long, M = medium, and S = short (Fig.4).
[b]Forests >50 years are considered to be usable for feeding by caribou.
[c]Proportion = Area forests >50 yr/(area forests >50 yr + area forests <50 yr). Large lakes are excluded from the calculation.
[d]Large Priority Zone 1 areas were divided into NWT A & B and NWT C & G.
[e]Three small zones were combined into one zone (Sask F).
[f]Sask. zones H-J were combined and given an average priority rating of 2.

There are several reasons why the Board is not prepared to recommend intensive management of the herds: (1) There is no strong will among traditional users and governments to manage caribou populations at high population size; (2) The precision of herd estimates of numbers is adequate to only monitor large-scale changes in herd numbers; (3) The accuracy of other possible indicators of population growth (harvest data, recruitment data, the natural mortality rate of caribou) is unknown; (4) Methods of assessing the state of the range are not adequate; (5) Management of predators is influenced by outside forces.

11 Fire Management Recommendations

Recommendation 1. **That fire management agencies in each jurisdiction attempt to meet goals for productive caribou range within community priority zones.**

Community priority zones for caribou hunting were established by caribou users in each community (A9). The maps for 13 communities were simplified to one map (Fig. 9) by removing overlapping zones; deleting A, B, and C letters from numbers; and accepting the highest rating for any area.

The occurrence of burns varies greatly across the forested winter ranges of the two herds. Consequently, **fire cycles** of three lengths were mapped (Fig. 4) to take these differences into account. The fire cycles are viewed as average, long-term (centuries) ecological changes and cannot be interpreted with recent burn data. Thus, the **fire management goals** are ecologically based. The reason for ecosystem-related fire management is the view that any attempt to greatly modify fire cycles would be prohibitively expensive and perhaps counter productive.

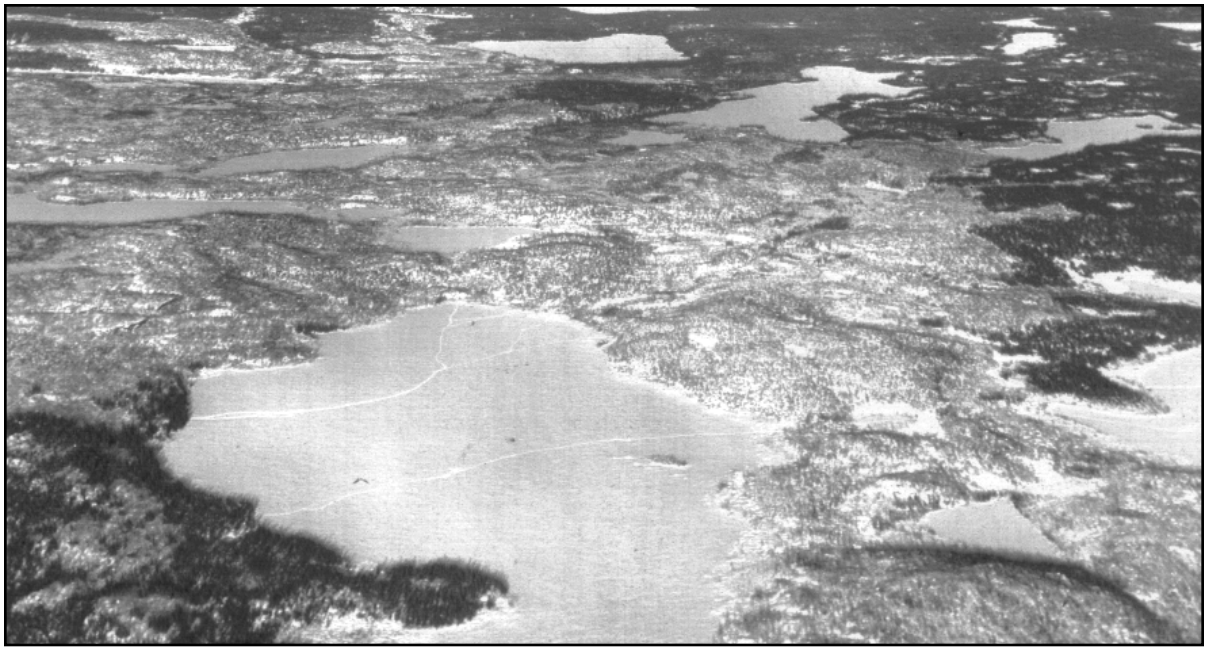
Fire management goals were established for each priority rating (Table 7). These goals are proportions of *productive range for caribou feeding* herein shortened to **"productive caribou range"** and defined as forests older than 50-70 years. The goals for priority rank 3 within fire management zones were pegged at the estimated natural proportions of forests older than 50 years in each fire cycle zone. Then goals were increased by 5% for priority rank 2 and 10% for priority rank 1.

The composite map of priority areas of the communities (Fig. 9) was modified into **fire management zones** (Fig.10) with the following steps: (1) adding fire cycle boundaries (Fig. 4); (2) adding jurisdictional boundaries; (3) including only areas within the limit of continuous forest or "forest limit" (*not* the limit of trees or "tree line"); (4) two large priority zones were divided into subzones (NWT A & B and NWT C & G); (5) small zones were grouped into larger zones and the priorities averaged; and (6) small zones created by changes in the fire cycle were removed and included in the adjacent larger area (Fig. 10).

The forest limit was based on a smooth line joining the approximate outer limits of continuous forest as shown on revised (metric) 1:250 000 topographic maps, and modified slightly by LANDSAT black and white scenes in November, February, and March; by the line showing the 1:1 ratio of forest to tundra in Timoney et al. (1992); by maps in Dredge (1992) and Dredge and Nixon (1992); and by field observations.

Decisions on whether fires should be suppressed depends on the present (P) proportion of productive caribou range relative to fire management goals (G) for a particular priority zone. These proportions, as percentages, are placed within each priority zone on the simplified priority map (Fig. 10). For example, the notation "30P/70G" in a fire management zone means that 30% of the range presently is productive foraging habitat for caribou and the goal is 70%. In theory, all fires would be actioned in that zone. A notation of 80P/70G means that goals are exceeded and no action is required. The fire management zones, the crude calculations of the proportion of productive caribou range as of late 1989, and the fire management goals are on the burn map.

The proportion of productive caribou range in 1989 was a crude first approximation. Accurate calculations should be made using a Geographical Information System (GIS).



Field checks would determine ages of burns mapped or recognizable on LANDSAT imagery.

Only burns up to 1989 are included in the calculations. The Board will request the jurisdictions to provide current information on burns. This task is necessary before the proportions of productive caribou range can be calculated for some of the fire management areas in Manitoba. Calculated range proportions do not include large (>10 km^2) lakes.

The calculations of areas occupied by burns is based on burn periphery mapping and are not adjusted for small lakes and unburned patches (inclusions) within burns. Inclusions are estimated to average 10% of burned areas. Such inclusions are little used by large groups of caribou but they can support small bands of mature bulls. Mature bulls tend to winter around the western and southern periphery of the main aggregations of cows, calves and young bulls. This behavior is thought to reduce their exposure to wolves.

Recommendation 2. **That fire management agencies attempt to meet goals within caribou habitat priority zones, if new data indicate the need.**

In future, the Board may recommend a widening of fire management beyond the community priority zones to **herd priority zones** within each jurisdiction as: (1) herd size increases naturally or is actively increased through reduced predation or hunting; or (2) new data indicates overuse of winter range by caribou. The herd priority zones are mapped in Figures 5-8. The goals for productive caribou habitat within each priority rating are the same as for the community priority zones (Table 7).

Recommendation 3. **That fire management agencies develop jurisdictional structures that will permit cooperative and cross jurisdictional fire management operations.**

Agreements should be established between and among jurisdictions such that detection and suppression operations are shared. For example, reciprocal agreements could mean that suppression costs by one jurisdiction in another would be repaid in kind at another time. Any support programs funded by the federal government should be, as much as possible, jurisdiction free.

Recommendation 4. **That fire management agencies enhance resource user participation in fire management.**

Greater participation by caribou users is requested for all stages of fire management within the caribou range. Enhanced roles include the setting of priority areas, other planning, suppression strategies, training of crews, and management. Experienced crews trained in initial attack should be available in each large community. Such crews should be able to action fires within hours of their detection.

Recommendation 5. **That fire management agencies obtain burn maps annually and that the fire history be updated periodically in the Geographic Information System in the central depository for the Board, the NWT Centre for Remote Sensing in Yellowknife.**

The burn map updating interval will depend on discussion and negotiation among the fire management agencies. In the meantime, the jurisdictions are encouraged to map all burns >1000 ha annually. The updating of present proportions of productive caribou range could range from 1 to 10 years. The adjustment of fire management areas at decade intervals has merit. The exact year of past burns would not matter with decade classes and the workload would be reduced. LANDSAT or other suitable imagery would be obtained in years 2000, 2010, etc. and all burns since the previous review would be mapped and placed in the previous decade. If NOAA "Geocomp" data are used, the composite imagery must be obtained every two or three years.

Jurisdictions are encouraged to map all fires >1000 ha visually or photographically using aircraft. All burns >1000 ha should be logged on "master" sets of maps at scales of 1:250 000 and 1:1 million. The Board may request summary maps from the jurisdictions from time to time. An update of the rate of burning should be available from analysis of areas burned annually within each jurisdiction. Calculations of areal rate of burning must be updated with data after 1982 for the NWT and Saskatchewan and after 1981 for Manitoba (Tables 4 & 5).

A uniform format and method of data storage of burn characteristics and statistics should be adopted with reference systems that include the number of the 1:250 000 map sheet, a UTM, and a latitude-longitude.

