FINAL REPORT ON THE EFFECTS OF THE TRANS-ALASKA PIPELINE ON MOOSE MOVEMENTS

By:

Victor Van Ballenberghe

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Special Report Number 23

JOINT STATE/FEDERAL FISH & WILDLIFE ADVISORY TEAM

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Joint State/Federal Fish and Wildlife Advisory Team
628 "F" Street
Anchorage, Alaska 99501

SPONSORED BY THE

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SUMMARY

Progress on the moose-pipeline technical evaluation project from October 1974 through June 1977 is reviewed. Tagging programs designed to clarify moose population identities along one 70-mile section of the Trans-Alaska Pipeline between Glennallen and Paxson resulted in the marking of 208 moose. Of 181 moose that wore numbered canvas collars, 165 were subsequently resighted a total of 703 times. Twenty-eight radio-collared moose were radio-tracked during a combined total of 35 moose years and 2427 relocations were obtained. The seasonal habitats used by the marked moose were identified and the extent, timing and duration of migratory movements were determined. Radio-collared moose that seasonally crossed the pipeline migrated a mean distance of 31 miles. Much variation in initiation of fall migration was observed between different individuals, and date of arrival on winter range during certain years was spread over a 6-week period. During winter 1975-76, a winter of much below normal snowfall, many moose migrated only a short distance and failed to contact the pipeline.

Of 1068 successful crossings of the pipeline during shallow snow conditions, 57 percent occurred where the vertical clearance was between 6 and 8 feet. Although certain moose crossed the pipeline under pipe as low as 49 inches, others were deflected in their movements by pipe as high as 168 inches above the workpad. The behavior of moose that were deflected by elevated pipeline is described and 14 instances where moose failed to achieve successful crossings are documented. Historical trends in snow depth for the Nelchina Basin are reviewed. Snow depths of 30 to 40 inches or more have occurred at Gulkana during one November, one December, and five Januaries during the past 34 years. Depths of this magnitude are hypothesized to cause extensive deflected movements of moose seeking to cross the pipeline. A deferred assessment of Industry's compliance with Stipulation 2.5.4.1 is recommended since environmental conditions critical to evaluation of the stipulation have not yet occurred. Six areas in need of further study are identified.

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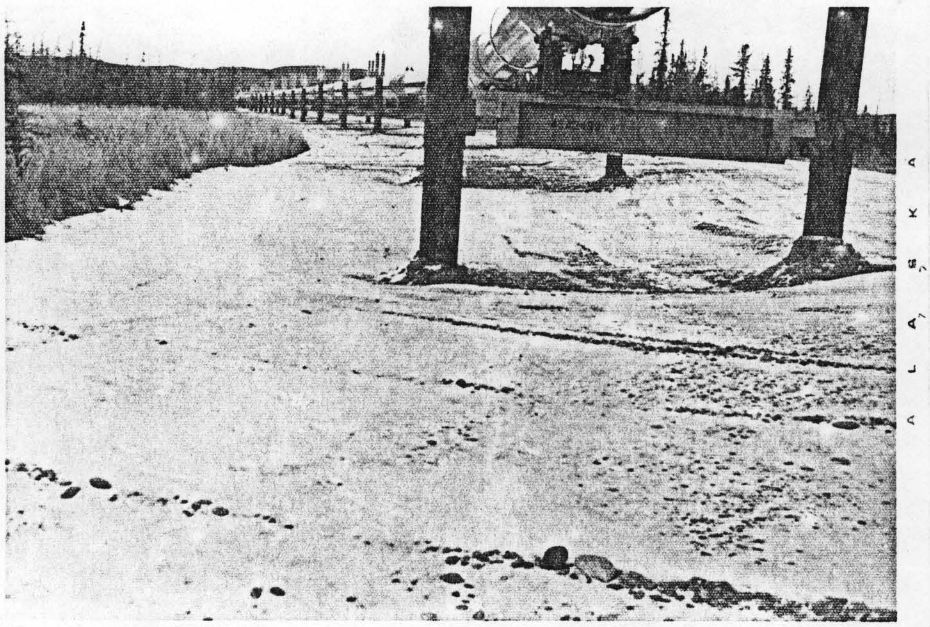
BACKGROUND

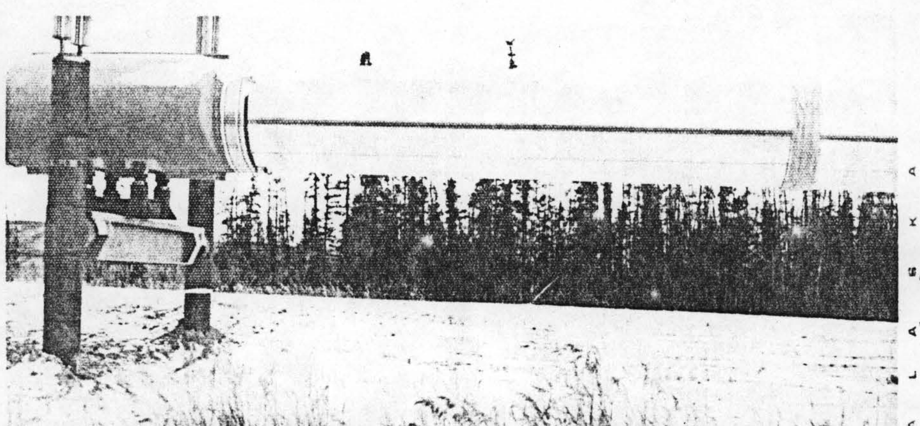
Construction of a 48-inch diameter hot oil pipeline from Prudhoe Bay to Valdez, Alaska presented the State of Alaska with numerous environmental concerns including potential restriction of free passage for moose (*Alces alces*) and other large mammals. The original construction plans called for burial of about three-quarters of the pipeline's total length (Hinman 1974). Subsequent geotechnical studies revealed the necessity for elevated construction in the ice-rich soils found along approximately 420 miles of the pipeline's 800-mile route. Here, the pipeline would have to rest on crossmembers supported by 18-inch diameter vertical support members (VSMs) set approximately 60 feet apart in parallel rows. Thus, an animal attempting to cross above-ground (A/G) sections of pipeline would have to pass through "windows" about 60 feet wide with bottom of pipe to top of workpad (BOP-TOP) distances varying from about 5 to 10 feet (Fig. 1). Additionally, in order to approach the pipeline, an animal would have to cross a workpad berm varying from several inches to several feet thick depending upon substrate characteristics and topography.

