Forest Succession and Range Conditions in Elk Winter Habitat in Kootenay National Park

By

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ABSTRACT

As a result of increased mortality on the Kootenay Parkway an assessment of current and past range conditions was conducted to determine the abundance, composition, and production levels of the elk winter range in Kootenay National Park.

Forest canopy composition and coverage was assessed using current (1978) and earliest (1945) air photo coverage. Data from the range assessment was combined with this range assessment to estimate range conditions both at 1978 levels and 1945 levels. An indication of change was thus produced.

Succession has resulted in a change from a majority of open meadows to closed forest. Forage resources in the Kootenay Valley have declined dramatically in the Park's history. The expansion of the Kootenay Parkway has offset this reduction somewhat. The highly palatable forage resources located along the Kootenay Parkway right-of-way are a concentrated, high quality resource amidst a low quality rangeland.

A vegetation/wildlife management plan specific to the Kootenay Valley is recommended. Research regarding a prescribed burning program should be the focus of this management plan. A prescribed burn program is a feasible means to create wildlife habitat as well as reducing the danger of large, dangerous fires that were common in the history of the Kootenay Valley.

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Chapter I
INTRODUCTION

1.1 BACKGROUND INFORMATION

Wildlife highway mortality is a serious problem in Canada's National Parks. This problem affects ungulate populations, reduces public safety, and results in substantial economic costs (Damas and Smith 1982). A significant number of highway mortalities of elk (plate 2), white-tailed deer, and mule deer, occur in Kootenay National Park (KNP) (Damas and Smith 1982; Poll *et al.* 1984). This has prompted the Canadian Parks Service to formally identify this issue as a park resource management concern (Kootenay National Park 1984).

Research is needed to document the factors which influence the presence of ungulates on the highway right-of-way (see plates 1 and 2). Vegetation changes, influencing natural ungulate ranges, and present highway corridor maintenance practices, have resulted in a concentration of animals along the highway (Kootenay National Park 1984). The location of the right-of-way through critical habitat and seeding of the wide roadsides with highly palatable plants have resulted in an attractive forage resource for ungulates in the Kootenay Valley (plate 3).

Plate 1: Bull elk in grassy meadow near highway.

Plate 2: Bull elk killed in collision with passenger vehicle on Highway #93.

Plate 3: Wide, seeded roadside on Highway #93 near MacLeod Meadows.

This attractive forage source, combined with conflicting transportation patterns has resulted in an unnatural reduction factor of the park's ungulates. An estimated 10% of the elk and white-tailed deer populations are being killed annually along the transportation corridor (Kootenay National Park 1984).

Highway mortality is an important, unnatural factor which is placing continued stress on the ungulate populations in Kootenay National Park. As a result of the high level of ungulate mortality on the Kootenay Parkway, this study was initiated for the Resource Conservation Division of Kootenay National Park in order to document previous and current range conditions in the Kootenay Valley. Through documentation of habitat change over time and accurate knowledge of present range conditions, management decisions regarding the mortality problem and wildlife habitat may better be evaluated.

1.2 PROBLEM STATEMENT

Fire suppression has been practised in Kootenay National Park since the park's inception in 1920. The natural succession in the absence of fire has likely resulted in a gradual reduction of open-forest and meadow habitats available for ungulates in the montane valley bottoms. Older-age forest stands may, however, have undergone self-thinning due to the death of old trees from disease and from wind throw of partially rotten stems. The extent of change in forest cover must be documented to determine whether or not elk winter range in KNP has decreased over the last several decades.

In addition to the above, an assessment is required to provide more information on the present condition of this rangeland. Since future consideration may be given to enhancing existing ranges, or creating new ranges away from the highway, baseline information on range condition would assist park managers in vegetation management and monitoring.

Management actions that may take place in the Kootenay Valley would benefit from the rangeland assessment and the ability to repeat such assessments in the future. Natural processes or management actions which result in alterations to the rangeland could then be compared to baseline conditions documented in this study.

1.3 LIMITATIONS AND ASSUMPTIONS

All field work pertinent to this study is specifically restricted to the critical elk winter habitat area outlined in this study. All data analysis and evaluation is restricted to these areas. It is assumed that by quantifying and subjectively documenting significant changes in montane grassland/shrub habitats, recent historic changes in available elk winter range can be documented.

1.4 OBJECTIVES

1. To estimate the extent to which forest cover has encroached on elk winter range in the Kootenay Valley of Kootenay National Park from earliest suitable photo record to present.

2. To estimate the areal coverage, relative abundance, and herbage biomass per hectare, of the grazing resource in each of the specified forest categories in selected montane ecosections of the Kootenay Valley.

3. To estimate the browse species composition, standing stock, and utilization in each of the specified forest categories in selected montane ecosections of the Kootenay Valley.

4. To estimate the change in available forage resources from earliest air photo record to present and discuss the rate of forest succession.

5. To discuss the extent to which the highway corridor grasslands have compensated for loss of native grasslands due to forest encroachment.

1.5 METHODS

Complete aerial photograph coverage of the Kootenay Valley is available for KNP from 1945, 1966, and 1978. These air photos were interpreted to determine areas of different forest canopy cover types which were then mapped onto a common base map . The changes in forest composition and coverage were measured and the areal amount of forest encroachment onto open areas, between 1945 to 1978 was then calculated.

The aerial photo comparison was supplemented with less objective historical information gleaned from review of journals and archival materials. In addition, the timing and extent of clearing of the roadside was reviewed through historical research.

Analysis of current range conditions was undertaken in a selected portion of the montane ecoregion of the Kootenay River Valley. The forage resources of different categories of forest canopy cover were evaluated in this area.

The Kootenay River Valley contains critical winter range for elk and moose, and summer range for white-tailed deer (Poll *et al.* 1984), this area is likely to be subject to the most intensive management actions in the future.

1.6 DEFINITIONS

KNP/Kootenay - Kootenay National Park.

Study area - the montane ecoregion of the Kootenay River Valley.

Graze/Grazing Resource - all forbs and graminiods, and woody plants less than 25cm high.

Browse/Browsing resource - woody plants greater than 25cm tall and less than 7cm in diameter at 1.5m (DBH).

Canopy Species - woody plants greater than 5cm in diameter at 1.5m in height (DBH).

Transportation Corridor/Kootenay Parkway - Highway #93.

Stem - that portion of woody growth which protrudes from the ground, or is a separate entity at ground level.

Twig - that portion of a woody plant which is lateral from the stem and at least 5cm in length.

Chapter II

REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

With human intervention in the natural process of wildfire, the cycle of regeneration (common in many ecosystems in North America) is often no longer available to create a diversity of habitat for wildlife. Elk habitats and food supply have been severely curtailed by human control of wildfire in North America. Fire was responsible for the creation of a mosaic of forest stands throughout the mountainous biome. This high diversity of natural habitat resulted in a combination of forage and cover highly preferred by elk and many other wildlife species. Post-fire succession of herbs and shrubs often provided excellent habitat for elk for 20-30 years after a fire (see plate 4), until the forest canopy again shaded out the ground-level vegetation (Lyon and Stickney 1966).

2.2 SUCCESSION AND FIRE

Succession, a directional change in a plant community which, barring interruption, follows a continuum from colonization to climax has been compared to the developmental stages of an organism (Clements 1916) with stages of birth, growth, maturity, and death. An ecosystem is such a type of organism, and is susceptible to exterior forces which may alter the stage of development along the continuum.

Fire is one of a multitude of forces that influence and control the development of ecosystems. The influence of fire dominates the history of forests as well as shrub communities and grasslands. With the possible exception of the wettest or coldest regions of the earth, all ecosystems on earth have been subject to periodic fires for millennia (Komerek 1963; Spurr and Barnes 1973).

Evidence indicates that most ecosystems in Canada have evolved with fire as a periodic factor (Lohnes 1981). Lightning fires have been noted as an integral part of our environment which, although variable in time and space, are rhythmically in tune with global weather patterns (Komarek 1967). Lightning fires are an important factor in ecological succession in most forests and in maintaining a productive mixture of habitat types (Figure 1). In natural ecosystems the vegetation regimes are seldom uniform but are a mosaic of individual areas which represent all successional seres from pioneer to climax. This mosaic is largely the result of fire.

Plate 4: Post-fire successional vegetation in the Vermillion Pass burn area, 25 years after burn.

Natural fires are normally limited in size and intensity (Lohnes 1981). Fires do not burn uniformly, often many unburned patches of vegetation remain within a burned area. This effect is a result of quantity and quality of fuel within the forest, the older and drier forest will burn whereas the patches of young, green vegetation will often survive. The result is an ecosystem rich in biological productivity and diversity (Barbour *et al.* 1980).

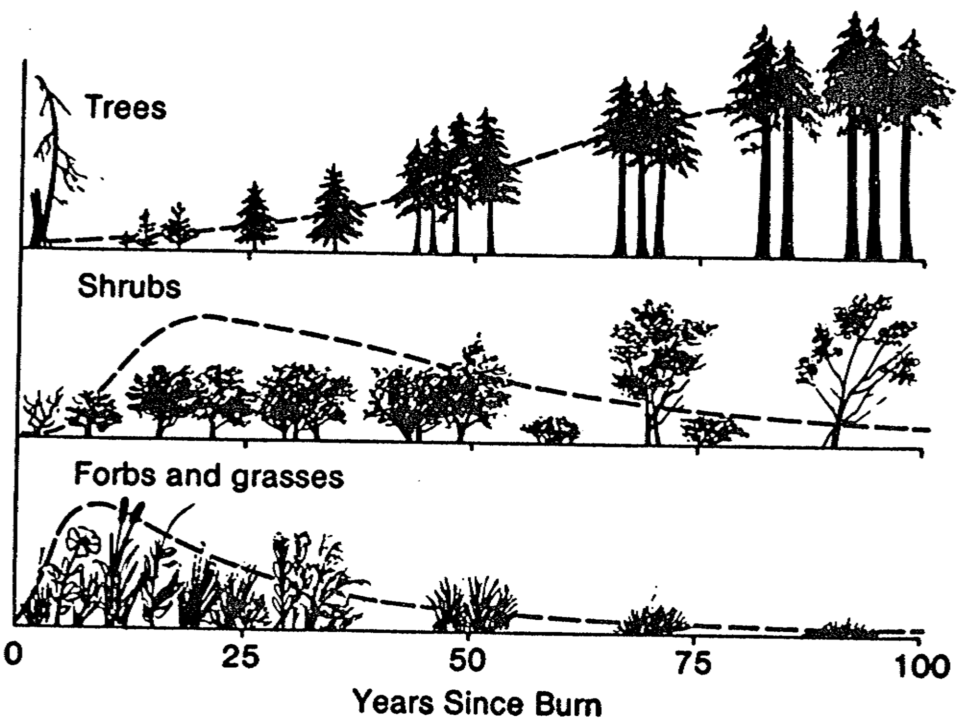


Figure 1. Natural postfire succession provides a succession from herbs immediately after fire, to shrubs, to a slow return of the forest canopy (from Lyon and Stickney 1966).

2.3 SUCCESSION AND NUTRIENT CYCLING

Early successional species usually achieve rapid growth rates on the supply of unutilized nutrients which occur after vegetation removal due to a disturbance. Provided with excellent conditions for growth on suitable sites vegetation succession begins. Colonizing species are able to maintain high growth and reproduction rates on the disturbed site until the pulse of nutrients is diminished (Peterson and Bazazz 1978). This growth pattern is known as the *r-selection* strategy.

Once the surplus of nutrients is utilized the *K-selection* strategy replaces r-selection. Long term occupancy of the site is characteristic, investment in roots and mycorrhizae increase, amount of carbon fixed increases and more effective use of nutrients occurs. As succession progresses, the accumulation of organic matter increases in both vegetative material and organic debris present. The organic debris acts as an insulator which cools the soil. Reduced soil and biomass temperatures slow the decomposition rate and promote accumulation of nutrients in the detritus. As this progression continues, a higher moisture content in the organic layer allows the establishment of bryophytes. The establishment of moss is associated with a decline in nutrient availability, further reduction in forest floor and mineral soil temperature and reduced organic matter decomposition (Van Cleve and Viereck 1981).

A decrease in the rate of litter decomposition and resultant slowed nutrient cycling, result in a deficiency of nutrients important to tree growth (Heilman 1966). Retarded tree growth and a longer term required for sexual maturation are thus characteristic of mature successional stages. Non-vascular plants and microbes become prevalent at this stage because they are effective competitors for reduced nutrient supplies (Van Cleve and Viereck 1981). The result is a forest floor deficient of quality forage resources for most ungulates.

As the nutrient exchange between organisms and environment slow, the plant community begins to show age and self-thinning due to wind throw of aged and dying trees in the climax community occurs. At any point in time, fire or flooding may act to set the system to an earlier stage of succession. Fire, acting as a rapid decomposer, replenishes reservoirs of some nutrients, depletes others, and changes the albedo and thickness of the surface soil layers. The nutrient conservation K-selection stage is then reversed to the start of an r-selection pattern (Van Cleve and Viereck 1981).

2.4 FIRE AND WILDLIFE

Fire has a great impact on wildlife habitat. After a fire sweeps through a forest ecosystem and one plant community is replaced by another, certain animal species find conditions unsuitable and their numbers decline, while other more highly specialized species disappear entirely (Monroe and Cowan 1944). At each stage a different aggregation of mammals and avifauna moves in, impelled by population pressure elsewhere. A different biota is eventually established, and as burned over areas become reforested this process reverses.

Fire has an immediate effect on wildlife populations, the major effects being the changes in food and cover. Growth of herbs and shrubs following a fire provides excellent food for a wide range of mammals, but especially for browsers such as deer, elk, and moose (Figure 1). By returning a habitat to early successional stages, certain wildlife species are favoured at the expense of species requiring later successional habitat. This is a natural ongoing process which, barring interference, continually reverses itself. Fire history record indicates that the average rate of return for a fire in the Kootenay Valley, prior to the parks's inception in 1920, was ninety-two years; these fires were usually of significant size (Masters 1989). The last major fires in the Kootenay Valley occurred in 1917 and 1926.

2.5 ELK IN KOOTENAY NATIONAL PARK

2.5.1 Population data

Historical distribution of elk in Canada indicates a range from British Columbia to southern Ontario (Banfield 1974). The early occurances of elk in KNP are not well documented. Records in park files indicate that elk were increasing in the 1930's and 1940's, perhaps in response to improved winter range conditions as a result of two major

Table 1. Maximum counts of elk in Kootenay National Park, 1952-1990 (from Poll *et al.* 1984, Poll 1989).

Year	Bulls	Cows	Calves	Yearlings			Unclass.	Total	Calves/ 100 cows
				M	F	U			
1952	123	720	156		109	-	-	1108	22
1953	151	751	94		142	-	-	1138	13
1954	111	325	38		18	-	381	873	12
1956	83	414	11		64	446	-	1018	3
Oct 1962	36	191	138	35	-	-	-	400	72
Nov 1963	68	260	117	39	-	-	-	484	45
Nov 1964	58	223	101	22	-	-	-	404	45
Nov 1965	46	188	100	20	-	-	-	354	53
Nov 1966	64	155	80	17	56	-	-	372	51
Nov 1967	58	238	102	16	26	4	-	404	43
Nov 1968	34	160	75	21	43	-	-	333	46
Oct 1969	54	157	69	11	31	-	-	322	43
Oct 1971	25	76	50	10	-	107	-	268	66
Oct 1973	20	172	50	16	35	-	-	293	29
Nov 1974	6	71	31	6	32	37	-	183	44
Nov 1976	14	133	49	26	31	25	-	278	37
Nov 1979	7	155	55	27	14	62	-	320	36
Nov 1980	-	-	-	-	-	-	-	204	-
Nov 1981	17	137	31	15	13	52	-	265	23
Nov 1982	21	154	64	17	7	-	-	264	42
Dec 1983	-	-	-	-	-	-	-	173	-
May 1984	10	154	-	-	-	-	115	305	-
Oct 1985	34	132	42	-	-	-	-	208	32
May 1986	18	150	-	-	-	-	5	217	-
Oct 1987	43	144	27	-	-	-	-	227	19
May 1988	-	-	-	-	-	-	-	113	-

fires, the latter encompassing some 6070 hectares (park files) in 1926. Munro and Cowan (1944) listed elk as widespread and common in KNP, and Cowan (1943) suggested that the major winter range was fully stocked. Maximum counts indicate that the elk population peaked in the early 1950's and has since been in decline (Table 1), likely as a result of forest succession on the habitat which was created by the 1926 and 1917 fires. Personal communication with park wardens has indicated that population estimates for the 1950's are inflated (Poll *et al*. 1984); however the decline in population is apparent and is blamed on severe winters and an overstocked winter range in the late 1940's and 1950's, as forest succession progressed.

2.5.2 Habitat Use

Selection of habitat by elk is conditioned by topography, weather, biological factors of forage and vegetation cover, and escape from recreationists, predators, and insects (Skovlin 1983). Table 2 lists the factors that interact to simultaneously influence elk habitat.

Elk occupy a variety of habitats in all three KNP ecoregions, (montane, subalpine, and alpine) during the summer. With the onset of winter the elk migrate from the lower subalpine slopes and valley bottoms in the Vermillion drainage system to the montane valley bottoms of the lower Vermillion and Kootenay River Valleys (Figure 2), where

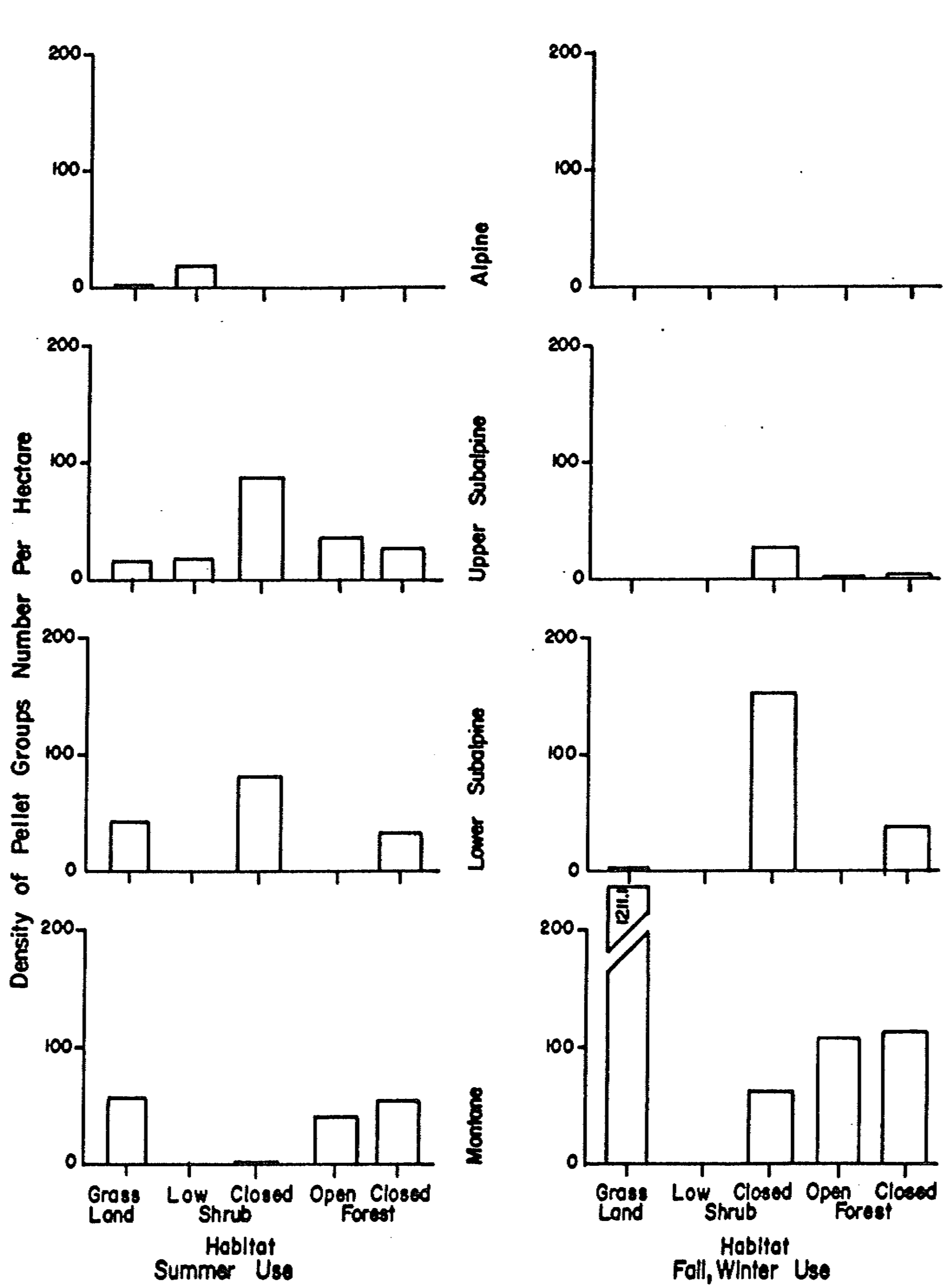


Figure 2. Elk seasonal use by KNP ecoregion from pellet count data (from Poll *et al.* 1984).

the snow accumulation is the lowest. Snow accumulation is a major determinant of the extent of winter range, the least accumulation occurring in the Wardle Flats area of the Vermillion Valley, and between Kootenay Crossing and McLeod Meadows in the Kootenay Valley (Poll *et al.* 1984). The

Table 2. Factors that influence habitat selection by elk (from Skovlin 1982).

Topographic	*Food*
A. Elevation	A. Availability
B. Slope 1. gradient 2. position of Slope 3. aspect	B. Quality
C. Land features	*Cover*
Meteorlogic	A. Cover type 1. hiding 2. thermal
A. Precipitation-snow 1. depth 2. condition	B. Density
B. Temperature 1. solar radiation a. radiation b. convection	C. Composition
C. Humidity	D. Site productivity
D. Barometric pressure	E. Structure
E. Wind 1. velocity 2. direction	F. Successional stage
	G. Configuration
	Space
	Water and Salt
	Specialized habitats
	A. Calving
	B. Wallows
	C. Trails

optimum diet for elk consists of a mixture of shrubs and grasses (Poll *et al.* 1984), (Table 3).

Meadow and shrubland produce the greatest vegetative diversity and potential forage areas for elk. The value of these areas is complicated by "edge effect". Prime forage producing habitats frequently have no tree strata to provide thermal cover. Consequently, their overall suitability value is lowered by the cover component. Ungulates exploit a shrubland or meadow community for food, and then move to an adjacent timbered area when thermal cover is required. Foraging habitats adjacent to forest communities, therefore, will be of a higher value to elk than areas greatly removed from adequate cover. Similarly, dense forest stands situated next to good foraging areas will be of greater cover value than the central cores of such stands which may be well removed from suitable forage sources.

Even more representative of forest succession, changes in moose populations suggest major change in the vegetation regime. The abundance of moose in Kootenay National Park has undergone more dramatic fluctuations than has any other ungulate in the park. Records from early park files indicate that moose were relatively common in the 1920's and underwent a dramatic increase though the 1930's (Poll *et al.* 1984).

Table 3. Highly important vegetation types for elk in KNP from pellet count groups (from Poll *et al.* 1984).

Vegetation type	Pellet groups/ha	Description
Spring and early summer		
O11	195.0	bluebunch wheatgrass-hairy wild rye-showy aster
C16	175.0	aspen/hairy wild rye-peavine
H8	175.0	yellow dryad-willow herb
C3	78.6	lodgepole pine/juniper/bearberry
C25	108.3	Engelmann spruce-subalpine fir-green alder
C11	100.0	lodgepole pine/feathermoss
C41	100.0	white spruce-subalpine fir/bunchberry
O14	75.0	Engelmann spruce-subalpine fir/rockwillow/bracted lousewort
C39	70.6	lodgepole pine/buffaloberry/bunchberry horsetail
Late summer, autumn and winter		
C1	108.8	Douglas fir/hairy wild rye
C9	175.0	lodgepole pine/dwarf bilberry
C16	325.0	aspen/hairy wild rye-peavine
C37	205.0	white spruce/buffalo berry/feathermoss
C44	177.8	spruce-aspen-lodgepole pine (paperbirch)/buffalo berry/pine grass
H8	600.0	yellow dryad-willow herb
H11	-	beaked sedge-water sedge
H10	759.0	bluebunch wheatgrass-hairy wild rye showy aster
O11	516.7	spruce/labrador tea/brown moss
S1	312.5	birch-shrubby cinquefoil-willow/brown moss

Since moose tend to favor shrubby, subclimax habitats created by interruption of natural succession by processes such as fire, it is only natural to assume that the moose populations increased in the Kootenay Valley as a result of the habitat created by the 1917 and 1926 fires. The fact that moose were considered common in the 1920's suggests that much greater parkland (shrub and deciduous forest) habitat existed in the park than what is present today. Although estimates from 1939 onward indicate that moose were decreasing steadily from the supposed 300 plus existing in the Kootenay Valley in the mid 1930's they were still considered the second most abundant game animal in KNP in the 1940's (Munroe and Cowan 1944). Today, park wildlife cards indicate an average of 21 sightings/year and it is considered unlikely that there are more than 75 moose in the entire park (Poll *et al.* 1984).

2.6 GENERAL PARAMETERS OF VEGETATION SAMPLING

The need for accurate measures and descriptions of species and communities has made it necessary to sample the vegetation. For descriptive and comparative purposes, and as a base for experimental or managerial purposes, the characterization of plant communities is often a necessity. Usually the members of an entire association cannot be counted or measured due to the abundance of species and large biomass of the community.

Vegetation sampling is a means by which an investigator can make inferences about a plant community based on information gathered from an intensive examination of a small portion of the population. Development of a sampling scheme which closely approximates the actual parameters of a community has been the guiding principle in the evolution of sampling methodology.

2.6.1 Sampling Parameters

There are many different types of sampling schemes employed today. These are basically determined by the parameters one wishes to investigate. The various general parameters include cover, production, biomass, utilization, density, and frequency. These parameters are often interrelated and are dependent upon the vegetation type being sampled.

Cover is defined as the proportion of the ground which appears covered when viewed from a perpendicular position to the community. Productivity is the rate of change in biomass per unit area over the course of a growing season or a year. Biomass is the weight of vegetation per unit area; synonyms often used are standing crop, stock and phytomass. Utilization is the amount of available vegetative matter which is harvested, usually by animals, in a particular season. Density is the number of plants rooted within each quadrat, and frequency is the percentage of total quadrats that contain at least one rooted individual of a given species.

2.6.2 Location of Sample Points

It is important that the sample points provide an unbiased estimate of the parameters of the vegetation being studied. Knight (1978) states four rules that should always be followed:

- Sample points should be distributed throughout the sample units and not just within a small portion of the sample unit.

- Sample points should be located without any bias of the investigator.

- Sample points should be located far enough within the sampling unit to avoid transition zones and the edge effect created by highways, rivers, and so forth, and

- The objective selection of random sample points is best accomplished with the use of a random numbers table.

2.6.3 Ground Cover Assessment

Size and Shape of Sample Plots

Selecting the proper size and shape of a plot is important for effective sampling and is directly related to the type of vegetation being sampled. After reviewing the literature (Clapham 1932; Cain and Castro 1959; Van Dyne *et al.* 1963; Daubenmire 1968; Lyons 1968; Kershaw 1973; and Barbour *et al.* 1980) the following generalizations can be presented:

- The type of vegetation community being sampled and the parameter being investigated should determine the plot size and shape.

- Optimum plot size and shape depends on the distribution of the species being studied, (i.e., larger plots are needed for sparser vegetation.

- Small sample units, although generally easier to use, have the potential to yield misleading results as vegetation species tend to be grouped together.

- More species are generally included in long, narrow (rectangular) plots.

- The larger the number of plots sampled and the more widespread their distribution - the higher the total number of species encountered.

It is generally agreed that rectangular plots are more accurate because species tend to be grouped together and a rectangular plot has a higher chance of intercepting several groups. A disadvantage of the long, narrow plot is a large margin in proportion to its area. This can be a problem when studying density or basal area because of the difficulty of deciding which borderline individuals should be included (Daubenmire 1968). Borderline cases may cause confusion as to whether or not a species should be included in the list; this is best solved simply by the inclusion of any species which had any portion of its aboveground biomass appear within a plot.

Amount of Sampling Required

In sampling a plant community it is evident that the number of species encountered is high at first and then declines until a point is reached when it is no longer useful to sample additional plots. A determination of the minimal, adequate, sampling area is thus useful in four ways (Daubenmire 1968):

- Determination of the least amount of area that need be studied to gather an accurate estimate of the parameters in question.
- Determining the smallest size for specific correlation of biotic assemblages with environmental factors.
- The sample used to characterize a stand is equal to the minimal area, and
- the minimal area serves as an additional trait of the diversity and richness of an association.

2.6.4 Browse Assessment

Techniques involved in vegetation analysis usually involve either the use of plots or points. Of these two approaches, plot surveys are simpler and more precise than many plotless techniques (Lyon 1968). Plots, however, are more time consuming, usually involving more measurements and manipulation of more data to reach precise estimates of vegetation parameters. While plots remain the major analysis method for herbaceous vegetation, plotless techniques are more commonly used for browse assessments.

Since the publication of Cottam's (1947) paper on the random pairs method, many techniques for browse assessment, using either point-to-plant or plant-to-plant distance measurements, have been described. Cottam and Curtis (1956) concluded that the most efficient of these methods were those in which distances were measured to four plants around random points.

Quarter Methods

Two field methods are discussed below. The first is called the Quarter methods, where distances are measured to the nearest individual in each quadrant around randomly located points.

Point-centered quarter: This method is the oldest of the quarter techniques, and as adapted for ecological use (Curtis and McIntosh 1950) each sampling unit is considered the centre of the four quarters (quadrants), with orientation given by the compass line of traverse. At each point, the closest individual to the point in each of the four quarters around the point is chosen as the sample. Distances are measured from the point to each of the four individuals.

Cottam and Curtis (1956) reported that the average of the four distances measured from a point is the square root of the mean area occupied by a single plant. The area estimate derived for each point is treated as a single observation for calculating variance (Lyon 1968).

Angle method: As described by Morisita (1957) this calculation method summarizes the areas of four adjacent quarters with radii equal to the measured distances. In effect, the plot examined consists of four unequal pie-shaped pieces. The total area of this irregular figure is treated as a single observation.

Quarter-order Methods

The second of the field methods is referred to as Quarter-order methods. Distances are measured to the third individual in each.

Wandering Quarter Methods

The last of the three field methods are called Wandering quarter methods. The wandering quarter, described by Catana (1963), involves measuring plant-to-plant distances along a meandering transect determined by a constant compass bearing and a 90 degree angle of inclusion centered on successive plants.

Shrub Measurements

Browse survey techniques are quite variable, in that, they can consist of simple observations of plant presence to precise measurements to determine biomass. There are, essentially, two types of these surveys. The first being reconnaissance surveys and the second being the more precise, but more time consuming, weight measurement methods.

Reconnaissance methods usually measure some of the following observations; number of stems or plants per unit area, frequency of occurrence on plots or at sample points, and percentage of plot covered by above-ground parts of each species. Presented below is a summary of some more common reconnaissance methods.

The Aldous Browse Survey Method: Aldous (1944) suggested the estimation of cover percentage within the feeding height of browsers on 0.417 ha. (1/100 acre) circular plots having a radius of 3.56 m. The percentage of available twigs that have been browsed are also estimated. This method is to some degree subjective but does remove a lot of guesswork. Telfer (1981) suggested that the plot size is too large and that a smaller size of 1.78m radius or 10 square metres in size be used. One of the great advantages of Aldous' method is the rapidity in which it can be used in the field.

Line and point intercept: This method has been used quite extensively over much of western North America and consists of the following measurements. A tape is stretched through the vegetation and the length of tape under each shrub crown is recorded by species (Canfield 1941). Point intercept involves recording shrub crowns by species intercepted by perpendicular lines above (or below) points at intervals along a tape (Dasmann, 1948). The results of both of these methods are usually presented as percentage of total tape length. Since crowns will overlap, the total of percentages for all species may exceed 100%. If more intensive data is required for estimates of twig utilization, selected shrubs and/or saplings can be selected for more indepth analysis.

Twig counts: More time consuming techniques involve counting all twigs within relevant species and height categories. Twigs are usually counted on plots but individual sample stems or branches can also be counted using distance methods, which will be discussed later. Twig counts provide a percentage utilization factor for each species.

The majority of these kinds of surveys are modifications of a procedure proposed by Passmore and Hepburn (1955). Twig counts have the advantage of providing acceptable estimates of utilization percentages below 60% at a relatively low cost (Jensen and Scotter 1977). However, counts provided those authors with poor estimates when utilization was greater than 60% (Telfer 1981). The vast differences in twig weights precludes the comparison among species.

Twig length: In western North America this method has been used extensively, but is considerably more labour intensive than the above method. This technique requires two surveys; one in the fall and one in the spring after browsing season (Nelson 1930; Smith and Urness 1962). The method is set up as follows: In fall, stems (or branches) are selected for study and tagged. The total length of new growth for all twigs on the sample stems is then measured. Percentage utilization on each species is determined by a spring survey when all remaining length growth of the previous year is measured.

Weight Estimates: The methods described above will produce only a qualitative evaluation of the actual amount of twig biomass available or utilized. For a better understanding of ungulate carrying capacity and significance of various browse species, actual weight data should be collected.

A double sampling, weight estimate method by Wilms *et al.* (1944) based on techniques proposed by Pechanec and Peckford (1937), involves a system that quickly provides reasonably accurate data on weight of the yield of twigs of the current year. The key factor in applying this procedure is to train observers to guess consistently the weights of classes of forage. Telfer (1981) has found that such consistency is quite possible in estimation of green weight of leaf and twig biomass. By clipping browse on a proportion of the plots, the estimated green weights can be reduced to oven-dry basis. Clipped material can be separated by species in the field and stored in labelled bags for drying later.

Methods designed to estimate browse yield and utilization in terms of weight require a two-step procedure. Data must be gathered on weight of browse components and on other parameters of individual shrubs. The methods must provide data for calculation of weight per unit of land area.

Measurement of yield of the current year, standing stock and utilization of browse can be handled by clip and weigh techniques and allometric modifications of such methods. Clip and weigh techniques involve clipping all twigs and leaves that are available within a predetermined range of heights. Material can be stored in labelled paper bags for laboratory determination of oven-dry weight. Alternately, material may be weighed on location and results expressed in terms of green weight. A compromise method involves drying a sub-sample of twigs or leaves from each species to determine a green weight/dry weight ratio for use in reducing all green weights to an oven-dry basis (Telfer 1983). Harlow (1977) recommended the compromise approach and suggested that three samples of at least 100g green weight from each species would be a suitable sample for determination of green/dry weight ratios.

Clipping studies have usually involved current annual growth of twigs and leaves (Harlow 1977), but can be used to measure standing stock by clipping a sample of twigs at some predetermined diameter (Schafer 1963). The clip and weigh technique is time-consuming but has been defended by Harlow (1977) as simple and accurate.

Other methods that are less accurate but quicker are based on the principle that the weight of plant parts is related to simply measured dimensions like stem, branch or twig diameter, and to combinations of those variables (Tufts 1919; Rutherford 1979). Rutherford (1979) presented examples from the literature showing a wide variety of relationships established by regression analysis for twig weight, leaf weight, and total plant biomass with various stem measurements.

The most precise estimates of browse weight involves twig counts in combination with twig weight estimates based on separate studies of oven-dry weight related to twig diameters. Both standing stock and current annual growth of twigs may be defined by an average diameter. Shafer (1963) used the mean diameter of browsed twigs to calculate mean standing stock for each species. He obtained a mean twig weight by clipping a sample of twigs of exactly that diameter for drying. Use of this method is also feasible for determination of utilization.

Since production and utilization of browse has been found to vary from year to year, new regressions may have to be calculated each year to relate yield to twig variables (Telfer 1981). Definitions of standing stock usually depend on intensity of browsing, and therefore, the relationship between standing stock and stem variables may be expected to vary from place to place and from year to year with changes in browsing pressure.

2.7 Assessment of Range Condition

Traditionally, differences of opinion have arisen as to whether range condition should be measured giving emphasis to rangeland productivity (Humphrey 1949) or to vegetation change (Dyksterhuis 1949). As the concept of range condition entails many attributes the most functional approach to measurement of range condition will be one that incorporates methods from both frameworks. Areas of primary concern are vegetation composition, productivity, and land stability. Whatever the attribute in question is, or whether the management option is to enhance the range for wildlife or domestic stock, the range condition must be measured in terms of vegetation.

Each vegetation measure will place different emphasis on the various forms of plants in the community (Wilson and Tupper, 1982). Biomass gives primary emphasis to large species and provides valuable information on the potential food base for wildlife and domestic livestock (Walmsley *et al.* 1980). Canopy cover is correlated with biomass but tends to give more emphasis to prostrate species (Wilson and Tupper 1982). Basal cover is a related measure used on perrenial-grass communities (Brown and Chambers 1983).

When natural communities are under consideration, an assessment of vegetation composition and ground coverage should be included in the analysis. If sample sites are to be used for future analysis of range trend then analysis of forage class composition is certainly required. By correlating cover/forage class composition and biomass of the grazing resource, and relative abundance, standing stock and utilization of shrub species, a relatively accurate assessment of present range condition and change over time can be achieved.

As forage production in the forest zone declines with increasing canopy cover (Dodd *et al.* 1972), measurements of forage resources can be correlated with tree-crown cover estimates from air photos. Assessments in different categories of canopy cover can then be compared to historical air photos to estimate the forage resource at different years within specific ecosections.

Chapter III
METHODOLOGY

3.1 OVERVIEW

Vegetation change through the recent history of the park was derived from air photographs with historic photos and documents to aid in subjective comparisons. All data on the present range condition was evaluated from range transects with randomly established sample points. Each sample point located a vegetation quadrat, clip plot, and random point. The quadrats and clip plots yielded quantitative measures reflecting the present condition of the grazing resource of the elk winter range in the Kootenay Valley of Kootenay National Park. The random points were used for point-centered quarter analysis of the browse resource, and information on canopy species density. These transects were permanently located to provide a replicative measurement system for future monitoring of range trend. The methods used for data collection and analysis were widely recognized, statistically valid, and designed to minimize subjectivity.