Recommendation 6. **That field checks be made to establish ages of all burns of unknown age that are mapped or recognizable on LANDSAT imagery and that attempts be made to classify mature (51-150 yr), old (151-250), and ancient (>250 yr) forests.**

Additional burn mapping must be done in Manitoba north of 58°N and by year 2000 burn mapping should be extended south to 57°N or the Churchill River in Saskatchewan and Manitoba. Age verification is needed for many mapped burns (Beverly and Qamanirjuaq Caribou Management Board, 1994c, 1994d: 1:1 million & 1:250 000 burn maps) in Saskatchewan and Manitoba and for some in the NWT. Burns in the past 50 years can be detected using LANDSAT imagery or by aerial reconnaissance. The ages of forests older than 50 years can be estimated into the three categories from the appearance of the oldest trees in the stand, excluding survivors from an earlier burn. This can be done from aircraft after observer training.

Recommendation 7. **That for all large fires (>10 000 ha), data be obtained on: (1) percentage of burn in unburned inclusions (upland and lowland); (2) age distribution of forest that burned; (3) percentage of upland and lowland that burned; (4) average fire severity indices; (5) forest characteristics at point of fire origin; (6) rate of spread; and (7) fuel-weather-fire relationships.**

Priority for such data are in descending order. The list grades from functional data for caribou management to fire behavior data that will improve predictions of fire effects. The fire severity indices should be developed by fire scientists. Criteria could include percent unburned inclusions, percentage of surviving trees, percentage of snags left unburned, degree to which the lichen mat is burned, and degree to which the duff layer is burned. Data are needed to determine fire susceptibility with age of forest stand and other characteristics, to test fire models, and to learn more about fire behavior and fire intervals in the transitional-forest ecosystem.

Initially, these data should be obtained for all large fires (>10 000 ha).

12 Future Burns And Wildlife Management

The following is a list of some items that should be addressed in order to improve information on the effects of fire on caribou and their habitat and on the forest ecosystem in general.

a) Revise user priority zones if and as required;

b) Revise natural fire cycle zones with improved data on the natural fire cycle or average fire return interval;

c) Revise, at 1-10 year intervals, proportions of forest older than 50 years in fire management zones;

d) Revise goals for productive caribou habitat in relation to community priority zones and fire cycle zones as more information is obtained;

e) Formulate fire management strategies for other species such as moose, furbearers, and birds and integrate the data for all species;

f) Manage fire in relation to objectives for the age distribution of forest successional stages or age classes post fire;

g) Formulate land management zones where fire and wildlife management objectives are related to different distributions of successional classes of forests depending on the important economic, cultural, and endangered species. For example, if moose was the focus species, the objective may be to manage at a fire cycle of 50-70 years; and

h) Obtain data on mozaics of forest age classes that sustain and optimize the production of individual wildlife species, integrate the results, and set objectives for fire and land management.

13 Limitations To Fire Management

13a. Budgets

Availability of funds to develop fire management capability and to suppress fires is an increasing constraint. Extra funds to suppress fires that were routinely obtained by order-in-council may no longer be available in some jurisdictions. Funds will always be found to protect life and essential infrastructures but protection of other values may decline.

Wildlife receives low priority because its economic value usually is low compared with timber and recreation values (there is a wildlife component in recreation). The barren-ground caribou is an exception in that the replacement value of meat is in the range of 12-15 million dollars just for the Beverly and Qamanirjuaq herds.

Wildlife will receive higher ratings if endangered species are implicated. The cultural value of caribou is known to be enormous but dollar values have not been proposed.

13b. Equipment and Personnel

The costs of maintaining sufficient equipment and personnel to be effective in suppressing fire in a severe fire year are enormous. Utilization can be low in years of few or small fires. One problem is the need to charter aircraft every year to maintain a certain level of surveillance and readiness. If aircraft are not committed they may not be available when needed.

There appears to be a need for crews to be more mobile among jurisdictions. There appears to be the need for trained contract crews that would be available as required.

13c. Remoteness

The remoteness of caribou winter range from fire centers is a major constraint in effective fire management. Access is almost entirely by aircraft. Fuel caches must be established for helicopters. Jet fuel degrades

in a few years. Landing strips are few. Remote weather stations must be established to obtain weather conditions. Costs escalate rapidly as supplies and people must be airlifted long distances.

13d. Weather and Severe Fire Conditions

Fires can grow rapidly under dry and windy conditions. Containment may be impossible until cool or wet weather occurs. Fires that can be suppressed probably would not attain large sizes with few exceptions. The result is that suppression of fires over the entire range is an impossible task. Suppression may be effective in local areas if efforts are focused there.

13e. Shortage of Trained Fire Crews

Lack of trained crews was identified as a problem during the busy 1979 season out of Fort Smith (Murphy et al. 1980). However, it is a problem that can be overcome.

To battle rising costs, trained firefighting crews would be available as required.

13f. Suppression Could Backfire

If fire suppression was successful for long periods, the resultant continuous mature and old forest would be subject to very large and huge burns in severe fire years. Multiple fires can occur in one lightening storm and they can grow rapidly. Without firebreaks caused by other fires, the prospect is to lose huge areas every 50 or 100 years. There is an argument that some fires should be allowed to burn when conditions are moderate. In theory, fires should be extinguished quickly when conditions are likely to lead to huge fires. Since future weather cannot be predicted with any certainty, the fire managers must walk a tightrope if they are managing for many small burns and no large or very large burns. It may be an impossible task over much of the range of the Beverly and Qamanirjuaq herds.

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In winter, caribou feed in open, mature forests of pine and spruce. Caribou are only one of many species that has adapted to the transitional forest, where fire plays a normal, essential role in the ecosystem.

Appendix 1. Settlement populations and their estimated harvest of caribou from the Beverly and Qamanirjuaq herds, 1982-83 through 1990-91.[a]

Jurisdiction/ Settlement	Approx. pop.[b]	Year of harvest[c]								
		82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90	90-91
Manitoba					800-		900-			
Brochet	650	100	400	350	1000	900	1400	1475	0	200
Lac Brochet	500	150	1239	1720	682	2758	828	1004	25	873
Tadoule Lake	450	405	308	152	1125	865	505	138	20	306
South Indian Lake	845				800					
Resident hunt						750	684	33	6	
Manitoba totals	2445	655	1947	2222	3607	5273	3417	2650	51	1379
Adjusted total[d]		819	2434	2778	4509	6591	4271[e]	2944	64	1724
Saskatchewan										
Camsell Portage	61	37	36	35	54	60	66	46	76	205
Uranium City	209	130	42	0	37	24	137	133	89	250
Fond du Lac	1026	1761	1297	1046	861	748	1283	840	894	822
Stony Rapids	276	244	213	92	169	56	80	83	24	89
Black Lake	1400	903	780	822	720	784	687	968	778	822
Wollaston Lake	900	1341	702	432	1003	471	500	316	632	850
Other		24	62	80	180	16	20	40		235
Saskatchewan totals	3872	4440	3132	2507	3024	2159	2773	2426	2493	3273
Adjusted total[d]		5550	3915	3134	3780	2699	3466	3033	3116	4091
Northwest Territories										
Fort Resolution	515	NA	51	NA	NA	NA	NA	NA	NA	NA
Fort Smith	(2512)[g]	260	464	NA	NA	NA	NA	NA	NA	NA
Snowdrift	286	NA	125	NA	NA	NA	NA	NA	NA	NA
Fort Reliance	11	NA	NA	NA	NA	NA	NA	NA	NA	NA
Baker Lake	1186	4945[h]	6476[i]	3248	1558	3753	5611	3018	4087[l]	2500
Chesterfield Inlet	316	613[j]	347[k]	235	23	75	611	289	313[l]	10
Rankin Inlet	1706	1483	1295	1195	1046	1606	2737	1766	1590[l]	1000
Whale Cove	235	376	418	613	548	674	700	704	576[l]	300
Arviat	1323	2343	2765	1854	2055	2580	2279	2753	2376[l]	1000
NWT reported	5578	9810	11310	7145	5230	8688	11938	8530	8950	4810
NWT totals (+NA)[f]		11560	13060	8895	6980	10438	13688	10280	10700	6560
Adjusted NWT total[d]		14450	16325	11119	8725	13048	17110	12850	13375	8200
All Jurisdictions										
Grand total	11895	16655	18139	13624	13611	17870	19878	15356	13244	11212
Adjusted grand total		20819	22674	17030	17014	22338	24848	19195	16555	14015
Double adjusted grand total[m]		26024	28343	21288	21268	27922	31059	23994	20694	17519

[a]In annual reports of the Beverly and Kaminuriak Caribou Management Board.
[b]Maximum population in annual reports of the Board.
[c]The reporting year is 1 July to 30 June.
[d]Adjusted by 20% (X 1.25) to account for underreporting.
[e]Higher value used.
[f]Estimate of 1750 for Fort Resolution (400), Fort Smith (300), Snowdrift(1000), and Fort Reliance (50).
[g]Population of Fort Smith omitted from totals because few hunt caribou.
[h]Baker L: Beverly 1553, Kaminuriak 2071, Wager 1321.
[i]Baker L: Beverly 3379, Kaminuriak 1132, Wager 1841.
[j]Chesterfield Inlet: Kaminuriak 70, Wager 543.
[k]Chesterfield Inlet: Kaminuriak 85, Wager 256.
[l]Data not available. These are average values of previous 7 years.
[m]Second adjustment of 20% to account for wounding and unretrieved losses.
Note: A few other caribou included in total for Sask. (Thomas 1991).
Note: NA = Not available.

Appendix 2. Terminology used in this report and in fire behavior, ecology, and management.

Conservation: The wise use of resources including protection from loss and management for sustainability of renewable resources. The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Fire frequency. Variously defined as the number of fires within a given area in a given period and the time interval between successive fires at the same site.

Fire occurrence. The presence of fire usually expressed as the number of fires in a given area in a given time period. A general term variously equivalent to fire frequency and rate of burns, i.e., also containing an areal scale.

Fire susceptibility. The likelihood that a fire will start from lightning in a forest. Equivalent to "likelihood" or "probability" of ignition.

Fire rate. The rate of spread of a fire.

Rate of burn. (Areal rate of burning). How much (proportion) of a given area burns over a stated period, usually expressed as an average, annual rate.

Natural fire rotation (period). The time required to burn an area equal to the size of that area. Some areas need not burn if some areas burn twice in that period.