Although research into reindeer and caribou (*Rangifer tarandus*) behavior in the presence of simulated pipeline structures had been completed prior to pipeline construction (Klein 1971, Child 1974,

Figure 1. Pipeline windows



View of an excavated Designated Big Game Crossing, looking along the pipe.



View of a pipeline window, looking across the pipeline.

Banfield 1974), no similar studies had been done with moose. Indeed, few intensive studies of moose movements and migrations in northern areas had been done (cf. LeResche 1974), and the timing, extent and duration of migration for most moose populations in Alaska were unknown. Several levels of interference with moose movements by an elevated pipeline were postulated ranging from simple restriction of daily wanderings to the effective blocking of the migrations of entire populations moving between seasonally used ranges. In the latter case, such populations could be eliminated if required habitats were not available on either side of the pipeline.

Potential problems resulting from the inability of moose to freely cross the pipeline corridor were recognized early in the planning process for the Trans-Alaska Pipeline. Alaska Department of Fish and Game biologists participated in meetings of the Interagency Fish and Wildlife Team and made recommendations to Alyeska Pipeline Service Company regarding design criteria that might facilitate free passage of moose. These recommendations were based largely on observations of moose behavior in the vicinity of the Davidson Ditch, a 48-inch above-ground water siphon built in 1925 in the Chatanika Valley north of Fairbanks. Minutes of the 4 January 1972 IFWT meeting detail these observations:

1) Moose moved under the pipe when it was more than 66 inches above the ground.

2) Established moose crossings under the pipe disappeared when the pipe settled to less than 5 feet above ground.

3) The maximum distance moose were observed to parallel the pipe without crossing was one-half mile.

4) No evidence of moose crossing over the pipe was observed even when the pipe was partially buried.

These observations and their interpretations were further detailed by Burris (12 September 1973 letter to M. J. Turner, BLM Division of Pipeline):

> From the different interpretations that others have made of our observations, I get the impression that many have concluded that if we maintain enough passage opportunities underneath the pipeline there will be no interference or interruption of natural moose movements. This certainly was not my conclusion and I do not believe that it was Dr. LeResche's conclusion. Dr. LeResche pointed out to the group at the December 13 meeting that moose adversely react to overhead objects in certain situations to the extent that they will not go under them. He pointed out that the surrounding vegetation and topography may even have a considerable influence on the visual impact of overhead objects. Even where the moose population has adapted to the presence of the Davidson Ditch there is evidence to show that they made a considerable effort to avoid the pipe and to travel around the ends of the siphons.

of moose along a 70-mile portion of the pipeline between Glennallen and Paxson in Southcentral Alaska was chosen. Here, the pipeline parallels the Richardson Highway through eastern portions of the Nelchina Basin (Fig. 2). All of the moose movement data and most of the data on moose-pipeline interactions were collected in the primary study area. Additional observations of successful and unsuccessful attempts of moose to cross the pipeline were contributed by biologists assigned to the Joint Fish and Wildlife Advisory Team (JFWAT). During winter 1976-77, efforts to collect data were concentrated between Big Delta and the Yukon River in northcentral Alaska.

The primary study area of 4000 square miles was located in the eastern quarter of the Nelchina Basin (62° north latitude, 146° west longitude), an area well described by Rausch (1969), and Bishop and Rausch (1974). Gulkana airport, 3 miles north of Glennallen in the southern portion of the study area, has been a site where systematic collection of weather data has occurred since 1943. These data from U.S. Weather Bureau and NOAA records show a dominant continental influence on the climate of the Nelchina Basin due to the shielding effects of the Chugach and Talkeetna Mountains. Temperature extremes, with a range of 156 Farenheit degrees between the record maximum and record minimum temperatures, and a mean annual precipitation of 11.2 inches reflect this continental influence. Four months, November through February, have average minimum temperatures below zero; mean January temperature is -8.8°F while July averages 68.2°F. The average length of the growing season is only 78 days with mean dates of the first and last frosts occurring on 21 August and 3 June, respectively. The record maximum depth of snow on the ground was 55 inches in March 1972; during most winters maximum snow depth has not exceeded 30 inches at Gulkana.

Major geographic features in the study area include the Gulkana, Gakona, and Chistochina Rivers (Fig. 2). These originate on the south slopes of the Alaska Range, flow roughly parallel to the pipeline across the floor of the basin (elevation approximately 1500 to 1800 feet), and empty into the Copper River. Foothills of the Alaska Range that border the study area on the north rise to about 2500 feet above the "flats" to the south. The Alphabet Hills west of the pipeline and the Gakona-Chistochina uplands east of the pipeline are the most significant of these.