3.2 STUDY AREA

The study area is known as the Kootenay River Valley, in KNP. The elk winter range is primarily restricted to this valley bottom. The air photo analysis was restricted to the montane ecoregion displayed in figure 3, and the range analysis was restricted to a smaller portion of the montane ecoregion which was recognized as critical habitat. The Ecological Land Classification (ELC), (Poll *et al.* 1984), noted this area as containing critical winter range for elk and moose and summer range for white-tailed deer, and indicated the importance of fluvial and morainal landforms in this valley. Since the optimal winter diet for elk consists of a mixture of shrubs and grasses (Poll *et al.* 1984) the range analysis was confined to the valley bottom which is most likely to support these lifeforms.

All range transects were established below 1212m (4000 ft), inclusive, between Nixon Creek/Pitts Creek trails and the East Kootenay Fire road south of Kootenay Crossing. This restriction included all montane (FR, AT, VL, HD) fluvial ecosections noted highly important to elk, and also included some glacial (DR) ecosections. Figure 4 illustrates the relationships among ecosites in the Kootenay Valley; most winters the elk remain confined to the fluvial ecosections.

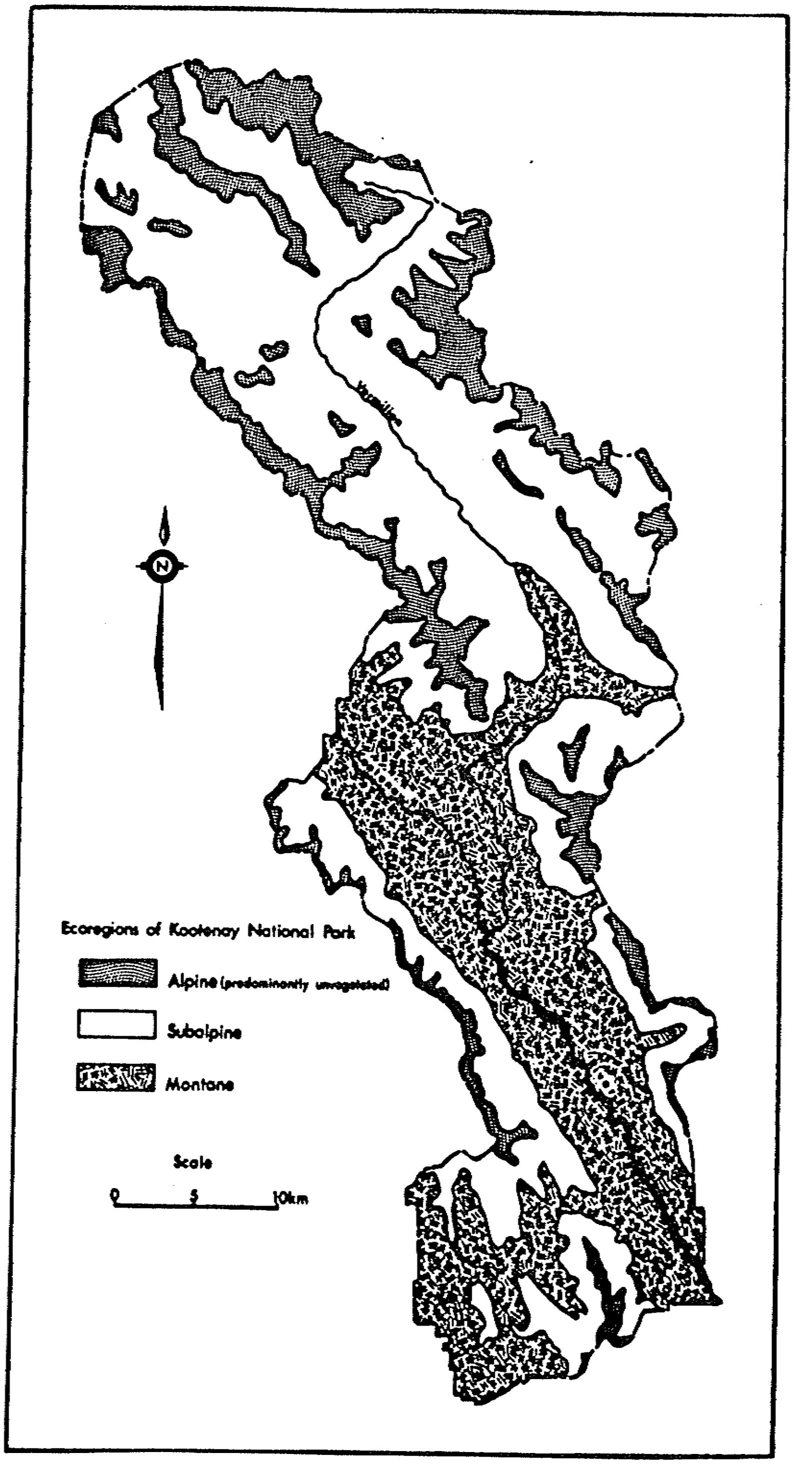


Figure 3. Ecoregions of Kootenay National Park, British Columbia (from Achuff *et al.* 1984).

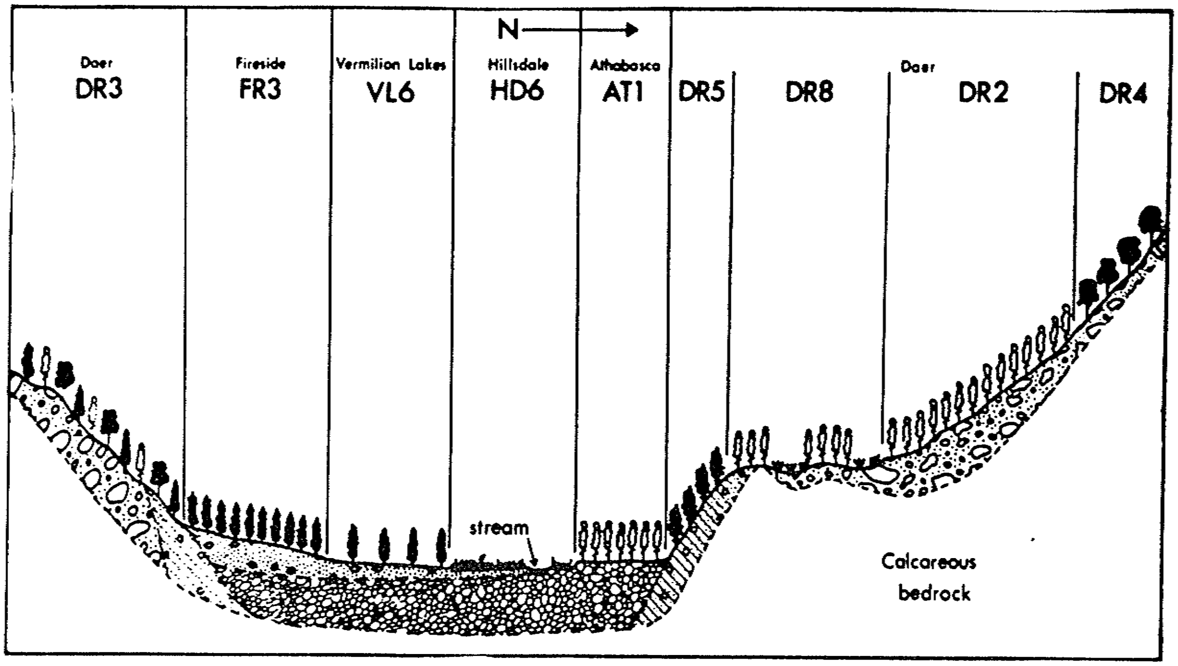


Figure 4. Landscape schematic of topographic relationships among ecosections in the Kootenay Valley (from Achuff *et al.* 1984).

3.3 DATA COLLECTION AND ANALYSIS

3.3.1 Forest Succession

Air Photos exist for KNP with dates ranging from 1924 to 1982 and scales from 1:5,000 to 1:66,000 (Map and Air Photo Reference Library - Edmonton; National Air Photo Library - Ottawa; Northern Forest Research Centre, Edmonton). Air-photo interpretation was undertaken to determine different categories of crown forest class in the montane region of the Kootenay Valley. Estimation of crown cover density was undertaken using an overlay dot grid.

Forest types were mapped onto air photos in the montane ecoregion of the Kootenay Valley and were then transferred and mapped onto a 1:50,000 scale map using a Bausch and Lomb, Stereo Zoom Transfer Scope.

By converting all photo scales to the 1:50,000 map scale and mapping the vegetation type for the latest suitable photo record, 1978, and for the earliest, 1945, a quantitative indication of tree and shrub encroachment onto open areas was provided for this time span. Mapping of the 1966 set of air photos was undertaken to refine the rates of forest succession between 1945 and 1978.

The aerial-photo comparison was supplemented with less objective historical information gleaned from review of journals and archival material, and observation and comparison with historic photographs.

The measurement of different forest canopy areas in each photo record was accomplished by the use of an electronic digitizing system. Digitizing is the process of assigning coordinate X-Y values either to points and drawing a line between them or to a symbol such as a circle representing a pole. A microcomputer assigns binary values to a map, line by line and symbol by symbol, and stores them in digital form (Ambrosia and Whiteford 1983).

3.3.2 Assessment of the Highway Corridor

As the highway corridor has forage resources on its periphery, the timing and extent of clearing associated with the roadside right-of-way was reviewed using historic material.

3.3.3 Assessment of Present Range Condition

Range Transects

The locations of range transects were chosen according to the amount of crown-canopy cover. Dodd *et al.* (1972) have concluded that air photo analysis is very useful in initiating range surveys of forage production in coniferous forests, and suggested that crown cover classes be divided into four categories: 0-20%, 21-35%, 36-55%, and greater than 55%.

As the above categories are very specific and difficult to identify on older and small-scale photo sets, forest crown cover was divided into the following classes for each set of air photos analyzed: greater than 40%, 10-40%, and less than 10%; within the first two canopy classes the vegetation was broken down into the following types: *Pinus contorta* (Lodgepole pine) forest, *Picea glauca* (white spruce)/*Pseudotsuga menziesii* (Douglas fir) forest, mixed forest (deciduous and coniferous), and within the last canopy class vegetation was divided into meadows, and wet meadows. Ground checks were conducted at each range transect to ensure proper interpretation of air photos. The vegetation canopy types chosen reflected the prime objective of quantifying forest encroachment onto open areas.

Each range transect was located within a homogeneous vegetation association representative of that forest class; and avoided transition zones. Vegetation quadrats and random points were located with the stratified random method (Knight 1978). A 200 m baseline was located through the middle of the sample unit. Points along this baseline were spaced 20 m apart. Using the first two digits on a random numbers table, a paired quadrat/random point was located that many metres perpendicular to the baseline. If the random number was even the sample point was on the right; if it was odd, it was on the left-hand side of the baseline (this was determined by the baseline facing predominantly north or west). The furthest peg from the baseline was considered the random point and was numbered. The second peg was aligned on the perpendicular axis from the baseline, these two pegs correspond to two holes in the sampling frame. Sampling size was primarily limited by time constraints, however, at least two transects were placed within each major vegetation type.

Sample Site Features

Each site featured a vegetation composition and coverage quadrat, an adjacent clip plot, and a random point marker. Two marker pegs were for each site. The furthest marker peg from the baseline was used as a random point for the point-centered quarter analysis of shrub composition.

The quadrat aligns two holes in the frame over the marker pins for placement for re-analysis. The species-composition analysis takes place on the right side of the pegs, the frame is then reversed for the clip-plot analysis, which will take place on the left side of the pegs. In order to provide for relocating, each transect was mapped on a photostat of an aerial photograph. The sites were marked with two 1 m pegs (the placement of the pegs corresponds to two holes in the quadrat frame), at vegetation height above ground, which were engraved with an identification number. The following information was recorded for each site: site identification number, location and vegetation type, and date established.

Sampling Quadrat/Frame

The sampling grid measured 75x100cm inside, and was constructed of lightweight steel. This grid employed levels and adjustable legs to ensure horizontal placement at the vegetation level. The grid was fitted with a removable pin frame which guided the placement of pins to ensure a vertical angle at every 200 millimetres for the length of the quadrat, five pins across the width of the quadrat, each pin being placed at 150mm. The grid featured a 10mm hole in two adjacent corners on one edge for accurate grid placement in the field (see plate 5).

Quadrat Analysis

All vegetation analysis was undertaken after August 30th, 1988 to allow for all plant species to reach the reproductive stage of their life cycle. Although the biomass of forbs had begun to decline by this time, this caused little concern as the study was primarily concerned with forage resources available for the winter season. All vegetation was identified with reference to field manuals (Pohl 1954; Cunningham 1958; Kuijt 1982; Scotter and Flygare 1986), and all data was recorded on forms prepared for the purpose and then input to a computer for analysis.

Vegetation analysis quadrats were established for collection and comparison of these data from the different forest-canopy zones that were determined from the air photo analysis. Sampling from these quadrats was taken by point quadrat analysis of species composition and coverage, and clipping of vegetation. Vegetation research in the field has usually required the use of quadrats $0.5m^2$ to $1.0m^2$ for the type of vegetation that was expected to be encountered in the herbage assay (Cole 1978; Barbour et al 1980; Brown and Chambers 1983, Cole 1983). By reason of these data the $0.75m^2$ quadrat is expected to produce accurate results for this study. The number of quadrats used in each site was determined largely by the amount of time available to the investigator.

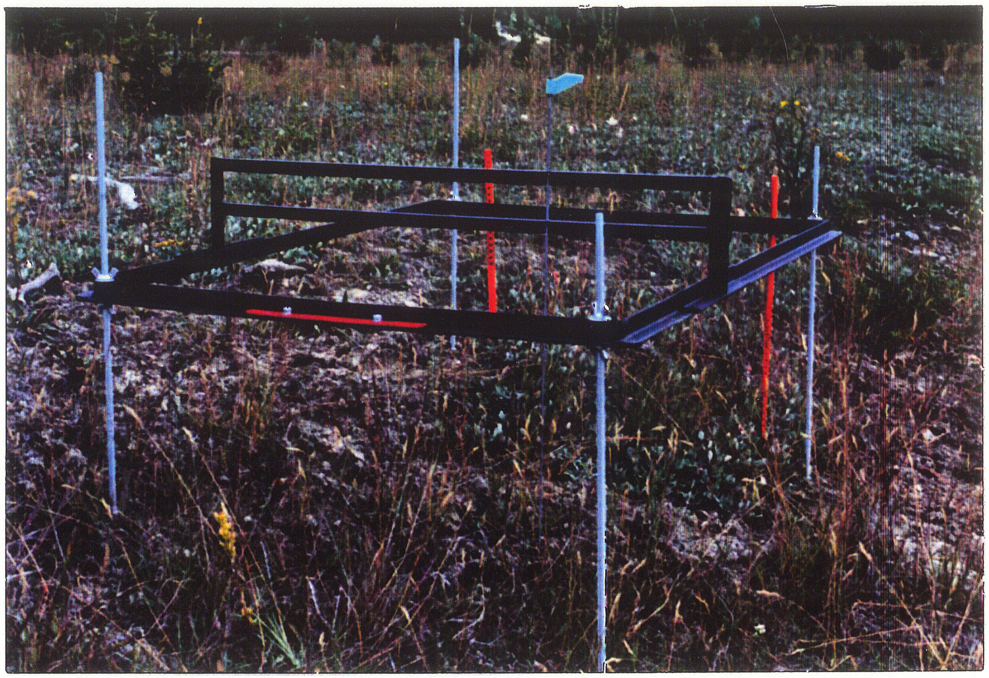


Plate 5: Quadrat and pin-drop frame positioned in a meadow area near the Kootenay River.

The point-quadrat method (Brown and Chambers 1983) can be used to determine aerial and/or basal cover and the species composition within a plant community. Five pins were lowered at five intervals within each quadrat for a total of 25 strikes per quadrat. The individual sharpened pins were lowered down through the vegetation canopy and the first vegetation contact or first contact with bare ground, gravel, rock, or litter was recorded (note that woody material exceeding 25cm in height is not recorded in this stage of analysis). Percent aerial cover for each species equals the sum of all first hits on vegetation divided by the sum of all first hits on vegetation plus first hits on bare ground, gravel, rock, and litter.

All species data were converted to forage classes for analysis. The level of species variability in nature is such that it would be impossible to arrive at a statistically valid sample of complex vegetation types without conversion to forage classes unless undertaking a much larger sampling effort. As the same design was applied to all sampling the same analysis was applied throughout.

Forest canopy type differences in understory vegetation were assessed by comparing the percent coverage by species and forage class, the proportion of bare ground and litter, and the available biomass per forage class (i.e., forbs, graminoids, woody vegetation). The coverage of palatable and non-palatable species, as determined from Poll *et al.* (1984) was then compared.

Productivity of the grazing resource, in terms of available biomass at the time of sampling, was measured by the harvest method. The available above-ground vegetation was harvested from the three dimensional volume of the quadrat (Brown and Chambers 1983). The vegetation within every second 0.75m^2 quadrat was clipped to ground level using hand shears or clippers. Parts of plants that were rooted within the quadrat, but did not occupy space within the volume were not harvested, while parts of plants that were not rooted within the quadrat but overlapped into the volume, were harvested. Vegetation was separated by forage class, air-dryed to a constant weight, and then weighed. Dry weights were recorded by forage class for each quadrat. Total biomass per hectare and percent composition per forage class were then calculated using the following formulae.

$$\text{Biomass} = \frac{\text{Total of dry weight values}}{\text{Total No. of quadrats sampled}} \times (\text{Quadrats/Area conversion})$$

$$\text{Percent Composition} = \frac{\text{Biomass for forage class}}{\text{Total Biomass for all classes}} \times 100$$

Browse Analysis

A minimum height of 25cm was used to determine browse; this was arrived at by determining the mean snow-depth value for Kootenay Crossing weather station for the past eight years in the months of December, January, and February. As the height at which a plant may be browsed is somewhat less than the mean snow depth (due to cratering, etc.), the standard deviation was subtracted from the mean to arrive at the figure used. Woody species less than 25cm in height were recorded in the quadrat analysis of the grazing resource.

Browse composition and utilization was determined at each sample point using the point-centered quarter method (Barbour *et al.* 1980). Quarters were set between true north and east, east and south, south and west, and west and north. The closest clump of browse greater than 25cm high (a clump may be one living stem or several) in each quarter was analysed and the distance from the random point was measured. The species was noted and the number of stems in the clump were counted. Twig counts on the closest stem were taken in the forage availability zone for elk, which was defined as 0.25 m to approximately 2.3 m (Nelson 1982) from the ground, and were multiplied by the number of stems in the clump. The density of stems and twigs (browsed and unbrowsed) per hectare was then calculated for each species, using the density equations below.

$$\text{density/hectare (D)} = \frac{10{,}000}{(\text{mean distance (m) of all shrubs})^2}$$

$$\text{species density/hectare} = \frac{(\text{distance (m) of species})}{(\text{distance (m) of all shrubs})} \times D$$

Twig counts noted the total numbers of twigs (unbrowsed and browsed of last winter) and then noted the number of twigs browsed in the last winter. The percentage of twigs browsed in the last winter provided an indication of the present level of use per each shrub species and the total number of twigs provided a measure of the standing stock which was available for the last winter.

Twig counts were then converted to weight measurements to provide estimates of standing stock and utilization of browse per hectare. An average diameter-at-point-of-browsing (DPB) was defined for each species (after Shafer 1963), and twigs of each species were clipped and weighed, distal to the defined diameter. Measurement of the DPB of each species was taken on 100 twigs of each species in each area, the mean calculated and the standard deviation added to the mean, as utilization has the possibility of being greater than the mean (Telfer 1981).

These twigs were then dried in the same fashion as the forage resource and weighed. The mean weight per species was then multiplied by the number of browsed twigs per species to arrive at a weight estimate per hectare for utilization, and multiplied by the total number of twigs to arrive at a weight estimate per hectare for standing stock or available browse.

3.3.4 Assessment of Historical Range Condition

The values determined for forage resources from the present assessment were then applied to the earlier air photos as they were mapped, and a graphical indication of the estimate of change in forage resources was attained. This estimate was undertaken by forage class (forbs, graminoids, shrubs) per canopy type only, because it was impossible to know what the species composition was at the time of the photo. Data of this nature must be interpreted with caution because no information was available on the herbaceous resources of the time. Early successional meadows were likely of a much different botanical composition than the fluvial meadows in the valley today.

3.3.5 Data Analysis

As outlined in the above sections, the data from each variable, for each sample site, was combined for each area to arrive at the data summaries for each forest canopy type. All variables of each analysis were subjected to standard statistical tests by using means, standard deviations, t-tests and associated probabilities where applicable.

Data from each vegetation quadrat was combined for each forest type to derive the mean percentage cover per forage type, and biomass per forage class/per hectare for each forest canopy type. Data from each random point was likewise combined to determine the browse resource, percent by species and weight factors of standing stock and utilization per species for each forest type. Student's t-tests were applied to determine the significance of differences between the forest categories, as well as to determine the level of variability within categories.

Chapter IV
RESULTS AND DISCUSSION

4.1 FOREST SUCCESSION

As discussed previously, discreet forest canopy types were identified and mapped for the study area. Each forest type represented homogenous upperstory vegetation within its boundaries. The understory vegetation in each canopy type, within an area identified as critical habitat in the KNP Ecological Land Classification (Poll *et al.* 1984), was analysed for species composition and production.

The range analysis was divided to survey two forage resource types, grazing and browsing. These forage types were defined by their availability to ungulates and their vegetative composition. The grazing resource, defined as all herbaceous material, and also that woody material less than 25 cm in height, was assessed by quadrat and clip plot. The browsing resource, defined as that woody material greater than 25 cm in height but less than 7 cm in diameter at breast height (DBH), was assessed by the point-centered quarter method in conjunction with a clip and weigh technique.

Two series of 1:50,000 scale maps, 1945 and 1978 photo series, were developed for the study area (map pockets in

Appendix VI). Both delineate discrete vegetation polygons for the entire study area, with each polygon containing an identity number and type code. These polygons can be referenced in the polygon file in Appendices IV and V and the size of the polygons can be accessed from that data.

Measurement of each polygon was undertaken and information was gathered regarding the amount and type of forest in 1945, 1966, and 1978. Change in canopy composition and extent, during the period extending from 1945 to 1978, was then calculated. Information gathered from the measurements of the forest types was then combined with range analysis data to arrive at weight estimates per hectare of the forage resource. Estimates of range conditions in both 1978 and 1945 were thus estimated and compared.

Three forest canopy types and two meadow types were recognized for the study area. This represented a simplification of the Ecological Land Classification (Achuff *et al.* 1984). The canopy types were chosen to provide a workable classification system for air photo interpretation at a variety of photo years and scales.

4.1.1 Forest Canopy Cover Types

Lodgepole Pine Forest (P).

This tree stratum was dominated by *Pinus contorta* (lodgepole pine) with scattered occurrence of *Populus* *tremuloides* (aspen) and *Picea glauca* (white spruce), and regenerating *P. glauca* in the understory (plate 6). The browsing resource was dominated by *Shepherdia canadensis* (buffalo-berry) and *Juniperus communis* (common juniper) The grazing resource was primarily composed of *Cornus canadensis* (bunchberry), *Linnaea borealis* (twinflower), *Calamagrostis rubescens* (pine grass), and some *Spirea lucida* (meadowsweet), as well as *Arcostaphylos uva-ursi* (common bearberry), and *Maianthemum canadense* (wild lily of the valley). Non-vascular plants were interspersed among the herbaceous layer with a dense cover of *Pleurozium scheberi* (feathermoss) underlying most of the herb stratum. There was a sparse amount of litter.

Spruce/Fir Forest (S/F).

This forest type was characterized by semi-open to dense stands of mature *P. glauca* with localized occurrences of *Pseudotsuga menziesii* (Douglas fir), with scattered occurrences of *P. tremuloides* (plates 7 and 8). The browse resource was sparse and composed of *P. tremuloides*, *J. communis*, and immature *P. glauca*, the latter usually in poor condition. The grazing layer was variable, and in those sites sampled, very sparse. *Linnaea borealis* occurred regularly with scattered occurrences of *Fragaria virginiana* (wild strawberry), *C. canadensis*, and *C. rubescens*. Other species such as *Trientalis borealis* (starflower), *Rubus pubescens* (dewberry), and *Pyrola spp.* were also present. A dense cover of *P. scheberi* was present under much of the herb stratum. The litter layer was mostly composed of deadfall and branches. Open *Picea/Abies* forest in the study area was predominantly the result of salvage logging which occurred in the MacLeod Meadows area between 1941 and 1945. This logging was undertaken to remove trees killed by pine beetle.

Mixed Forest (MW).

Mixed forests occur on drier, well drained southerly aspects of the study area (no photo). This forest type was dominated in the tree stratum by *P. tremuloides* and *P. glauca*, with *P. menziesii* also occurring. *Shepherdia canadensis*, young *P. tremuloides*, *J. communis*, and *Rosa acicularis* (prickly rose) dominated the browse resource along with some regenerating *P. glauca*. *Elymnus innovatus* (Hairy wild-rye), *F. virgiana*, *L. borealis*, and other forbs such as *Aster conspicuus* (showy aster) were common in the herb stratum. In conjunction with the herbs and low shrubs, plant litter provided a dense ground cover.

Meadow (M).

Meadows were lacking a tree component and occurred on dryer, rapidly drained areas (plate 9). This vegetation type is an early successional stage, dominated by herbaceous vegetation and graminoids. The browse layer was dominated by *Potentilla fruticosa* (shrubby cinquefoil) and *Eleagnus commutata* (wolfwillow), *S. canadensis* and young *P. glauca* also occur. Dominant species in the herb layer included *Dryas drummondii* (yellow mountain avens), *Danthonia spicata* (poverty oatgrass), *Poa spp.* (bluegrass), and *F. virginiana*. *Oryzopsis asperifolia* (rice grass), *E. innovatus*, *Aster spp.*(aster), *Hedysarum sulphurescens* (yellow hedysarum), and some *Solidago spp.* (goldenrods) also occurred with some regularity.

Wet Meadow (WM).

Lacking a tree component, this vegetation type was characterized by open mature *Salix spp.* (willows) interspersed with wet sedge meadows (Plate 10). The browse resource was composed of the willows which vary in size and

Plate 6: Closed pine forest type, note browse layer of buffalo-berry and occurrence of juniper.

Plate 7: Closed spruce forest type, note predominance of non-vascular vegetation.

Plate 8: Open spruce forest, note successional growth of spruce trees at edge of forested clump.

Plate 9: Meadow area on an old floodplain of the Kootenay River, note the succession of small spruce trees.

Plate 10: Wet meadow near Daer Pond, note the thick growth of willows and bog birch in the sedge layer.

species. The larger willows provided a significant browse resource. *Carex spp.* (sedges) meadows supported stands of smaller *Salix* and *Betula glandulosa* (bog birch) which, often because of hedging, were no higher than the *Carex spp.* themselves. The herb layer was dominated by *Carex* tussocks 30-50 cm in height. Litter cover was moderate and usually overshadowed by live growth.

4.1.2 Forest Succession in the Study Area

The montane region of the Kootenay Valley within KNP occupies approximately 31 000 hectares. Three forest canopy types and two meadow types are present within this region.

The forest canopy types and meadow areas, recognized as being closed or open components and, in the latter case, wet or dry, were divided as such for the mapping and analysis. The following figure illustrates the areal extent of change in these forest types during the period from 1945 to 1978.

Lodgepole Pine

The extent of canopy change was greatest in the *P.contorta* forests and the meadow areas. Closed *Pinus* forest in 1945 accounted for 3799 ha. Total succession over the 33 year period resulted in an increase of 11990 ha, an increase

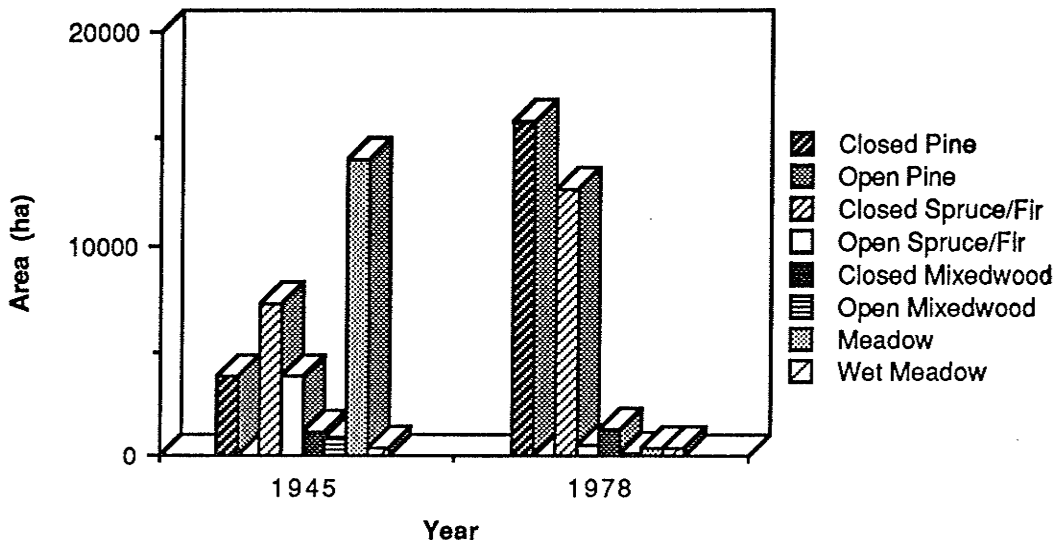


Figure 5. Extent of change in forest canopy types.

of 316% of the original area covered with *Pinus* forest. Closed *Pinus* forest today (1978 values) occupies 15789 ha or 51% of the montane ecoregion. Open *Pinus* forest exhibited little change during this time period, decreasing only slightly from 22 to 20 ha, 0.06% of the study area.

Spruce/Fir Forest

Closed *Picea/Abies* forest increased markedly from 7202 ha in 1945 to 12624 ha in 1978. This represented an increase of 75% of the original total from 1945. Open *Picea/Abies* decreased by a greater percentage from 3855 ha to 504 ha, an 87% decrease during this time span. Closed *Picea* forest and open *Picea* forest presently account for 40% and 1.6% of the study area, respectively.

Mixedwood

Mixedwood areas exhibited different levels of change depending on whether or not the area was closed forest or open forest. Closed mixedwood underwent only 13% change in area, from 1161 ha to 1311 ha. Open mixedwood, however, decreased from 861 ha in 1945 to 177 ha in 1978, an 80% change in area. Mixedwood forest recently (1978) accounted for 4% and 0.6% of the study area in the closed and open categories, respectively.

Meadow Areas

Meadows decreased by 13539 ha from 13973 ha in 1945 to only 434 ha in 1978, a reduction of 96.9% of the original area covered by meadows. Meadow areas in the valley today account for only 1.4% of the valley area. Wet meadows underwent comparatively insignificant change from 433 ha to 363 ha during this time span, a reduction of 16% of the original area. Wet meadows account today for only 1.2% of the montane ecoregion.

Predominant vegetation change in the study area has been forest encroaching onto open areas (Figure 6). In 1945 the study area was primarily composed of meadow type vegetation, accounting for 44.6% of the study area (13973 ha). Today (1978 survey) the predominant vegetation regime was that of closed forest which accounted for 94.9% or 29724 ha of the valley area, and meadow cover types accounted for only 1.4% of the total montane ecoregion. Also attributing to the increase in closed forest is the change in open forest from 15.1% (4738 ha) to 2.2% (700 ha) of the study area. Comparitively minor changes occurred only in the wet meadow category, decreasing from 1.4% (433 ha) to 1.2% (363 ha).

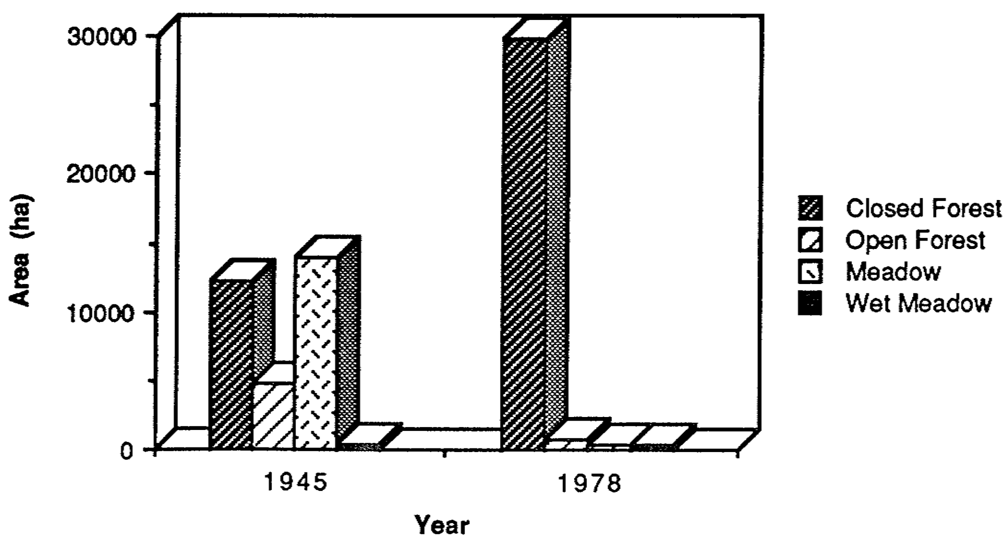


Figure 6. Extent of forest succession by cover type.

4.2 PRESENT RANGE CONDITION

4.2.1 <u>Grazing Resource</u>

Species Composition

Data collected from the grazing resource included vegetation coverage and production biomass. Species composition information was converted to forage classes for statistical analysis. Figure 7 illustrates the relative percentage of forage class cover, non-vascular vegetation and litter/bare ground in each forest and meadow category.

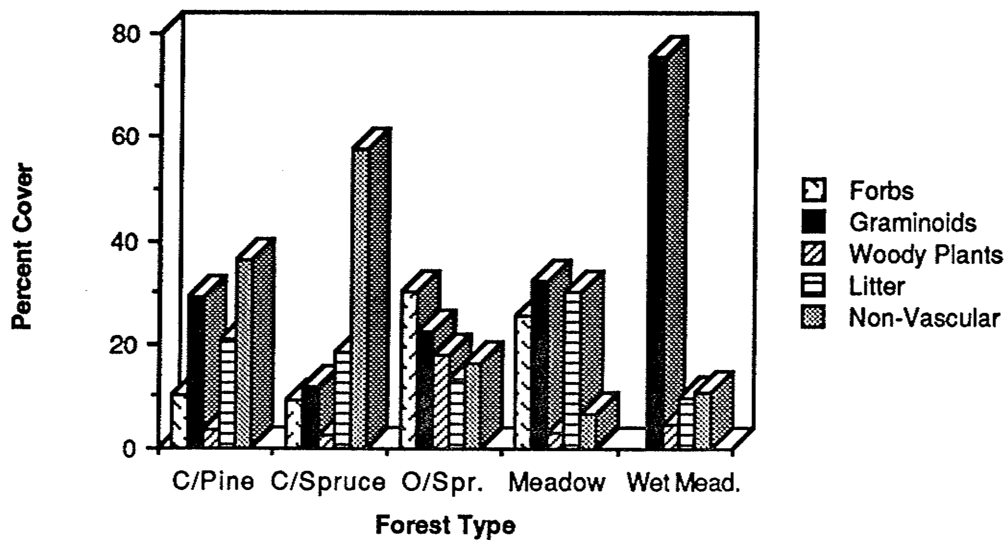


Figure 7. Relative percent coverage by forage class of the grazing resource.

As illustrated in figure 7 the closed pine and closed spruce categories were dominated by non-vascular plants, graminiods, and litter. Closed *Pinus* forest exhibited a 36% cover of non-vascular material, 30% graminoids and 21% litter. The non-vascular layer in the closed spruce forest is, however, much greater (58%) and the litter layer is higher than the graminoid layer, 18% and 12%, respectively. Forbs and woody plants accounted for almost identical cover values, 10% and 4%, and 9% and 3% for pine and spruce, respectively.

Cover values in the open spruce forest were relatively even. Cover values of 30%, 22%, and 18% accounted for forbs, graminoids, and woody plants, respectively. Non-vascular plants covered 16% and litter accounted for 13% of the surface layer.

Meadow areas are dominated in cover by graminoids. The graminoid cover in the wet meadow areas, accounted for 76% of the coverage. The other categories all occupied less than 10% cover each. In dry meadows, graminoids accounted for 32% of the ground cover while litter followed with 30%, mostly dead graminoids. Forbs accounted for 27% of the cover in the meadows. Non-vascular and woody plants accounted for 7% and 3%, respectively.

Biomass

Production measurements were taken by the harvest method. Weight measurements of each forage category were taken from the dried samples. Table 4 provides the raw values of the forage resource collected from the field.

Raw data values were then calculated to a standard measure of kilograms/ha by the equations in section 3.3.3. Figure 8 illustrates the relationship of production levels in the various forest categories. As illustrated, the greatest

Table 4. Biomass (grams/0.75 m2) sample values of the grazing resource in each forest canopy cover type.

	Forbs	Graminoids	Woody Plants
Closed Pine			
Mean	14.9	16.3	14.1
S. Dev	12.5	13.8	22.3
Closed Spruce			
Mean	8.4	10.5	0.0
S. Dev	7.0	11.7	0.0
Open Spruce			
Mean	19.5	28.0	22.8
S. Dev	16.1	20.8	18.9
Meadow			
Mean	50.4	47.7	19.5
S. Dev	26.2	24.6	29.4
Wet Meadow			
Mean	50.9	100.4	23.9
S. Dev	27.9	30.2	15.9

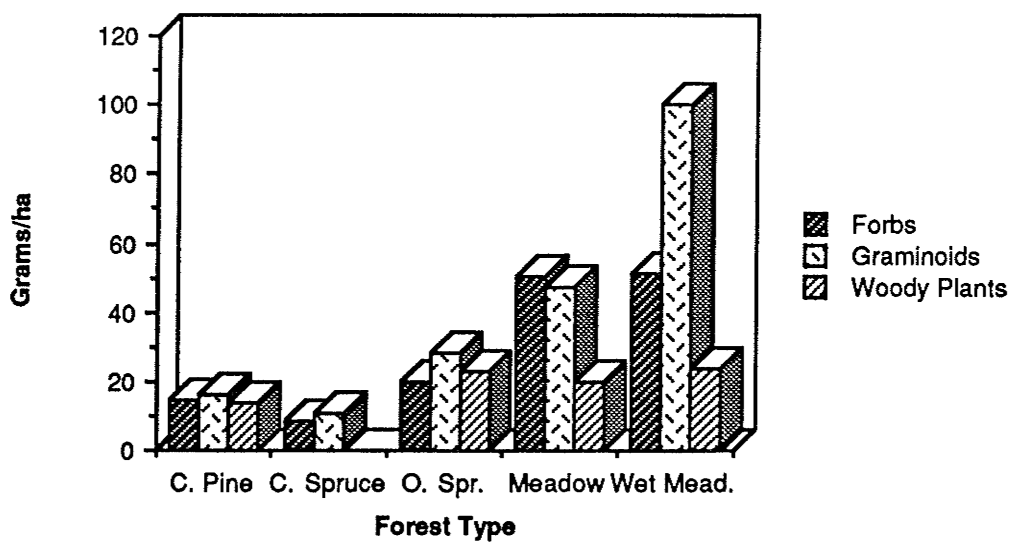


Figure 8. Production biomass of the grazing resource in each of the forest categories.

levels of production occurred in the open areas, whereas the forested areas had the lowest levels of biomass production.