Fire cycle. Same as natural fire rotation. "Cycle", as used here, does not imply there is some constant repeatable time between burns at any one site or a repeatable average value for a large area. Some reserve the term for events with about constant intervals between like events, e.g. high populations of hares about every 10 years.

Fire return interval. The interval between fires at any one site or the average interval at any one site or the average interval at many sites.

Fire intensity. The amount of heat produced by a fire.

Fire severity. The effects of a fire on the system, including effects on permafrost, soil, duff and litter, and the three layers of vegetation (surface, shrub, and canopy).

Fire management. Activities that influence the occurrence or extent of fire, including fire suppression, prescribed fire, fuel reduction or increase, etc.

Fire suppression. The act of preventing fire or extinguishing it.

Prescribed fire/burn. A fire that is intentionally set by fire managers.

Fire scar. A portion of the circumference of a tree that was killed by a fire. It leaves a mark in the annual growth that can be used to determine when (year and season) the fire occurred.

False scar. A scar not of fire origin. Examples are animal chewing of the cambium (inside the bark), axe marks, damage from a falling tree, lightning, etc.

Flammability. The degree to which a forest will burn once ignition occurs.

Initial attack. The first visit to a fire, usually in the first few hours after ignition, by a special crew in an attempt to extinguish it while it is tiny.

Observation Zone. An area where fire occurrence is recorded but no action is taken to suppress the fire.

Serotonous cones. Cones of some pine and, to a lesser extent spruce, that often remain closed until exposed to high temperatures — usually from a fire.

Duff. Dead organic material that accumulates on the surface of the ground. Usually it is renewed by falling leaves, twigs, etc. and dead surface vegetation, such as lichens and moss, faster than it is decomposed and converted into soil by micro-organisms. Peat is composed primarily of dead moss.

Mineral soil. The layer below the duff and composed of parent material or soil. Seeds of pine grow best when in contact with mineral soil.

Appendix 2. cont'd

Succession. Changes in the species composition or relative abundance at various stages after fire or some other disturbance. The term is associated with changes in vegetation but it can apply to animals as well. Stages are described and given a time frame based on the dominant vegetation. These are arbitrary delineations of continuous processes.

Old growth: No "correct" definition. Relatively old. Late succession. It refers to a period when large trees have reached their maximum or near-maximum growth (height and circumference), some are dying, some are dead but standing, and some have fallen. Obviously old growth varies with the major tree species.

Science: knowledge; comprehension or understanding; knowledge coordinated, arranged and systematized (Webster).

Vegetation mozaic. The distribution, size, and shape of vegetation types in space. The vegetation types may be different species combinations or different successional stages, or both.

Wildlife management. The art and science of influencing the numbers, distribution, composition, productivity, mortality, and conservation of wildlife species through hunting regulations; other regulations on human activities; habitat preservation, conservation and manipulation; reintroductions and transfers; predator management; and parasite and disease management. The objective usually is to maintain high population numbers or at least stabilize the "boom and bust" of natural populations.

Appendix 3. Fire susceptibility in age classes of forests in the southern Northwest Territories (Rowe et al. 1975).

Age class (yr)	Average percent burned per year in age class			
0 - 20	0	0.375		
21 - 40	0.75			
41 - 60	1.10	0.90		
61 - 80	0.70			
81 - 100	4.81	2.93	2.24	
101 - 120	1.05			
121 - 140	3.08	1.54		
141 - 160	0			
161 - 180	2.00	4.57	4.79	
181 - 200	7.14			
201 - 220	0	5.00		
221 - 240	10.0			

Appendix 4. Metric burn size classes adopted by Thomas (1994b).

Burn size class	Burn size (ha)	Burn size (km^2)	Upper size of burn as a square	Common term for size
1	to 1	to 0.01	100 X 100 m	Spot
2	>1-10	0.11-0.1	333 X 333 m	Tiny
3	>10-100	0.11-1	1 X 1 km	V. small
4	>100-1000	1.1-10	3.3 X 3.3 km	Small
5	>1000-10 000	10.1-100	10 X 10 km	Medium
6	>10 000-100 000	100.1-1000	33.3 X 33.3 km	Large
7	>100 000-1 000 000	1000.1-10 000	100 X 100 km	V. Large
8	>1 000 000	>10 000		Huge

V = very.

Appendix 5. Rates of burning in a 12 727 km^2 area in northern Saskatchewan in periods before 1960 as calculated by Scotter (1964) and adjusted by expected re-burn rates for Rutledge Lake (Rowe et al. 1975).

Period	Age class	Scotter's burn rate[a] (mean %/yr)	Estimated percent reburned[b]	Correction factor	Adjusted burn rate (mean %/yr)
1945-1959	1-15	0.66	0	0	0.66
1930-1944	16-30	0.45	6	1.06	0.48
1910-1929	31-50	0.48	21	1.27	0.61
1885-1909	51-75	0.45	41	1.69	0.76
1840-1884	76-120	0.21	83	5.88	1.23

[a]Scotter 1964.

[b]Rowe et al. 1975.

Note: The correction factors probably are high for the Saskatchewan study area (the Stony Rapids 1:250 000 map sheet).

Appendix 6. Fire statistics for the 116 778 km^2 Caribou Range Subdistrict, 1966-1982 (Ferguson 1983).

	Entire area			West of 108°W[a]			East of 108°W[a]		
Year	Number of fires	Area burned (ha)	Rate of burning (%)	Number of fires	Area burned (ha)	Rate of burning (%)	Number of fires	Area burned (ha)	Rate of burning (%)
1966	41	13 485	0.12	30	9 332	0.16	11	4 153	0.07
1967	10	3 934	0.03	3	118	<0.01	7	3 816	0.07
1968	1	<1	<0.01	1	<1	<0.01	0	0	0.
1969	24	3 970	0.03	19	3 754	0.06	5	216	<0.01
1970	48	142 106	1.22	35	96 068	1.64	13	46 038	0.79
1971	48	201 716	1.73	44	198 678	3.40	4	3 038	0.05
1972	33	14 321	0.12	25	13 433	0.23	8	888	0.02
1973	88	113 855	0.97	40	22 982	0.39	48	90 873	1.56
1974	6	113	<0.01	5	113	<0.01	1	<1	<0.01
1975	23	29 548	0.25	19	28 168	0.48	4	1 380	0.02
1976	35	176 963	1.52	23	100 793	1.72	12	76 170	1.31
1977	17	45 257	0.39	15	44 556	0.76	2	701	0.01
1978	18	6 943	0.06	18	6 943	0.12	0	0	0.
1979	48	750 981	6.43	39	749 149	12.81	9	1 832	0.03
1980	27	228 646	1.96	22	172 685	2.95	5	55 961	0.96
1981	31	106 366	0.91	23	16 136	0.28	8	90 230	1.55
1982	35	60 918	0.52	25	37 131	0.63	10	23 787	0.41
Total	533	1 899 122	0.96[b]	386	1 500 039	1.51[b]	147	399 083	0.40[b]

[a]Area west of 108°W = 5 849 km^2; area east of it = 5 828 km^2.

[b]Average annual rate of burning.

Appendix 7. Fire statistics for 101 581 km^2 of caribou range north of 58°N in Saskatchewan.

Year	Hectares burned[a]	Percent of total area[b]	Area less large lakes(%)[c]	Area less water (%)[d]
1973	149 238	1.47	1.69	1.94
1974	8 088	0.08	0.09	0.10
1975	82 692	0.81	0.94	1.07
1976	75 034	0.74	0.85	0.97
1977	1 109	0.01	0.01	0.01
1978	29 451	0.29	0.33	0.38
1979	159 799	1.57	1.81	2.07
1980	722 649	7.11	8.19	9.37
1981	26 930	0.27	0.31	0.35
1982	3 003	0.03	0.03	0.04
Totals	1 257 994	12.36	14.26	16.30
Average/year		1.24	1.43	1.63