Black spruce (*Picea mariana*) forests dominate many areas below 2500 feet elevation. Tree densities thin significantly between 2500 and 3000 feet and dense shrub understories of dwarf birch (*Betula nana*) and various willow species (*Salix* spp.) occur in most subalpine areas. Sedge (*Carex* spp.) meadows are common throughout the study area and some of the numerous small lakes contain stands of aquatic plants that moose utilize during the ice-free seasons. The major drainages and their headwaters contain riparian willow communities, upland willow communities, and balsam poplar (*Populus balsamifera*) stands that moose use extensively during certain seasons. Burns resulting from man-caused and lightning strike fires are present in the study area, but few fires have burned significant acreages during the past 20 years.

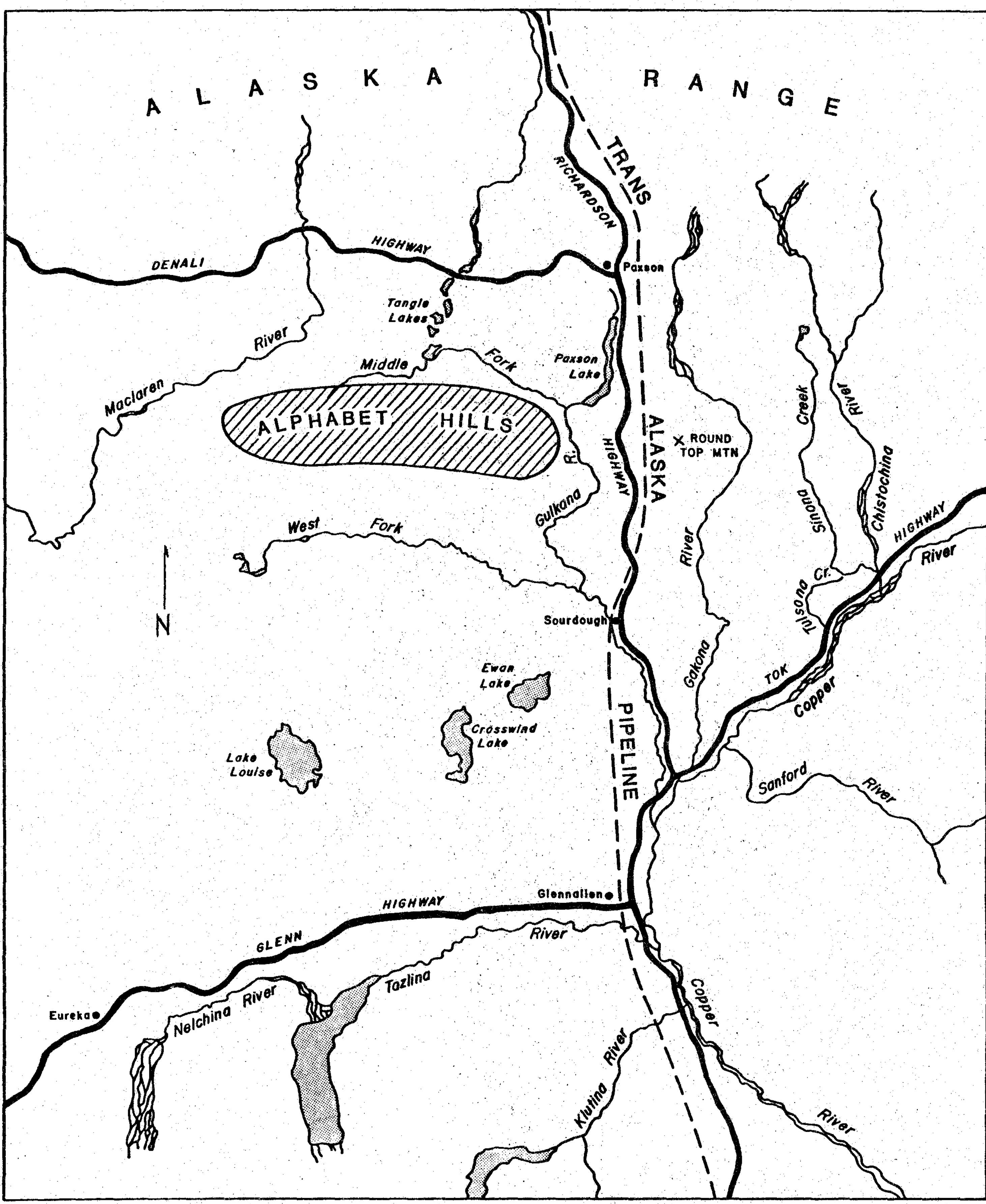


Figure 2. The Study Area--Nelchina Basin

Moose Populations in the Study Area

Moose herd composition counts have been conducted annually in portions of the Nelchina Basin since 1952 by personnel of the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game, and a generalized history of moose population trends is available (Rausch 1969, Bishop and Rausch 1974).

In the early 1950s moose numbers throughout the Nelchina Basin were thought to be increasing, calf survival to six months appeared excellent and bull:cow ratios were not significantly affected by hunting (Bishop and Rausch 1974). Moose numbers peaked about 1960 and, despite severe winters in 1961-62 and 1965-66 during which extensive mortality occurred, moose densities exceeding 1 per square mile were thought to persist over the Basin as a whole through the late 1960s (Rausch 1969).

Calf:cow ratios obtained during November surveys declined from a mean of 42.6:100 during the period 1960-1963 to a mean of 28.5:100 during 1965-1971. During the 1971 hunting season 1815 moose were harvested. The winter of 1971-72 produced a record snowfall, extensive mortality occurred among all age classes and the lowest calf:cow ratio (17.7:100) ever recorded in the Nelchina Basin during the period 1952-1971 was observed the following November (Bishop and Rausch 1974). Calf:cow ratios have remained low through 1976 (Table 1), and the combined effects of poor recruitment, hunting, predation losses, and winter mortality have reduced moose numbers by perhaps 50 percent since the late 1960s. During the three winters of this study extensive mortality of moose was not evident and moose numbers appeared to remain stable despite relatively low recruitment rates.