Closed spruce forest accounted for 112 kg/ha of forbs and 139 kg/ha of graminoids, no woody material was collected in biomass plots in the closed spruce forest. Closed pine forest accounted for 199, 217, and 188 kg/ha of forbs, graminoids, and woody plants, respectively.

Forage values in the open spruce forest were somewhat higher than in closed forest. Weights measured at 260 kg/ha for forbs and 373 and 304 kg/ha for graminoids and woody plants, respectively.

Production of forbs and graminoids was much higher in the meadow areas. Little difference, however, was noted in production of woody material. Graminoid production (1339 kg/ha) was much higher in wet meadows than any other forest category. Graminoid production in dry meadows was only 636 kg/ha, less than half that of the wet meadow values. Respectively, these values were roughly four times and two times the amount found in other forest categories. Forb production measured 636 kg/ha and 672 kg/ha for wet meadows and meadows, whereas woody material produced only 260 kg/ha and 319 kg/ha for the same categories.

Grazing resource values for the montane ecoregion were estimated by mulitplying the area of the present range categories by their respective biomass/hectare figures achieved from the forest canopy analysis (see maps in Appendix VI). The following figure illustrates the total amounts of available forage biomass available in the montane ecoregion. Values are 5 611 938 kgs, 6 761 788 kgs,and 3 809 285 kgs, for forbs, graminoids, and woody material, respectively.

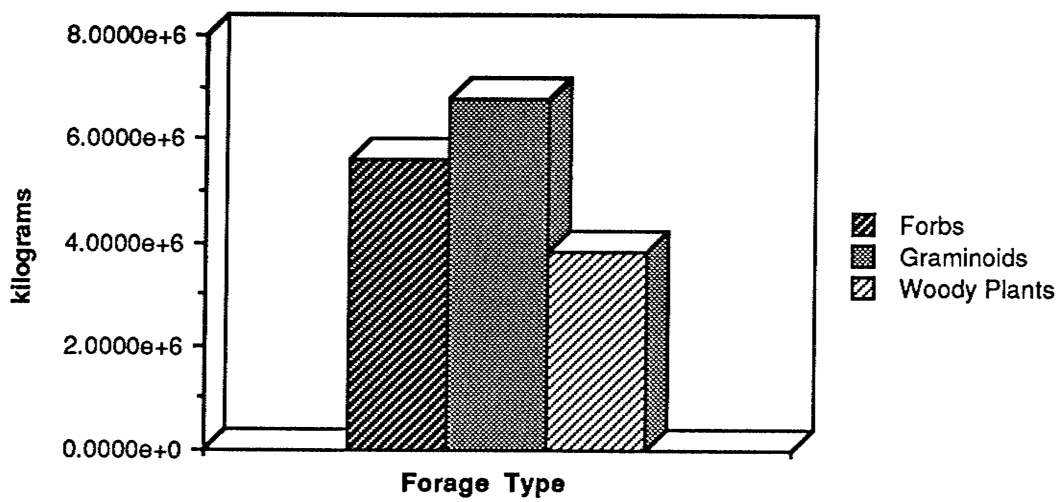


Figure 9. Total biomass of the grazing resource in the montane ecoregion.

Certain forest types which did not occur within the critical wildlife area of the range inventory were not sampled. An assumption was made that production of forage types in the open pine, and mixedwood categories was the same as the production in the open spruce forest type. This assumption was based on similar cover types noted in the biophysical inventory (Achuff *et al.* 1984).

4.2.2 Browse Resource

Species Composition

The browse resource was assessed using the point-centered quarter method. Data was collected on the standing stock and utilization of browsed species, as well as characteristics of those species within the individual communities.

A total of nineteen shrub species were accounted for by the point-centered quarter method. The individual species and relative percentages of these species, which made up the browse resource, varied widely between forest categories. The following discussion summarizes the attributes of the shrub layer in each community type (field data on file at N.R.I and Canadian Parks Service W.R.O.).

In order of stem density, the closed pine forest category was composed of *Shepherdia canadensis*, *Pinus contorta*, *Juniperus communis*, *Populus balsamifera*, *Salix spp.*, and immature *Picea glauca*.

As evidenced by figure 10, this forest category was dominated by *S. canadensis*, accounting for 57% of the stem density, *P. contorta* accounted for 15%, and *J. communis* and *P. balsamifera* densities were 10% of the community each. *Salix spp.* and *P. glauca.* were a minor component at 6% and 1%, respectively. Mean heights of the browse resource (available in Appendix II) ranged from 2.02 m for *P. glauca* to 0.31 m for *P. balsamifera*.

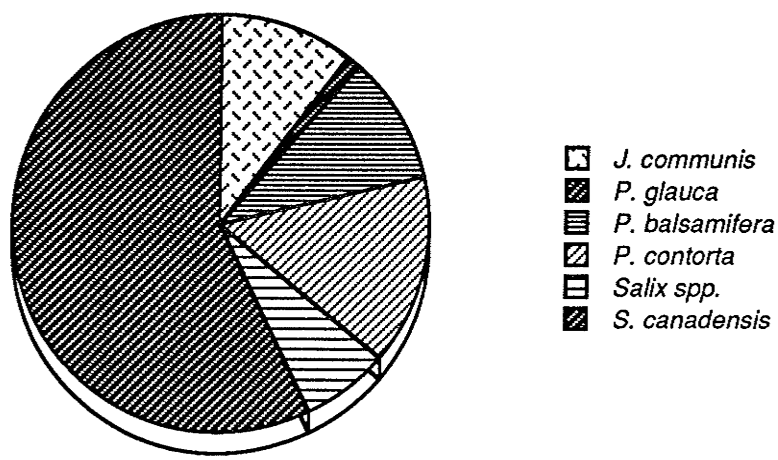


Figure 10. Relative percent stem density of each species contributing to the browse resource in the closed *Pinus* forest category.

Closed spruce forests were composed predominantly of *S. canadensis*, *P. glauca*, and *J. communis*, 49%, 34% and 10%, respectively (Figure 11).

Other species, including *Betula glandulosa, P. tremuloides, Potentilla fruticosa (shrubby cinquefoil), Amelanchier alnifolia* (saskatoon) and *Rosa spp.*, collectively accounted for less than 8% of the shrub stem density in closed *Picea*. Mean shrub heights in this forest category ranged from 0.81 m for *P. tremuloides* to 0.44 m for *Rosa spp.*

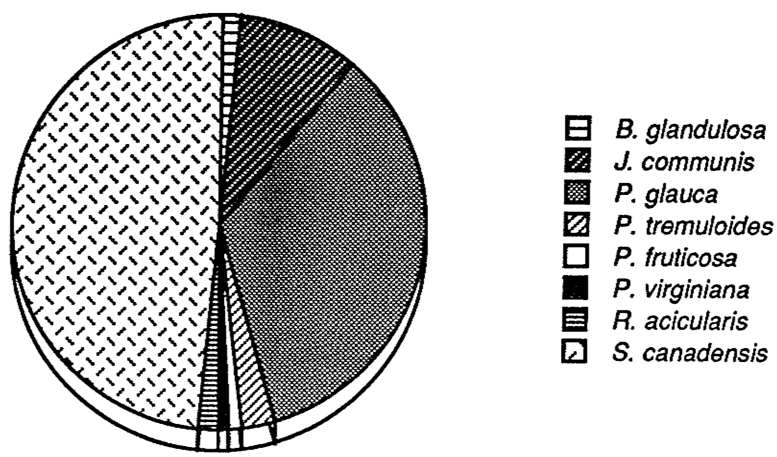


Figure 11. Relative percent stem density of each species contributing to the browse resource in the closed *Picea* forest category.

Open spruce forests and meadow areas were the most diverse of vegetation categories sampled. Ten shrub species were recorded in the open spruce category (Figure 12). This forest was dominated by *S. canadensis* and *J. communis*, which accounted for 47% and 29% of the relative stem density, respectively. Other species of significant density included *Ledum groenlandicum* (Labador tea) and young *Picea*, accounting for 7% each. Other species (*Amelanchier alnifolia, Acer glabrum, Lonicera utahensis, Menziesia glabella, Populus balsamifera and Rosa woodsii*) accounted for less than 10% of the browse resource. Mean heights ranged from 1.45 m (*P. glauca*) to 0.32 m (*R. acicularis*).

Ten species of shrubs were also recorded in meadow areas. Stem density (Figure 13) in meadow areas was dominated by *P. fruticosa* (44%), immature *P. glauca* (18%),

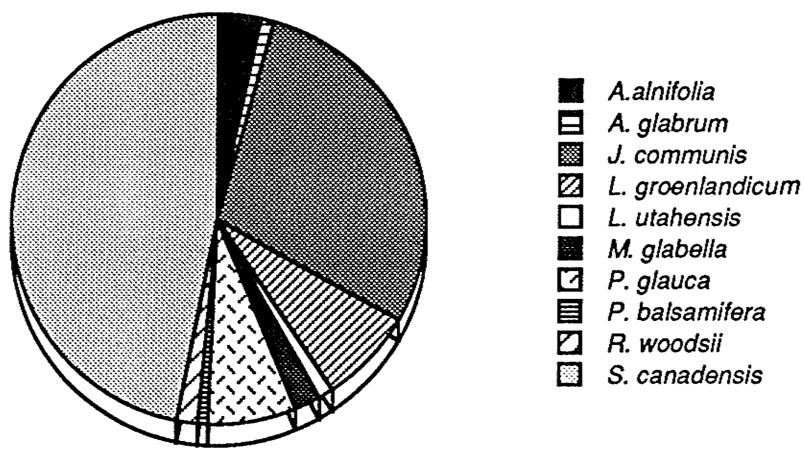


Figure 12. Relative percent stem density of each species contributing to the browse resource in the open *Picea* forest category.

and *E. commutata* (11%). Other species such as *P. balsamifera, R. acicularis, Salix spp.*, and *S. canadensis* ranged between values of 8% and 5%. *Betula glandulosa* and *A. alnifolia* were also recorded with stem densities of less than

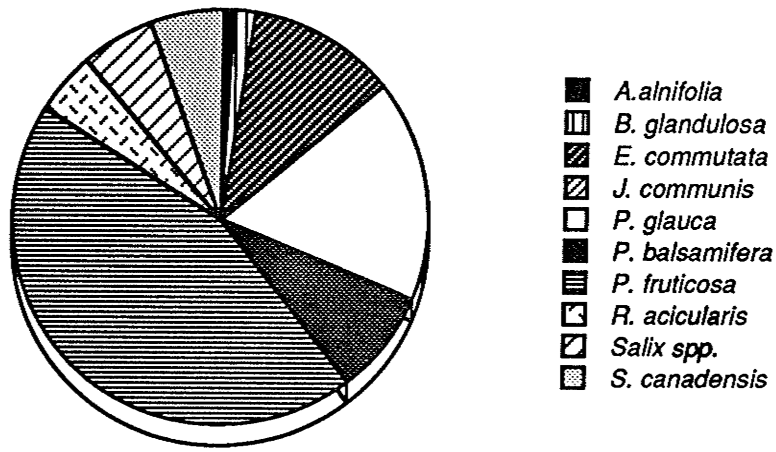


Figure 13. Relative percent stem density of each species contributing to the browse resource in the meadow category.

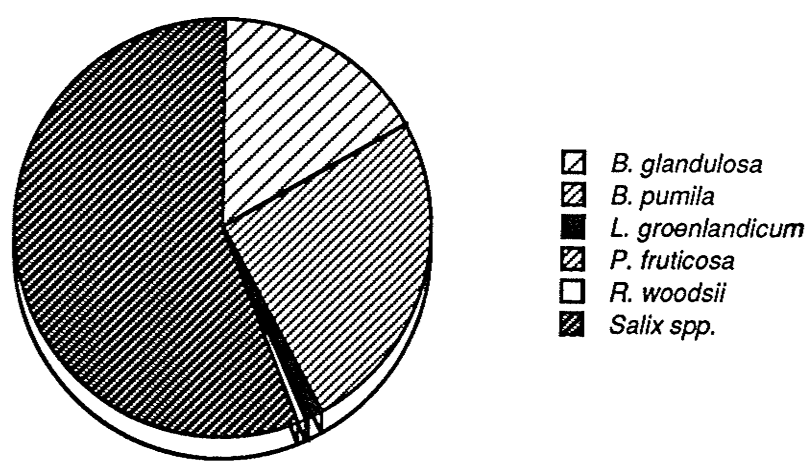


Figure 14. Relative percent stem density of each species contributing to the browse resource in the wet meadow category.

3% of the total between the two of them. Mean heights of these species were comparatively low, ranging from 0.94 m for *P. glauca* to 0.31 m for *Salix spp.*, the latter height likely due to hedging by ungulates.

Wet meadow categories, contributing significantly to the production biomass, were a simpler shrub composition than were dry meadow areas. A total of six shrub species were recorded in the wet meadow category. As illustrated by figure 14, these meadows were dominated by *Salix spp.* and *Betula spp.* which accounted for 56% and 42%, respectively. The other species accounted for approximately 2% all together. Mean shrub heights in this vegetation category ranged from 1.65 for *B. glandulosa* to 0.03 for *Rosa* bushes.

Standing stock and utilization

Biomass of the browse resource was measured in terms of standing stock and utilization per forest canopy type. Standing stock of the browse resource did not necessarily correspond to the species density described above as biomass was based on the clip and weigh method. Weights of species and their levels of utilization differed greatly between forest categories (Table 5). The weights for clipped twigs are applied to the number of twigs in each forest category to arrive at the biomass figures for the browse resource.

Total standing stock in the closed *Pinus* forest was measured at 151 kg/ha, 7% or 10 kg/ha of which was utilized during the 1988-89 winter season. As evidenced by figure 15 the standing stock was dominated by *S. canadensis* which

Table 5. Weights (grams) of browsed twigs per species in each forest category.

	Closed Pine	Closed Spruce	Open Spruce	Meadow	Wet Meadow
Amelanchier.alnifolia	-	-	0.32	0.29	-
Acer glabrum	-	-	0.10	-	-
Betula glandulosa/pumila	-	0.15	-	0.10	0.14
Eleagnus commutata	-	-	-	0.23	-
Juniperus communis	0.19	0.17	0.26	0.26	-
Ledum groenlandicum	-	-	0.31	-	0.25
Lonicera utahensis	-	-	0.18	-	-
Menziesia glabella	-	-	0.25	-	-
Picea glauca	0.29	0.21	0.39	0.32	-
Populus tremuloides	-	0.48	-	-	-
Populus balsamifera	0.41		0.46	0.46	-
Potentilla fruticosa	-	0.12	-	0.15	0.15
Prunus virginiana	-	0.40	-	-	-
Pinus contorta	0.56	-	-	-	-
Rosa acicularis	-	0.14	-	0.13	-
Rosa woodsii	-	-	0.10	-	0.10
Salix spp.	0.41	-	-	0.54	0.61
Shepherdia canadensis	0.55	0.52	0.43	0.56	-

accounted for 92 kg/ha of browse, 3.2 kg/ha of which was utilized by ungulates. *Pinus contorta*, *P. glauca*, *P. balsamifera*, and *J. communis* each accounted for 17, 13, 13, and 11 kg/ha. *Salix spp.* made up the final amount at 6 kg/ha. Utilization occurred on all species except *P. glauca* and *J. communis*.

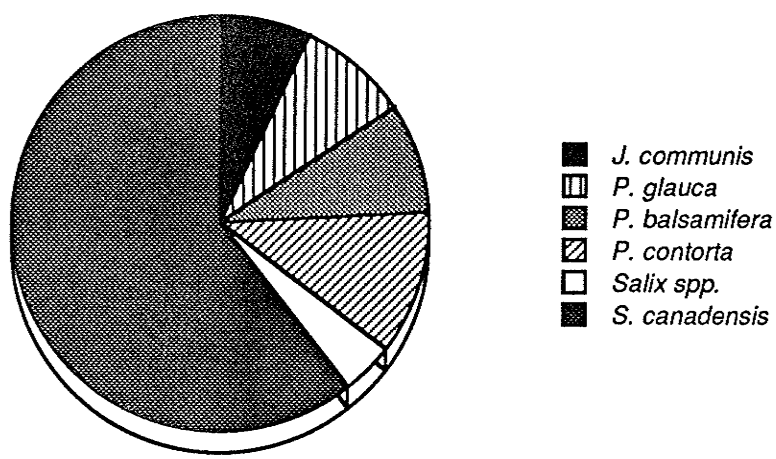


Figure 15. Relative proportions of standing stock of each species contributing to the browse resource in the closed pine forest category.

Closed *Picea* forest accounted for a total of 17 kg/ha of standing stock and 0.07 kg/ha of utilization. Illustrated in figure 16 are the relative proportions of standing stock per species. *Shepherdia canadensis* was the dominant producer in this forest type (14 kg/ha) with a small amount of biomass (2 kg/ha) accounted for by *P.*

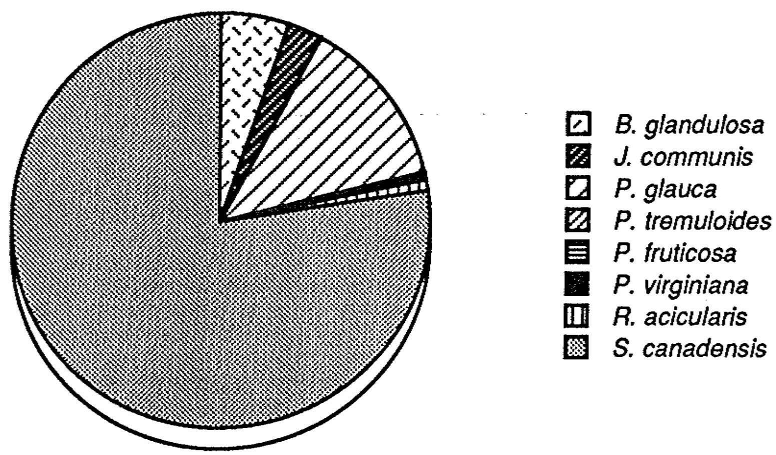


Figure 16. Relative proportions of standing stock of each species contributing to the browse resource in the closed spruce forest category.

glauca. The remainder of species accounted for less than 1 kg/ha together. Utilization was confined to *P. tremuloides* and *Prunus virginiana*.

Standing stock measured at 1462 kg/ha, and utilization at 5 kg/ha, in the open *Picea* forest. As illustrated in figure 17, this production was divided primarily between *L. groenlandicum* (628 kg/ha), *J. communis* (461 kg/ha) and *S. canadensis* (314 kg/ha). *Picea glauca* accounted for 51 kg/ha, and the remaining four species less than 2 kg/ha. Utilization was almost completely restricted to *S. canadensis*.

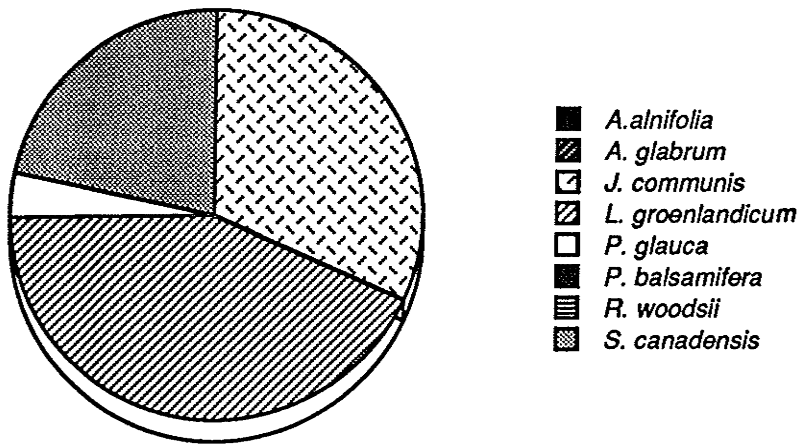


Figure 17. Relative proportions of standing stock of each species contributing to the browse resource in the open *Picea* forest category.

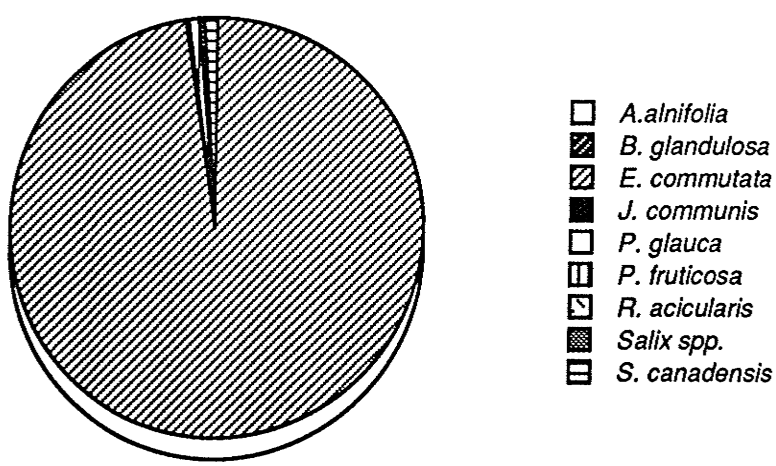


Figure 18. Relative proportions of standing stock of each species contributing to the browse resource in the meadow category.

Browse production was only slighty higher in the meadow category than in the open spruce forest type. Standing stock measured at 1551 kg/ha, utilization was measured at 8 kg/ha. Figure 18 illustrates the proportion of standing stock per species. Biomass was almost completely restricted to one species, 97% of standing stock (1511 kg/ha) was composed of *E. commutata*. *Shepherdia canadensis*, *P. fruticosa*, *P. glauca*, and *Salix spp.* accounted for 18 13, 6 and 3 kg/ha, respectively. The remaining four species accounted for less than 1 kg in total. Utilization was primarily limited to *P. glauca*, *S. canadensis*, and *Salix spp.* accounting for 3, 3, and 1 kg/ha, respectively. *Betula glandulosa*, *E. commutata*, and *A. alnifolia* also indicated some use, but less than 1 kg in all, the majority of this on the small amount of *A. alnifolia* present.

Wet meadows accounted for a small amount of woody browse. Standing stock, primarily accounted for by *Betula spp.* and *Salix spp.* (Figure 19), was measured at 382 kg/ha. Utilization, much higher than in any other community, accounted for completely on *Salix spp.*, was 59 kg/ha or 15% of the standing stock.

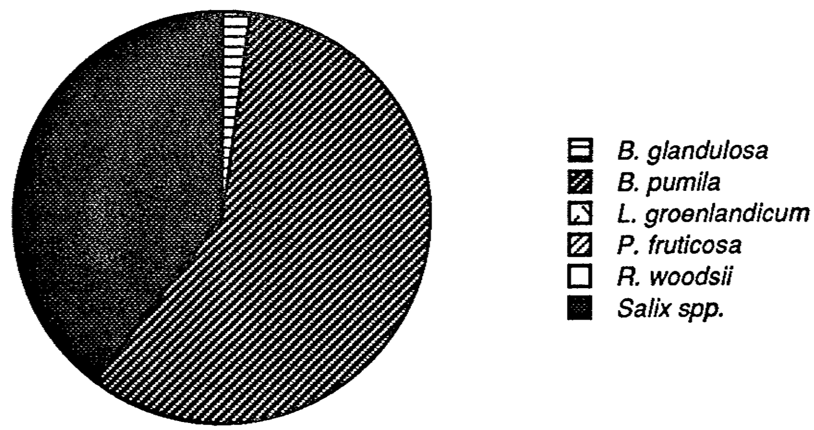


Figure 19. Relative proportions of standing stock of each species contributing to the browse resource in the wet meadow category.

Large differences existed in the browse resource between the forested and open vegetation categories. Figure 20 summarizes these differences and illustrates the relationship between canopy cover and production of browse. Overall differences in the amounts of browse production and utilization, in the Kootenay Valley are noted as a whole for each forest category in figure 21. These figures were arrived at by calculation of the respective forest areas multiplied by the production/hectare (as in the herbage calculations).

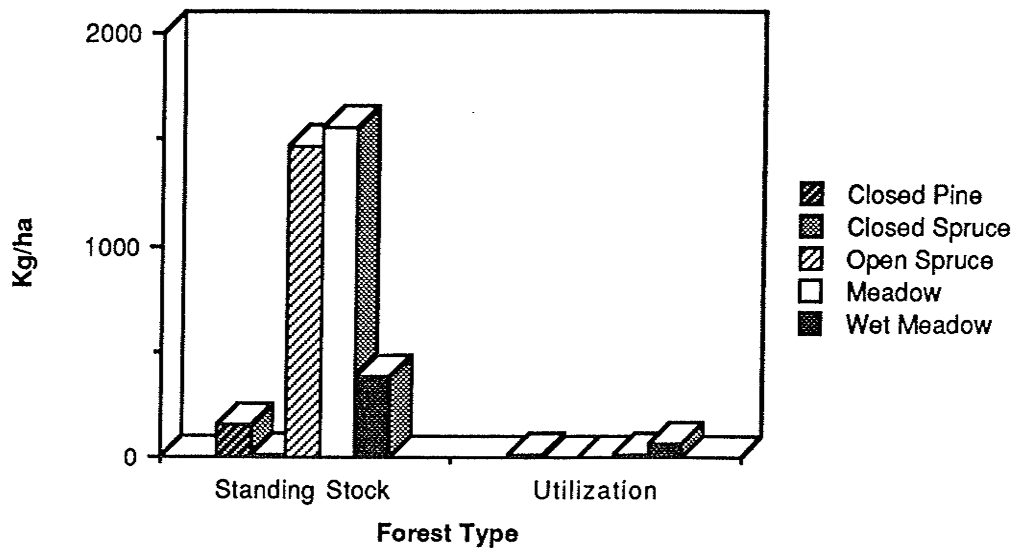


Figure 20. Relative productivity of standing stock and utilization in each forest category (kg/ha).

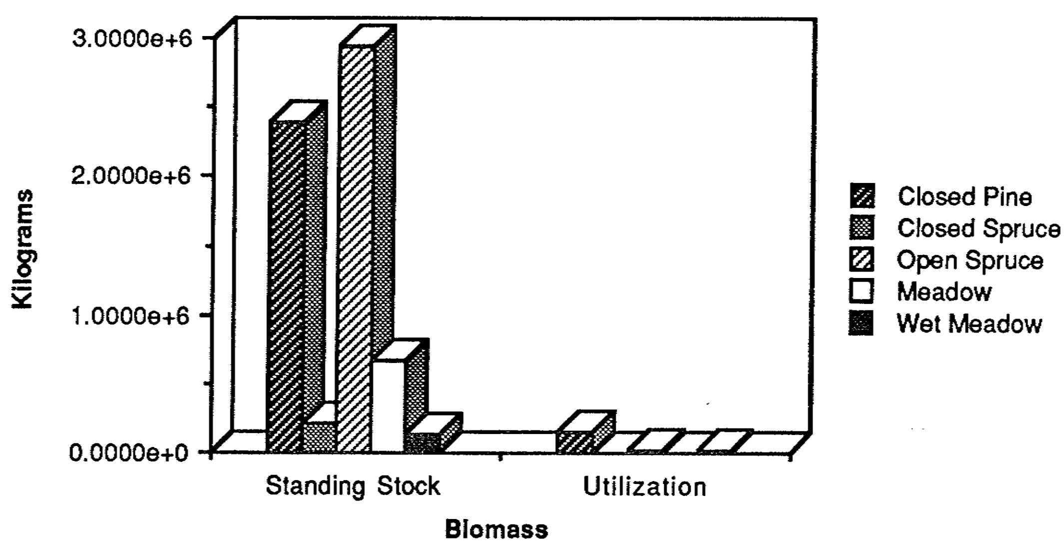


Figure 21. Total standing stock and utilization by forest category for the montane ecoregion.

Browse production within open areas was much higher than that of the closed forest (Figure 20). However, the much greater amounts of closed forest in the Kootenay Valley provided larger amounts of biomass for the valley as a whole. The total standing stock and utilization, irrespective of forest type, for the montane region of the Kootenay Valley was calculated at 6 353 666 kg and 191 919 kg, respectively. The relative amounts of the browse resource are displayed in figure 22.

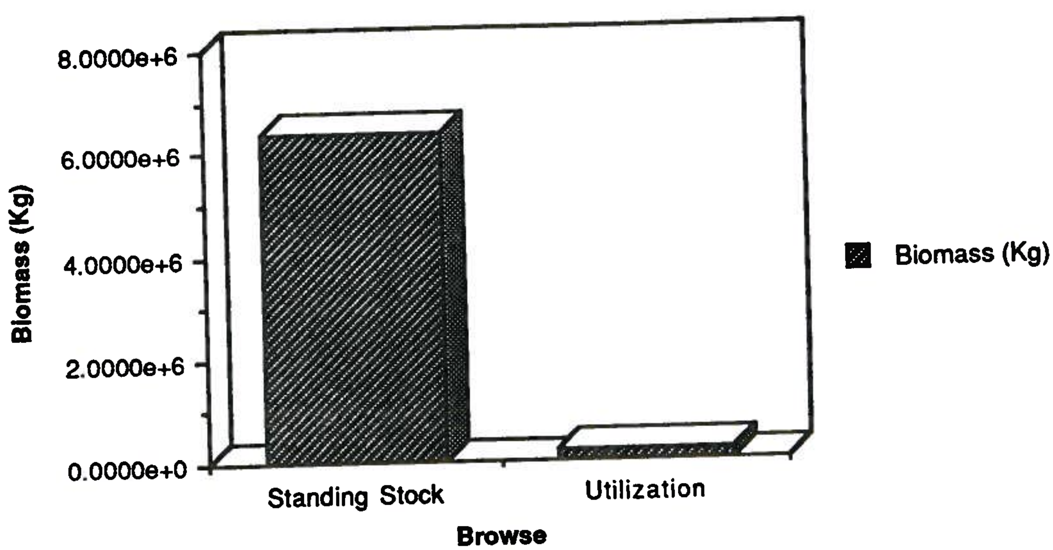


Figure 22. Total standing stock and utilization of browse in the montane ecoregion.

4.3 HISTORICAL RANGE CONDITION

4.3.1 Grazing Resource

Forage production in 1945 was estimated by backward extrapolation of production values measured in the critical habitat area. Extrapolation of this type assumes that forage resources per hectare were the same for respective forest canopies in 1945 as those surveyed on 1978 photos.

Grazing resource values for 1945 correspond to 12 779 055 kg, 13 497 573 kg, 5 606 940 kg for forbs, graminoids, and woody material, respectively. This information suggests a general reduction in forage resources in the grazing resource during the 33 year period of forest canopy

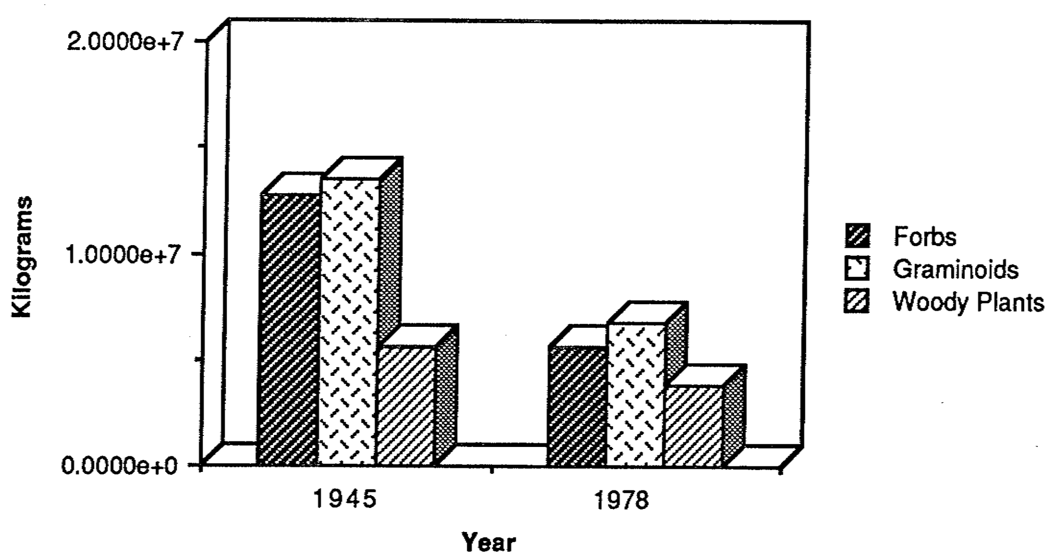


Figure 23. Biomass of forage types in the grazing resource in 1945 as compared to 1978.

comparison. Figure 23 illustrates the relative amounts of grazing resource in 1945 as compared to 1978. Based on the assumption that understory compositions are identical for the forest categories, reductions of 56%, 50%, and 32% occurred for the grazing resource categories of forbs, graminoids, and woody material, from 1945 to 1978.

4.3.2 Browse Resource

Biomass production of the browse resource was assessed by the same method as the forage resource. Utilization was not computed because of the complicating factor of a possibly much different ungulate population.

Figure 24 illustrates the relative differences in the browse resource as computed with 1945 area values and 1978 area values. This illustrates, comparable to the change in grazing resources, a net loss of browse in the study area during the 33 year period. Values in 1945 are equivalent to 31 166 638 Kg as compared to 6 353 666 Kg in 1978. This represents an 80% loss of the original browse resource. Figures 25 and 26 illustrate the relative biomass and composition (graze and browse) of the forage resources of the Kootenay Valley in both 1945 and 1978. In 1945 the

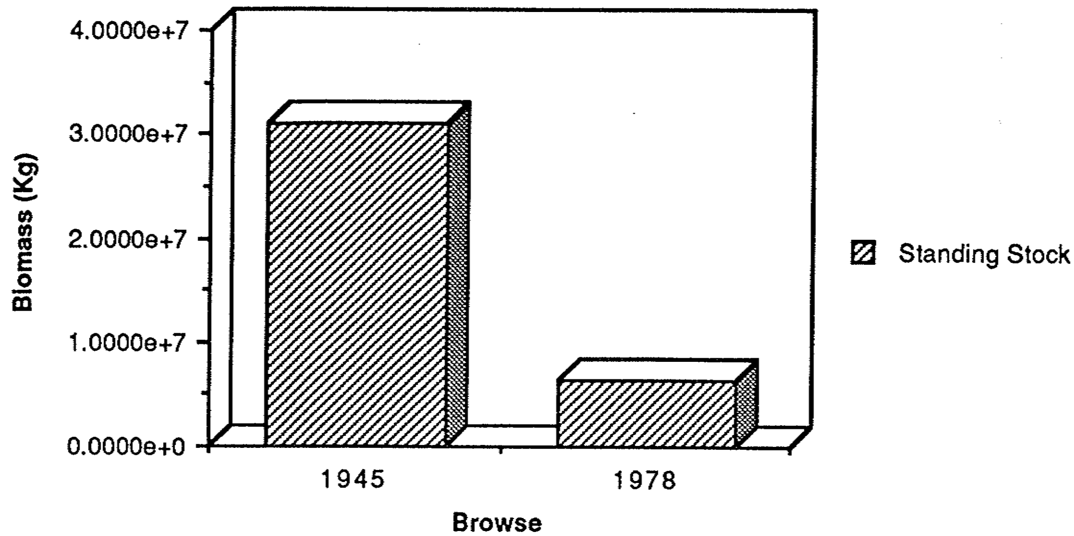


Figure 24. Biomass of browse resource in forest types for entire study area, 1945 compared to 1978.

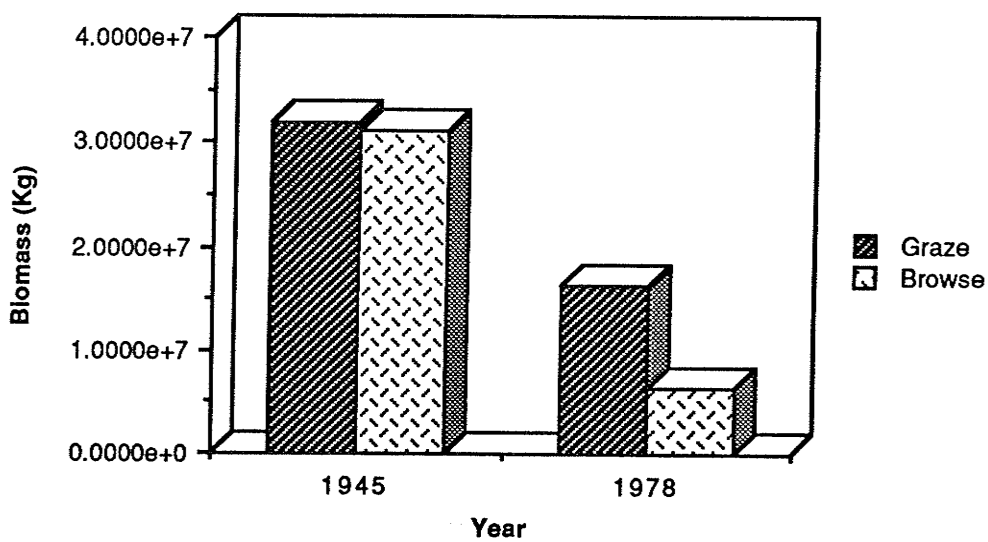


Figure 25. Grazing and browsing resources for entire study area, 1945 compared to 1978.