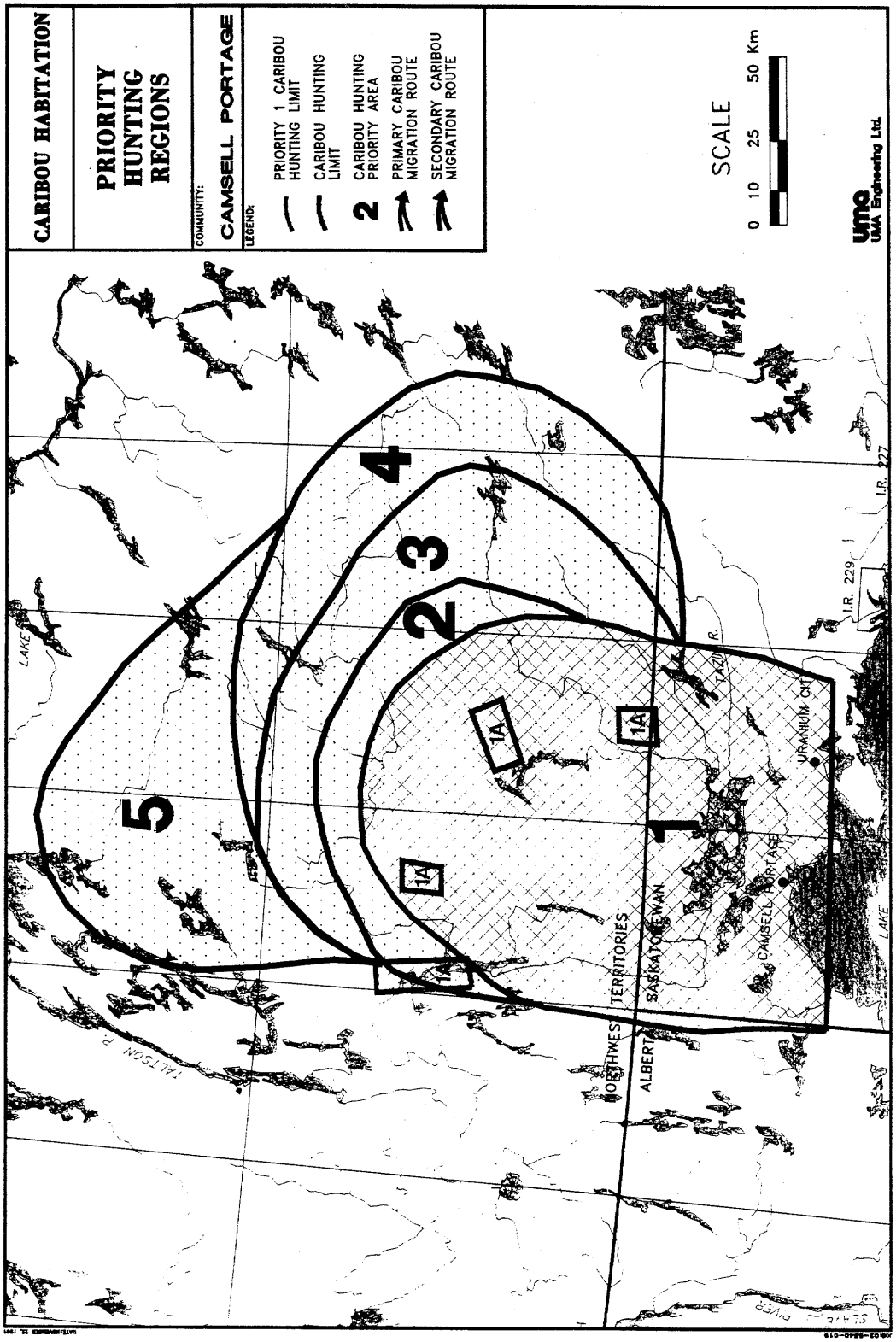
[a]Converted from acres in MacAuley (1983).
[b]Total area calculated as 101 581 km^2 (10 158 000 ha): Tazin L.=12 489; Fond du Lac=12 472; Stony Rapids=12 549; Phelps L.=12 371; Wollaston L. =12 922; Pasfield L.=12 919; Livingstone L.=12 925; William R.=12 934.
[c]Total area less 13.51% large lakes (>200 ha)=13 622 km^2: Tazin L.= 5518; Fond du Lac=1625; Stony Rapids=1413; Phelps L.=1237; Wollaston L.= 2509; Pasfield L.=762; Livingstone L.=294; William R.=264.
[d]Land=77 087 km^2: Tazin L.=5245; Fond du Lac=9105; Stony Rapids=9412; Phelps L.=9278; Wollaston L.=8529; Pasfield L.=11 511; Livingstone L.=11 984; William R.=12 023.

Appendix 8. Fire statistics for 1972 through 1981 by map sheet for 76 464 km^2 of caribou range in Manitoba north of 58°N and west of 96°W.

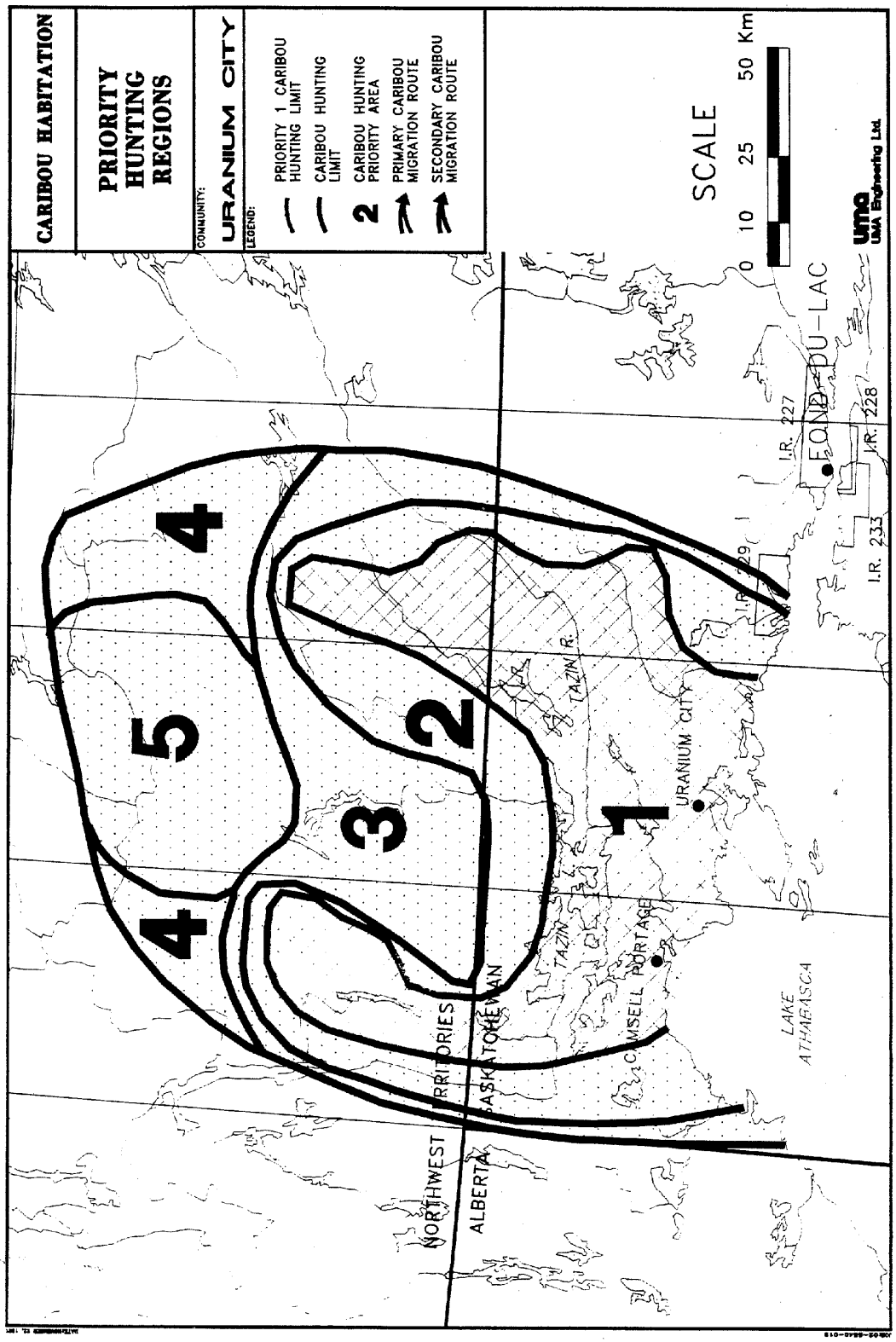
Map sheet	Total area (km^2)	Adjusted area i.e. less lakes & tundra (km^2)	Area burned (km^2)	Average annual rate of burning (percent)[a]	
				on total	on adjusted
Whiskey Jack	12 961	10 789	2 541	2.0	2.4
Kasmere Lake	12 600	10 781	1 305	1.0	1.2
Tadoule Lake	12 933	11 128	1 891	1.5	1.7
Munroe Lake	12 516	6 770	1 396	1.1	2.1
Shethanei L.	12 904	10 724	228	0.2	0.2
Nejanilini L.	12 550	2 393	65	0.1	0.3
Totals	76 464	52 586	7 425	1.0	1.4

Note: data on area burned converted from square miles in Manitoba Wildlife Branch (1983).
[a]Calculated as [(area burned/ total area)/10] X 100.

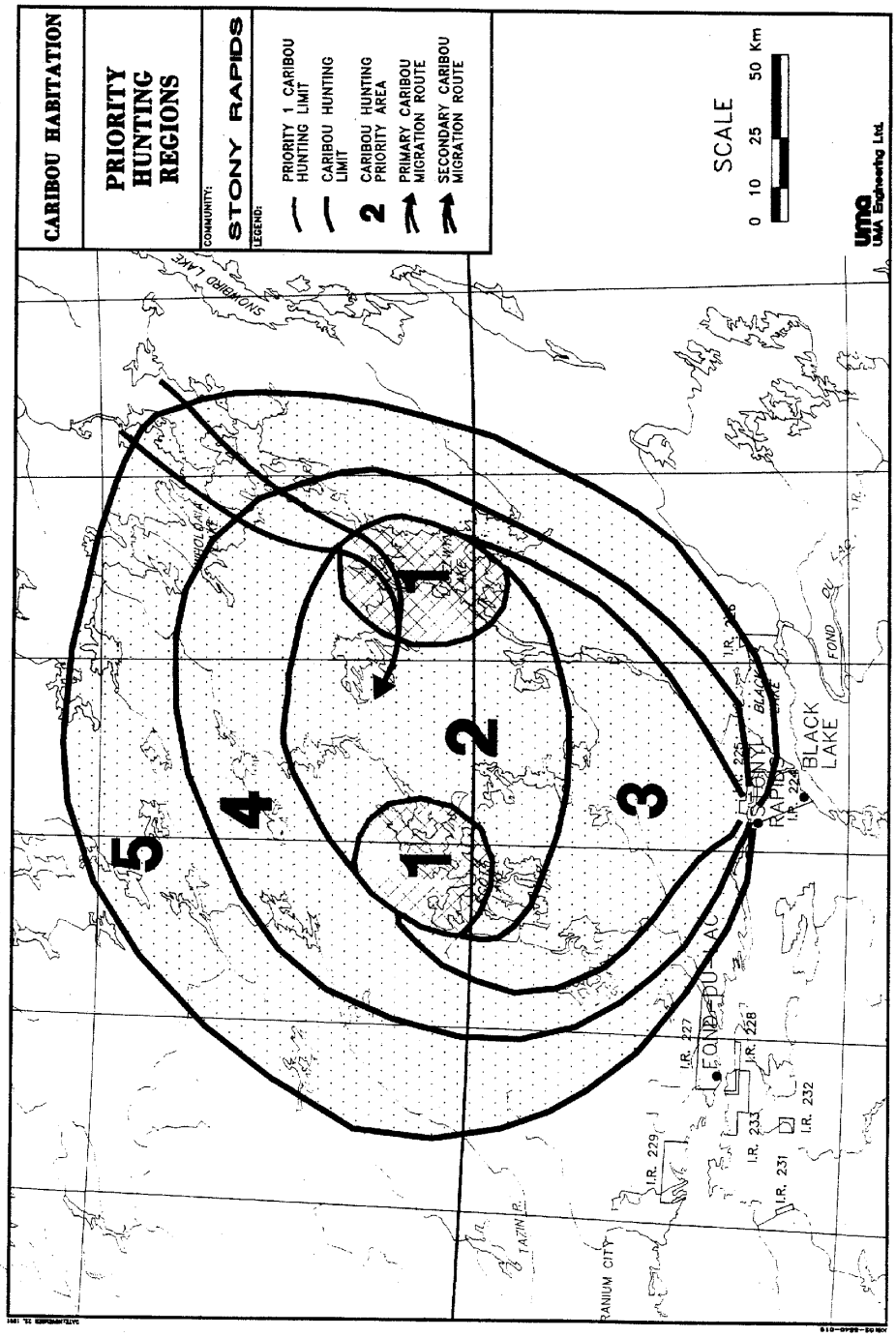
Appendix 9. Maps delineated by hunters in each community on the winter range of the Beverly and Qamanirjuaq herds of caribou. They show priorities for caribou hunting (Maps reduced from Dantouze 1991, 1992):