Composition count data for the period 1973 through 1976 for the Alphabet Hills and upper Gakona River are provided in Table 1. The total sample actually observed provides a minimum estimate of the number of moose present in each area.

Tagging Operations and Monitoring Flights

In order to identify moose population segments, determine the extent of migratory movements, and delineate seasonally important habitats adjacent to the pipeline, moose were marked with canvas collars or were fitted with radio transmitter collars. Canvas collars were color coded and bore 6-inch high numerals readable during low passes with fixed-wing aircraft. Radio collars were distinguishable by discrete frequencies. Thus, each marked moose was individually identifiable.

Moose were immobilized with succinylcholine chloride (Anectine, Burroughs Wellcome Co.) injected with Cap-Chur equipment (Palmer Chemical and Equipment Company) employed from a Bell 206B helicopter. Blood samples were drawn from immobilized moose and one incisor was extracted from some individuals for age determination (Sergeant and Pimlott 1959). Tagging was conducted when moose were concentrated in post-rutting groups or were confined on their winter range.

Table 1. Composition count data for the Alphabet Hills and upper Gakona River areas, 1973-1976. Data were from this study for Alphabet Hills in 1975 and 1976, and from unpublished data of the Alaska Department of Fish and Game.

	Alphabet Hills			Upper Gakona River		
Year	Bulls per 100♀♀	Calves per 100♀♀	Total Sample	Bulls per 100♀♀	Calves per 100♀♀	Total Sample
1973	20.5	17.5	608	21.2	14.1	211
1974	22.6	26.6	903	31.5	21.3	136
1975	19.3	10.5	667	12.9	26.9	130
1976	27.9	19.5	780	22.2	21.3	155

Monitoring flights were made on a regular weekly basis during all seasons to locate radio-collared moose and search for collared individuals, but more intensive efforts were made to radio-track moose during their migrations. Radio-tracking was accomplished with Piper PA18-150 or STOL Cessna 180 fixed-wing aircraft equipped with directional yagi antennas (Mech 1974). Radio-collared moose were circled repeatedly until seen. Approximately 95 percent of all radio locations were visually confirmed; dense vegetation, poor light conditions, or air turbulence occasionally prevented visual observation. Data collected for each radio fix included map location, date, time, weather parameters, habitat type, observed associates and activity. Collared moose were frequently seen incidental to radio-tracking or in the company of radio-collared moose. Flights to deliberately search for collared moose were limited to those times of the year when large numbers of moose were visible due to increased daytime activity or use of semi-open habitats.

Moose-Pipeline Interactions

During the first pipeline construction season, March through November 1975, data on moose tracks crossing the workpad and evidence of deflected movements resulting from construction were collected by JFWAT surveillance biologists incidental to their other duties. By November 1975, lengthy segments of elevated pipeline had been constructed in certain areas and systematic data collections on successful crossings of the pipeline were begun in the Fairbanks and Glennallen areas. Because less than 10 miles of pipeline had been installed north of Glennallen, an 18-mile segment of elevated pipeline between the Tazlina River and Squirrel Creek was chosen for study.

During the 1976 construction season, cursory observations on the effects of construction on moose movements were again recorded. Construction of the pipeline was nearly complete by early winter and efforts to collect data on crossings by moose and evidence of deflected movements were renewed in the areas east of Fairbanks. Data collection in the Glennallen area was expanded to include newly installed A/G pipeline in the area between Glennallen and Paxson where migration across the pipeline would occur for the first time.

The pipeline workpad was driven with a motor vehicle or a snow machine and data were recorded where moose made successful or unsuccessful attempts to cross the pipeline. For successful crossings, the specific location, number of moose involved, habitat type, direction of travel, snow depth on the pad and under the pipe, and vertical clearance were recorded. A sketch of the track pattern in relation to the pipeline also was made. Deflected movements were defined as those cases where tracks clearly indicated that a moose had approached the pipeline on the workpad but failed to cross during one or more attempts. Snow depths and vertical clearances were recorded for each deflection and the subsequent activities of the moose were noted.

During summer 1977 data were collected in the Tazlina-Squirrel Creek section of the primary study area on asbuilt dimensions of the pipeline and on the proportion of certain vegetation types that occurred adjacent to the pipeline. Systematic sampling points at every 10th VSM were located; BOP-TOP measurements were recorded and the vegetation adjacent to the pipeline was categorized as one of six types on the basis of overstory species that dominated the stand.

Statistical comparisons used in this report included Spearman's Rank Correlation Coefficient (Gibbons 1971) for comparing the agreement in rank order of two values. The technique of Neu et al. (1974) was used to construct confidence intervals (based on family confidence coefficients) to determine preference for or avoidance of a given vegetation type, segment of the pipeline, or BOP-TOP clearance.

The term Alignment Sheet (AS) as used in this report refers to "blueprint" construction drawings representing a pipeline segment approximately 6 miles long. These are numbered consecutively starting at the southern end of the pipeline. The primary study area included the pipeline segments represented by AS 16 (including Squirrel Creek) through AS 30 (adjacent to Paxson Lake).

FINDINGS

Tagging Programs

Tagging programs conducted during fall and spring seasons in 1974, 1975, and 1976 resulted in the capture and marking of 208 moose in northern portions of the primary study area (Table 2). During the autumn tagging operation efforts were made to tag approximately equal numbers of moose in areas east and west of the pipeline corridor. The spring 1975 tagging was conducted in the wintering areas of moose tagged the previous autumn. Because the sex ratios of the moose populations in the study area were strongly skewed in favor of females (Table 1), attempts were made to simulate naturally occurring sex ratios in the tagged sample.