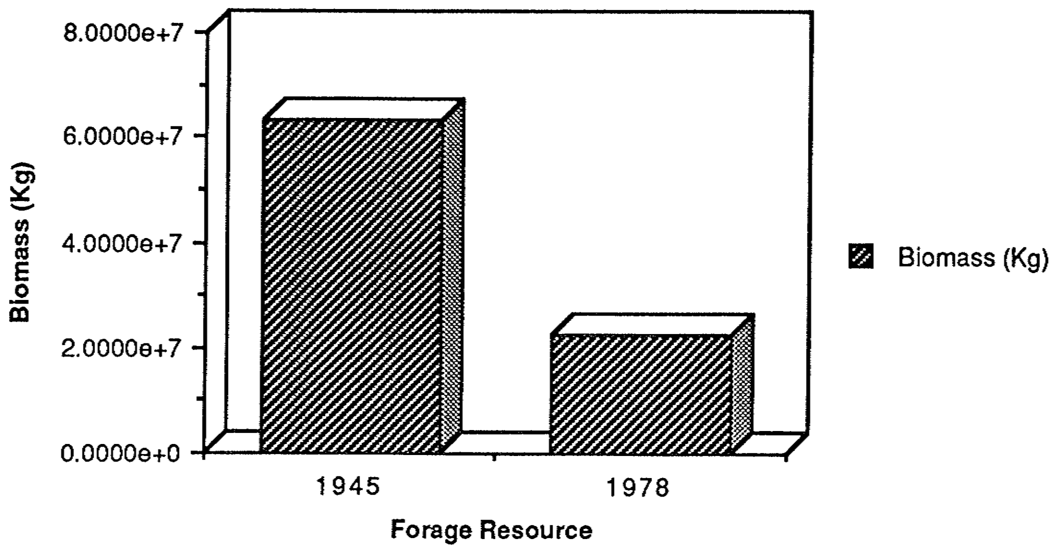


Figure 26. Comparison of the forage resource for entire study area 1945-1978, irrespective of forage type.

grazing and browsing resources provided relatively similar amounts of forage (Figure 25), whereas in 1978 the grazing resource provided approximately double the amount of the browse. Figure 26 summarizes the total forage resources of both 1945 and 1978, irrespective of forage types. Respective values are 63 050 205 Kg and 22 536 696 Kg, a 64% reduction from 1945 to 1978.

4.4 DISCUSSION

4.4.1 Forest Succession

A detailed biophysical inventory of Kootenay National Park was initiated by the Canadian Parks Service in 1981.

Vegetation associations from the biophysical inventory recognized within the study area include the montane vegetation associations of *Populus tremuloides/Elymnus innovatus-Lathyrus spp.(peavine)*, *Picea glauca/Potentilla fruticosa/Arcostaphylos uva-ursi*, *Pinus contorta/Shepherdia canadensis/Aster conspicuus*, as well as wet meadow and meadow types.

Vegetation associations similar to the study area have also been noted in Kananaskis country. *Pinus contorta/Shepherdia canadensis-Pleurozium scheberi* and *Picea engelmannii* (Engelmann spruce)-*Abies lasiocarpa* (sub-alpine fir)/*Menziesia ferruginea* (false azalea)-*Pleurozium scheberi* associations have been noted by Kondla (1978), and by Kirby and Ogilvie (1969). Berg (1979) undertook a range and wildlife inventory of the Wind-Pigeon-Ribbon Creek Complex of Kananaskis Country. As part of this inventory he described and mapped the vegetation mosaic of the montane zone occurring in the Canmore corridor. The predominant vegetation associations noted were *Pinus* and *Picea* with small components of mixed forest and grassland.

The distribution of vegetation types in the Kootenay Valley is varied and, in the case of meadow types, reflects the biophysical parameters of the study area. Differences among forest types, however, are indicative of the historical processes such as wildfire.

Lodgepole pine forest, a seral habitat which is commonly replaced by white spruce, was predominant in the study area, and was most common in the southern and northern portions of the valley. These vegetation types were largely the result of the 1917 and 1926 wildfires. The spruce/fir forest type, representing a climax stage of succession occurred primarily near the center of the study area. A transitional stage between aspen and white spruce forest, mixedwood forest type occurred only in limited distribution. The south facing slopes in the vicinity of Daer tower and at the lower end of the Kootenay Valley supported the greatest concentration of this forest type.

Both the meadows and wet meadows are maintained primarily by the biophysical parameters of soils, geography, and water. The meadow areas, usually an early successional stage, are distributed along the Kootenay and Vermilion Rivers and maintained primarily by the flood cycle which prevents permanent establishment of a tree canopy. The wet meadows are a successional stage between the emergent sedge meadows and the drier upland sites occurring on poorly drained soils. This habitat type occurred in limited distribution throughout the study area, and was most predominant in the Dolly Varden Creek area.

Fire has been the predominant disturbance influencing forest succession in KNP. Except for the present meadow

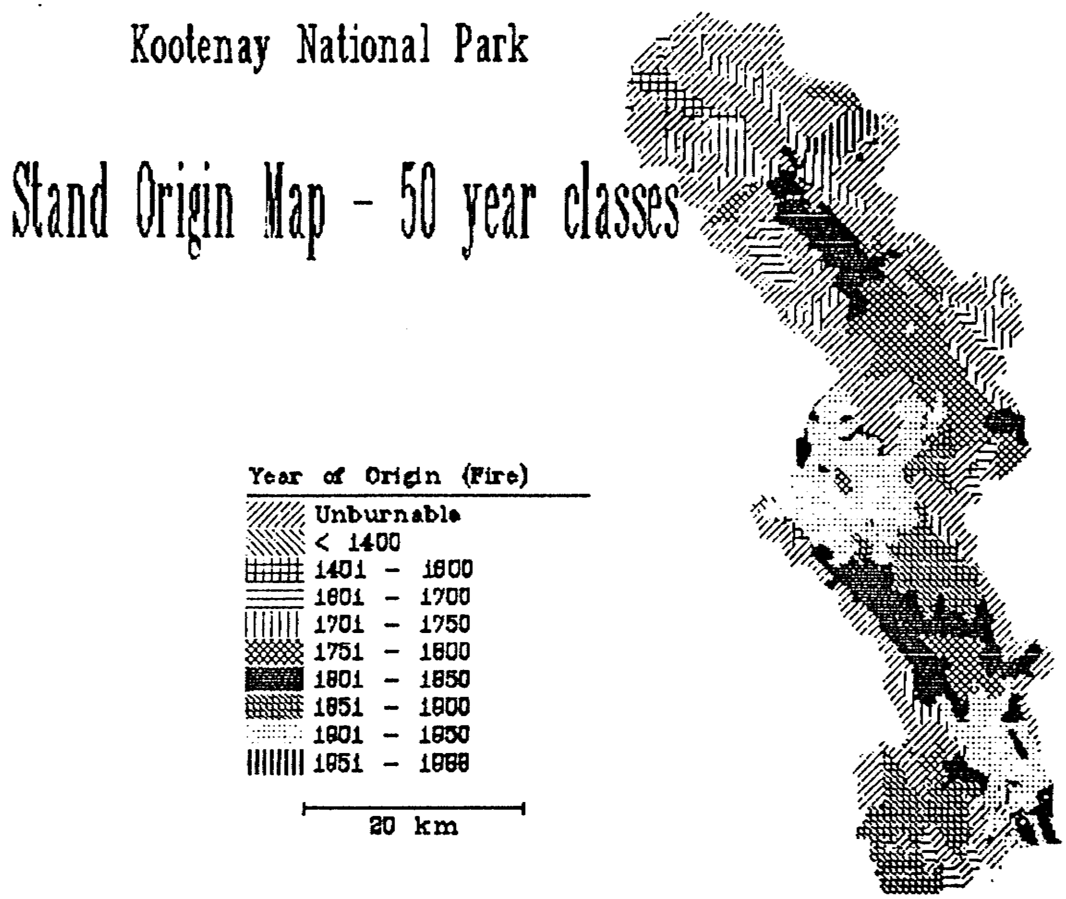


Figure 27. Stand-origin map of KNP (from Masters 1989). This map represents forest stand ages since time of last fire.

areas, which appeared to influenced by other biophysical parameters (e.g., topography, drainage), the forest canopies were representative of the fire history of the valley.

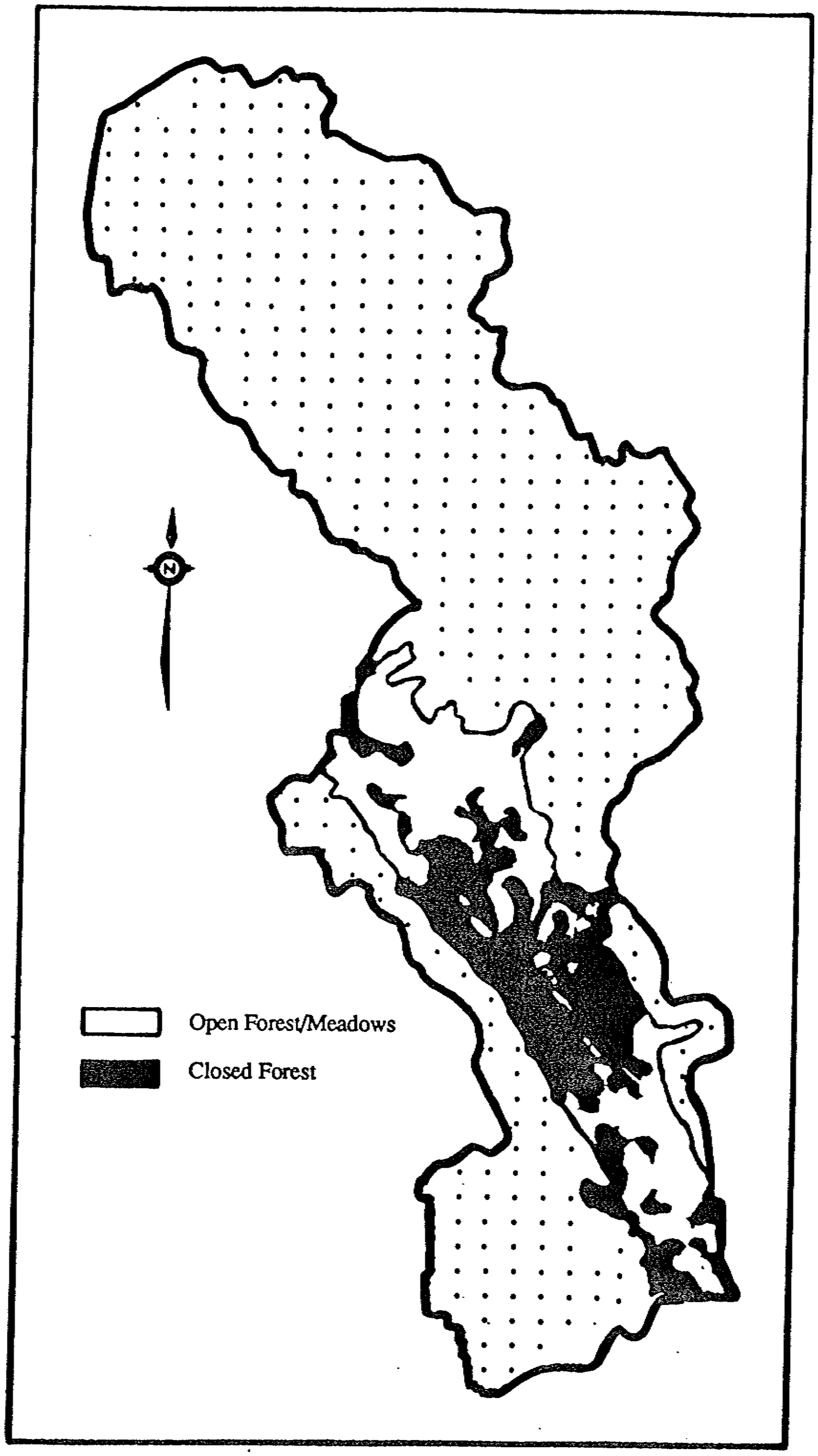


Figure 28. Distribution of closed forest versus open forest/meadow areas in 1945. The majority of meadows at this time were likely an early successional stage of *Pinus contorta*.

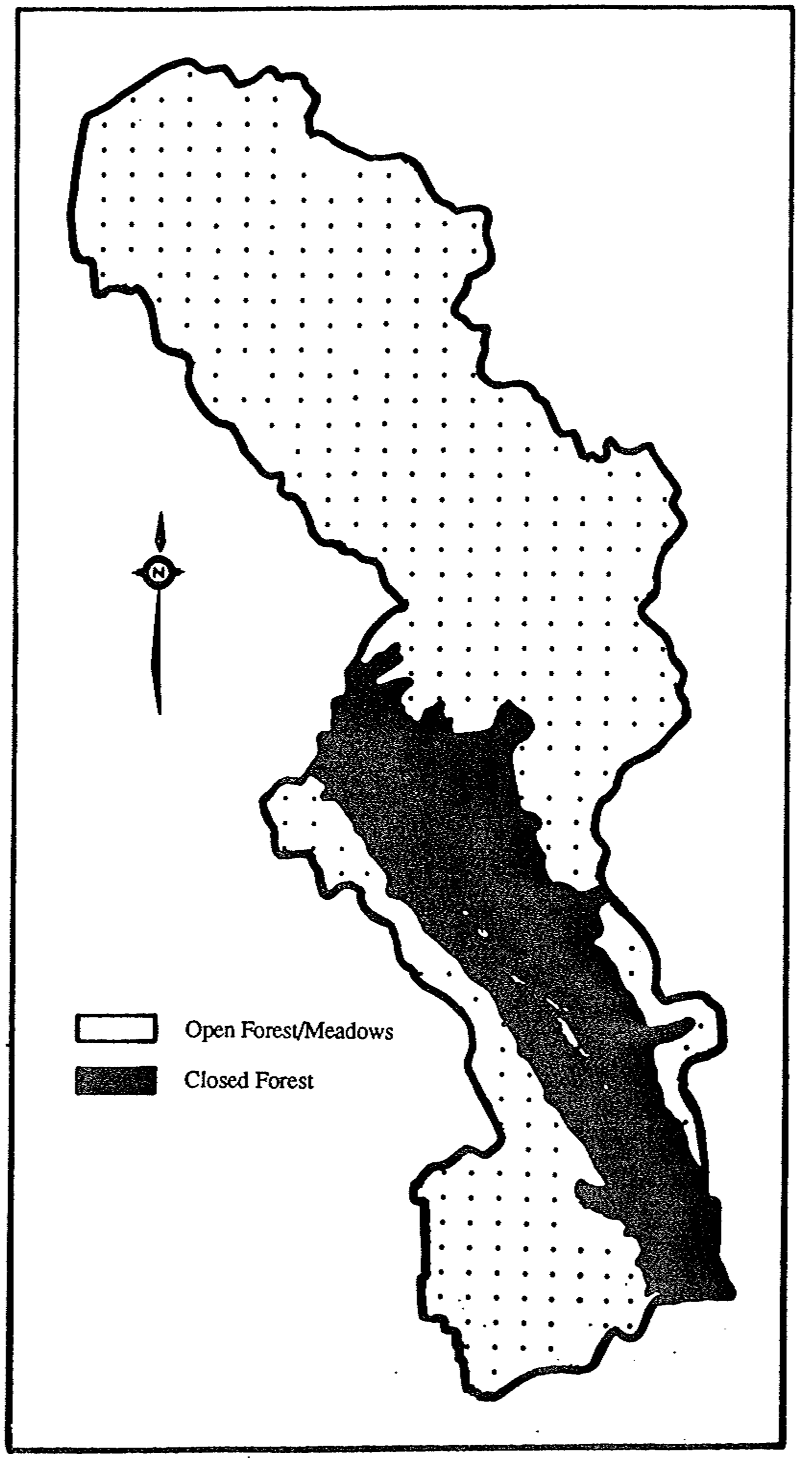


Figure 29. Distribution of closed forest versus open forest/meadow areas in 1978. Note that the majority of meadow areas are too small to be visible at this scale.

Figure 27 from Masters (1989) illustrates the forest fire history of KNP. The distribution of forest types described here, and shown in figures 28 and 29 (illustrated more specifically on the map sheets), correspond to the different stand ages illustrated by Masters (1989). Achuff *et al.* (1984) have also described successional forest types in KNP. *Pinus contorta* and *Populus tremuloides* communities are considered successional whereas other dominant species in the study area (*Picea glauca* and *Pseudotsuga menziesii*) are climax species. These classifications also apply to the 1945 communities, the meadows predominant in 1945 were mostly an early successional stage of *Pinus contorta*. As the meadows in this assessment are predominantly the result of fluvial activity, rather than fire, the accuracy of the extrapolation in this study is questionable and must be viewed with caution.

The rate of forest succession is illustrated by figure 30. This figure, based on three points in time, illustrates a simplification of the actual successional process.

No further succession could be determined between 1966 and 1978 photo sets. Although there is no doubt that succession is continually occurring, the forest cover categories (10-40% and >40% cover) are too broad to determine

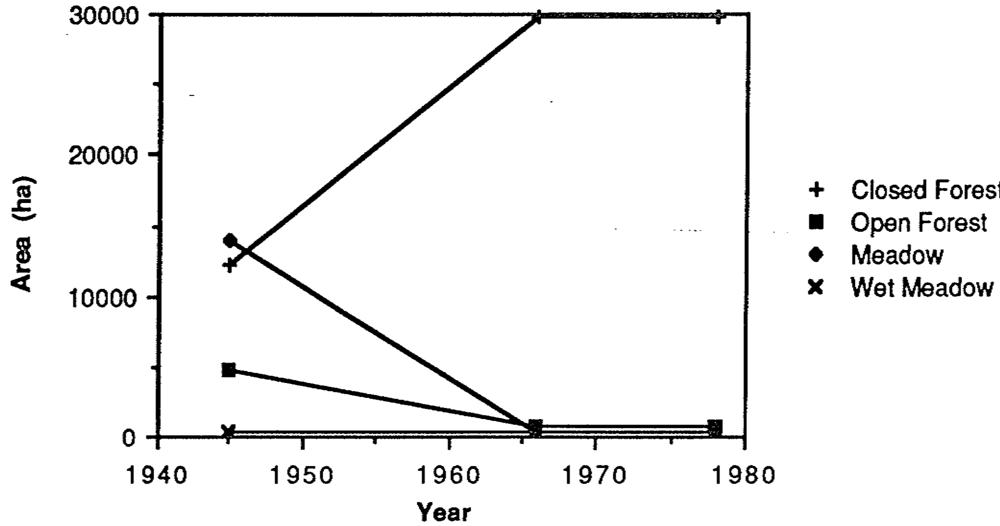


Figure 30. Change in forest categories from 1945 to 1966 to 1978.

changes in the forest canopy boundaries as tree size is the major change in later succession. Only a small change was noted in the boundary of wet meadows. To accurately assess the succession occurring within a forest canopy detailed field studies must be conducted over a longer time interval.

Achuff *et al.* (1984) have noted that most of the study area is in an intermediate successional stage. Typical successional sequence would illustrate rapid successional rates with an eventual slowing of forest encroachment as canopy species reach climax (Peterson and Bazzaz 1978; Achuff *et al.* 1984). Based on this information the successional rate would likely look like that shown in figure 31 which

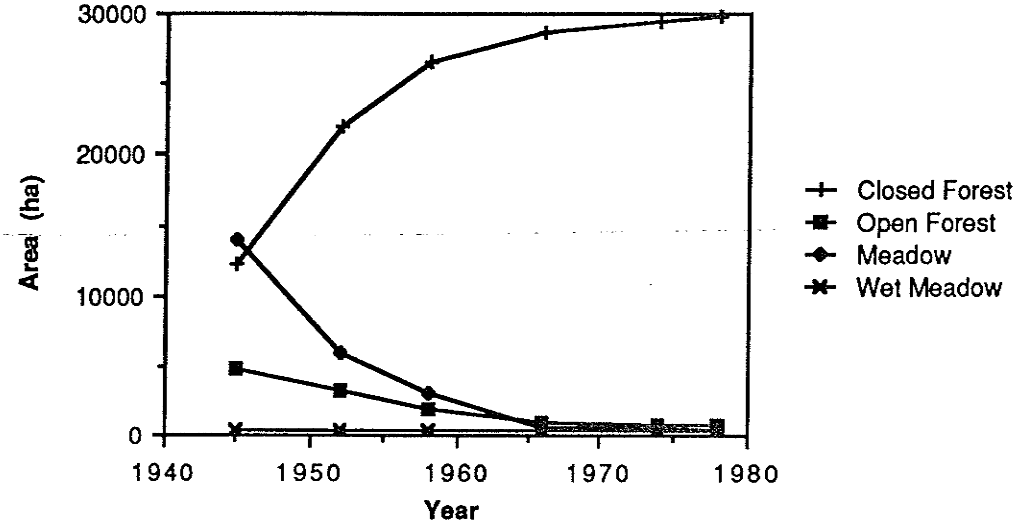


Figure 31. Curved rates of forest canopy change from 1945 to 1978.

illustrates rapid initial changes in plant cover and then slowing rates as the forest canopy matures.

4.4.2 Range Condition

The data collected in the range surveys of the critical winter habitat suggest that forage resources are less abundant in closed forest communities as compared to open habitats which are lacking tree canopies. That understory vegetation varies inversely with overstory is recognized as a universal ecological response (Skovlin 1982), and has been demonstrated by a number of authors (Arnold 1950; Pace 1958; McConnell and Smith 1971; and Clary *et al.* 1975).

Statistical analysis of data was undertaken to compare differences in the variables between different canopy communities. Analysis of this type is complicated by the extreme variability in natural vegetation communities. As discussed in section 3.3.4, data was combined according to forage type for each forest category for statistical analysis. Appendix II contains tables of the means of each variable and its standard deviation. In many of these situations the tables reflect both the limited sample size and the areal distribution of the vegetation categories. For example, a small mean value and a high standard deviation (often the case with woody vegetation in the grazing resource) illustrates a sparsely distributed forage type which grows in clumps. One should also take into consideration that an anomaly in the vegetation community can produce a large standard deviation that will produce misleading results. Thus, care must be taken in interpreting the statistical tests applied to comparisons of the forest communities, especially when dealing with such a small sample size and applying the tests to the raw data.

Grazing Resource

Significant differences existed in the forage class coverage of the grazing resource in most forest categories. T-tests were used to compare each variable (forbs, graminoids, woody plants) between different forest categories (tables indicating the t-statistics and their significance levels are located in Appendix II). In all cases the null hypothesis (i.e., no significant difference between communities) was rejected at the 95% confidence level if the level of significance was less than 0.05.

The majority of communities have significantly different cover levels of forbs. Only two out of ten comparisons were noted as similar cover values. Comparisons between closed pine and closed spruce, and between open spruce and meadow communities, were insignificant.

Graminoid cover was also different between most communities. Three out of ten comparisons noted cover as similar. Similarities occurred between closed pine, open spruce, and meadows. Graminoid cover in closed pine and closed spruce, compared to forb cover, conversely had no similarity. Graminoid values for open spruce and meadows were similarly insignificant as were forbs.

Significant differences in cover of woody plants were not common. Significant differences existed only between closed pine and open spruce, closed spruce and open spruce, and open spruce and both meadow categories.

Many of the differences between forage class coverage extended to differences in forage class production. As with the coverage data, T-tests were used to compare the variables between different forest categories and the same hypothesis (i.e., null hypothesis of no difference) was rejected at the same confidence level.

Differences in production of forbs occurred in six out of ten comparisons. Biomass of forbs was not significantly different between closed pine, closed spruce, and open spruce. Similar values also occurred between meadows and wet meadows.

While production of forb biomass differed primarily between forested and meadow communities, graminoid production was different between almost all communities. Graminoid production was similar only in two out of ten comparisons; closed pine and closed spruce, and closed pine and open spruce.

Although differences existed between communities for the majority of production levels, biomass data for woody plants differed only in three out of ten comparisons. Woody plant production in the closed spruce forest was not similar to any other forest or meadow category. This difference was primarily because no woody material was collected in the grazing resource of the closed spruce forest. Based on the limited sample size (see previous discussion), it is unlikely that any significant differences occurred between any forest categories regarding production of this variable.

Browse Resource

Eight variables were measured in the browse resource analysis, four of these variables pertained to descriptions of the community as well as providing information for calculation of the standing stock and utilization of the browse resource. Four of these variables pertained directly to the standing stock and utilization of the browse resource.

Significant differences existed between a small majority of the forest categories compared in the browse resource. T-tests were used to compare each variable (density, number of twigs, number of twigs browsed, height, weight of twigs, weight of twigs browsed, standing stock and utilization) between different forest categories (tables indicating the t-statistics and their significance levels are located in Appendix 5). In all cases the null hypothesis (i.e., no significant difference between communities) was rejected at the 95% confidence level if the level of significance was less than 0.05.

As the first six variables noted above are precursors to the calculation of twig weights/hectare, which are the indicators of standing stock and utilization, only the latter two variables will be discussed here. T-statistics and significance levels are available for all variables in Appendix II.

Significant differences occurred in standing stock of the browse resource in six out of ten comparisons at the 95% confidence level. Closed spruce and closed pine were significantly different between the two of them. Open spruce was similar to all other categories. Both meadows and wet meadows tested as being significantly different from both closed forest categories but not from the open spruce forest. Wet meadows were significantly different from dry meadows.

Seven of ten comparisons were different in comparison of utilization levels. Utilization levels were significantly different between the open spruce category and the closed pine and closed spruce categories. Utilization levels were also different between the meadow areas and the closed spruce forest. No significant difference was recorded between the open spruce forest and the meadow category. The utilization in the wet meadow category was significantly different from all other categories.

Analysis of previous range condition

As the historic range analysis was based on the data gathered on present range condition the above discussion also applies to the historic range situation. Degrees of error are difficult to apply to this analysis. Error is inherent when determining the boundaries of vegetation communities and increases with decreasing air photo scale. Levels of error in digitizing were calculated at 1.20%.

Although no detailed information on understory vegetation conditions is available from 1945, the relative populations of ungulates lend credibility to the extrapolation of forage estimates. As the valley is largely indicative of historical fires, the boundaries of the 1945 vegetation communities have likely changed very little since the 1917 and 1926 fires. The majority of meadow areas in the study area were likely composed of pine similar to the Vermilion Pass area today. In this situation the forest canopy would have soon started to shade out the understory vegetation, hence reducing the available forage resources. This process would explain the decline of moose (a browse dependent species) in the middle to late forties and the decline of elk populations in the middle 1950's.

Loss of natural range has been compensated for to a certain extent by the provision of high quality forage on the seeded roadsides of the Kootenay Parkway. Constructed in 1921, the Kootenay Parkway was an extremely narrow roadway, in comparison to today's right-of-way. Although no information is presently available on the actual size of the cleared roadsides, the right-of-way at that time was only 10 m in width.

The 10 m right-of-way is a stark contrast to today's Parkway. The present Kootenay Parkway was rebuilt and completed in 1964. Present right-of-way varies in size but measures an average of 66 m, of which the paved roadway accounts for 14 m (D.Poll, pers.comm). These characteristics result in an average measure of 52 metres of seeded roadside.

In a comprehensive study of ungulate mortality on the Kootenay Parkway, Poll (1989) measured an average forage production of 1738 kg/ha. At a mean seeded area of 52 m in width there are 214 hectares of roadside forage available, between Olive Lake and Wardle Creek, for utilization by ungulates. This corresponds to a total of 371 674 kg of highly palatable forage available on the Kootenay Parkway within the study area. This amount of forage is only slightly less than half the total amount of herbaceous material (811 305 kg) produced by wet meadows, the most productive natural community, in the entire study area. When compared to the meadow areas presently in the Kootenay Valley, the Parkway resource comprises 52% of the total amount (710 999 kg) produced by natural meadow areas in the montane zone.

Chapter V
CONCLUSION

5.1 SUMMARY

Major vegetation changes have occurred in the 33 year time period between 1945 and 1978. These changes have had a profound effect on the ungulate populations of the Kootenay Valley over this time span. The resultant vegetation mosaic represents a greatly reduced area of open meadow communities. Ninety-five percent of the montane region of the Kootenay Valley is now closed forest and meadow areas make up less than one and one-half percent of the total montane ecoregion. In comparison, meadow areas accounted for 44.6% of the study area in 1945.

The range inventories illustrate that forage production decreases with increasing canopy cover. As most of the Kootenay Valley is now closed forest, the majority of forage resources are sparsely distributed. From 1945 to 1978, forbs, graminoids, and woody plants underwent reductions in biomass production of 56%, 50%, and 36%, respectively. Browse standing stock in the montane region of the Kootenay Valley today accounts for approximately 20% of that available in previous years (1945). The result is a low volume of forage resources/hectare in the elk winter range.

Combined with factors such as forage palatability, edge habitat, and salting of the roadways during winter highway operations the Parkway grasslands comprise a concentrated, high quality, forage resource in the midst of sparsely distributed, low quality alternatives. In search of adequate forage resources for the winter season these conditions result in a concentration of ungulates (particularly elk) feeding on the right-of-way grasslands.

These animals are habituated to highway traffic. The elk concentrate their feeding on both sides of the highway, frequently cross the highway, and often lick the salts directly off of the roadbed, while displaying little reaction to vehicles on the Parkway. The high level of mortality resulting from ungulate/vehicle conflicts is both a public safety and a park management concern.

5.2 RECOMMENDATIONS

A number of mitigative opportunities can be tested for reduction of the high level of ungulate mortalities on the Kootenay Parkway (Poll 1989). Further research should be undertaken, however, to investigate manipulation of the ungulate populations through modification of the vegetation regime present in the Kootenay Valley. A detailed vegetation/wildlife habitat management plan should therefore be developed specific to the Kootenay Valley.

This plan should be based on two major objectives:

- Reduction of wildlife use on the Kootenay Parkway.
- Creation of new ungulate habitat in areas of the valley separated from the Parkway.

The two objectives above are mutually exclusive in that reduction of wildlife use on the Kootenay Parkway will require creation of additional habitat if the present population is to be maintained. Uncertainty is involved, however, as to whether creation of distinct habitat will result in reduction of use on the Parkway or merely a larger population with continued ungulate use of the Parkway grasslands.

The fire history of KNP (Masters 1989) suggests that fire suppression has likely had little effect on the present vegetation associations in the study area. The vegetation changes and ungulate history of the park have, however, displayed a definite relationship. The availability of useful foraging habitat in conjunction with thermal cover profoundly influences the distribution and population of ungulates.

Assuming that "initial attack and suppression" of wildfires is to be a continued policy in KNP, the realization that a natural forest will eventually burn, regardless of suppression strength, must be accepted. Therefore, the following recommendations should receive consideration in the development of a Kootenay Valley vegetation/wildlife habitat plan:

- A prescribed burn or controlled burn program should be implemented in KNP. Not only will this program reduce the potential of major fires which were common in the park's history, but the most likely and natural method for habitat creation is fire. Areas of closed forests should be investigated for such consideration of such planning. The maps enclosed with this document contain detailed information on the forest stands in the Kootenay Valley and may be used as a basis for planning. Areas suited for such consideration may be between Daer Pond and the Kootenay River, between the Kootenay River and Settler's Road, or any lower areas of the west-facing slopes of the Kootenay Valley. All areas are well removed from the Parkway and are presently dominated by closed forest.

- As any such management plan will be an evolving strategy of understanding the processes of fire, ungulate use, and habitat, a monitoring strategy for vegetation change should be implemented which will expand on the baseline information provided in this assessment. As this survey is based on limited field sampling, additional sampling sites should be established. Site sampling should be expanded to include all vegetation types noted in the air photo assessment as well as to increase the level of accuracy. Sampling should take place in three year sets as range conditions are known to vary from year to year.

- Monitoring of the vegetation communities can presently take a wide time frame, (e.g., survey {3 years in duration} every 10 years) between surveys. However, the occurrence of any interruptions, natural or planned, in the valley's present successional sequence, (e.g., fire) should result in yearly monitoring of the early successional trends. Additional information collected should include monitoring of overstory vegetation at each point for record of forest succession. As well, information on wildlife use of both manipulated and natural habitats should be collected.

- Monitoring of ungulate mortality on the Kootenay Parkway must be continued. This provides direct information on mortality trends and the effects of mitigative procedures. As well, regardless of suppression actions, a natural forest will eventually undergo the cyclic process of fire and forest succession. Therefore, efforts should be made to record and understand the interrelationships of fire, vegetation, and wildlife. Ungulate presence on the Parkway is an integral portion of this required knowledge.

5.3 CONCLUSION

Forest succession is a cyclic process by which natural vegetation associations alternate the *r-selection* and *K-selection* strategies of vegetation community development. Fire, which plays a natural role in this cyclic process, has largely been absent from its role in the Kootenay Valley since the major fires of 1917 and 1926.

Succession from open habitats to closed forest habitats, has largely slowed in the Kootenay valley with the majority of the valley now under closed forest canopy. Forage resources in the montane ecoregion of the Kootenay

Valley are sparse and low quality, particularly when compared with the Parkway grasslands.

This investigation has documented and quantified the changes in the forest canopy coverage of the montane ecoregion in the Kootenay Valley of Kootenay National Park from 1945 to 1978. From this an estimate of available forage resources and an extrapolation of the changes in such resources since 1945 has been produced. In addition, baseline data and transects were established for monitoring vegetation conditions within the elk winter range in the Kootenay valley.

The results of this study confirm suggestions that the vegetation communities of the Kootenay Valley have undergone major changes in the park's history. These changes, a result of post-fire forest succession, have had major effects on the ungulate populations in the history of Kootenay National Park, and presently influence ungulate presence and mortality on the Kootenay Parkway. Management actions affecting the role of fire and/or the vegetation regime of Kootenay National Park will have significant long-term influences and must therefore be carefully evaluated and monitored.

6.0 LITERATURE CITED

Achuff, P.L.; Holland, W.D.; Coen, G.M.; Van Tighem, K., editors. Ecological Land Classification of Kootenay National Park. British Columbia. Vol. 1. Integrated Resource Description. Alberta Inst. of Pedology: Publication No. M-84-10; 1984.

Aldous, S.E. A deer browse survey method. J. Mamm. 25:130-136; 1944.

Alberta Forestry, Lands and Wildlife. Alberta Remote Sensing Center Information Pamphlet; 1988.

Ambrosia V.A.; Whiteford G.T. Aerial Photograph Interpretation in Remote Sensing. Introduction to Remote Sensing of the Environment. 2nd ed. Richason, B.F. editor. National Council for Geographic Education. Dubuque, IO: Kendall/Hunt Publishing Co.; 1983.

Arnold, J.E. Changes in ponderosa pine bunchgrass ranges in northern Oregon resulting from pine regeneration and grazing. J. For. 48:118-126; 1950.

Banfield, A.W.F. The Mammals of Canada. National Musuems of Canada. Univ. Toronto Press; 1974.

Barbour, M.G.; Burk, J.H.; Pitts, W.D. Terrestrial Plant Ecology. CA: Benjamin/Cummings Publishing Company; 1980.

Berg, B.P. Range and wildlife inventory of the Wind-Pigeon-Ribbon Creek Complex, Kananaskis Country. Calgary, AB: Dept. Recreation Parks and Wildlife; 1979

Bray, J.R.; Curtis J.T. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27:325-349; 1957.

Brown, R.W.; Chambers, J.C. Methods for Vegetation Sampling and Analysis on Revegetated Mined Lands. Forest Service General Technical Report INT-151. Ogden, UT: Intermountain Res. Stat. U.S. Dept. of Agriculture; 1983.

Cain, S.A.; de O. Castro, G.M. Manual of Vegetation Analysis. New York: Harper & Row; 1959.

Canadian Department of Forestry. Native Trees of Canada. Ottawa, ON: Queen's Printer and Controller of Stationery; 1963.

Canfield, R.H. Application of the line interception method in sampling range vegetation. J. For. 39:388-394; 1941.

Catana, A.J. The wandering quarter method of estimating population density. Ecol. 44:349-360; 1963.

Clapham, A.R. The form of the observational unit in quantitative ecology. J. Ecol. 20:192-197; 1932.

Clary, W.P.; Kruse, W.H.; Larson, F.R. Cattle grazing and wood production with different basal areas of ponderosa pine. J. Range Manage. 28:434-437; 1975.

Clements, E.S. Plant Succession: an analysis of the development of vegetation. Washington, D.C: Carnegie Institution of Washington Publ. 290; 1916.

Cole, D.N. Estimating The Susceptibility Of Wildland Vegetation To Trailside Alteration. J. App. Ecol. 15:281-286; 1978.

Cole, D.N. Assessing and Monitoring Backcountry Trail Conditions. Forest Service Research Paper INT-303. Ogden, UT: Intermountain Res. Stat., U.S.Dept.of Agriculture; 1983.

Cottam, G. A point method for making rapid surveys of woodlands. Bull. Ecol. Soc. Amer. 28:60; 1947.

Cottam, G. and J.T. Curtis. The use of distance measures in phytosociological sampling. Ecol. 37:451-460; 1956.

Cowan, I. McT. Report on the game conditions in Banff, Jasper, and Kootenay National Parks. Ottawa, ON: Dept. of Indian Affairs and Northern Development, National and Historic Parks Branch;.1943.

Cunningham, G.C. Forest Flora of Canada. Bulletin 121. Ottawa, ON: Forestry Branch, Dept. of Northern Affairs and Natural Resources; 1958.

Curtis, J. T.; McIntosh,R.P. The interrelationships of certain analytic and synthetic phytosociological characters. Ecol. 31:434-455; 1950.

Damas and Smith. Wildlife mortality in transportation corridors in Canada's National Parks. Vol. I. Unpubl. report. Report produced for Parks Canada by Damas and Smith, Ottawa, ON: A Division of D.S.L. Consultants; 1982.

Dasmann, W.F. A critical review of range survery methods and their application to deer range management. California. Fish and Game 34:189-207; 1948.

Daubenmire, R.F. Plant Communities. New York: Harper & Row; 1968.

Dodd, C.J.H; McLean, A; Brink, V.C. Grazing values as related to tree-crown covers. Can. J. For. Res. 2:185-189; 1972.

Dyksterhuis, E.J. Condition and management of range land based on quantitative ecology. J. Range Manage. 2:104-115; 1949.