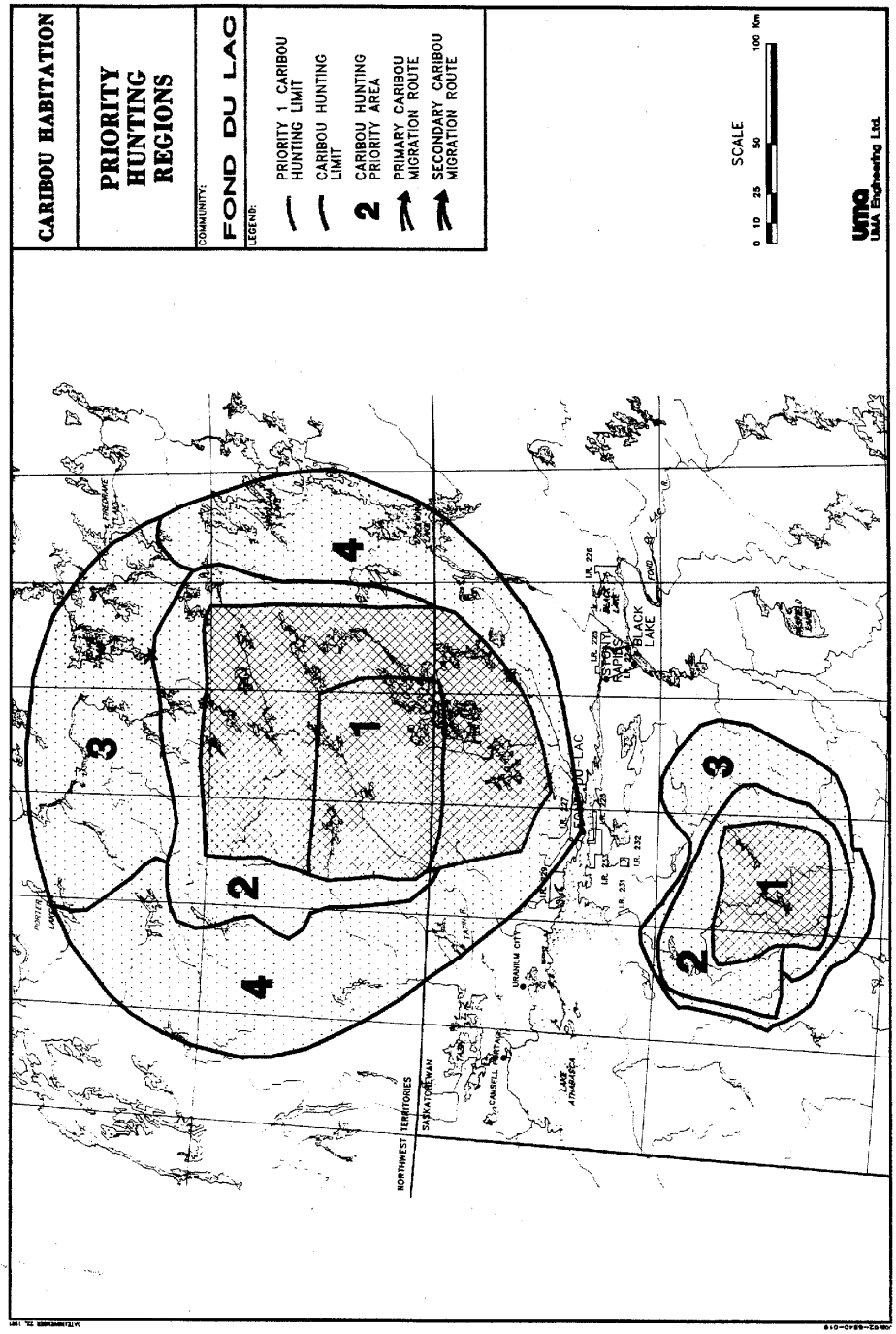
Map 1. Camsell Portage



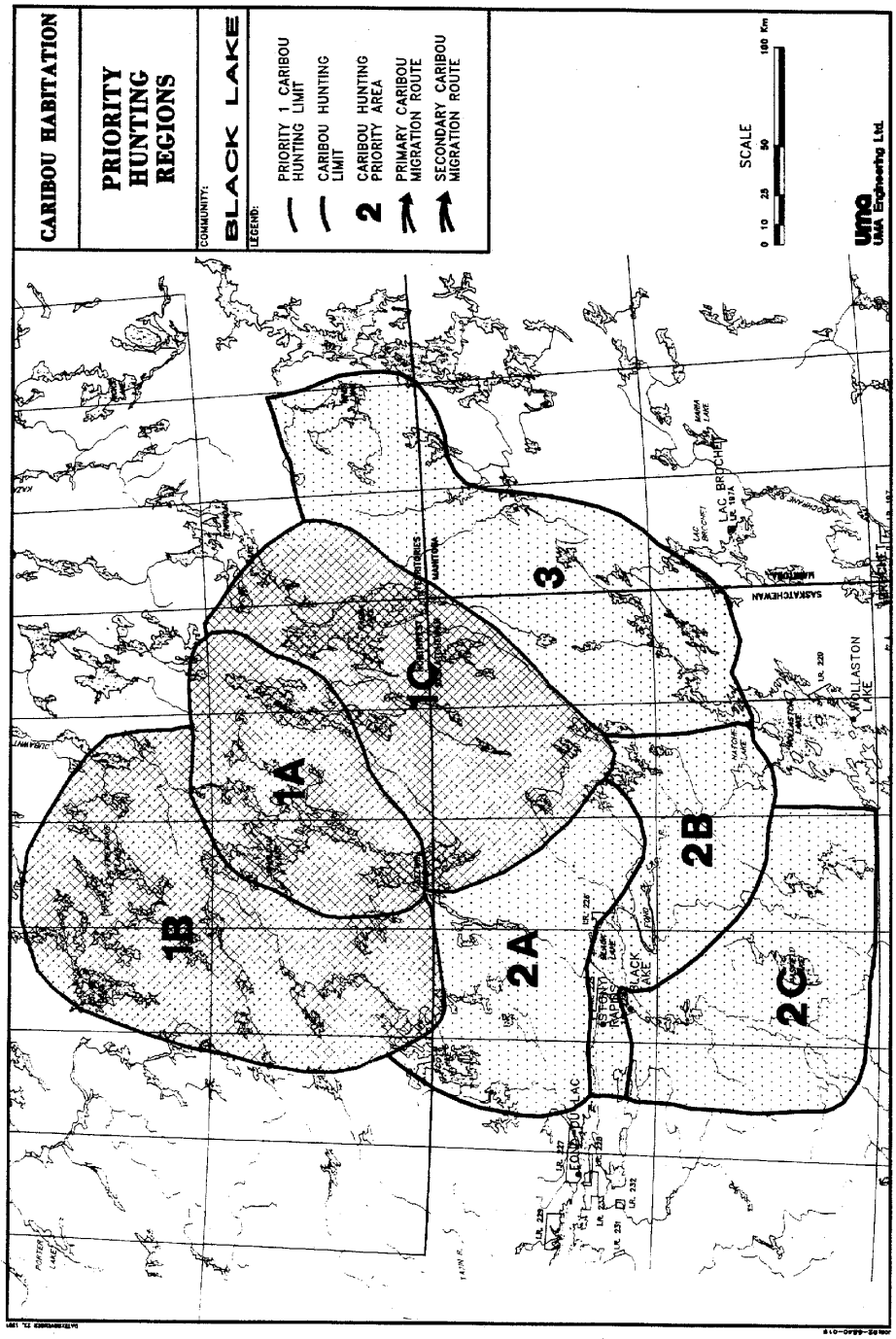
Map 2. Uranium City



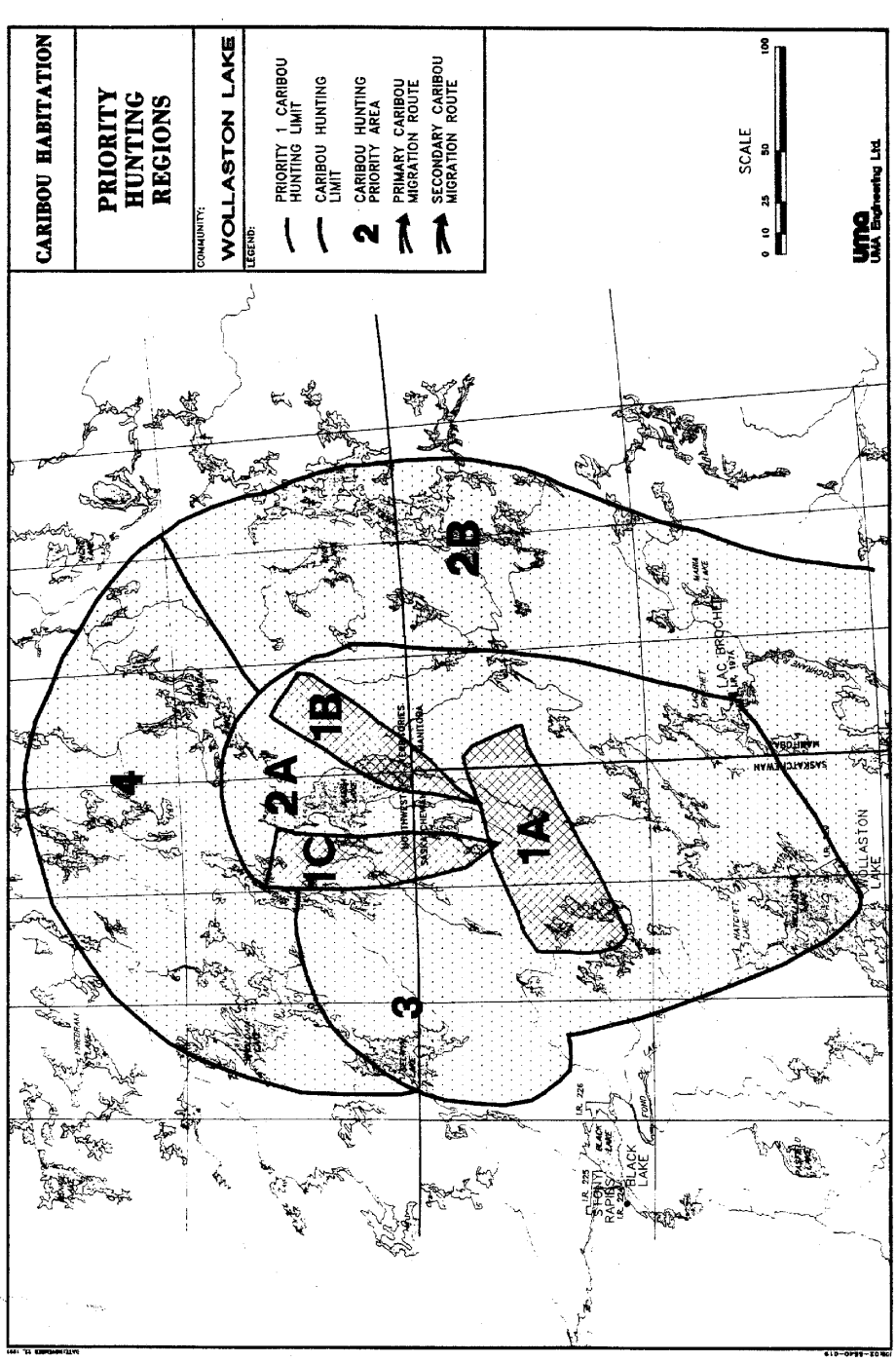