Of 115 female moose tagged during October 1974 and March 1975 for which age data were available, 56 (49%) were 10 years old or older. Small moose, possibly representing young cohorts, were deliberately avoided during the tagging operations and many moose that were darted failed to become immobilized perhaps due to superior physiological condition and/or youthful resilience. Thus, it is likely that the age structure of the tagged animals was older than the actual age structure of the populations sampled.

During the March 1975 tagging program 59 adult female moose were rectally palpated to determine if fetuses were present or absent. Fifty-one (86%) were judged to be pregnant and much variation was noted between the relative size of the fetuses.

Table 2. Summary of moose tagged in the study area from October 1974 through October 1976.

Tagging Site	Month-Year Tagged	Numbered Canvas Collars Males	Numbered Canvas Collars Females	Radio Collars Females	Radio Collars Males
Alphabet Hills	October 1974	4	29	--	--
Upper Gakona R.	October 1974	3	31	--	--
Pipeline Corridor	November 1974	--	3	--	17
Lower Gulkana, Gakona and Chistochina Drainages	March-April 1975	--	66 1/	2	7
Alphabet Hills	Oct-Nov 1975	--	24	1	4 2/
Upper Gakona R.	Oct-Nov 1975	--	21	1	2 3/
Upper Gakona R.-Alphabet Hills	October 1976	--	--	4 4/	7 4/

1/ Includes 3 moose with malfunctioning radios replaced with canvas collars.

2/ Includes 2 moose that were reradioed and 2 moose that previously wore canvas collars.

3/ Includes 1 moose that was reradioed and 1 moose that previously wore a canvas collar.

4/ Includes 7 moose that were reradioed and 2 moose that previously wore canvas collars.

Movements of Collared Moose

A total of 181 moose wore canvas collars bearing individually identifiable numerals during the study period. Of these, 16 were not subsequently resighted and 703 resightings were obtained for the remaining 165 individuals. Some of the moose that were never relocated were probably present in the study area but were undetected, others may have left the area, and still others probably perished due to various mortality factors. Four collared moose were known to have been killed by wolves (*Canis lupus*) in the study area and a hunter turned in the collar of one moose that he reported had been killed by a grizzly bear (*Ursus arctos*).

A mean of 4.3 relocations per moose was obtained for those animals resighted subsequent to tagging. Only 27 percent of the moose seen were observed more than five times each and 18 percent were seen only once; most of these were seen shortly after they were tagged but not subsequently.

Moose tagged in the eastern Alphabet Hills west of the pipeline during autumn (Fig. 2) were found to either winter there in small numbers, to migrate south onto the Crosswind Lake-Ewan Lake flats, or to move to the general vicinity of the lower Gakona River. One moose spent winter 1975-76 well south of the study area near Kenny Lake, about 30 miles south of Glennallen. Moose tagged during autumn in the Alphabet Hills returned there during spring or summer in subsequent years; only one was observed outside the Alphabet Hills. The basic migratory pattern of these moose, therefore, was to move south or southeast during early winter, to travel up to 35 miles between seasonally used ranges, and to return north or northwest during spring to their summer range in the Alphabet Hills.

Moose tagged during autumn in the upper Gakona River east of the pipeline were observed to winter either near the upper Gakona River, in the general vicinity of the lower Gakona River, or to move southeast out of the study area toward the Nabesna Road. Those that traveled to the lower Gakona River occupied the same areas that certain individuals from the Alphabet Hills used. Like the Alphabet Hills moose, the upper Gakona River population moved back to traditionally used summer-fall ranges in subsequent years. Of 22 moose collared in the upper Gakona River during fall 1975, 19 were seen there during fall 1976, and none were seen elsewhere. The general pattern of movement for this population as revealed by the collared moose, then, was a south or southeast migratory movement during early winter with certain individuals moving up to 69 miles and leaving the study area. Spring and early summer movements were north and northwest and resulted in occupancy of traditionally used summer and autumn ranges.

Two collared moose, one adult bull and one adult cow, provided evidence of interchange between the moose populations of the upper Gakona River and the Alphabet Hills. The bull was collared near the Gakona Glacier in autumn 1974 but was observed in the Alphabet Hills during the rut in both 1975 and 1976. The cow was also tagged near the Gakona Glacier but spent winter 1976-77 near the north end of Paxson Lake. No collared moose that summered in the Alphabet Hills were ever observed in the vicinity of the upper Gakona River during any season. The sightings described above suggest that only a very limited interchange of individuals occurred between the two discrete moose populations.

Of 63 moose tagged in the winter range of the Alphabet Hills and upper Gakona moose populations, 11 were found to remain there during subsequent summer and fall seasons. These individuals evidently were nonmigratory and occupied areas yearlong that were used by large numbers of other moose only during winter.

One moose tagged during March 1975 spent autumn 1975 near the Maclaren River northwest of the Alphabet Hills. This suggests that moose from other unidentified populations were moving through the study area, and sharing certain seasonally used ranges with the tagged moose.

Because relatively few collared moose were relocated more than 4 or 5 times each and since many moose were frequently seen shortly after tagging and then never seen again, little useful data describing specific movement patterns of moose in the study area were obtained from collared moose. Additional data collected in subsequent years may significantly supplement the information obtained through mid-1977. Generally, data from the collared individuals can supplement knowledge of movement patterns displayed by the radio-collared moose, provide additional data on the traditionality of range use, and furnish data on extreme movements not detected by radio-collared moose due to the smaller number of animals wearing radio collars.