Harlow, R.F. A technique for surveying deer forage in the southeast. Wild. Soc. Bull. 5:185-191; 1977.

Heilman, P.E. Change in distribution and availability of nitrogen with forest succession on north slopes in interior Alaska. Ecol. 47:825-831; 1966.

Humphrey, R.R. Field comments on the range condition method of forage survey. J. Range Manage. 2:1-10; 1949.

Jensen, C.H.; Scotter, G.W. A comparison of twig-length and browsed-twig methods of determing browse utilization. J. Range Manage. 30:64-67; 1977.

Kershaw, K.A. Quantitative and Dynamic Plant Ecology. 2nd ed. New York: American Elsevier; 1973.

Kirby, C.L.; Ogilvie, R.T. The forests of the Marmot Creek Watershed Research Basin. Ottawa, ON: Dept. of Fisheries and Forestry. Can. For. Ser. Pub. 1259:1-37; 1969.

Kootenay National Park, Resource Conservation. Kootenay National Park Conservation Plan. Radium Hot Springs, B.C.; 1984.

Kondla, N. An Overview Vegetation Survey of Kananaskis Provincial Park. Edmonton, AB:Alberta Dept. Recr. Parks and Wild.; 1978.

Knight, D.H. Methods for sampling vegetation. An instruction manual. Laramie, WY: Univ. Wyoming, Dept. Botany, Ark Industries; 1978.

Komarek, E.V. Fire, research, and education. Proc. Tall Timbers Fire Ecol. Conf., no. 2:181-187. Talahassee, FL: Tall Timbers Res. Stat.; 1963.

Komarek, E.V. Fire - and the ecology of man. Proc. Tall Timbers Fire Ecol. Conf., no. 6:143-170. Talahassee, FL: Tall Timbers Res. Stat.; 1967.

Kuijt, J. A Flora of Waterton Lakes National Park,. Edmonton, AB: Univ. Alberta Press; 1982.

Lohnes, D. Towards a new fire policy. Ottawa, ON: Natural Resources Bulletin, Parks Canada. Spring ed.; 1981.

Lyon, L.J.; Stickney, P.F. Two forest fires and some specific implications in big game habitat management. Proc. West. Assoc. State Game and Fish Comm. 46:181-193; 1966.

Lyons, J.D. An Evaluation of Density Sampling in a Shrub Community. Missoula, MT: Univ. Montana; 1968.

Masters, A.M. Fire History of Kootenay National Park, B.C. Radium Hot Springs, B.C: Unpublished internal report, Canadian Parks Service; 1989.

McConnell, B.R; Smith, J.G. Response of understory vegetation to ponderosa pine thinning in eastern Washington. J. Range Manage. 23:203-212; 1971.

Morisita, M. A new method for the estimation of density by the spacing method applicable to non-randomly distributed populations. Physiol. and Ecol. 7:134-144; 1957.

Munro J.A.; Cowan, I. McT. Preliminary report on the birds and mammals of Kootenay National Park, B.C. Can. Field Nat. 58:34-51; 1944.

Nelon, E.W. Methods of studying shrubby plants in relation to grazing. Ecol.11:764-769; 1930.

Nelson, J.R., Leege T.A. Nutritional Requirements and Food Habits. Elk of North America. Thomas, J.W.; Toweill, D.E. editors. A Wildlife Management Institute Book. Harrisburg, PA: Stackpole Books; 1982.

Olson, W.; Blyth, C. Third Annual Browse Survey - Herd Recommendations Report. Elk Island National Park, AB: Resource Conservation. Unpubl. rep. for Parks Canada; 1985.

Olson, W. Methods for Browse Analysis. Elk Island National Park, AB: Personal Notes. Unpubl.; 1988.

Pace, C.P. Herbage production and composition under immature ponderosa pine stands in the Black Hills. J. Range Manage. 11:238-243; 1958.

Passmore, R.C.; Hepburn, R.L. A land method for appraisal of winter range of deer. Ontario: Dept. of Lands and Forests Research Paper 29; 1955.

Pechanec, J.F.; Pickford, G.D. A weight estimate method for the determination of range or pasture production. Amer. Soc. Agron. 29:894-904; 1937.

Peterson, D.L.; Bazzaz, F.A. Life cycle characteristics of *Aster pilosus* in early successional habits. Ecol. Monogr. 44:73-88; 1978.

Pohl, R.W. How to Know the Grasses. Iowa: WM. C. Brown Co. Publishers; 1954.

Poll, D.M. Wildlife Mortality on the Kootenay Parkway Kootenay National Park. Radium Hot Springs, B.C.: Environment Canada, Canadian Parks Service; 1989.

Poll, D.M.; Porter M.M.; Holroyd, G.L.; Wershler, R.M.; Gyug, L W. Ecological Land Classification of Kootenay National Park. Vol. II. Wildlife Resource. Edmonton,.AB: Canadian Wildlife Service, (for) Parks Canada, Western Region; 1984.

Revill, R.D. and Associates. Ecological Effects of Fire and its Management in Canada's National Parks: a synthesis of the literature. Calgary, AB: Unpubl. rep. to Parks Canada, Volumes 1,2, and 3; 1978.

Rutherford, M.C. Plant-based techniques for determining available browse and browse utilization: a review. Bot. Rev. 45:203-228; 1979.

Scotter, G.W.; Flygare; H. Wildflowers of the Canadian Rockies. Edmonton, AB: Hurtig Publishers Ltd; 1986.

Shafer, E.L. The twig-count method for measuring hardwood deer browse. J. of Wild. Manage 27:428-437; 1963.

Skovlin, J.M. Habitat Requirements and Evaluations. Elk of North America. Thomas, J.W.; Toweill D.E. editors. A Wildlife Management Institute Book. Harrisburg, PA: Stackpole Books; 1982.

Smith, A.D.; Urness, P.J. Analysis of the twig-length method of determining utilization of browse. UT: State Dept. Fish and Game Publ. 69-9; 1962.

Spurr, S.H.; Barnes, B.V. Forest Ecology. New York: Ronald Press Co.; 1973.

Telfer, E.S. Range Trend Studies at Elk Island National Park. A Project Plan. Edmonton, AB: Canadian Wildlife Service; 1972.

Telfer, E.S. Browse Inventories: Techniques and Evaluation. Symposium on Census and Inventory Methods for Population and Habitats. Miller, F.; Gunn, A.; Hieb, S. editors. Moscow, ID: Forest, Wildlife and Range Exp. Stat. University of Idaho; 1981.

Tufts, W.P. Pruning of deciduous fruit trees. Calif. Agric. Exp. Stat. Bull. 313; 1919.

Van Cleve, K.; Viereck, L.A. Forest Succession in relation to nutrient cycling in the boreal forest of Alaska. Forest Succession, Concepts and Application. West, D.C.; Shugart H.H., Botkin, D.B. editors. New York: Springer-Verlag; 1981.

Van Dyne, G.M.; Vogel, W.G.; Fisser, H.G. Influence of plot size and shape on range herbage production estimates. Ecol. 44:746-759; 1963.

Walmsley, M.; Utzig, G.; Vold, T.; Moon, D.; van Barneveld, J. editors. Describing ecosystems in the field. Victoria, B.C.: RAB Tech, Paper 2/Land Manage. Rept. #7. Brit. Col. Min. Envr./Min. For.; 1980.

Wilms, H.G.; Costello, D.F.; Klipple,, G.E. Estimating forage yield by the double sampling method. J. Amer. Agron. 36:194-203; 1944.

Wilson, A.D.; Tupper, G.J. Concepts and factors applicable to the measurement of range condition. J. Range Manage. 35:684-689; 1982.

APPENDICES

7.1 APPENDIX I: Scientific names and common names of plant species noted in text, appendices, or field data.

Appendix I: Scientific names and common names of plant species noted in text, appendices, and field data.

SCIENTIFIC NAME	COMMON NAME
Tree Layer	
Abies lasiocarpa	alpine fir
Picea engelmannii	engelmann spruce
Picea glauca	white spruce
Pinus contorta	lodgepole pine
Populus tremuloides	aspen
Populus balsamifera	balsam poplar
Pseudotsuga menziesii	douglas fir
Shrub Layer	
Acer glabrum	maple
Alnus crispa	green alder
Amelanchier alnifolia	saskatoon
Betula glandulosa	bog birch
Betula pumila	birch
Elaeagnus commutata	wolf willow
Juniperus communis	ground juniper
Ledum groenlandicum	common labrador tea
Lonicera utahensis	red twin-berry
Menziesia glabella	false huckleberry
Picea glauca	white spruce
Populus balsamifera	balsam poplar
Populus tremuloides	aspen
Pinus contorta	lodgepole pine
Potentilla fruticosa	shrubby cinquefoil
Prunus virginiana	chokecherry
Rosa acicularis	prickly rose
Rosa woodsii	common wild rose
Salix spp.	willows
Shepherdia canadensis	buffalo berry
Vaccinium caespitosum	dwarf bilberry
Herb-Dwarf Shrub Layer	
Agropyron spp.	wheat grass
Agrostis gigantea	creeping bent
Anemone parviflora	anemone sp.
Antennaria pulcherrima	showy everlasting
Arctostaphylos uva-ursi	common bearberry

..... Appendix I continued

Appendix I. continued

SCIENTIFIC NAME	COMMON NAME
Herb-Dwarf Shrub Layer Con't	
Arnica cordifolia	arnica sp.
Aster ciliolatus	lindley's aster
Aster conspicuus	showy aster
Aster sp.	aster sp.
Betula glandulosa	bog birch
Calamagrostis inexpansa	northern reed grass
Calamagrostis rubescens	pine grass
Carex aquatilis	water sedge
Carex rostrata	sedge
Carex spp.	sedges
Castilleja spp.	indian paint brush sp.
Cornus canadensis	bunchberry
Danthonia intermedia	timber oatgrass
Danthonia spicata	poverty oat grass
Deschampsia caespitosa	tufted hair grass
Dryas drummondii	yellow dryad
Dryas integrifolia	white dryad
Elymus innovatus	hairy wild rye
Epilobium angustifolium	fireweed; great willow herb
Epilobium spp.	willow herb
Festuca ovina	sheep fescue
Fragaria virginiana	wild strawberry
Habenaria hyperborea	northern green orchid
Hedysarum sulphurescens	milk vetch
Juncus sp.	rush sp.
Juniperus communis	ground juniper
Lathyrus ochroleucus	peavine
Linnaea borealis	twin flower
Lonicera involucrata	bracted honeysuckle
Lonicera utahensis	red twin-berry
Maianthemum canadense	wild lily of the valley
Menziesia glabella	false huckleberry
Mitella nuda	bishop's cap; mitrewort
Muhlenbergia glomerata	bog muhly
Muhlenbergia richardsonis	mat muhly
Oryzopsis asperifolia	grass.sp.
Oxytropis campestris	late yellow locoweed

..... Appendix I continued

Appendix I. continued

SCIENTIFIC NAME	COMMON NAME
Herb-Dwarf Shrub Layer Con't	
Picea glauca	white spruce
Pleurozium scheberi	feathermoss
Poa compressa	canada bluegrass
Poa interior	bluegrass
Poa palustris	fowl bluegrass
Poa pratensis	kentucky bluegrass
Poa sandbergii	sandberg bluegrass
Poa spp.	bluegrass sp.
Potentilla fruticosa	shrubby cinquefoil
Pyrola secunda	one sided wintergreen
Pyrola virens	wintergreen
Ribes lacustre	bristly black currant
Rosa acicularis	prickly rose
Rosa woodsii	common wild rose
Rubus pubescens	dewberry; running raspberry
Salix scouleriana	willow sp.
Salix spp.	willow sp.
Shepherdia canadensis	buffalo-berry
Solidago multiradiata	goldenrod sp.
Solidago spp.	goldenrod sp.
Solidago spathulata	goldenrod sp.
Spiraea lucida	meadowsweet
Taraxacum laevigatum	red seeded dandelion
Trientalis borealis	starflower
Viburnum edule	low bush cranberry; mooseberry

..... Appendix I concluded.

7.2 APPENDIX II: Statistical information and summary tables.

Appendix II. Statistical Information

Table 1. T-statistics and significance values found in comparing the cover of forbs in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	0.41	3.87	3.38	5.86
Signif.	0.687	**0.000**[1]	**0.002**	**0.000**
Closed Spruce				
T-stat.		3.20	2.66	3.47
Signif.		**0.003**	**0.011**	**0.001**
Open Spruce				
T-stat.			0.96	6.44
Signif.			0.341	**0.000**
Meadow				
T-stat.				6.42
Signif.				**0.000**

1. Values in **bold** illustrate significant differences between forest categories.

Table 2. T-statistics and significance values found in comparing the cover of graminoids in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	3.16	1.29	0.50	11.05
Signif.	**0.003**[1]	0.207	0.623	**0.000**
Closed Spruce				
T-stat.		2.28	3.86	12.62
Signif.		**0.028**	**0.000**	**0.000**
Open Spruce				
T-stat.			1.89	11.05
Signif.			0.065	**0.000**
Meadow				
T-stat.				8.15
Signif.				**0.000**

1. Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 3. T-statistics and significance values found in comparing the cover of woody in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	0.41	3.37	0.08	0.37
Signif.	0.683	**0.002**[1]	0.936	0.712
Closed Spruce				
T-stat.		3.66	0.08	0.76
Signif.		**0.001**	0.936	0.449
Open Spruce				
T-stat.			4.14	3.11
Signif.			**0.000**	**0.003**
Meadow				
T-stat.				0.85
Signif.				0.398

1. Values in **bold** illustrate significant differences between forest categories.

Table 4. T-statistics and significance values found in comparing the cover of litter in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	0.60	1.53	2.18	3.44
Signif.	0.552	0.134	**0.035**[1]	**0.001**
Closed Spruce				
T-stat.		0.96	2.65	0.79
Signif.		0.345	**0.011**	0.437
Open Spruce				
T-stat.			3.42	0.79
Signif.			**0.001**	0.437
Meadow				
T-stat.				5.33
Signif.				**0.000**

1. Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 5. T-statistics and significance values found in comparing the weights of forbs in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	1.42	0.72	3.97	3.77
Signif.	0.173	0.482	**0.001**[1]	**0.002**
Closed Spruce				
T-stat.		1.99	4.92	4.77
Signif.		0.062	**0.000**	**0.000**
Open Spruce				
T-stat.			3.31	3.10
Signif.			**0.003**	**0.006**
Meadow				
T-stat.				0.04
Signif.				0.968

[1]. Values in **bold** illustrate significant differences between forest categories.

Table 6. T-statistics and significance values found in comparing the weights of graminoids in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	1.02	1.48	3.65	7.97
Signif.	0.320	0.155	**0.001**[1]	**0.000**
Closed Spruce				
T-stat.		2.32	4.44	8.75
Signif.		**0.032**	**0.000**	**0.000**
Open Spruce				
T-stat.			2.07	6.15
Signif.			**0.050**	**0.000**
Meadow				
T-stat.				4.59
Signif.				**0.000**

[1]. Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 7. T-statistics and significance values found in comparing the weights of woody in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	2.00	0.93	0.48	1.09
Signif.	0.061	0.363	0.633	0.289
Closed Spruce				
T-stat.		3.86	2.08	4.78
Signif.		**0.001**[1]	**0.049**	**0.000**
Open Spruce				
T-stat.			0.31	0.15
Signif.			0.760	0.885
Meadow				
T-stat.				0.42
Signif.				0.681

1. Values in **bold** illustrate significant differences between forest categories.

Table 8. T-statistics and significance values found in comparing the browse height in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	2.93	1.93	4.40	0.94
Signif.	**0.004**[1]	0.056	**0.000**	0.347
Closed Spruce				
T-stat.		1.43	6.53	3.52
Signif.		0.155	**0.000**	**0.001**
Open Spruce				
T-stat.			6.49	2.78
Signif.			**0.000**	**0.006**
Meadow				
T-stat.				3.15
Signif.				**0.002**

1. Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 9. T-statistics and significance values found in comparing the browse distance in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	6.76	1.23	2.75	0.74
Signif.	**0.000**[1]	0.220	**0.006**	0.460
Closed Spruce				
T-stat.		7.23	3.60	3.43
Signif.		**0.000**	**0.000**	**0.001**
Open Spruce				
T-stat.			3.42	1.21
Signif.			**0.001**	0.227
Meadow				
T-stat.				1.02
Signif.				0.310

[1] Values in **bold** illustrate significant differences between forest categories.

Table 10. T-statistics and significance values found in comparing the # of twigs browsed in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	3.46	1.32	1.36	2.49
Signif.	**0.001**[1]	0.190	0.176	**0.014**
Closed Spruce				
T-stat.		2.18	2.25	2.75
Signif.		**0.031**	**0.026**	**0.007**
Open Spruce				
T-stat.			1.76	2.60
Signif.			0.080	**0.010**
Meadow				
T-stat.				2.31
Signif.				**0.022**

[1] Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 11. T-statistics and significance values found in comparing the # of twigs in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	0.90	2.11	1.89	2.20
Signif.	0.371	**0.036**[1]	0.061	**0.030**
Closed Spruce				
T-stat.		2.15	2.19	2.50
Signif.		**0.034**	**0.030**	**0.013**
Open Spruce				
T-stat.			2.21	1.78
Signif.			**0.028**	0.078
Meadow				
T-stat.				0.32
Signif.				0.748

1. Values in **bold** illustrate significant differences between forest categories.

Table 12. T-statistics and significance values found in comparing the gram weight of browsed twigs in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	3.64	2.15	1.18	2.56
Signif.	**0.00**[1]	**0.033**	0.241	**0.012**
Closed Spruce				
T-stat.		1.83	2.10	2.76
Signif.		0.069	**0.038**	**0.006**
Open Spruce				
T-stat.			1.76	2.66
Signif.			0.081	**0.009**
Meadow				
T-stat.				2.62
Signif.				**0.010**

1. Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 13. T-statistics and significance values found in comparing the gram weight of twigs in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	1.28	2.02	1.03	2.02
Signif.	0.203	**0.045**[1]	0.302	**0.045**
Closed Spruce				
T-stat.		2.08	1.55	2.61
Signif.		**0.039**	0.122	**0.010**
Open Spruce				
T-stat.			2.22	1.74
Signif.			**0.028**	0.083
Meadow				
T-stat.				0.62
Signif.				0.538

1. Values in **bold** illustrate significant differences between forest categories.

Table 14. T-statistics and significance values found in comparing the **weight of twigs/ha** in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	3.82	1.37	2.74	2.46
Signif.	**0.00**[1]	0.174	**0.007**	**0.015**
Closed Spruce				
T-stat.		1.36	2.12	2.37
Signif.		0.176	**0.035**	**0.019**
Open Spruce				
T-stat.			1.58	1.12
Signif.			0.116	0.265
Meadow				
T-stat.				2.41
Signif.				**0.017**

1. Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 15. T-statistics and significance values found in comparing the gram **weight of browsed twigs/ha** in each forest category.

	C Spruce	O. Spruce	Meadow	W. Meadow
Closed Pine				
T-stat.	1.45	2.55	1.95	2.89
Signif.	0.149	**0.045**[1]	0.052	**0.004**
Closed Spruce				
T-stat.		2.65	2.05	2.90
Signif.		**0.009**	**0.042**	**0.004**
Open Spruce				
T-stat.			0.44	2.52
Signif.			0.661	**0.012**
Meadow				
T-stat.				3.11
Signif.				**0.002**

[1]. Values in **bold** illustrate significant differences between forest categories.

Appendix II. continued

Table 16. Percent cover values of the grazing resource in each forest canopy cover type.

	Forbs	Graminoids	Woody Plants	Litter[1]	Non-Vascular
Closed Pine					
Mean	10.4	29.2	3.6	20.8	36.0
S.Dev	8.8	19.2	6.3	12.4	18.4
Closed Spruce					
Mean	9.4	11.8	2.8	18.2	57.8
S.Dev	13.3	15.5	6.0	14.7	22.7
Open Spruce					
Mean	30.0	22.4	17.8	13.26	16.4
S.Dev	20.8	13.9	16.6	18.22	13.2
Meadow					
Mean	25.6	32.0	3.1	30.3	6.7
S.Dev	17.1	19.4	4.7	16.3	10.7
Wet Meadow					
Mean	0.0	75.5	4.4	9.8	10.6
S.Dev	0.0	16.4	7.2	6.6	11.0

Appendix II. continued

Table 17. Percentage density of species in each forest category.

	Closed Pine	Closed Spruce	Open Spruce	Meadow	Wet Meadow
Amelanchier alnifolia			3.2	0.7	
Acer glabrum			1.0		
Betula glandulosa		1.5		1.6	16.7
Betula pumila					25.4
Eleagnus commutata				11.3	
Juniperus communis	10.4	9.8	28.5	0.0	
Ledum groenlandicum			7.4		1.1
Lonicera utahensis			1.1		
Menziesia glabella			2.0		
Picea glauca	1.0	34.2	6.9	17.6	
Populus tremuloides		2.7			
Populus balsamifera	10.1		0.8	8.0	
Potentilla fruticosa		0.7		44.4	0.4
Prunus virginiana		0.7			
Pinus contorta	14.8				
Rosa acicularis		1.8		4.8	
Rosa woodsii			1.8		0.6
Salix spp.	6.6			5.7	55.9
Shepherdia canadensis	57.2	48.8	47.2	5.8	

Appendix II. continued

Table 18. Percentage of the number of twigs on a species in each forest category.

	Closed Pine	Closed Spruce	Open Spruce	Meadow	Wet Meadow
Amelanchier alnifolia			0.0	0.1	
Acer glabrum			0.2		
Betula glandulosa		1.0		0.3	20.0
Betula pumila					40.8
Eleagnus commutata				2.7	
Juniperus communis	13.6	11.3	24.1	3.5	
Ledum groenlandicum			62.6		0.8
Lonicera utahensis			0.1		
Menziesia glabella			3.5		
Picea glauca	16.0	21.0	1.3	56.9	
Populus tremuloides		0.5			
Populus balsamifera	5.5		0.0	5.2	
Potentilla fruticosa		0.5		26.7	0.1
Prunus virginiana		0.6			
Pinus contorta	5.3				
Rosa acicularis		0.4		0.0	
Rosa woodsii			0.0		0.0
Salix spp.	4.0			1.4	38.3
Shepherdia canadensis	55.5	64.8	8.2	3.1	

Appendix II. continued

Table 19. Percentage of the number of browsed twigs of a species in each forest category.

	Closed Pine	Closed Spruce	Open Spruce	Meadow	Wet Meadow
Amelanchier alnifolia			0.0	0.1	
Acer glabrum			16.1		
Betula glandulosa		0.0		0.6	0.0
Betula pumila					0.0
Eleagnus commutata				19.2	
Juniperus communis	0.0	0.0	7.4	0.0	
Ledum groenlandicum			5.4		0.0
Lonicera utahensis			12.8		
Menziesia glabella			0.0		
Picea glauca	0.0	0.0	0.0	0.3	
Populus tremuloides		27.0			
Populus balsamifera	34.0		0.0	53.8	
Potentilla fruticosa		0.0		0.3	0.0
Prunus virginiana		59.5			
Pinus contorta	10.7				
Rosa acicularis		2.7		0.0	
Rosa woodsii			0.0		0.0
Salix spp.	21.3			14.5	
Shepherdia canadensis	34.0	10.8	58.4	11.3	100.0

Appendix II. continued

Table 20. Mean height of species in each forest category.

	Closed Pine	Closed Spruce	Open Spruce	Meadow	Wet Meadow
Amelanchier alnifolia			0.39	0.40	
Acer glabrum			0.60		
Betula glandulosa		1.10		0.34	0.69
Betula pumula					1.64
Eleagnus commutata				0.42	
Juniperus communis	0.47	0.46	0.77	0.40	
Ledum groenlandicum			0.76		0.36
Lonicera utahensis			0.49		
Menziesia glabella			1.24		
Picea glauca	2.02	1.71	1.45	0.94	
Populus tremuloides		1.83			
Populus balsamifera	0.31		0.61	0.35	
Potentilla fruticosa		0.71		0.51	0.61
Prunus virginiana		0.50			
Pinus contorta	0.57				
Rosa acicularis		0.44		0.33	
Rosa woodii			0.32		0.30
Salix spp.	0.46			0.31	0.65
Shepherdia canadensis	0.85	0.82	1.05	0.61	

..... Appendix II concluded.

7.3 **APPENDIX III:** Field transect locations and diagrams.

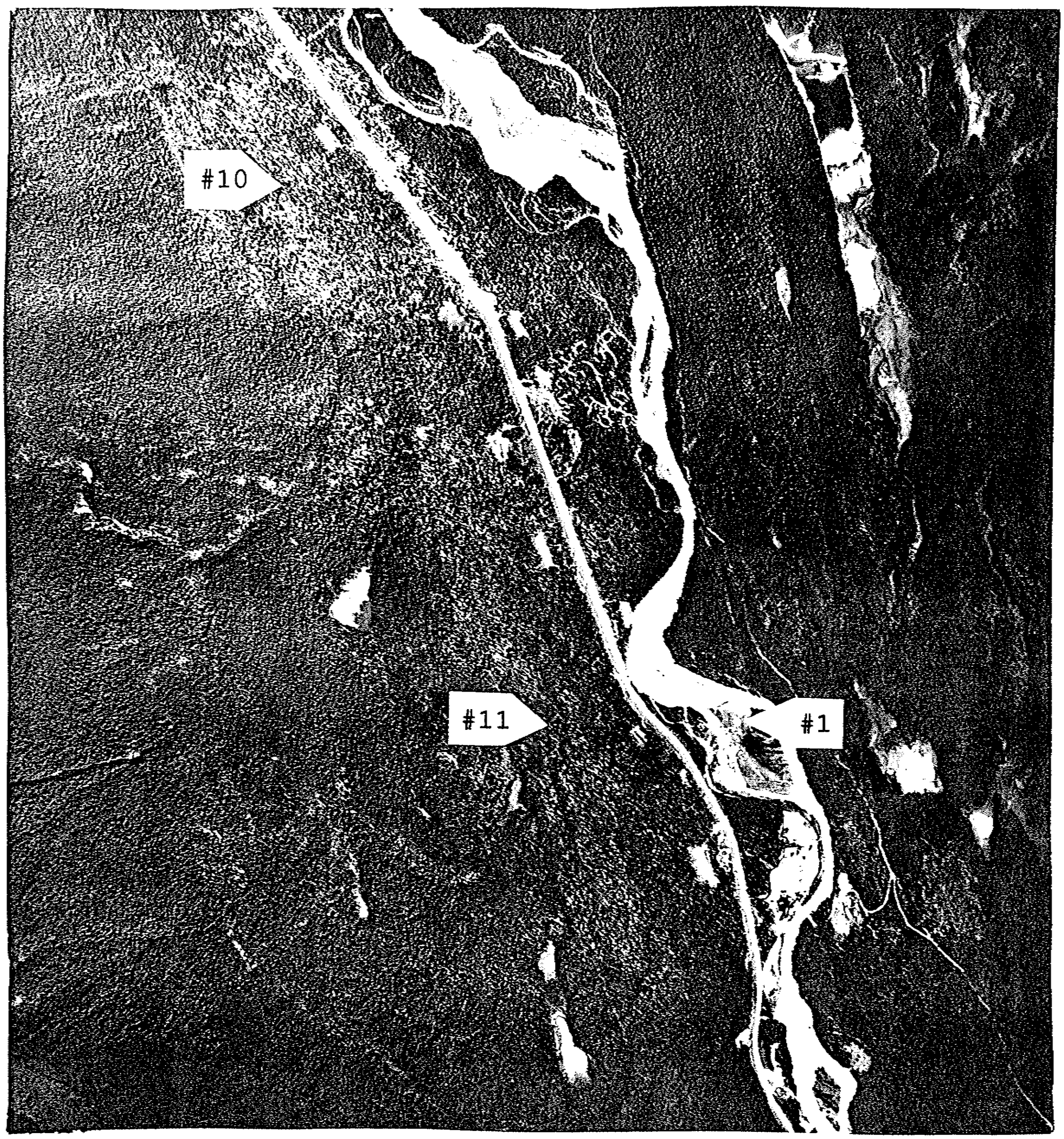
Appendix III. Transect site locations and diagrams.

Range transect locations are as plotted on the four air photographs included. Schematic of each transect is also included, transects number from 0 m to 200 m starting at the bottom of each diagram, and the plots are numbered consecutively from the bottom also. By using the diagrams, which illustrate how the plots are located from the centre line one can easily locate all plots once only one has been located.

Appendix III continued

Aerial photograph #1. 1978 survey photo #A24986-50.

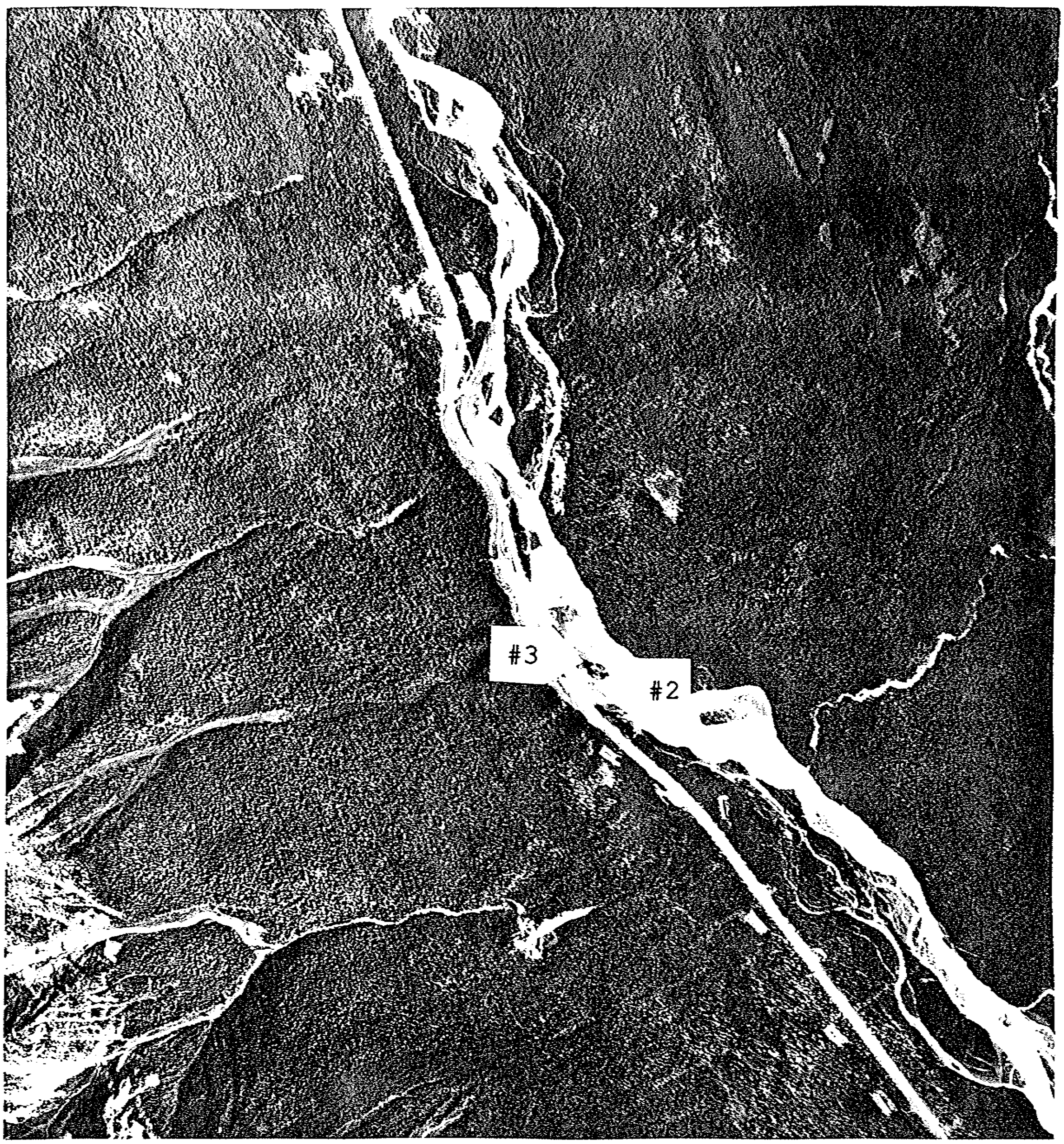
This photograph locates transects #1, #10, and #11. These transects are located in a fluvial meadow, open spruce forest, and open spruce forest, respectively.



Appendix III continued

Aerial photograph #2. 1978 survey photo #A24986-28.

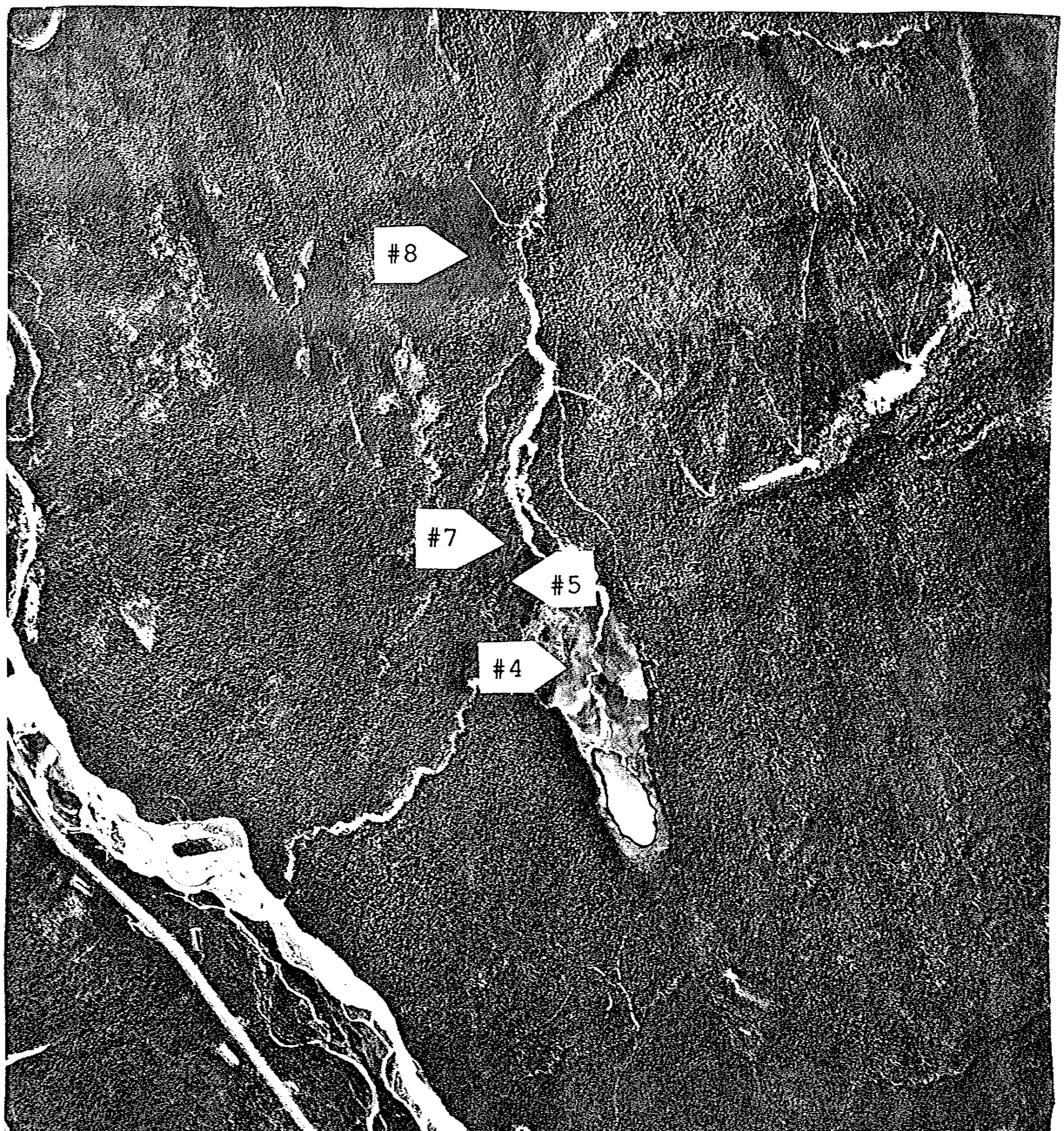
This photograph locates transects #2 and #3, these transects are both located in a fluvial meadow bordering the Kootenay Parkway.



Appendix III continued

Aerial photograph #3. 1978 survey photo #A24986-52.