Map 3. Stony Rapids



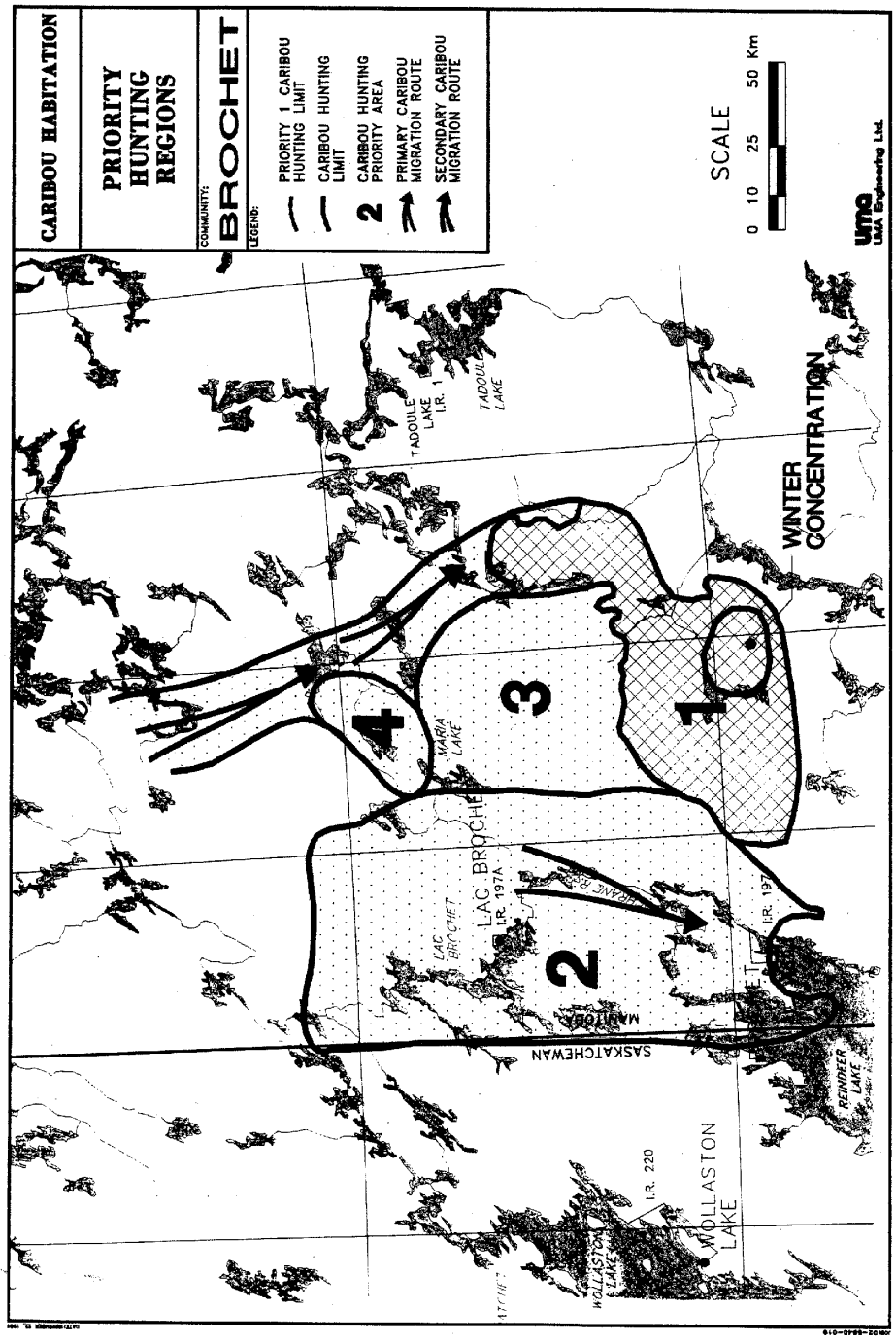
Map 4. Fond du Lac



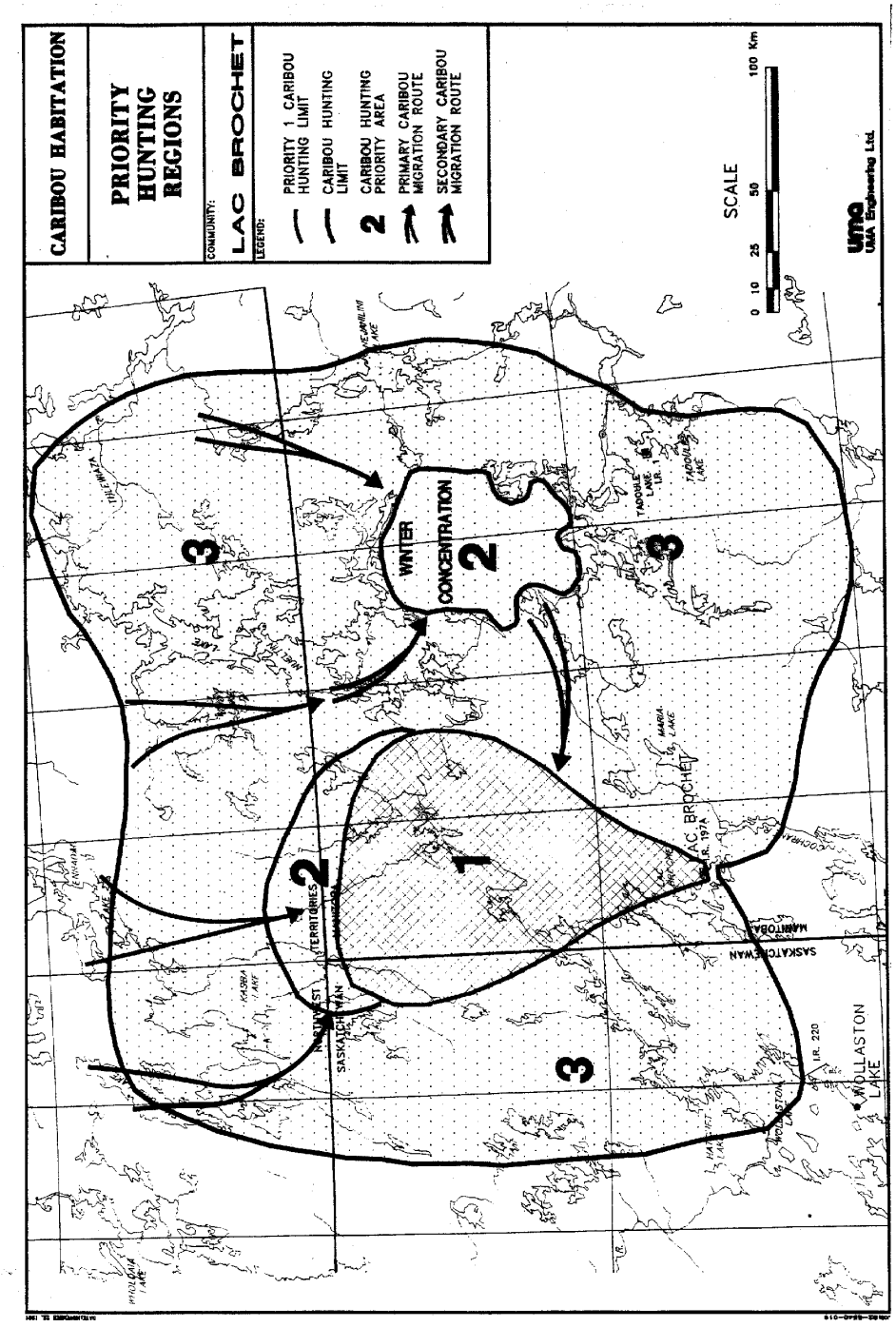
Map 5. Black Lake



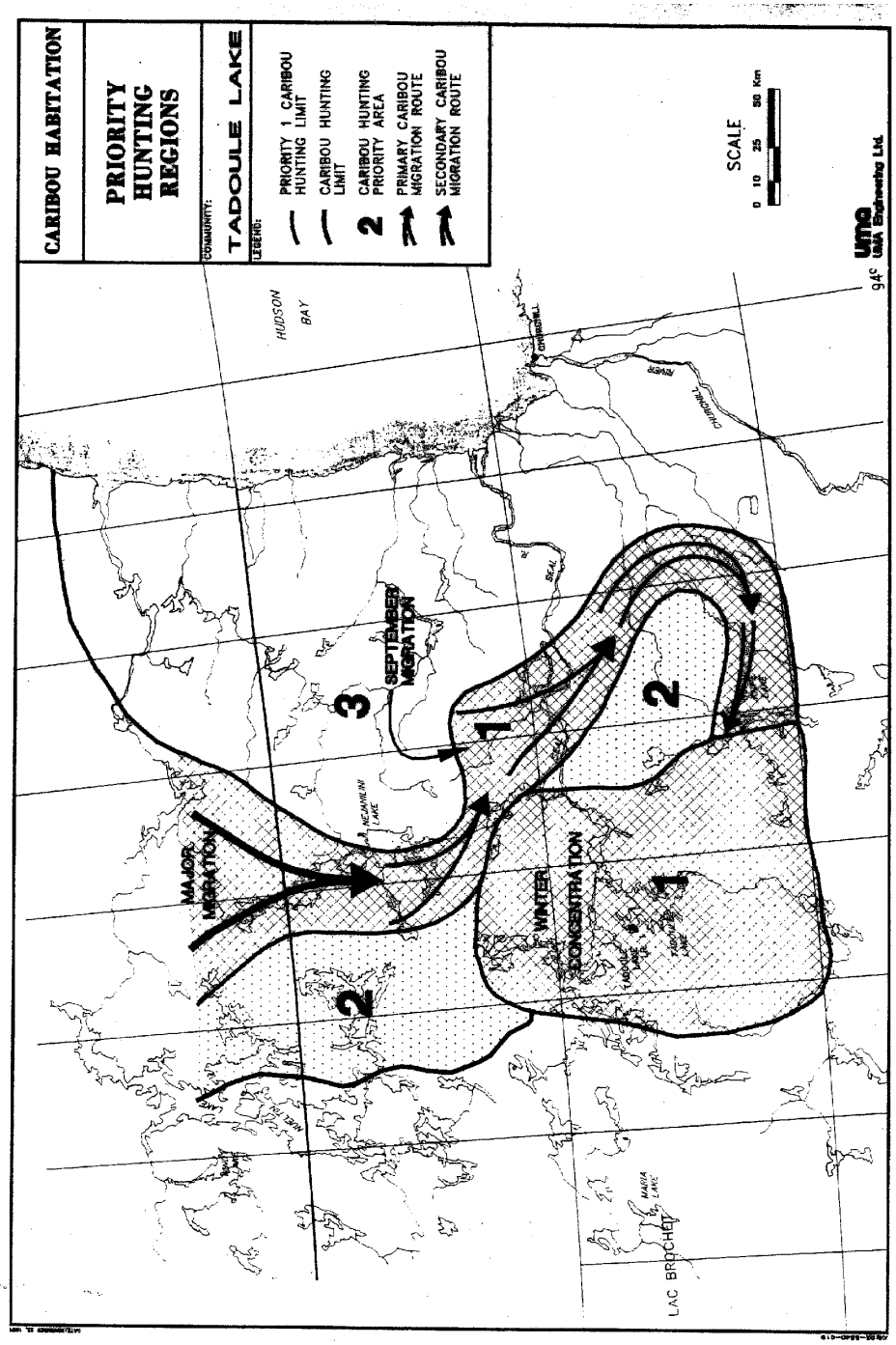