Movements of Radio-Collared Moose

Moose were radio-collared in the study area both as a means to define specific movement patterns as well as to provide individuals whose behavior near the pipeline could be compared with a known history of movements. Seventeen moose were radio-collared in November 1974 and radio-tracked through the fall 1974 migration. Nine additional radios were placed on study animals during March 1975 and by late July 1975 all of the original radios had expired. Additional collaring efforts in November 1975 and October 1976 resulted in the recapture of several moose with expired transmitters, the renewal of their radios, and the addition of four new study animals of which two had previously worn numbered canvas collars.

Twenty-eight radio-collared moose yielded significant movement data. A total of 2427 telemetry locations was obtained from the instrumented animals that were radiotracked during a combined total of 35 moose years. The longest period of continuous contact with an instrumented moose was 27 months. Over 150 relocations exist for certain of these animals.

A technical publication, Migratory Behavior of Moose in Southcentral Alaska, describing the basic movement patterns of moose in the primary study area, was prepared during 1977 and is in press as part of the Transactions of the XIII International Congress of Game Biologists. A summary of findings follows:

1) Autumn migration began as early as 1 November but some moose failed to migrate during certain years until early February.

2) Cows with calves tended to migrate before cows without calves or bulls, but much variation was observed within all segments of a given population.

3) Certain moose moved directly to winter range during a 10-day period while others took up to six weeks to move a similar distance. Moose began arriving on winter range by mid-November but most did not arrive until mid-December or later.

4) Year-to-year differences in the extent and timing of autumn migration were well correlated with snow depth. During one winter of much below normal snow depth, certain radio-collared moose failed to migrate or moved short distances toward wintering areas used in previous years. Migratory shortfall ranged from 10 to 29 miles that winter; the marked moose used traditional winter ranges the following year when deeper snow conditions occurred.

5) Spring migration was initiated between mid-April and mid-June; by late May most study animals had begun extensive movements.

6) Most radio-collared moose moved rapidly back to summer range once they had begun to migrate. Significant year-to-year variation in date of arrival on summer range was not observed.

7) Spring movements of most pregnant cows were timed so that parturition occurred on summer range. However, certain cows gave birth on their winter range and migrated during mid-summer.

8) Straight-line movements as short as 5 miles and as long as 59 miles between seasonally occupied ranges were documented.

9) Radio-collared moose demonstrated loyalty to seasonal home ranges. Limited data suggested that migratory routes were also traditionally used.

10) Certain moose were nonmigratory. These individuals were permanent residents of the winter range of migrants whose density on that range during a given winter depended largely on environmental conditions.

These findings and the above description of the movements of moose wearing numbered canvas collars serve to describe the basic migratory movement patterns of moose in the primary study area.

The radio-collared moose used a variety of seasonal habitats in common with the moose wearing numbered collars. Those from the Alphabet Hills migrated southeast during early winter and several inhabited a large burn northeast of Sourdough. Others continued southeast and either wintered in the extensive spruce forests and riparian deciduous communities near the lower Gakona River or occupied another large burn near Tulsona Creek. Some spent portions of winter 1974-75 and winter 1976-77 in the plant communities found on the bars of the Copper River near the mouth of the Chistochina River. This area is adjacent to the Tulsona burn and some moose commonly spent portions of their winter period in both localities. Two of the radio-collared moose were yearlong residents of the Tulsona burn.

Several moose were radio-collared in the Paxson area in November 1974 and wintered there either in the spruce-shrub habitats near Paxson Lake or in the willow flats of the Gulkana River south of Paxson. These areas have supported wintering moose for many years and the present population that moves very short distances between seasonal ranges is apparently a remnant of a much larger population that inhabited the area in previous years.

Radio-collared moose from the upper Gakona River population and those radio-collared near Round Top Mountain shared the winter ranges of the Alphabet Hills moose.

Moose-Pipeline Interactions

Movements of marked moose

Thirty-nine collared moose from the Alphabet Hills-Gulkana River-Tangle Lakes complex of summer ranges were known to have crossed the pipeline right-of-way one or more times post capture. Of these, 17 crossed the pipeline after construction in the primary study area was complete in autumn 1976. Some of the collared moose that were not known to cross the pipeline may have crossed undetected, may have perished, or may not have crossed. Because most of the observations of moose that did cross the pipeline were made after migration was complete, few data were obtained on location of crossing, time spent near the right-of-way, or date of crossing. The radio-collared moose provided these kinds of data.

Table 3 summarizes data on crossings of the pipeline right-of-way by 11 radio-collared moose during the six seasonal migrations that occurred during this study. These moose spent the summer-autumn period from 8 to 31 miles west and northwest of the locations where they encountered the pipeline during migration. Some traveled as far as 28 miles to reach winter range after crossing the pipeline during fall migration; others wintered on or near the right-of-way.

Variation in proximity of the pipeline to the summer range of individuals and year-to-year variations in environmental conditions acted to provide a 2-month period, mid-November through late January, when radio-collared moose crossed the pipeline during the fall migration.

Table 3 . Certain migratory parameters for radiocollared moose that crossed the Trans-Alaska Pipeline right-of-way during seasonal migrations, November 1974 through spring 1977.