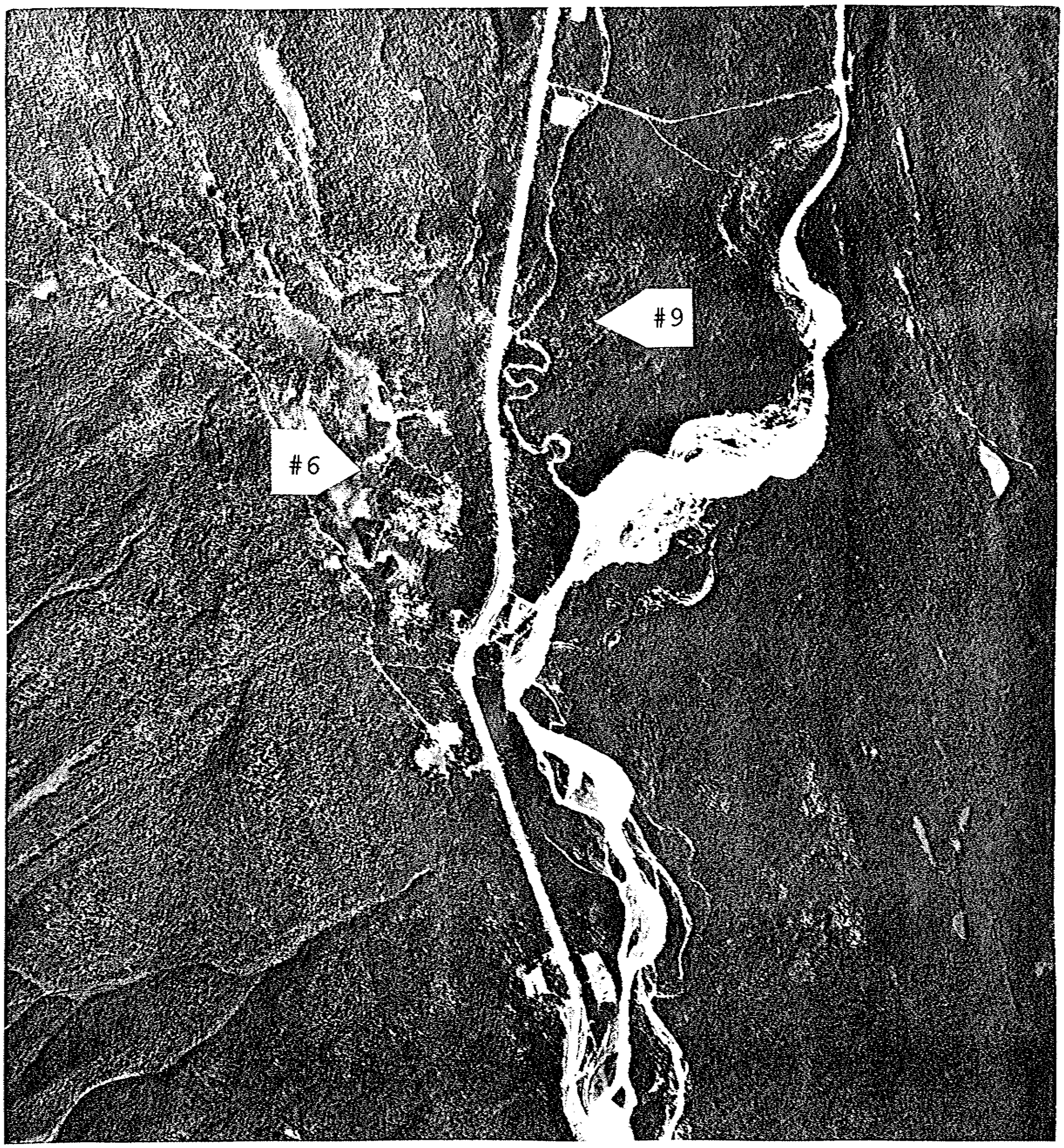
This photograph locates transects #4, #5, #7, and #8. These transects are located in a wet meadow, closed spruce forest, closed spruce forest, and closed pine forest, respectively.



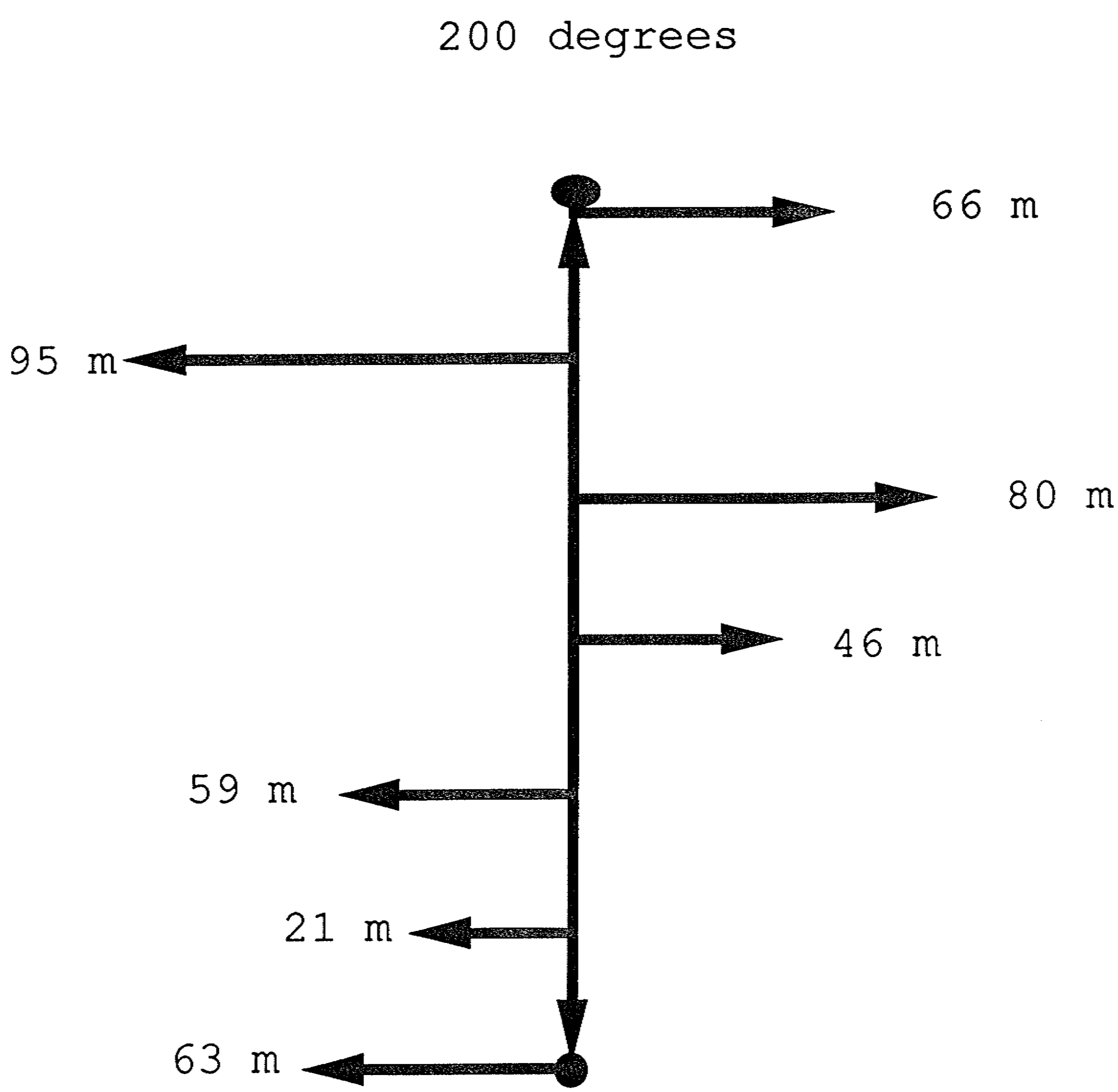
Appendix III continued

Aerial photograph #4. 1978 survey photo #A24986-26.

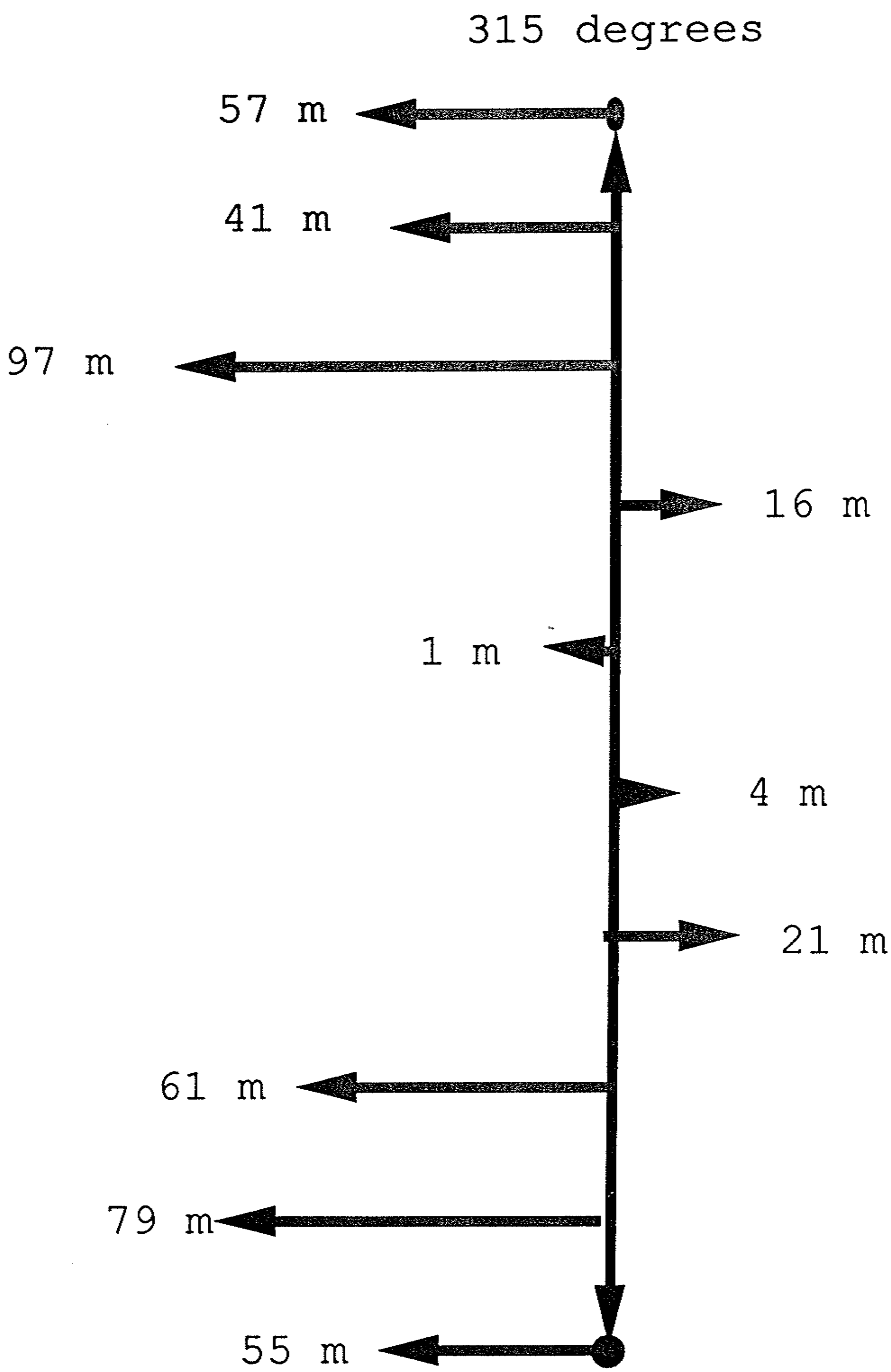
This photograph locates transects #6, and #9. These transects are located in a wet meadow and a closed pine forest, respectively.



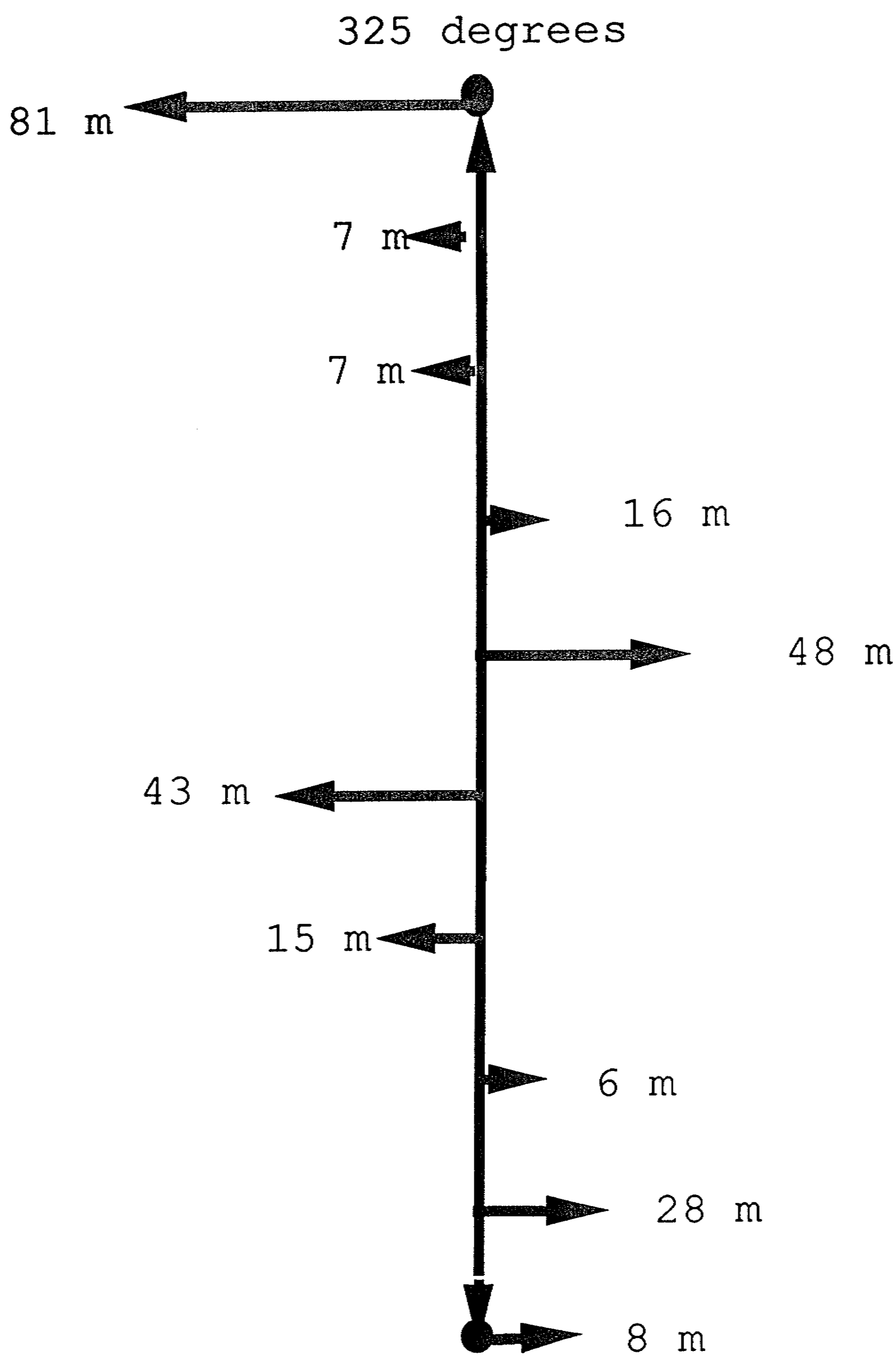
Range Transect 1.



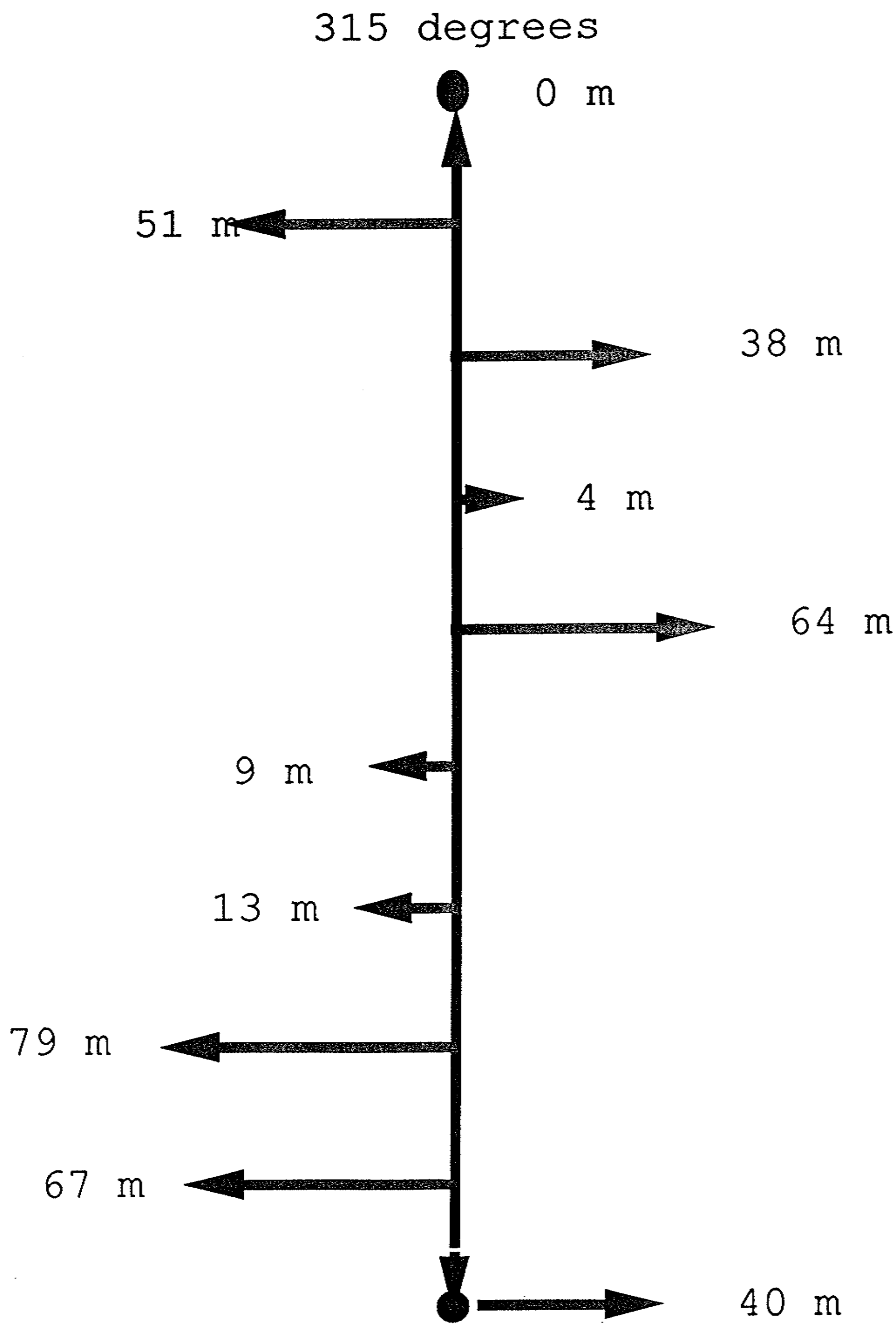
Range Transect 2.



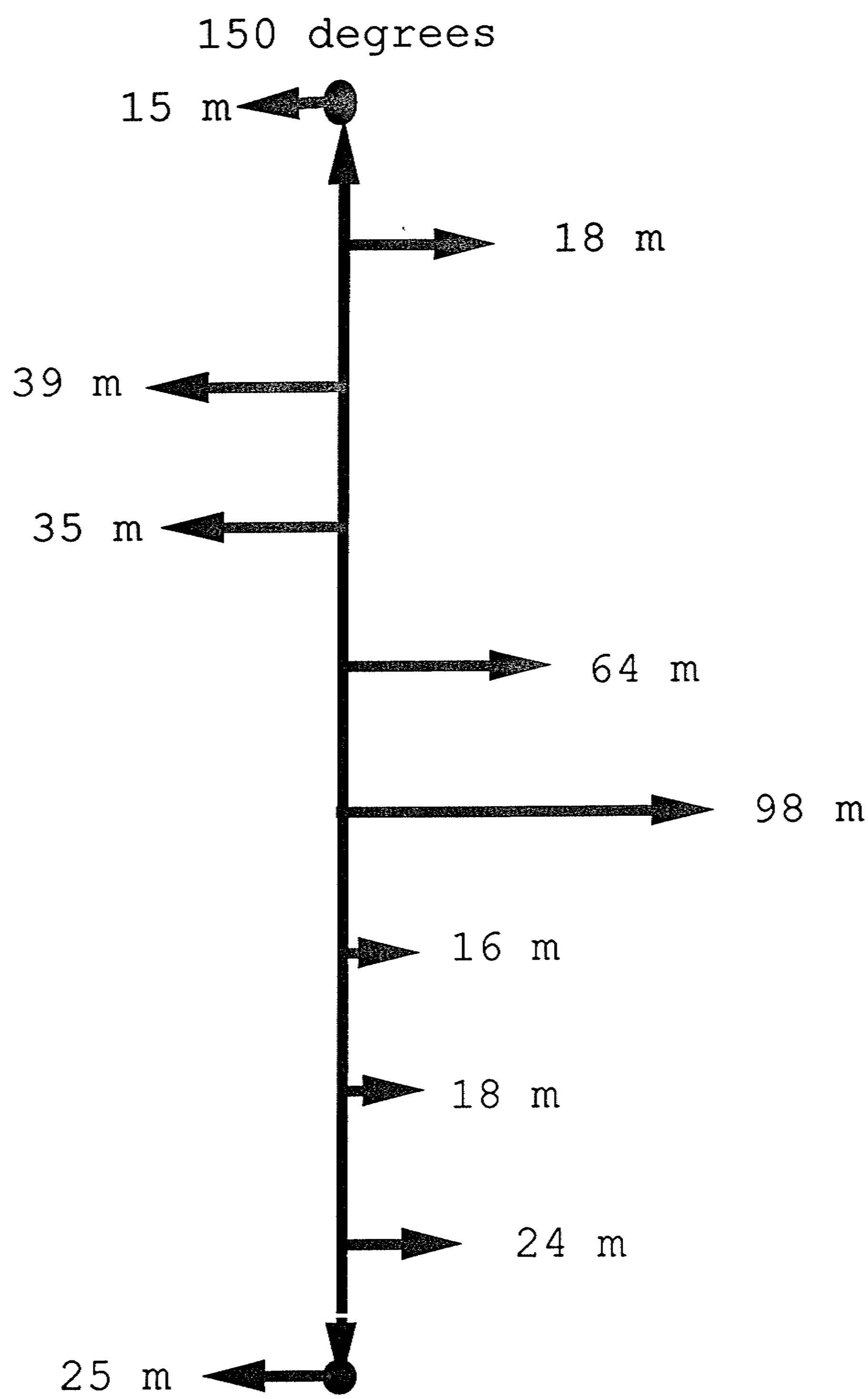
Range Transect 3.



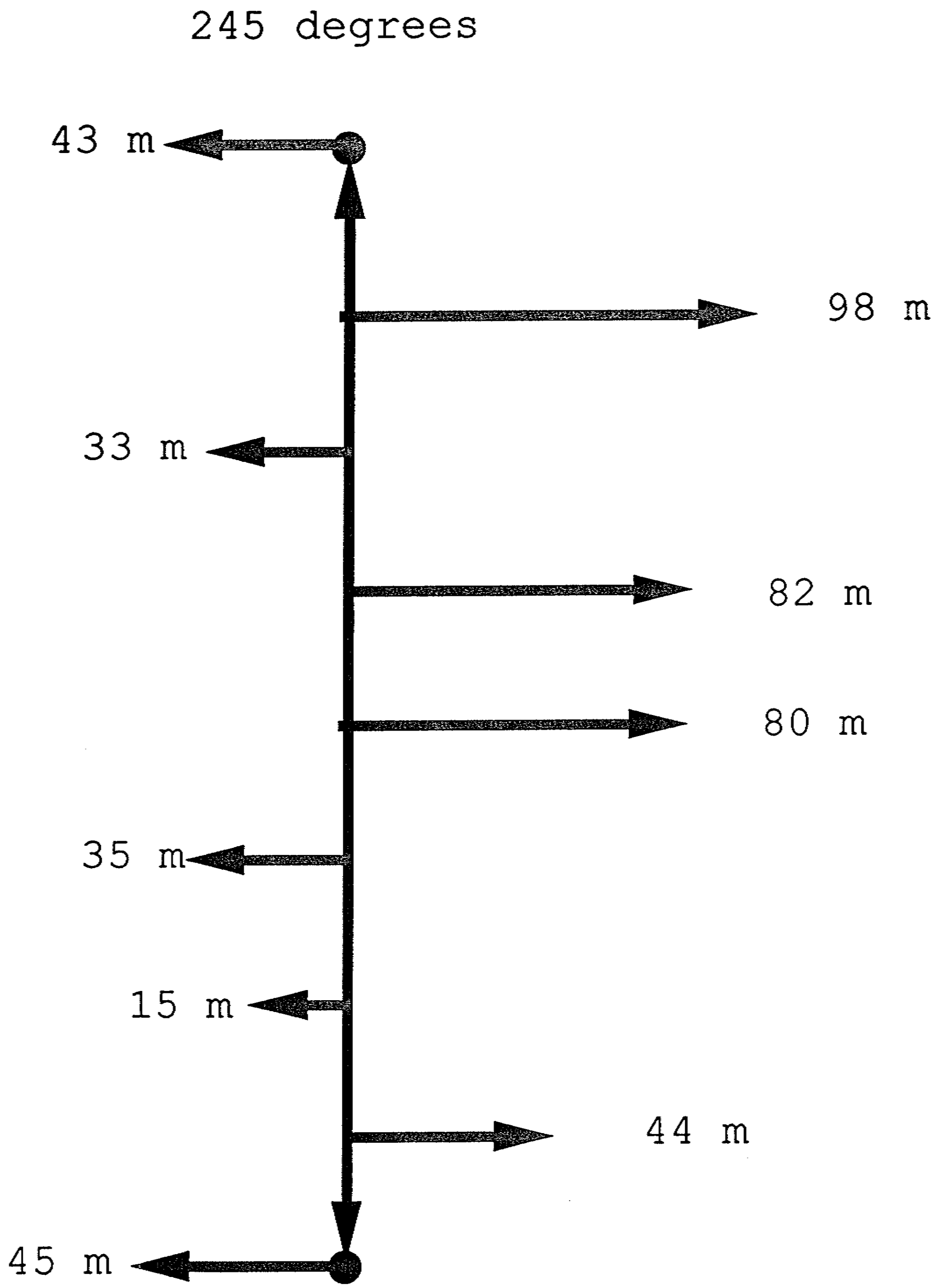
Range Transect 4.



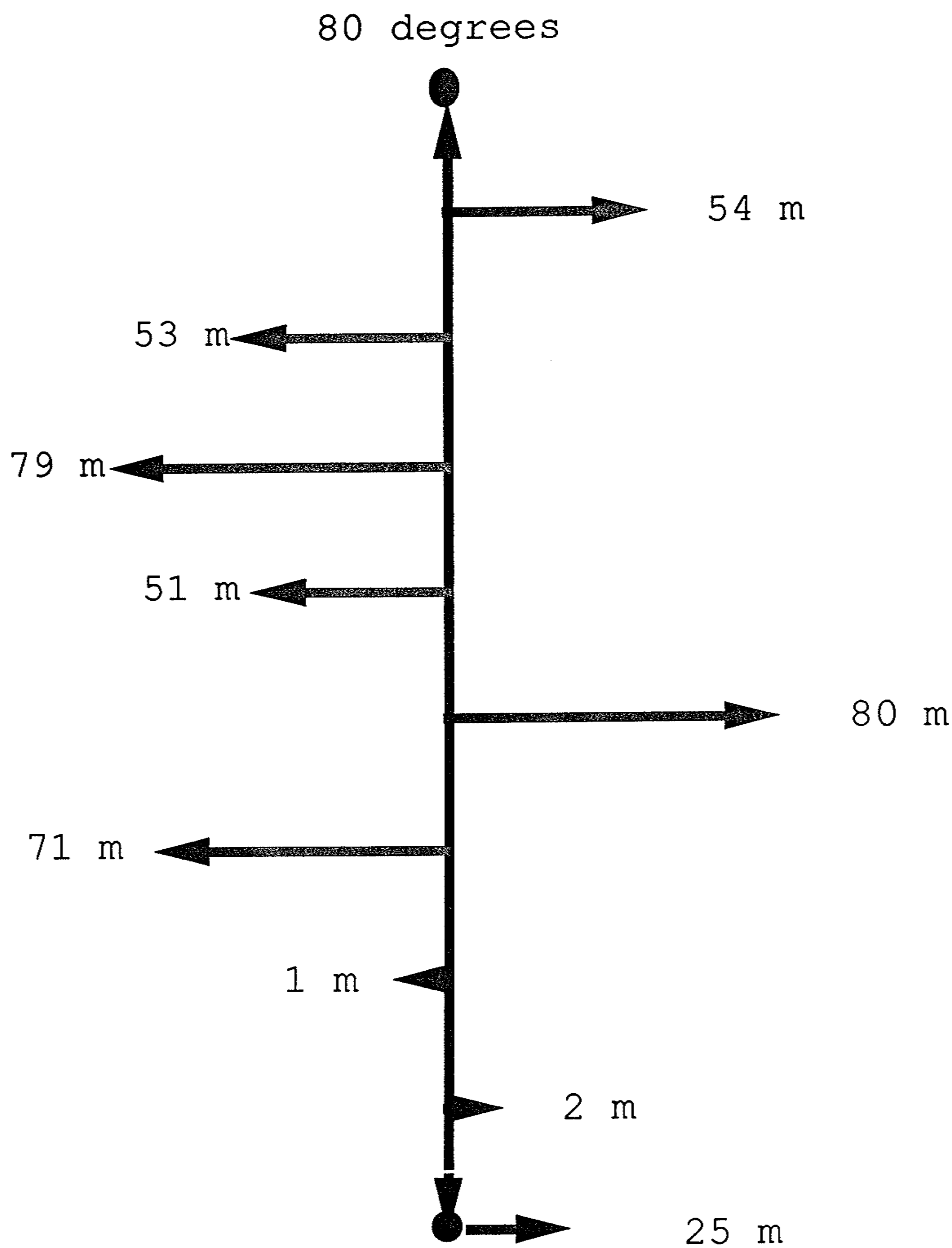
Range Transect 5.



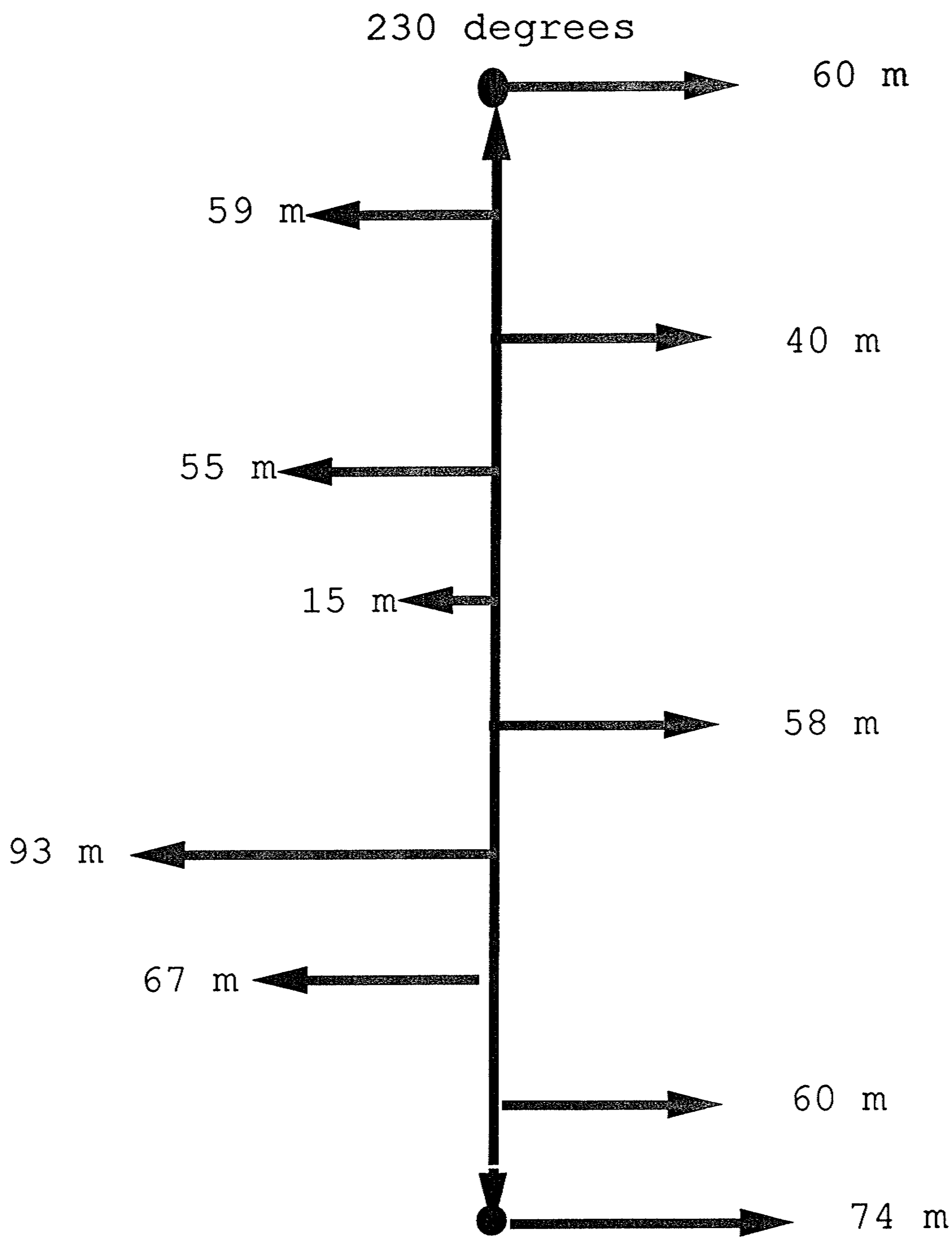
Range Transect 6.



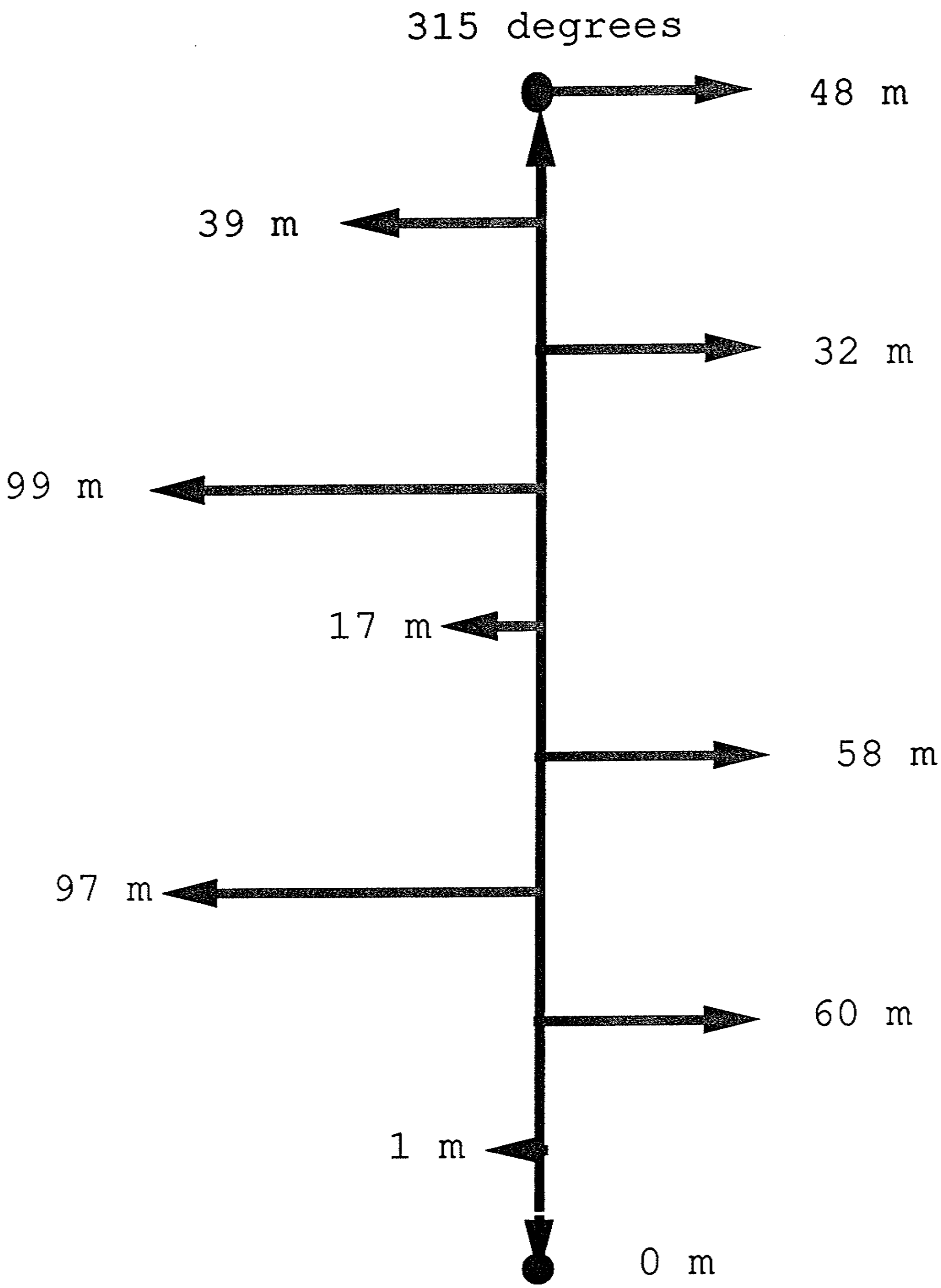
Range Transect 7.



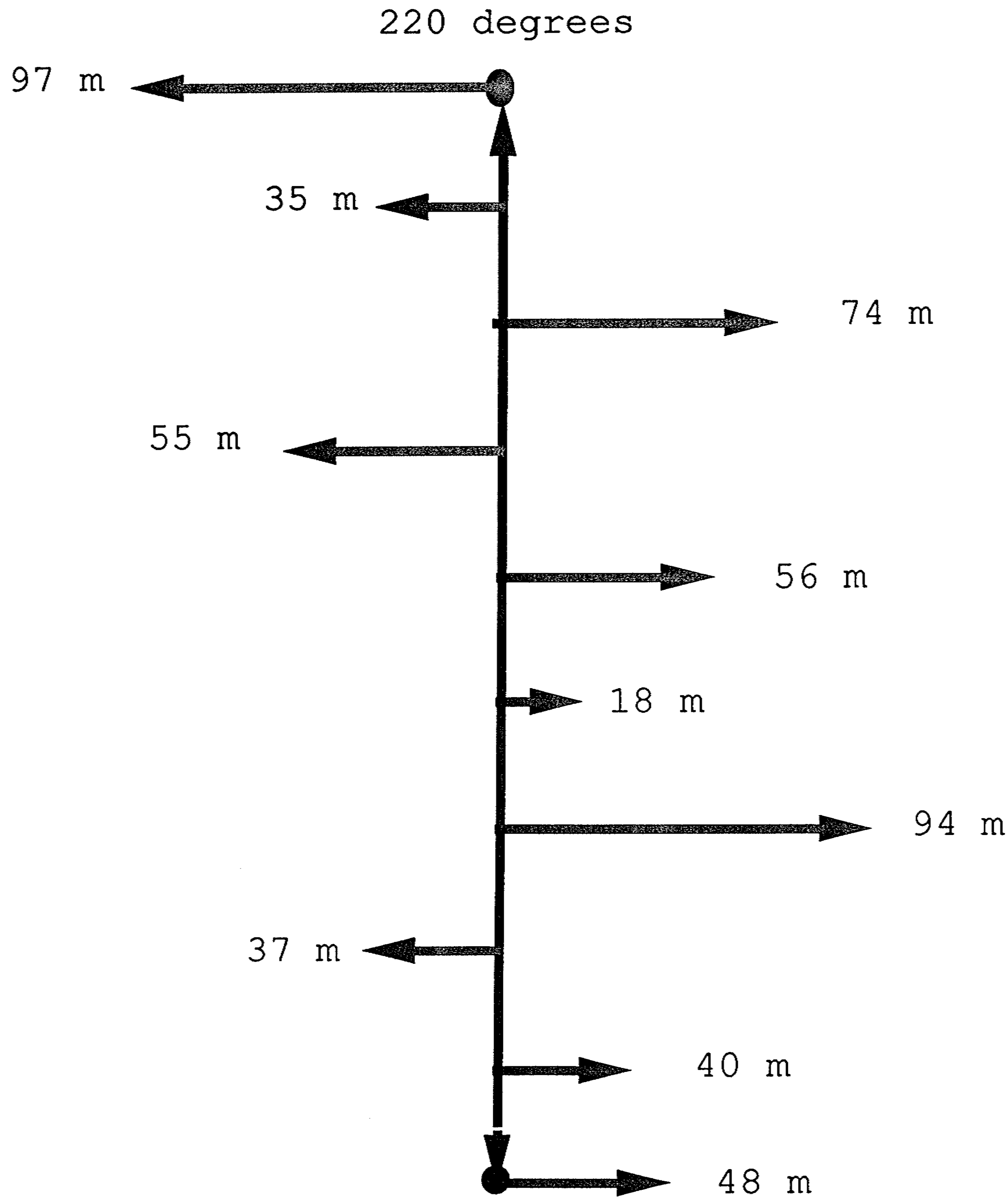
Range Transect 8.