Map 6. Wollaston



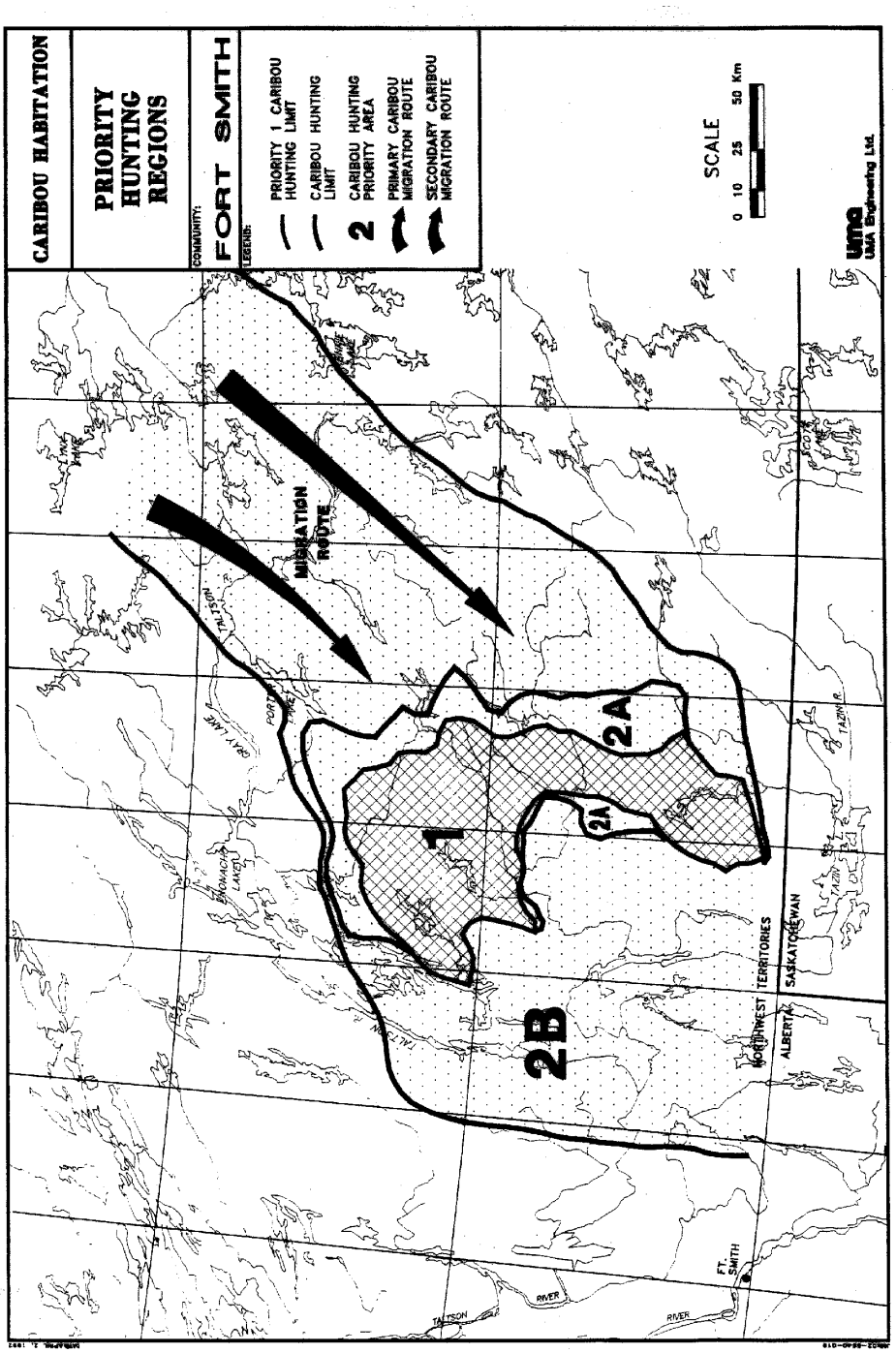
Map 7. Brochet



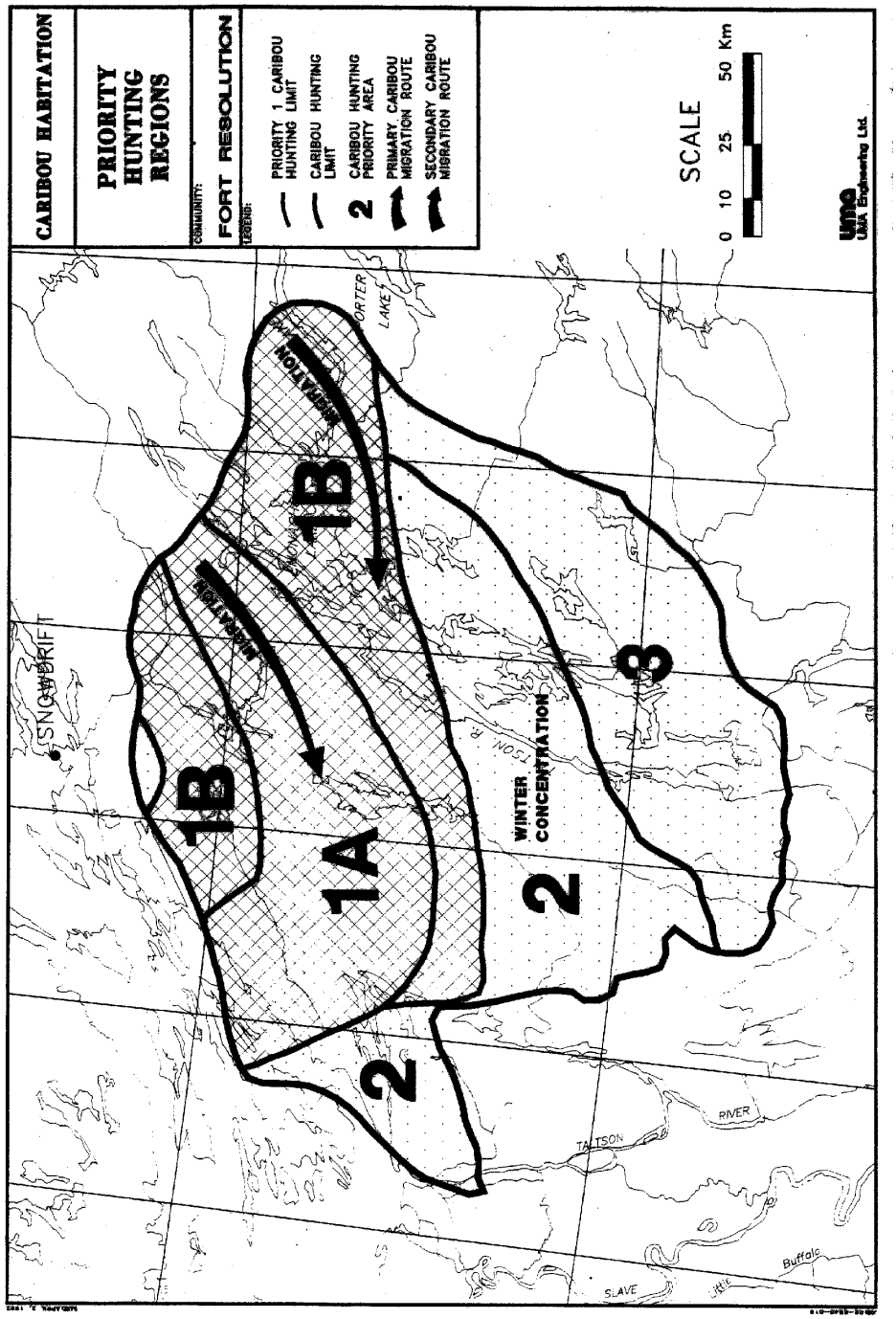
Map 8. Lac Brochet



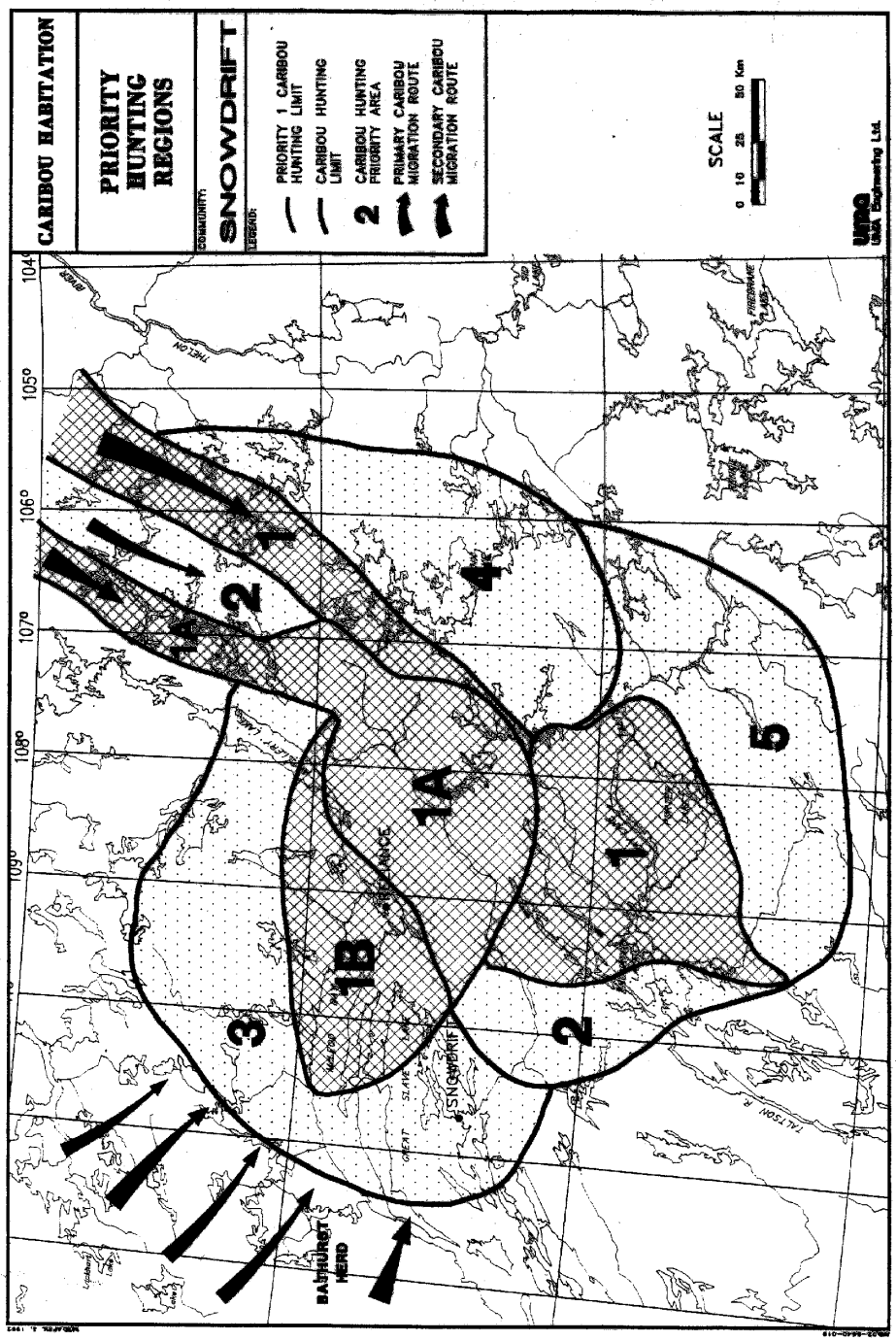