Moose Number	Sex	Migratory Season	Dates of Migration	Linear Distance From Summer Range to Pipeline(mi.)	Linear Distance From Pipeline to Winter Range (mi.)	Approx. Period Spent in Proximity to Right-of-way	Location of Summer Range	Location of Winter Range
900	F	Winter 1974-75	20 Nov.-11 Dec.1/	13	28	Undetermined, but occurred prior to 20 Nov.	Eastern Alphabets	Mouth of Chistochina R.
800	F	Winter 1974-75	20 Nov.-31 Jan.1/	—	24	5 Dec.-17 Jan.	Undetermined	Copper R. east of Gakona R. mouth
960	F	Winter 1974-75	5 Dec.-17 Jan.	11	0	20 Nov.-5 Dec. wintered on row after 1 Jan.75	Upper Gulkana R.	Hogan Hill
970-74	F	Winter 1974-75	14 Jan.-11 Feb.	14	4	14 Jan.-21 Jan.	Middle Fork Gulkana R.	Sourdough Burn
950	F	Winter 1974-75	10 Dec.-16 Jan.1/	--	11	3 Dec.-18 Dec.	Undetermined	Upper Gulkana R.
850	M	Winter 1975-76	12 Dec.-26 Dec.	8	7	12 Dec.-25 Dec.	Upper Gulkana R.	Sourdough Burn
023	F	Winter 1975-76	29 Jan.-16 Mar.	16	8	24 Feb.-16 Mar.	Eastern Alphabets	Sourdough Burn
023	F	Winter 1976-77	10 Dec.-29 Dec.	16	8	16 Dec.-22 Dec.	Eastern Alphabets	Sourdough Burn
850	M	Winter 1976-77	16 Nov.-9 Dec.	8	7	17 Nov.-30 Nov.	Upper Gulkana R.	Sourdough Burn
040	F	Winter 1976-77	9 Dec.-16 Dec.	12	26	10 Dec.-15 Dec.	Eastern Alphabets	Mouth of Chistochina R.
032	F	Winter 1976-77	2 Dec.-5 Jan.	23	25	16 Dec.-22 Dec.	Tangle Lakes	Mouth of Chistochina R.

continued

Table 3 . (continued)

Moose Number	Sex	Migratory Season	Dates of Migration	Linear Distance From Summer Range to Pipeline(mi.)	Linear Distance From Pipeline to Winter Range (mi.)	Approx. Period Spent in Proximity to Right-of-way	Location of Summer Range	Location of Winter Range
830	F	Winter 1976-77	18 Nov.-9 Dec.	11	3	19 Nov.-9 Dec.	Middle Fork Gulkana R.	Round Top Mountain
970-74	F	Winter 1976-77	2 Dec.-5 Jan.	14	4	14 Dec.-5 Jan.	Middle Fork Gulkana R.	Sourdough Burn
960	F	Spring 1975	9 May-16 July	11	0	Continuous prior to 9 May	Upper Gulkana R.	Hogan Hill
900	F	Spring 1975	15 Apr.-24 June	13	28	12 June-23 June	Eastern Alphabets	Mouth of Chistochina R.
040	F	Spring 1975	7 May-2 July	12	26	16 May-19 May	Eastern Alphabets	Mouth of Chistochina R.
032	F	Spring 1975	7 May-4 June	23	25	16 May-19 May	Tangle Lakes	Mouth of Chistochina R.
023	F	Spring 1975	13 June-24 June	16	8	13 June-23 June	Eastern Alphabets	Sourdough Burn
048	F	Spring 1975	1 May-23 May	31	3	1 May-14 May	Central Alphabets	Sourdough Burn
850	M	Spring 1975	13 June-24 June	8	7	13 June-23 June	Upper Gulkana R.	Sourdough Burn
032	F	Spring 1976	9 Apr.-19 May	23	3[2/]	19 Apr.-5 May[3/]	Tangle Lakes	Southwest of Round Top Mountain
023	F	Spring 1976	12 June-16 June	16	8	12 June	Eastern Alphabets	Sourdough Burn
850	M	Spring 1976	6 May-25 May	8	9	6 May-21 May[3/]	Upper Gulkana R.	Sourdough Burn

continued

Table 3. (continued)

Moose Number	Sex	Migratory Season	Dates of Migration	Linear Distance From Summer Range to Pipeline (mi.)	Linear Distance From Pipeline to Winter Range (mi.)	Approx. Period Spent in Proximity to Right-of-way	Location of Summer Range	Location of Winter Range
023	F	Spring 1977	14 June-9 July	16	8	15 June-29 June	Eastern Alphabets	Sourdough Burn
040	F	Spring 1977	8 May-1 June	12	26	16 May	Eastern Alphabets	Mouth of Chistochina R.
032	F	Spring 1977	8 May-3 June	23	25	20 May	Tangle Lakes	Mouth of Chistochina R.
830	F	Spring 1977	28 Apr.-25 May	11	3	28 Apr.-8 May	Middle Fork Gulkana R.	Round Top Mountain
970-74	F	Spring 1977	18 May-23 May	14	4	19 May-21 May	Middle Fork Gulkana R.	Sourdough Burn
850	M	Spring 1977	14 May-mid.July	8	9	15 May-22 May 4/ 14 June-29 June	Upper Gulkana R.	Sourdough Burn

1/ Migration underway before moose were radioed in Nov. 1974.

2/ Moose failed to migrate full distance to traditional winter range.

3/ Includes at least two crossings of the pipeline.

4/ Moose migrated to summer range, returned to winter-range, migrated back to summer range one month later.

During spring, crossings occurred between mid-April and late June with most in the one-month period mid-May to mid-June.

Serial records of crossings of the right-of-way by individual radio-collared moose are provided in Table 4. Radio contact for 11 instrumented moose ranged from periods including 1 migration to periods including all 6 migrations from fall 1974 through spring 1977. Only two migrations, fall 1976 and spring 1977, included the pipeline post-construction segment of this study.

Year-to-year variations in the extent of seasonal migratory movements are reflected in the relative proportion of radio-collared moose that crossed the right-of-way each year (Table 4). During winter 1974-75 and winter 1976-77 environmental conditions in the Alphabet Hills summer range caused 10 of 11 and 6 of 7 radio-collared moose, respectively, to move across the pipeline right-of-way. Only two of six instrumented moose displayed similar movements during autumn 1975 when snow conditions allowed many moose to remain in or near their summer range throughout the winter. Two moose, 023 and 850, crossed the right-of-way during five consecutive migrations. All other instrumented moose displayed a less consistent tendency to cross the right-of-way.