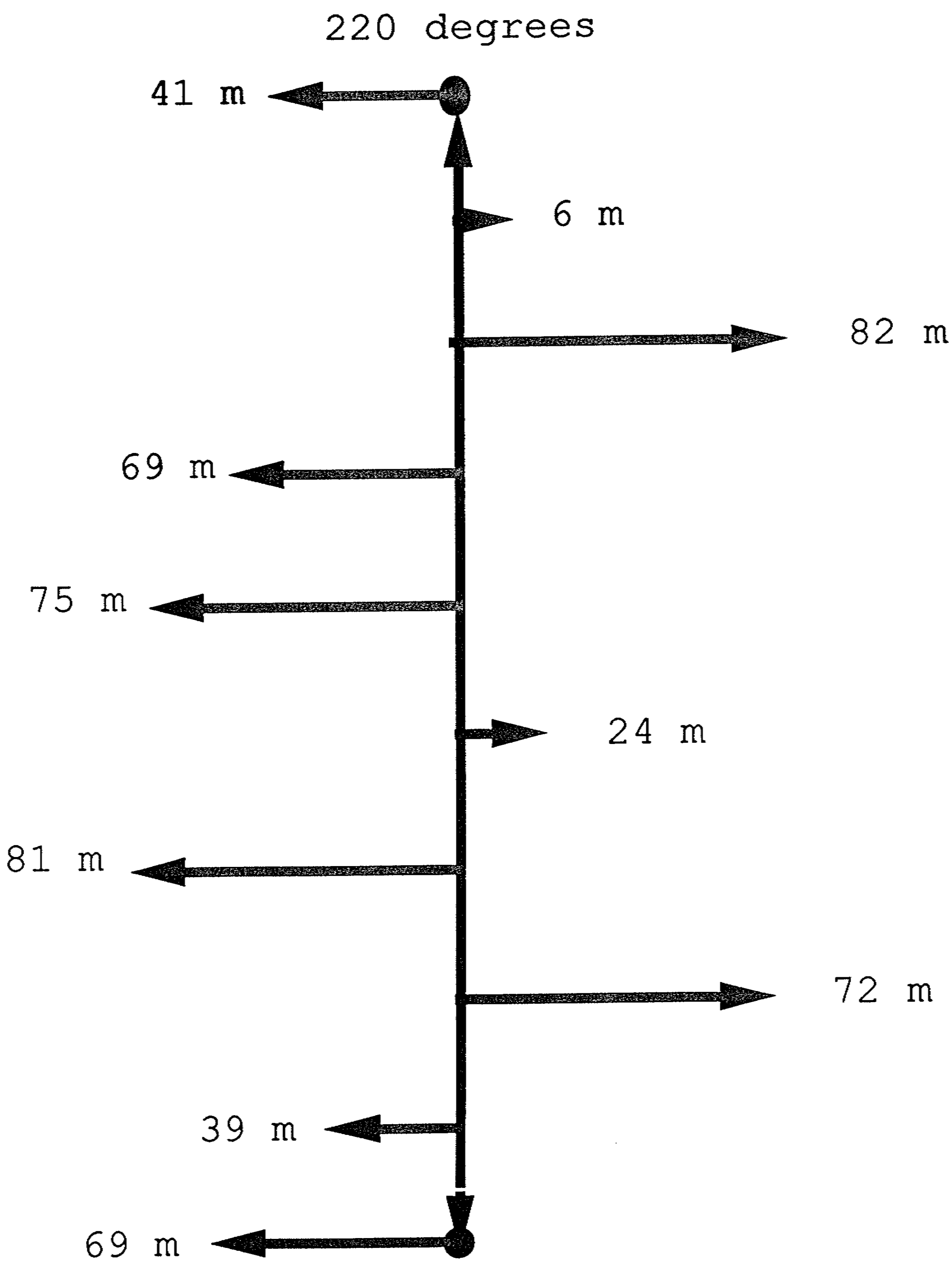
Range Transect 9.



Range Transect 10.



Range Transect 11.



Appendix III concluded.

7.4 APPENDIX IV: Polygon data for 1945 forest coverage.

Appendix IV. KNP 1945 Polygon Data

Polygon Labels	Hectares	Polygon Labels	Hectares
cmw1	447.22	cs/f1	26.22
cmw2	32.08	cs/f2	3.78
cmw3	9.36	cs/f3	6.42
cmw4	10.62	cs/f4	10.37
cmw6	39.71	cs/f5	62.72
cmw7	12.66	cs/f6	8.71
cmw8	20.67	cs/f7	33.05
cmw9	12.64	cs/f8	6.33
cmw10	12.89	cs/f9	275.03
cmw11	55.19	cs/f10	30.32
cmw12	73.94	cs/f11	12.25
cmw13	324.51	cs/f12	25.03
cmw14	4.49	cs/f13	50.92
cmw15	13.22	cs/f14	5.52
cmw16	42.30	cs/f15	4.36
cp1	14.40	cs/f16	35.19
cp3	282.31	cs/f17	12.31
cp4	19.81	cs/f17	12.31
cp5	41.54	cs/f18	220.17
cp6	12.49	cs/f19	2.96
cp7	17.48	cs/f20	20.26
cp8	11.86	cs/f21	137.55
cp9	3.06	cs/f22	351.07
cp10	461.20	cs/f23	83.31
cp11	211.80	cs/f24	16.81
cp12	560.39	cs/f25	120.21
cp13	914.57	cs/f26	1140.77
cp14	107.92	cs/f27	10.92
cp15(e)	233.45	cs/f28	46.70
cp16(e)	93.07	cs/f29	51.97
cp17(e)	35.53	cs/f30(e	79.58
cp18	68.85	cs/f31	41.42
cp19	27.15	cs/f31	45.19
cp2	13.80	cs/f32(e	32.43
cp20	7.05	cs/f33(e)	236.67
cp21	213.46	cs/f34	24.96
cp22	87.78	cs/f35	132.83
cp23	344.67	cs/f36	6.58
cp24	4.22	cs/f37	8.04
cp25	3.99	cs/f38	12.64
cp26	7.35	cs/f39	7.46

Appendix IV continued.

Polygon Labels	Hectares
cs/f40	9.62
cs/f41	131.38
cs/f43	2622.20
cs/f44	2.37
cs/f45	1.08
cs/f46	15.27
cs/f47	330.21
cs/f48	35.37
cs/f49	60.81
cs/f51	2.47
cs/f52	13.02
cs/f53	4.98
cs/f54	7.26
cs/f55	3.25
cs/f55	7.32
cs/f56	72.40
cs/f57	3.33
cs/f58	10.11
cs/f59	3.53
cs/f60	16.24
cs/f61(e)	223.71
cs/f62	14.91
cs/f63(e)	1.39
cs/f64(e)	1.27
cs/f65(e)	2.26
cs/f66(e)	7.16
cs/f67	10.09
cs/f68(e)	5.86
cs/f69(e)	26.42
cs/f70(e)	58.91
cs/f71(e)	46.68
m1	3.84
m2	16.31
m3	168.10
m4	4.10
m5	3.56
m6	20.95
m7	6.48
m8	8.72
m9	4.45
m10	15.50
m12	727.51

Polygon Labels	Hectares
m13	100.03
m14	10.38
m14	10.38
m15	1338.10
m16	28.14
m17	16.50
m18	1486.76
m19	136.83
m20	5.93
m21	25.85
m22	42.16
m23	17.79
m24	5.35
m25	3.33
m26	31.64
m27	10.91
m28	24.41
m29	8.35
m30	221.80
m31(e)	51.87
m32	33.41
m32	52.27
m34	227.05
m35	14.77
m36	3.50
m37	607.79
m38(e)	37.27
m39(e)	6.06
m40	14.96
m41	7.38
m42(e)	51.91
m43(e)	280.45
m44(e)	26.32
m45(e)	13.86
m46(e)	25.73
m47(e)	29.16
m48(e)	103.23
m49(e)	27.97
m50	88.26
m50(e)	19.22
m51	1.83
m52	3.21

Appendix IV continued

Polygon Labels	Hectares	Polygon Labels	Hectares
m53	7.96	os/f16	3.95
m54	4.87	os/f17	39.71
m55	187.59	os/f18	1681.74
m56	55.59	os/f19	14.55
m57	64.28	os/f20	19.59
m58	12.06	os/f21	46.11
m59	3.18	os/f22	7.74
m61	23.20	os/f23	261.19
m62	2.35	os/f24(e)	19.68
m63	29.82	os/f25	56.77
m64	5.94	os/f26(e)	22.76
m65	7.11	os/f27	52.93
m66	3.32	os/f28(e)	47.83
m67	2075.21	os/f29	48.12
m68	0.07	os/f30	9.82
m69(e)	3822.75	os/f31	13.95
omw1	70.91	os/f32	57.18
omw2	2.15	os/f33	33.10
omw3	453.10	os/f34	21.86
omw4	179.28	os/f36(e)	18.67
omw5	48.58	os/f37	6.73
omw6	12.48	os/f38	68.05
omw7	57.05	os/f39	11.83
omw8(e)	37.27	os/f40	36.97
op1	21.57	os/f41	3.31
os/f1	33.22	os/f41(e)	524.33
os/f2	163.55	os/f42(e)	24.16
os/f3	14.54	wm1	7.48
os/f4	132.85	wm2	7.12
os/f5	23.44	wm3	39.54
os/f6	35.10	wm4	5.73
os/f7	28.59	wm5	50.42
os/f8	21.38	wm6	6.98
os/f9	5.22	wm7	4.92
os/f10	13.63	wm8	36.60
os/f11	74.51	wm9	2.32
os/f12	4.79	wm10	2.84
os/f13	10.35	wm11	1.24
os/f14	46.36	wm12	2.87
os/f15	16.45	wm13	52.44
		wm14	5.74

Appendix IV continued

Polygon Labels	Hectares
wm15	30.05
wm16	1.76
wm17	3.50
wm18	7.81
wm19	82.47
wm20	40.33
wm21	3.15
wm22	4.06
wm23	11.86
wm24	16.89
wm25	5.09

Appendix IV concluded.

7.5 APPENDIX V: Polygon data for 1978 forest coverage.

Appendix V.   KNP 1978 Polygon Data

Polygon Label	Hectares
cmw1	4.19
cmw2	230.27
cmw3	704.41
cmw4	334.31
cmw5	37.37
cp1	327.09
cp2	57.31
cp3	23.32
cp4	164.63
cp5	39.54
cp6	13.61
cp7	9.23
cp8	26.63
cp9	42.23
cp10	11.31
cp11	1.90
cp12	8.47
cp13	65.10
cp14	666.56
cp15	1342.92
cp16	1290.20
cp17	257.64
cp18	143.97
cp19	28.34
cp20	140.34
cp21	8.90
cp22	43.89
cp23	4.82
cp24	7.85
cp25	28.41
cp26	14.72
cp27	24.38
cp28	231.51
cp29	345.28
cp30	187.63
cp31	38.53
cp32	43.85
cp34	13.86
cp35	19.20
cp36	146.15
cp37	3.13
cp38	6.06

Polygon Label	Hectares
cp39	14.60
cp40	2.37
cp41	189.24
cp42	432.11
cp43	855.97
cp44	1037.73
cp45	24.64
cp46	11.48
cp47	3.34
cp48	3.76
cp49	942.62
cp50	277.26
cp51	95.02
cp52	32.06
cp53	8.76
cp54	3863.12
cp55	28.87
cp56	387.75
cp57	35.91
cp58	1713.79
cs/f1	85.67
cs/f2	291.49
cs/f3	185.02
cs/f4	207.71
cs/f5	778.45
cs/f6	284.28
cs/f7	7.83
cs/f8	27.89
cs/f9	49.96
cs/f10	13.67
cs/f11	3.63
cs/f12	21.64
cs/f13	44.49
cs/f14	6.66
cs/f15	10.43
cs/f16	127.36
cs/f17	25.93
cs/f18	19.62
cs/f19	3676.73
cs/f20	3745.20
cs/f21	32.15

Appendix V continued

Polygon Label	Hectares
cs/f22	30.96
cs/f23	24.44
cs/f24	3.54
cs/f25	42.94
cs/f26	59.84
cs/f27	145.72
cs/f28	470.02
cs/f29	277.61
cs/f30	155.13
cs/f31	38.54
cs/f32	157.66
cs/f33	9.88
cs/f34	168.99
cs/f35	23.45
cs/f36	8.75
cs/f37	12.21
cs/f38	9.26
cs/f39	3.26
cs/f40	2.17
cs/f41	1.20
cs/f42	3.18
cs/f43	7.42
cs/f44	18.21
cs/f45	5.36
cs/f46	26.30
cs/f47	4.97
cs/f48	59.84
cs/f49	46.20
cs/f50	823.23
cs/f51	6.94
cs/f52	2.32
cs/f53	17.51
cs/f54	6.50
cs/f55	304.85
m1	2.02
m2	7.33
m3	6.54
m4	17.71
m5	9.73
m6	8.18
m7	5.26

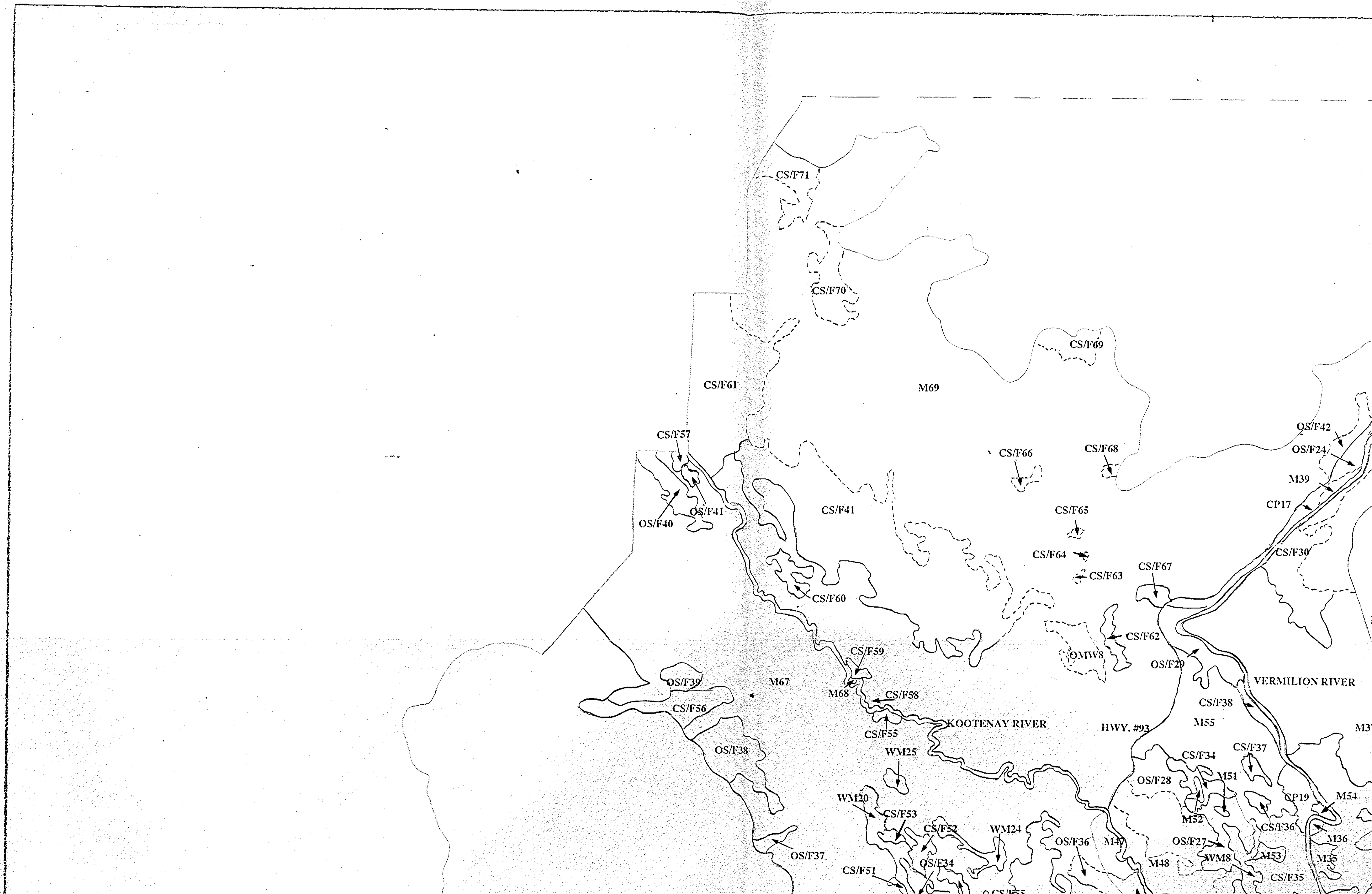
Polygon Label	Hectares
m8	5.60
m9	3.33
m10	7.49
m11	20.11
m12	20.03
m13	3.36
m14	11.08
m15	34.61
m16	23.47
m17	8.70
m18	9.01
m19	1.92
m20	11.66
m21	6.32
m22	22.92
m22	21.72
m23	21.46
m24	3.56
m25	35.19
m26	8.16
m27	1.49
m28	7.98
m29	16.36
m30	8.67
m31	25.30
m32	17.16
m33	8.19
m34	12.72
omw1	33.01
omw2	34.39
omw3	109.39
op1	19.88
os/f1	401.81
os/f2	45.24
os/f3	56.41
wm1	2.07
wm2	2.83
wm3	9.78
wm4	6.10
wm5	63.87

Appendix V continued

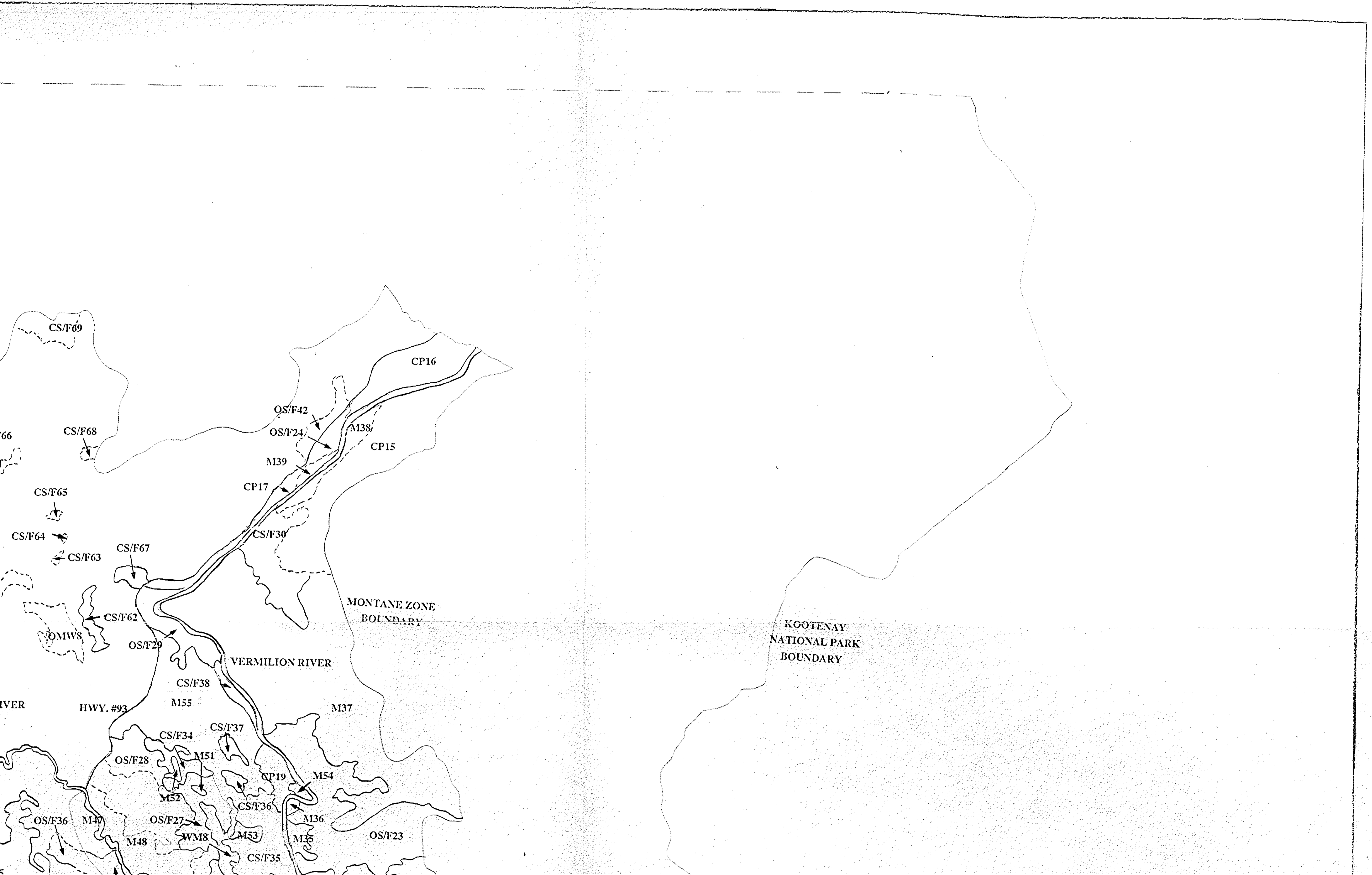
Polygon Label	Hectares
wm6	10.70
wm7	1.89
wm8	7.31
wm9	2.06
wm10	5.43
wm11	29.00
wm12	5.16
wm13	7.67
wm14	9.58
wm15	28.62
wm16	6.48
wm17	45.68
wm18	3.25
wm19	24.73
wm20	2.86
wm21	1.41
wm22	12.55
wm23	3.19
wm24	3.68
wm25	10.22
wm26	39.01
wm27	12.85
wm28	2.19
wm29	1.82
wm30	0.70

Appendix V concluded.

7.6 APPENDIX VI: Maps.

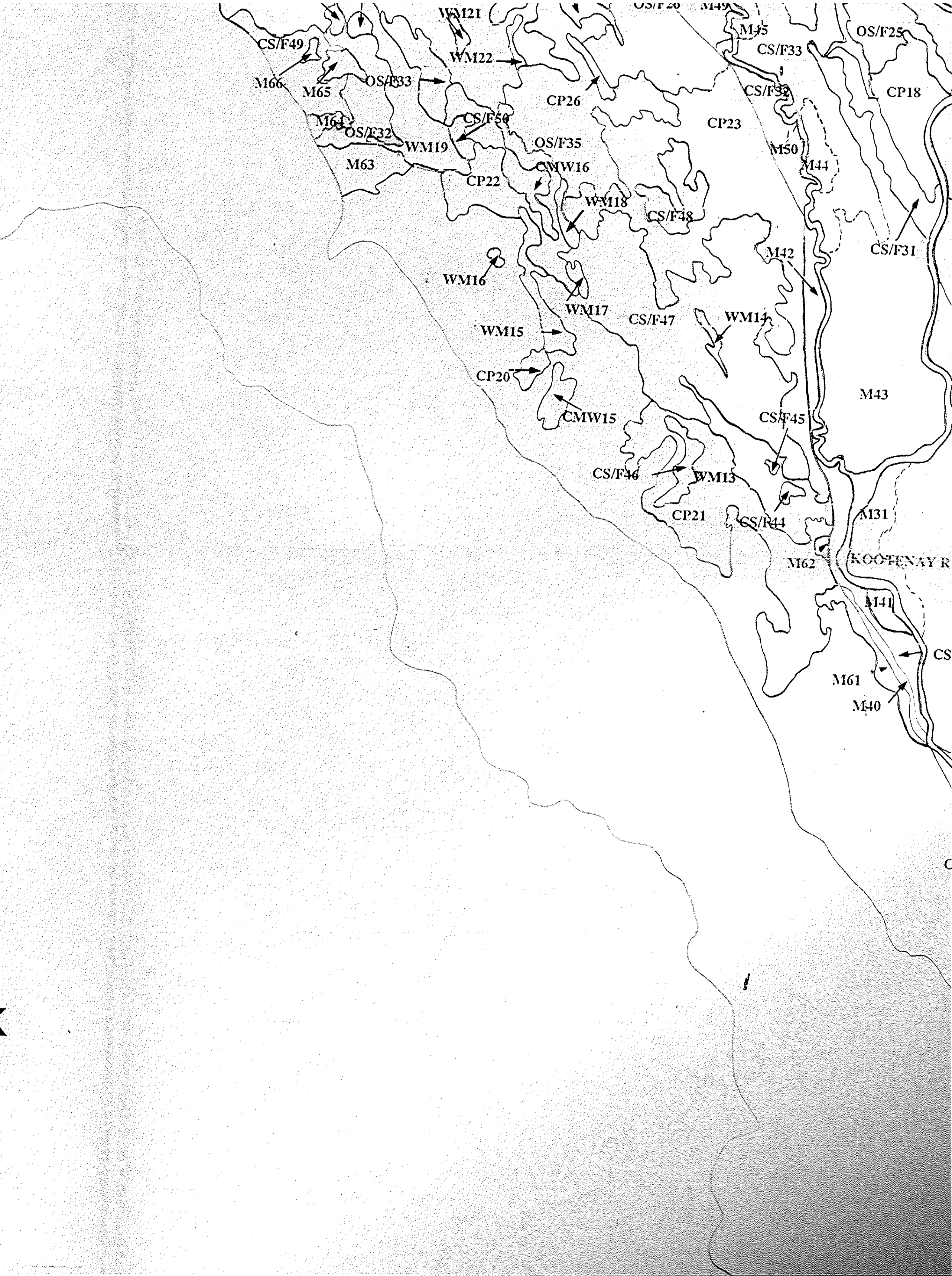


CS/F71
CS/F70
CS/F69
M69
CS/F61
CS/F57
CS/F66
CS/F68
OS/F42
OS/F24
M39
CP17
OS/F41
OS/F40
CS/F41
CS/F65
CS/F30
CS/F64
CS/F63
CS/F67
CS/F60
CS/F62
OMW8
OS/F29
CS/F59
VERMILION RIVER
M67
OS/F39
M68
CS/F58
CS/F38
CS/F56
KOOTENAY RIVER
HWY. #93
M55
CS/F55
CS/F37
OS/F38
WM25
CS/F34
OS/F28
M51
CP19
M54
WM20
M52
CS/F53
CS/F36
CS/F52
WM24
OS/F36
M36
OS/F27
OS/F37
WM8
M53
M35
M48
CS/F51
OS/F34
CS/F35



CS/F69
CP16
OS/F42
OS/F24
M38
CP15
CS/F68
66
M39
CP17
CS/F65
CS/F30
CS/F64
CS/F67
CS/F63
MONTANE ZONE
BOUNDARY
KOOTENAY
NATIONAL PARK
BOUNDARY
CS/F62
OMW8
OS/F29
VERMILION RIVER
CS/F38
IVER
HWY. #93
M55
M37
CS/F34
CS/F37
OS/F28
M51
CP19
M54
M52
CS/F36
OS/F36
M47
OS/F27
M36
WM8
M53
M35
OS/F23
M48
CS/F35

1945 FOREST CANOPY CLASSIFICATION OF THE KOOTENAY VALLEY KOOTENAY NATIONAL PARK




M34
CP18
CP14
OMW7
CP26
CS/F32
CP23
CS/F28
OS/F35
M50
OMW6
M44
CMW16
OMW5
WM18
M33
CS/F48
CS/F31
M42
CS/F27
M32
CMW13
WM17
CS/F47
WM14
CS/F29
CMW12
M43
CP13
CMW15
CS/F45
OMW4
CS/F46
WM13
CS/F26
OS/F21
CP21
CS/F44
M31
M62
KOOTENAY RIVER
M30
CS/F25
M29
M26
CP12
M41
WM7
CS/F23
CS/F31
WM6
M61
CMW12
M40
WM5
CS/F24
CMW9
CP11
CMW11
OMW3
M28
CMW10
CMW8
CS/F40
M60
OS/F31
CS/F39
OS/F20
WM4
M27
OS/F19
OS/F30
M58
WM3
CS/F41
M56
M57
CP10
CMW14
OS/F18
M25
WM1
WM12
M24
WM2
M23
CS/F43
CS/F42
CP9
WM11

MAP LEGEND

MAP SYMBOLS	FOREST CATEGORIES
CP	Closed Pine
OP	Open Pine
CS/F	Closed Spruce/Fir
OS/F	Open Spruce/Fir
CMW	Closed Mixedwood
OMW	Open Mixedwood
M	Meadow
WM	Wet Meadow

<u>Example</u>:

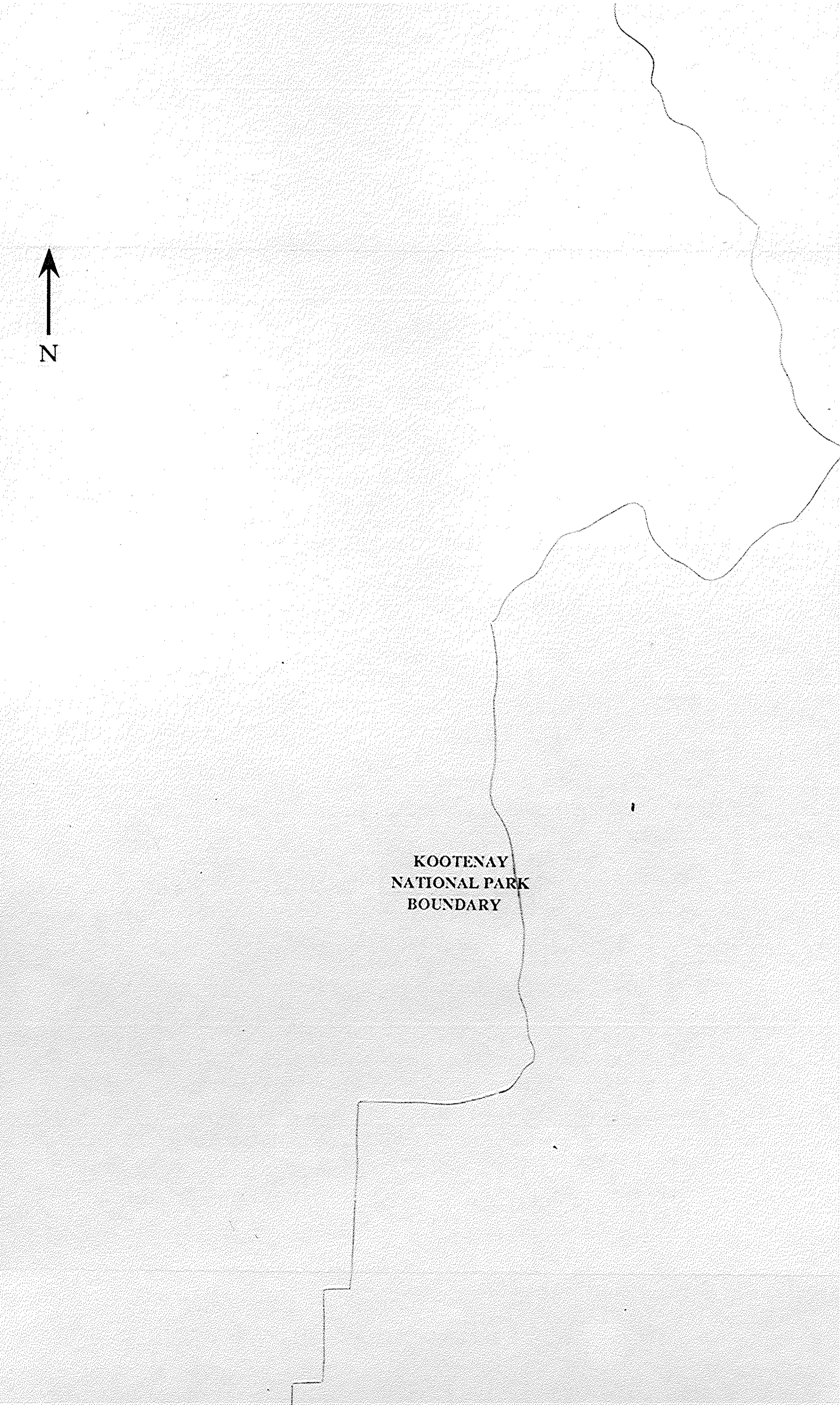
forest category

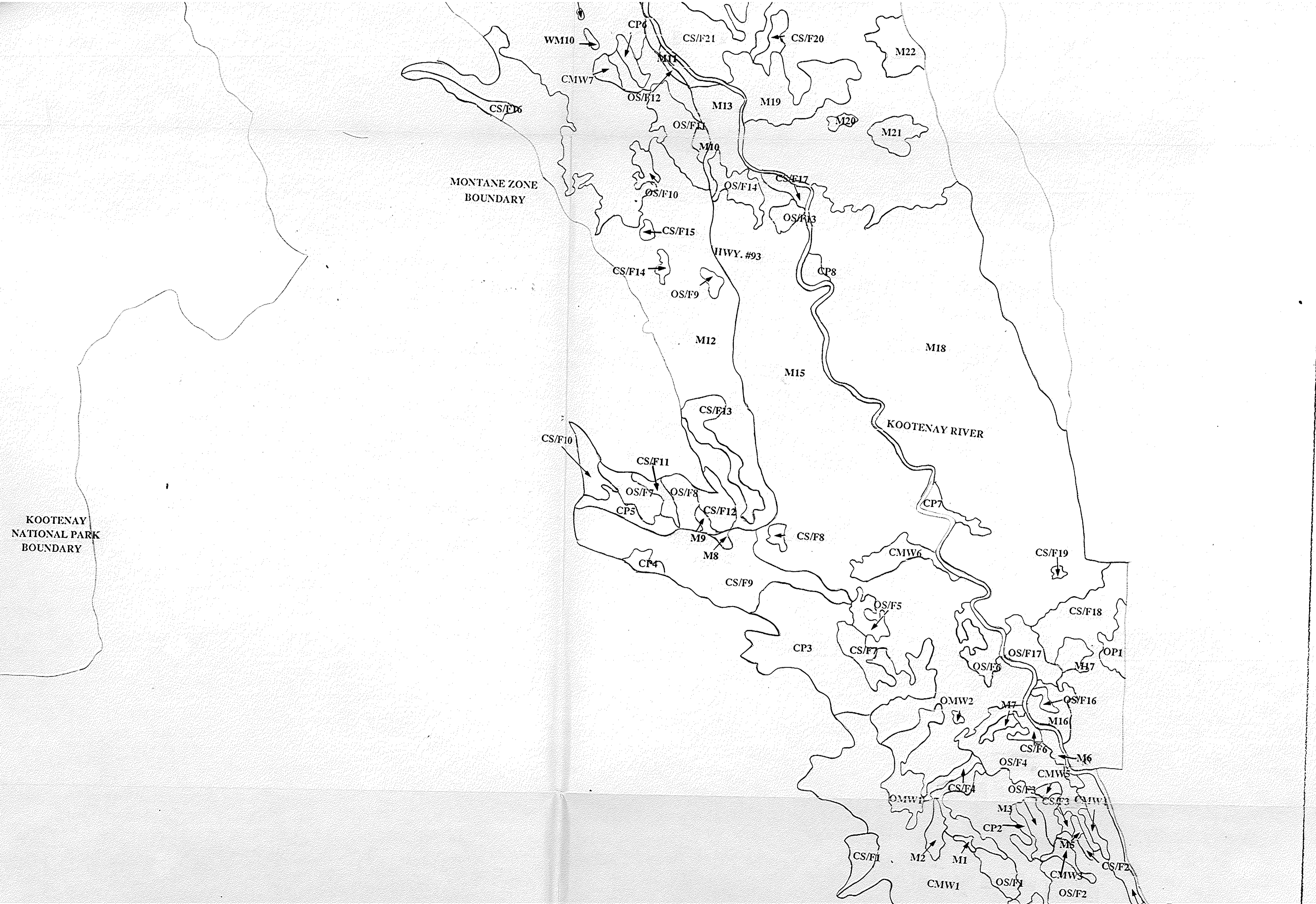
CP 20

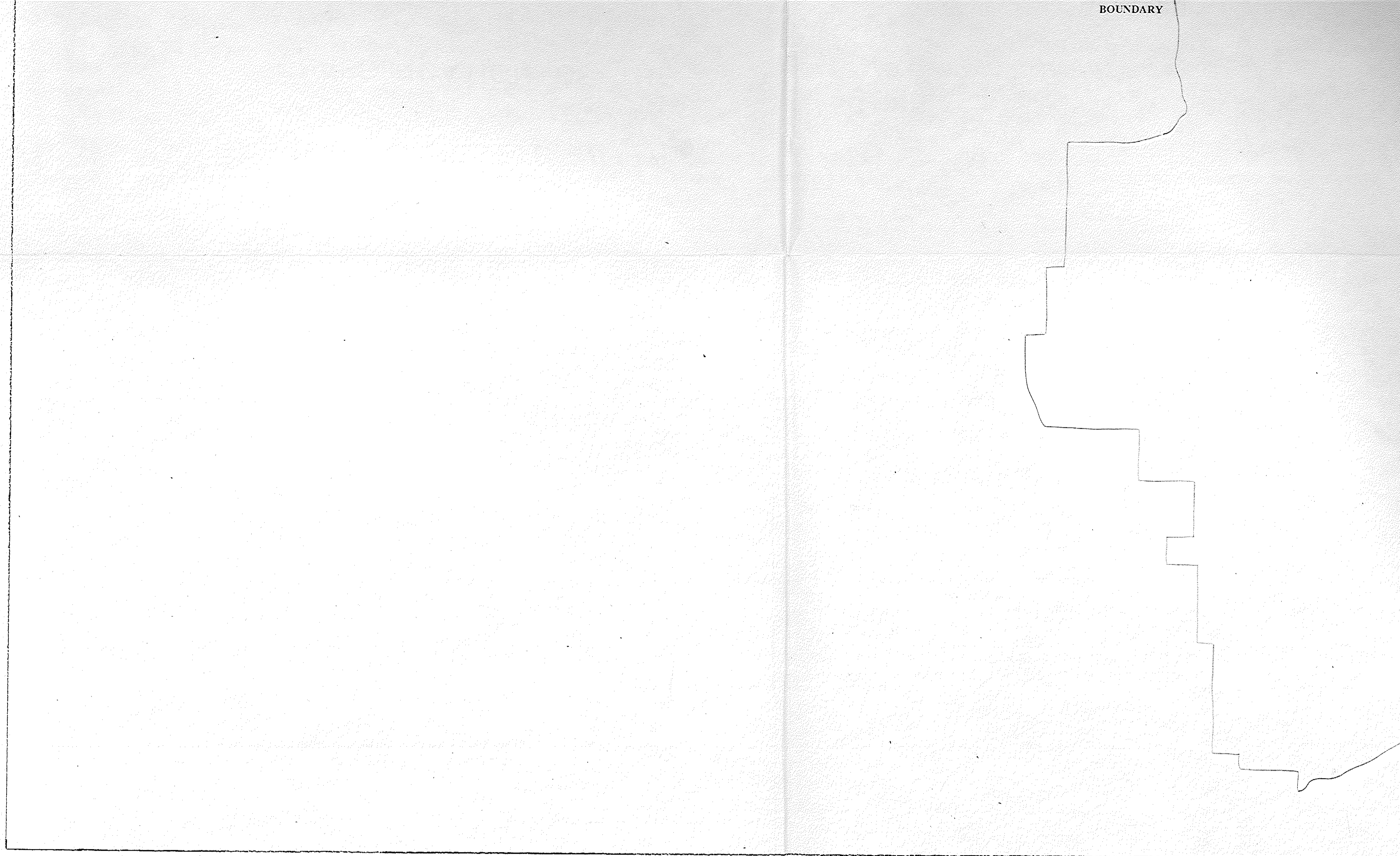
polygon number*

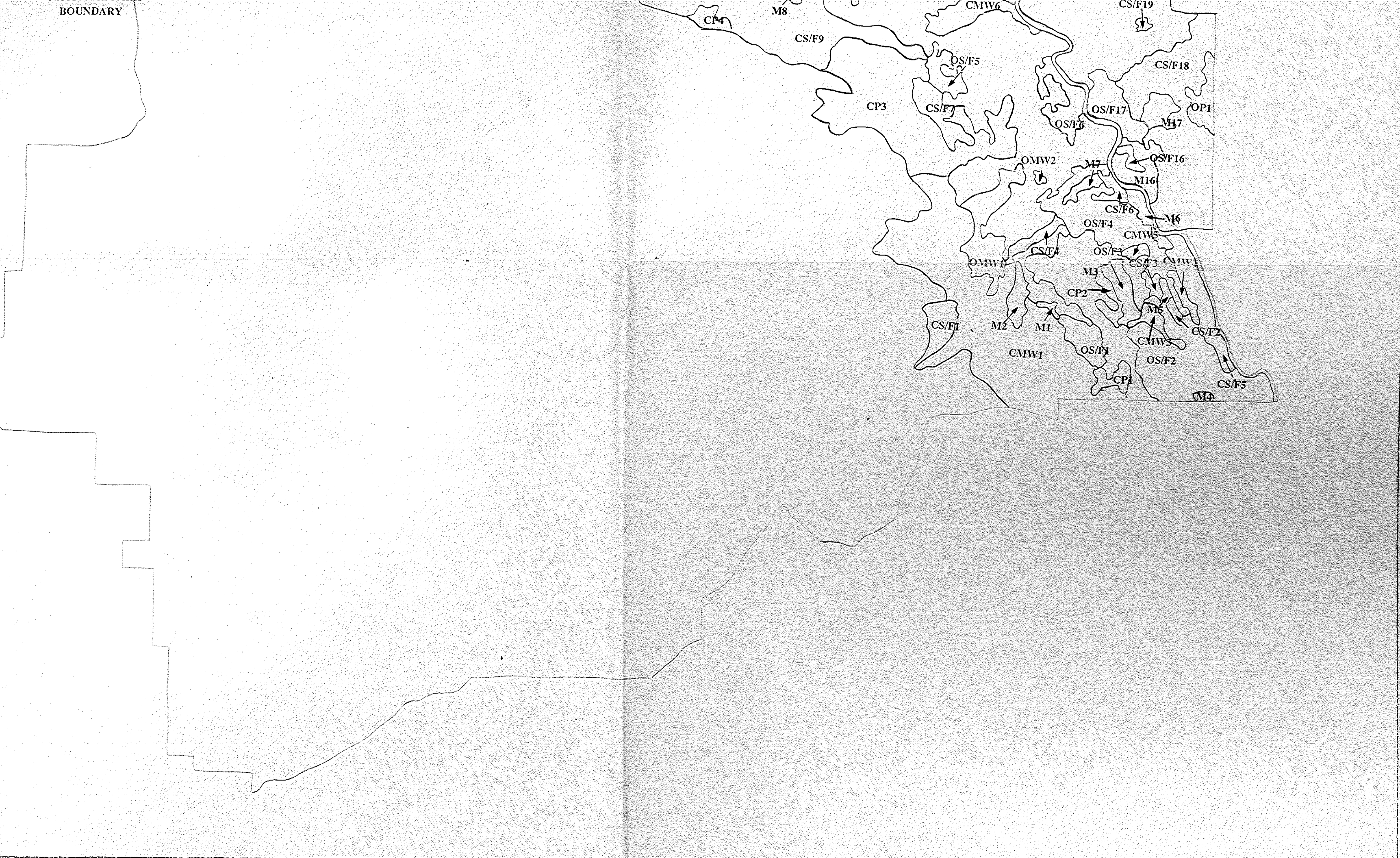
* polygon number and segment number may be referenced in Appendix 6 for site specific data

Map scale 1:50000
Dashed lines are estimated boundaries




CP6
WM10
CS/F21
CS/F20
M22
M11
CMW7
OS/F12
CS/F16
M13
M19
OS/F11
M20
M21
M10
MONTANE ZONE
BOUNDARY
CS/F17
OS/F14
OS/F10
OS/F13
CS/F15
HWY. #93
CS/F14
CP8
OS/F9
M12
M18
M15
CS/F13
KOOTENAY RIVER
CS/F10
CS/F11
OS/F7
OS/F8
CP7
CP5
CS/F12
KOOTENAY
NATIONAL PARK
BOUNDARY
M9
CS/F8
M8
CMW6
CS/F19
CP4
CS/F9
OS/F5
CS/F18
CP3
CS/F7
OS/F17
OP1
OS/F6
M17
OMW2
M7
OS/F16
M16
CS/F6
M6
OS/F4
CMW5
CS/F4
OS/F3
OMW1
CS/F3
CMW1
M3
CP2
M5
CS/F1
M2
M1
CMW3
CS/F2
CMW1
OS/F1
OS/F2


BOUNDARY


BOUNDARY
CMW6
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CP4
M8
CS/F9
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CS/F18
CP3
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OS/F17
OP1
OS/F6
M17
OMW2
M7
OS/F16
M16
CS/F6
M6
OS/F4
CMW5
CS/F4
OS/F3
CS/F3
CMW1
OMW1
M3
CP2
CS/F1
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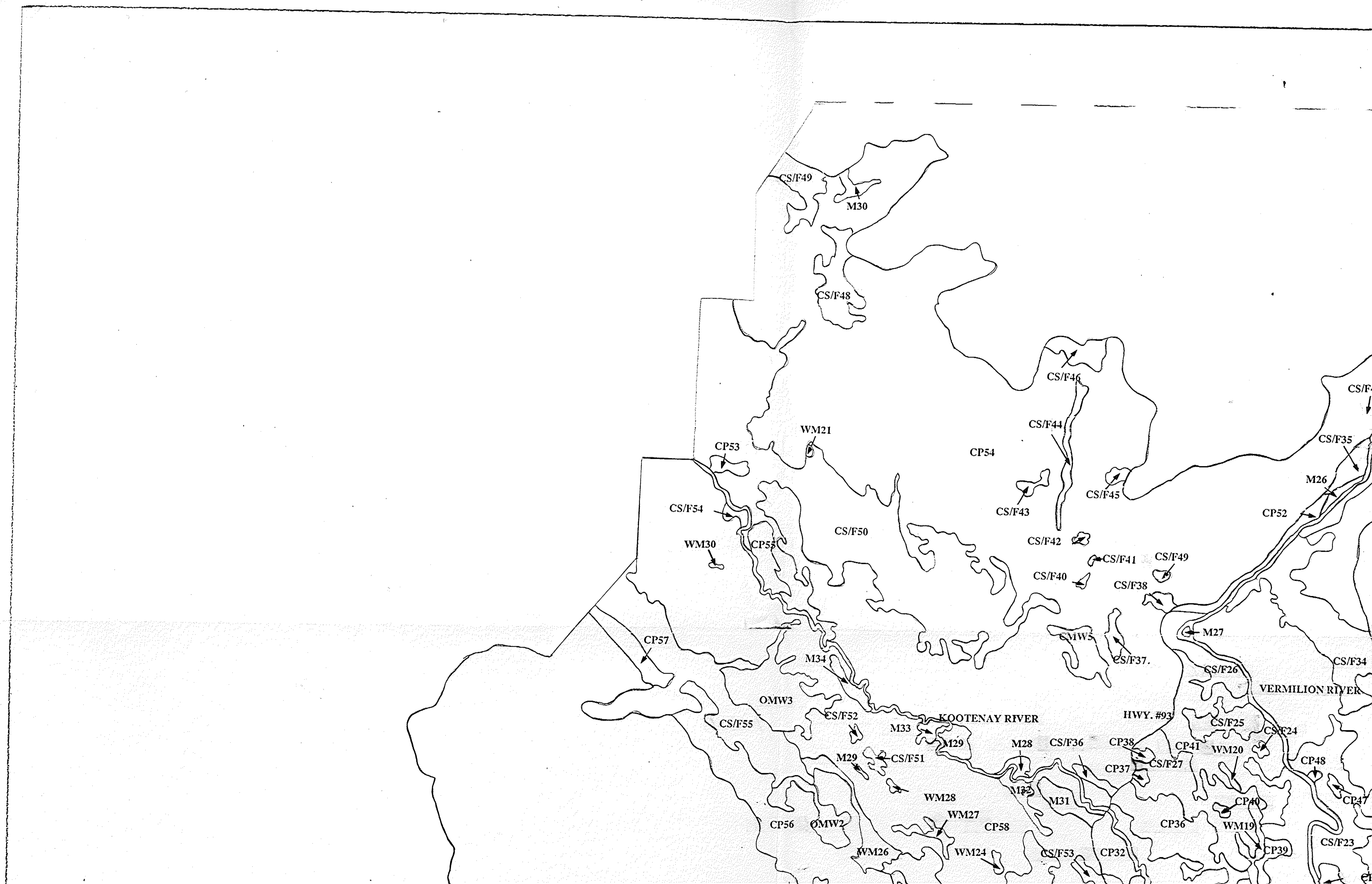
M5
CS/F2
CMW3
CMW1
OS/F1
OS/F2
CP1
CS/F5
M4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CS/F44
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WM21
CP53
CS/F43
CS/F45
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CS/F54
CS/F50
WM30
CP55
CS/F42
CS/F41
CS/F49
CS/F40
CS/F38
M27
CMW5
CS/F37.
CP57
M34
CS/F34
CS/F26
VERMILION RIVER
OMW3
CS/F52
KOOTENAY RIVER
HWY. #93
CS/F55
M33
M29
CS/F25
CS/F24
M28
CS/F36
CP38
CP41
WM20
M29
CS/F51
CS/F27
CP48
CP37
M32
M31
CP40
CP47
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WM27
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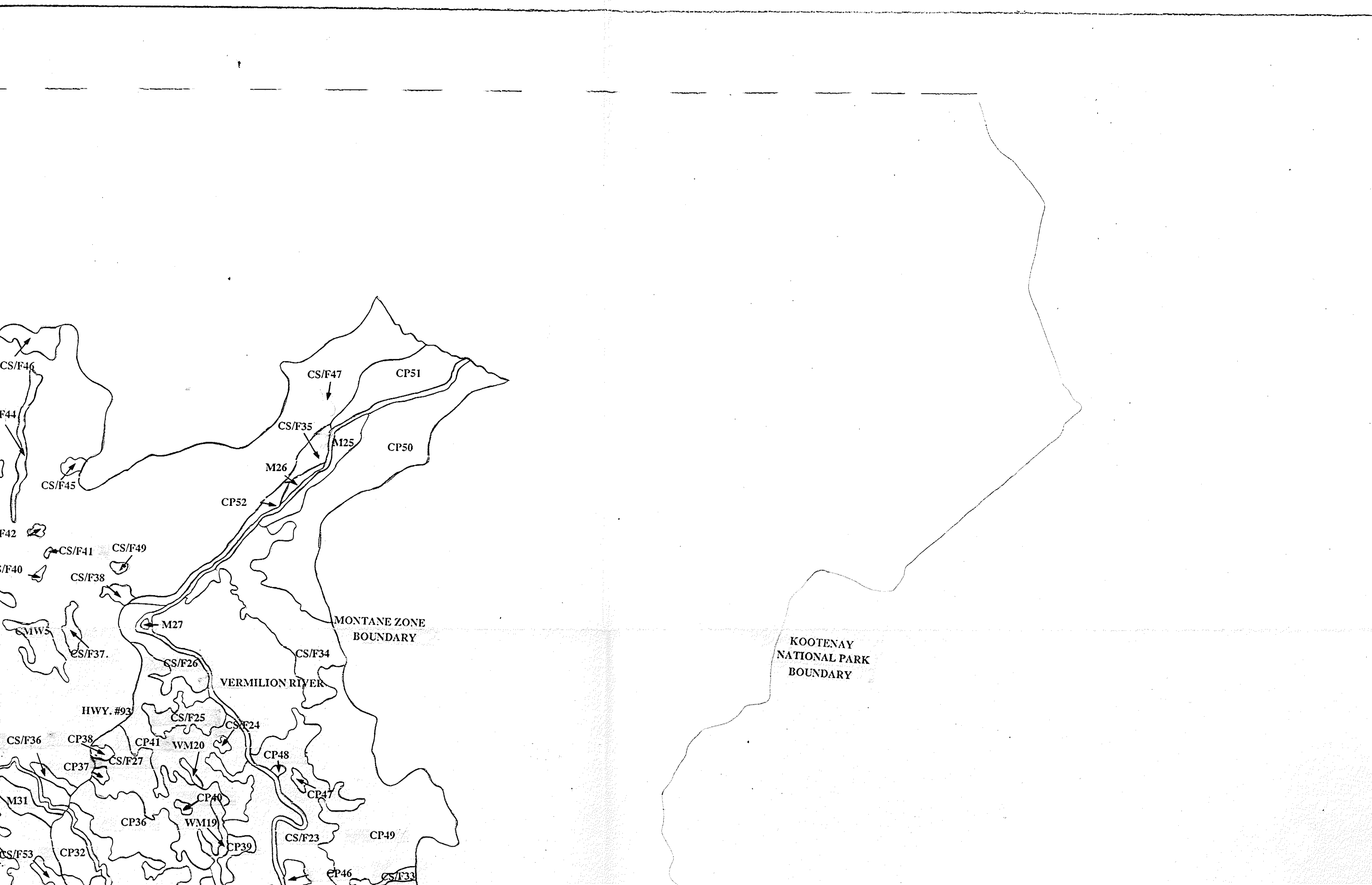
CP36
WM19
CS/F23
WM26
WM24
CS/F53
CP32
CP39


CS/F46
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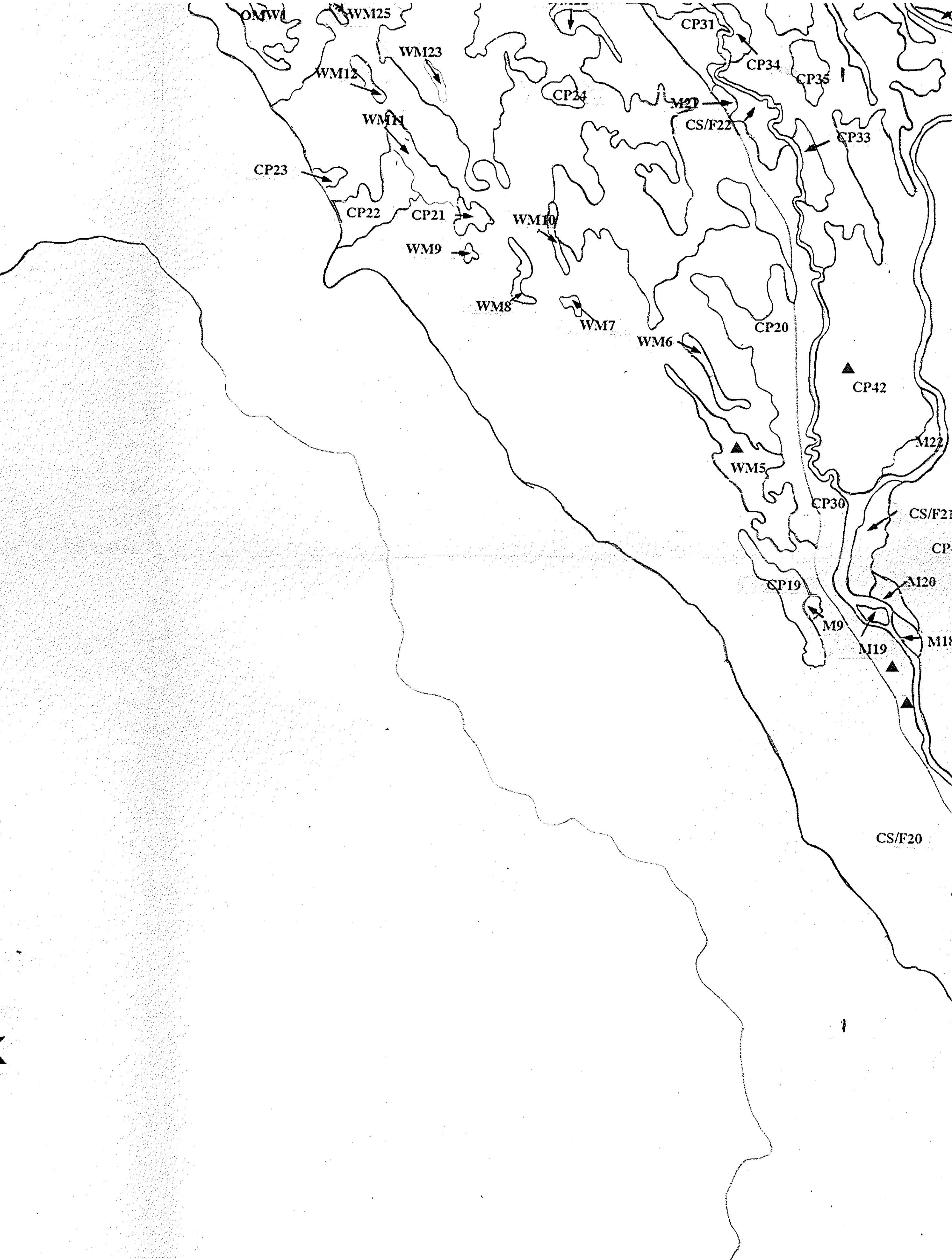
CS/F38
CMW5
CS/F37.
CS/F47
CP51
CS/F35
M25
CP50
M26
CP52
M27
MONTANE ZONE
BOUNDARY
CS/F34
CS/F26
VERMILION RIVER
HWY. #93
CS/F25
CS/F24
CS/F36
CP38
CP41
WM20
CS/F27
CP48
CP37
CP47
M31
CP40
CP36
WM19
CP39
CS/F23
CP49
CS/F53
CP32
CP46
CS/F33
KOOTENAY
NATIONAL PARK
BOUNDARY

1978 FOREST CANOPY CLASSIFICATION OF THE KOOTENAY VALLEY KOOTENAY NATIONAL PARK




CP34
CP35
CP45
CP24
M21
CS/F22
CP33
M10
CMW4
WM7
WM6
CP20
CP42
M23
CS/F56
CP44
M22
WM5
CP30
CS/F21
CS/F31
CP43
CS/F29
CP19
M20
CS/F30
M9
M19
M18
OP1
WM18
CMW3
WM17
CS/F18
CP29
CS/F20
CS/F17
M15
WM16
OS/F3
M17
WM15
CS/F16
CP28
CS/F15
M14
OS/F2
M13
WM14
CS/F19
OS/F1
M12
WM13
CP27
M11
M16

MAP LEGEND

MAP SYMBOLS	FOREST CATEGORIES
CP	Closed Pine
OP	Open Pine
CS/F	Closed Spruce/Fir
OS/F	Open Spruce/Fir
CMW	Closed Mixedwood
OMW	Open Mixedwood
M	Meadow
WM	Wet Meadow
▲	Forage evaluation sampling site

Example:

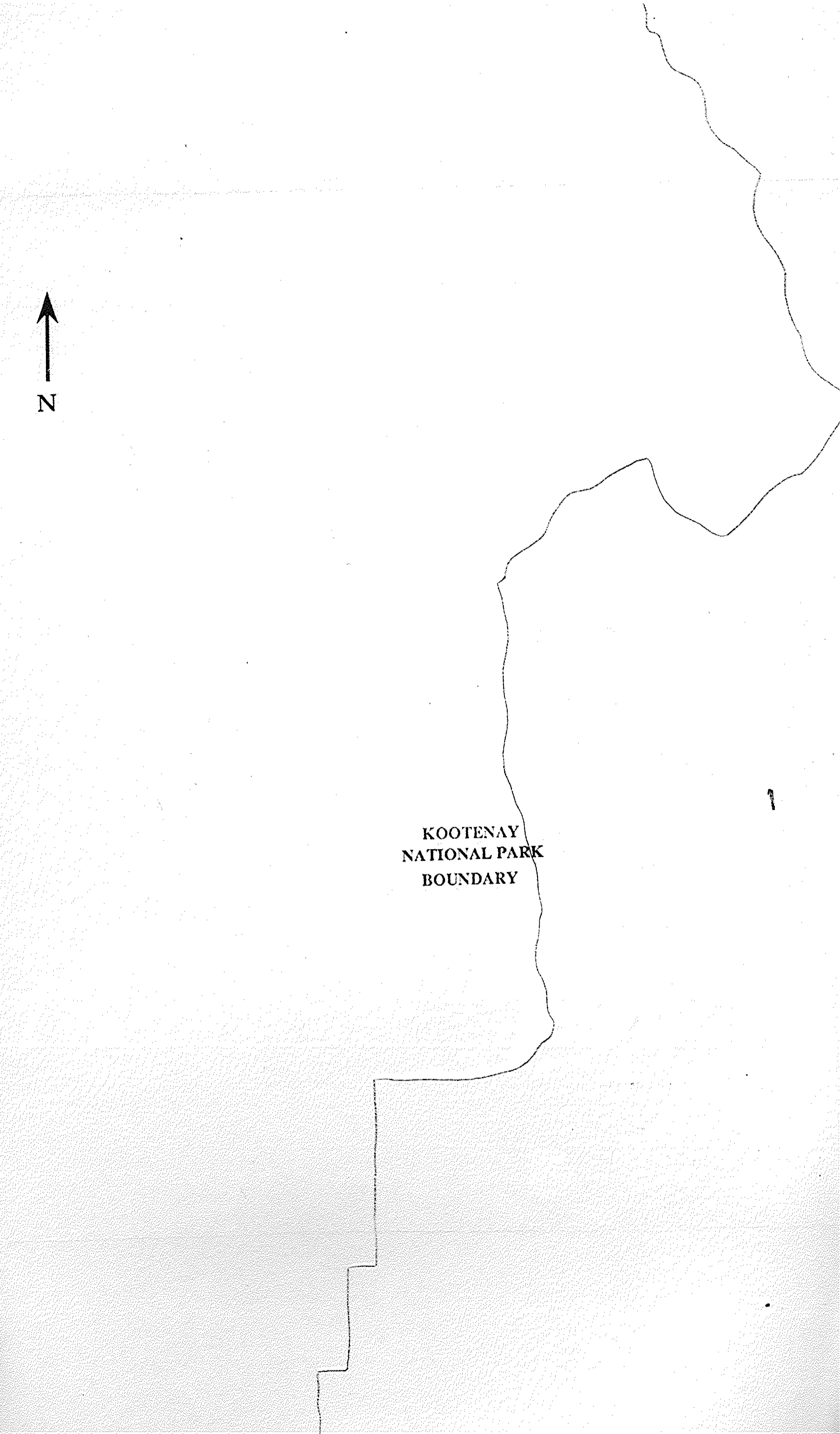
forest category

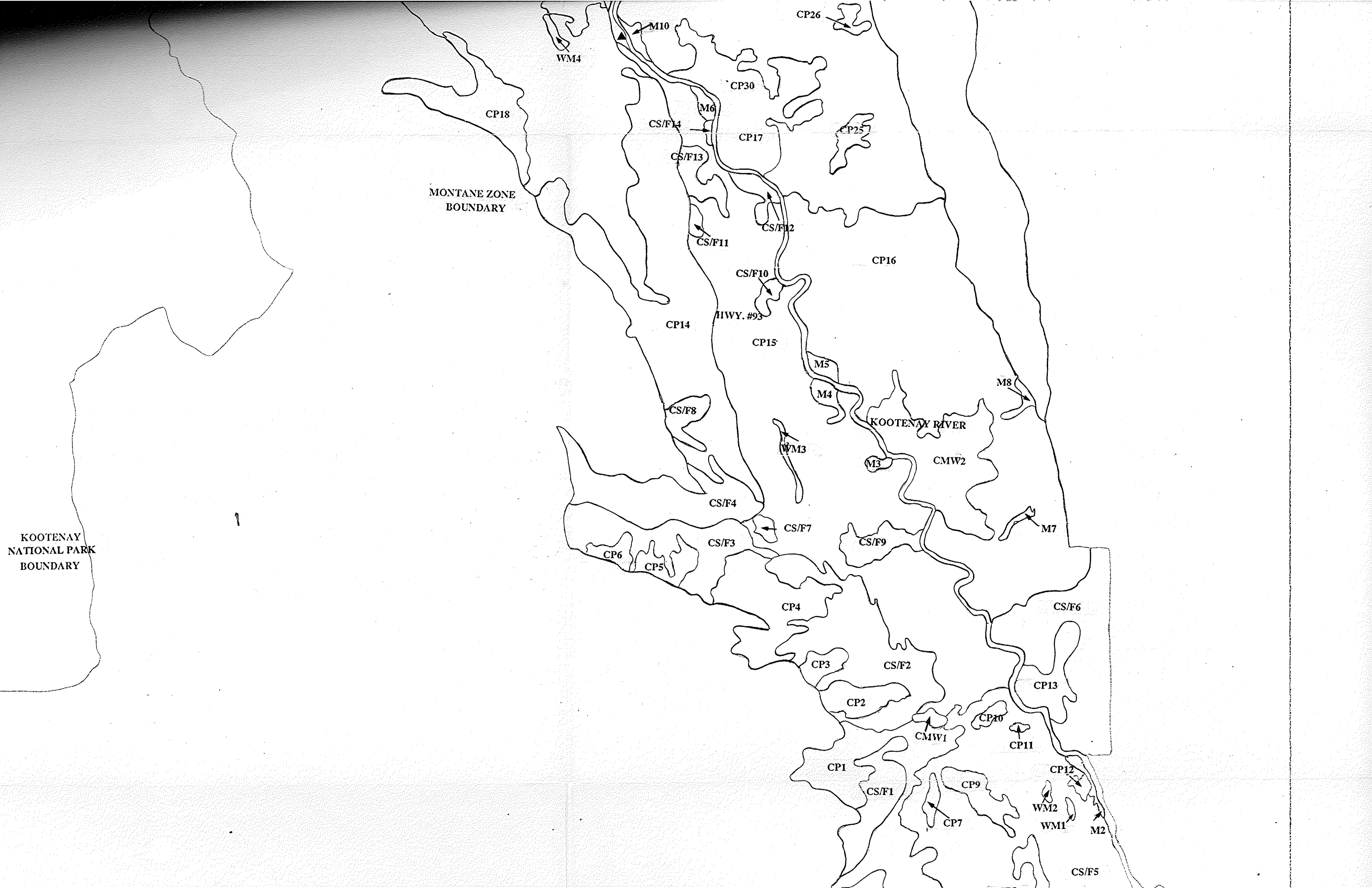
CP 20

polygon number*

* polygon number and segment number may be referenced in Appendix 6 for site specific data

Map scale 1:50000





CP26
M10
WM4
CP30
CP18
M6
CS/F14
CP17
CP25
CS/F13
MONTANE ZONE
BOUNDARY
CS/F12
CS/F11
CP16
CS/F10
HWY. #93
CP14
CP15
M5
M8
M4
CS/F8
KOOTENAY RIVER
WM3
M3
CMW2
CS/F4
M7
CS/F7
KOOTENAY
NATIONAL PARK
BOUNDARY
CS/F3
CS/F9
CP6
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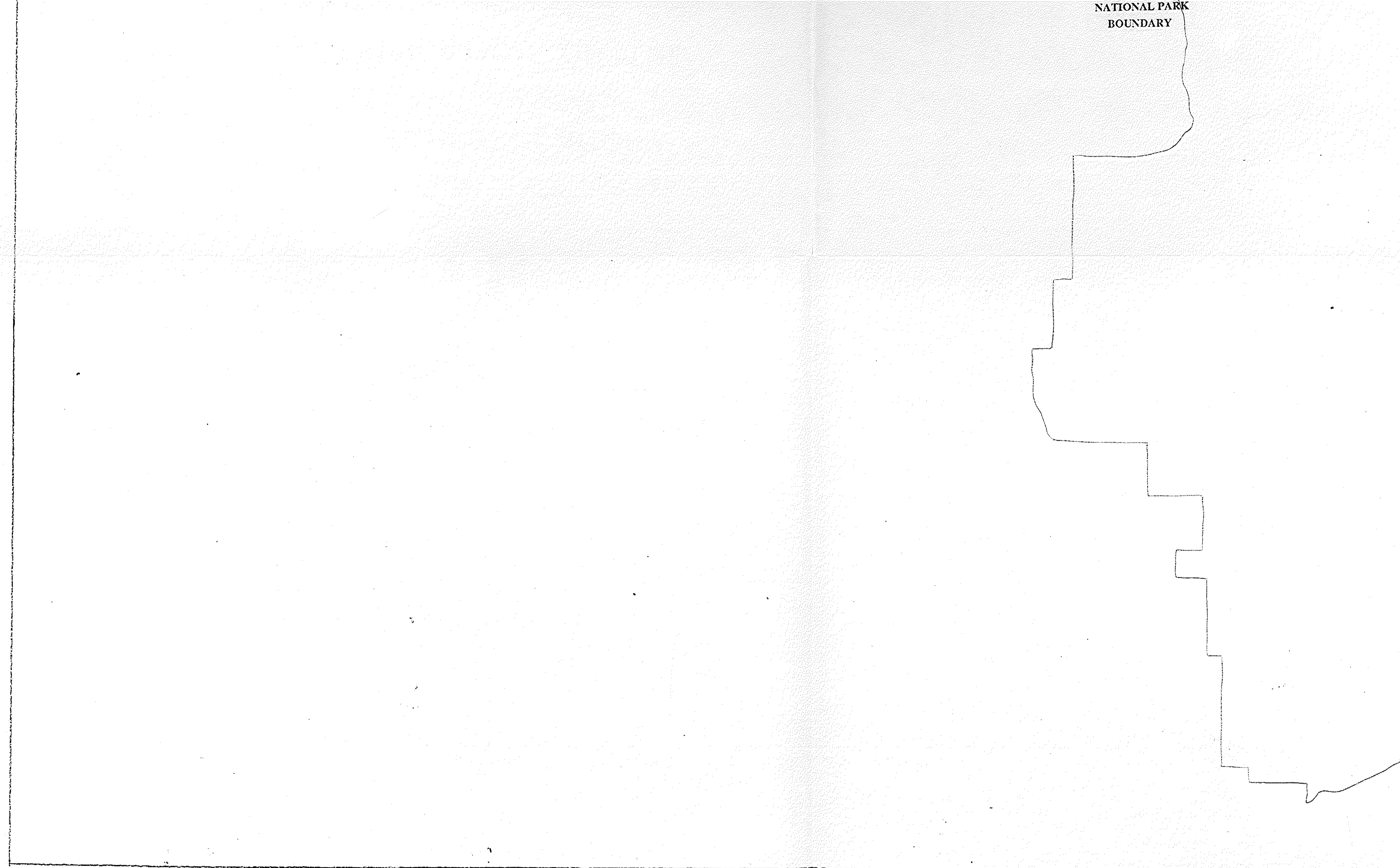
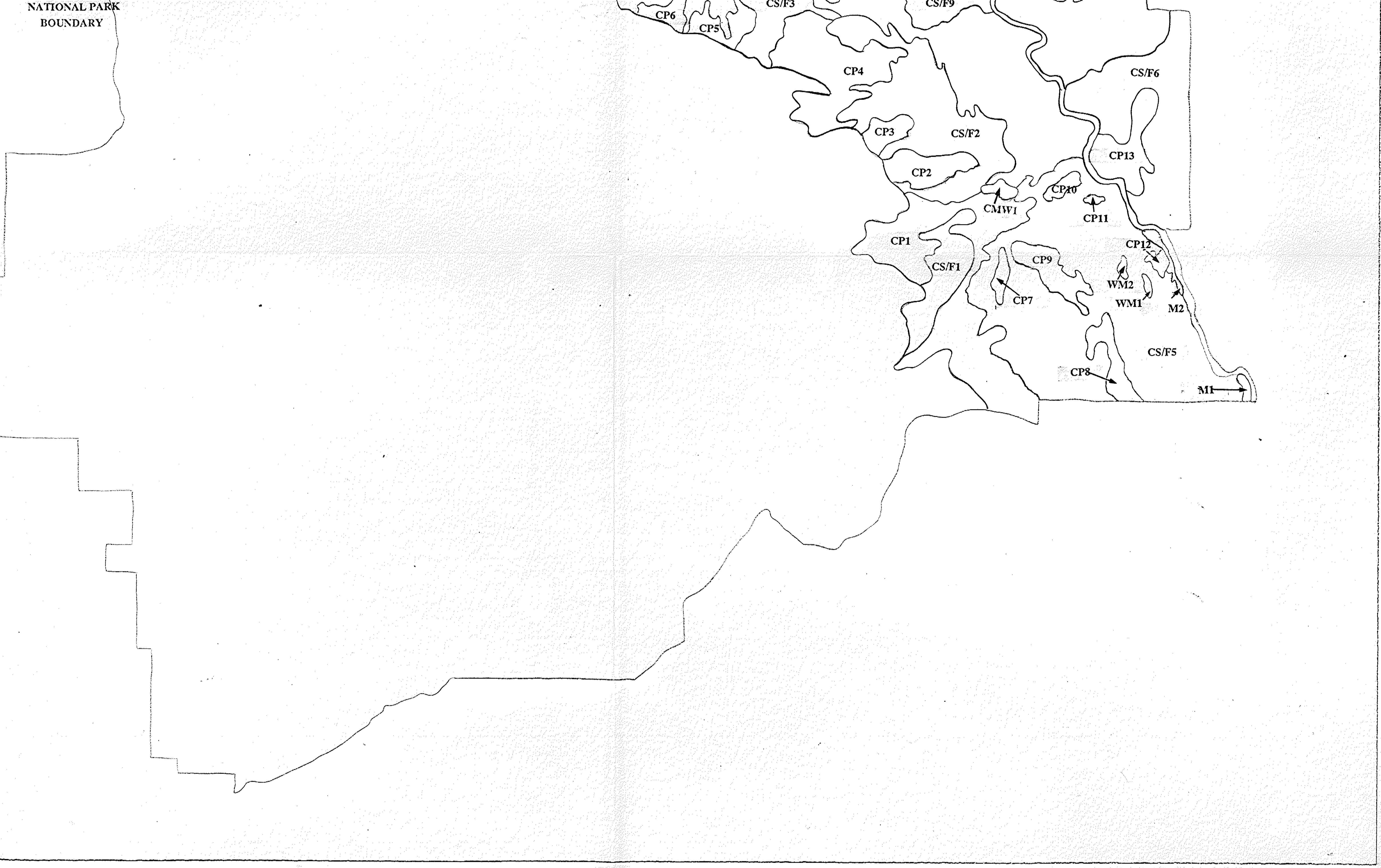
CS/F6
CP4
CP3
CS/F2
CP13
CP2
CP10
CMW1
CP11
CP1
CP12
CP9
CS/F1
WM2
CP7
WM1
M2
CS/F5


NATIONAL PARK
BOUNDARY


NATIONAL PARK
BOUNDARY
CS/F3
CS/F9
CP6
CP5
CP4
CS/F6
CP3
CS/F2
CP13
CP2
CP10
CMW1
CP11
CP1
CP12
CS/F1
CP9
WM2
CP7
WM1
M2
CS/F5
CP8
M1