Map 9. Tadoule Lake



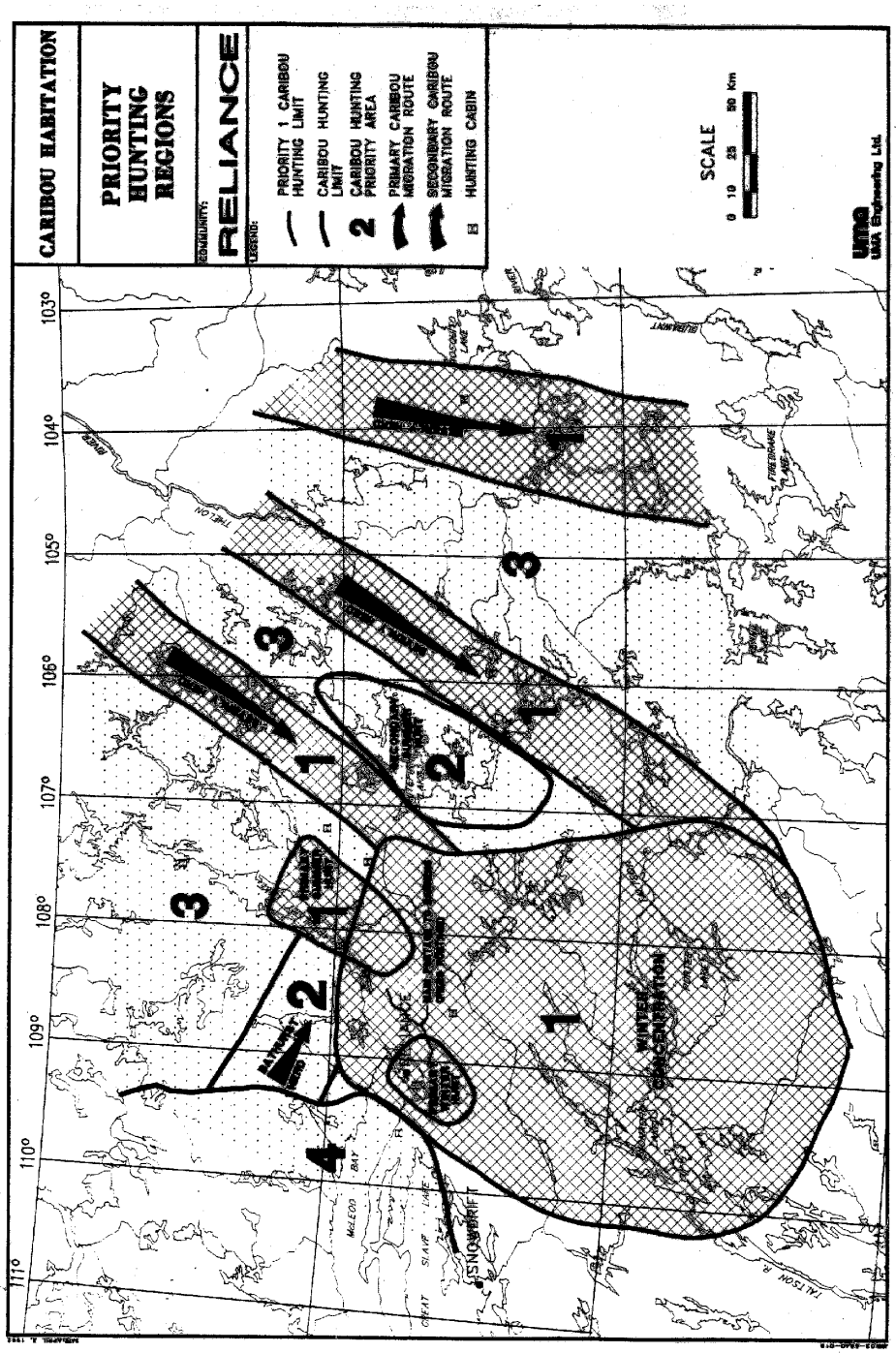
Map 10. Fort Smith



Map 11. Fort Resolution



Map 12. Snowdrift (Lutsel K'e)



Map 13. Reliance