Individual variation in migratory behavior during a given year (Table 4) suggested that moose had variable threshold values for snow depth as a stimulus for migratory movements. For example, moose 048 failed to contact the pipeline during winter 1976-77 despite conditions that were relatively severe. Moose 830, which had no previous record of crossing the right-of-way, crossed during winter 1976-77.

Certain radio-collared moose contacted the pipeline during non-migratory seasons since the pipeline passed through portions of their summer or winter home range. Moose 840-75, a member of the upper Gakona River population, spent the period 25 July-30 July 1976 near the pipeline east of Paxson. During this period she crossed above ground sections of the pipeline on at least two occasions. This moose migrated south to the vicinity of the Sourdough burn during early November and on 30 November she was again seen near elevated pipe about 3 miles north of Sourdough. By 3 December she had crossed the pipeline at least twice and had moved about 2 miles east. The straight line distance between the pipeline segments this moose crossed in July and December was 29 miles. A radio-collared bull exhibited a similar pattern; his winter range included an area adjacent to the pipeline 2 miles north of Glennallen. During early winter 1976-77 several crossings of the pipeline by this study animal were documented.

In those cases where moose were radio-tracked intensively enough to establish migratory routes (e.g. moose 032, 040, 023, and 850), it was apparent that the same basic routes were being used for migration as had been used during previous seasons. Moose 040 and 032 utilized the area immediately adjacent to Haggard Creek during all migratory seasons as a travelway adjacent to the pipeline. Moose 023 and 850 crossed the pipeline during five migrations between the south tip of Hogan Hill and the Gulkana River crossing. Most instrumented moose and many of their

Table 4. Individual records of radio-collared moose that crossed the Trans-Alaska Pipeline right-of-way during one or more seasonal migrations, fall 1974 through spring 1977.

	Season - Year					
Moose Number	Fall 1974	Spring 1975	Fall 1975	Spring 1976	Fall 1976	Spring 1977
900	X*	X	--	--	--	--
800	X	--	--	--	--	--
960	X	X	--	--	--	--
950	X	--	--	--	--	--
970-74	X	--	--	--	X	X
830	0	0	0	0	X	X
023	--	X	X	X	X	X
850	--	X	X	X	X	X
040	--	X	0	0	X	X
032	--	X	0	X	X	X
048	--	X	0	0	0	0

* X = Moose crossed right-of-way.
0 = Moose did not cross right-of-way.
-- = Moose not radiotracked during seasonal migration.

associates crossed the pipeline between the Gulkana River crossing and Round Top Mountain. This segment of the pipeline is represented on portions of Alignment Sheets 27 through 29.

Behavior of unmarked moose: effects of construction on movements of moose

A. Townsend and C. Kay, pipeline surveillance biologists, contributed data collected during 1975 and 1976 in the Fairbanks area on deflected moose movements due to pipeline construction activities. These data are summarized below.

Moose behavior was determined from tracks on the workpad. All observations of deflected movements were caused by pipe that had been welded and blocked up from 1 to 6 feet above the workpad surface by wooden cribbing. Where the pipe to ground clearance was 1-2 feet, 4 instances involving 10 adult moose and 2 calves were observed where moose approached the pipe on the workpad and were either immediately deflected or paralleled the pipe for a short distance and returned in the direction of approach. Two instances involving three adults and one calf were observed where moose paralleled the pipe and moved around the end and across the workpad. The distances these animals were deflected were 1760 and 420 feet, respectively.

One case was observed where a moose crossed under pipe cribbed 68 inches high. The moose had paralleled the pipeline 180 feet, attempted to cross through a vertical clearance of 56 inches, declined to cross but moved 60 feet farther and crossed under.

In September 1975 Townsend observed an instance where a pair of twin calves had been separated by a long section of cribbed pipe. His description of the observation follows:

> On September 10, 1975, I observed a multitude of moose tracks on AS 58 near station 1562. The story these tracks told as nearly as I could interpret them is as follows. A cow moose with two calves approached the pipe, which was welded together and resting on cribbing in the center of the workpad for about one mile without a break, from the end. One calf and the cow walked parallel to the pipe between the pipe and open ditch. The second calf paralleled the pipe on the side near the vegetation line. At station 1562 the calf with the cow crawled under the pipe where there was 2-1/2 feet clearance. Both the calves and the cow, now separated by the pipe, paced up and down parallel to the pipe for about 1000 feet at least 6-8 times. Finally the cow bellied over the pipe at one of the lowest points, 61 inches top of pipe to top of pad, and joined her twin calves. The evidence that the cow went over the pipe was the two feet wide dust free band on top of the pipe and deep hoof prints directly out from the polished area. The cow and calf tracks left the pipe at a 90° angle across the workpad and into the vegetation. These were the only adult moose tracks on the east side of the pipe in that vicinity that day.

In the Glennallen area, L. Adler contributed two observations of adult moose that were thwarted in their attempt to cross cribbed pipeline in January 1976. These occurred on AS 16 where short segments of A/G pipe were not yet installed.

Moose were also deflected by deep ditches opened for burial of below-ground installation of pipeline. H. Hosking reported observing a bull moose travel along an open ditch for one-third mile on 7 July 1975. The moose attempted to cross three times, and was finally able to swim across at a place where water had filled a portion of the ditch.

<u>Behavior of unmarked moose in the presence of A/G pipeline</u>

Data on 1068 successful crossings of A/G pipeline by moose were recorded during this study. A frequency distribution of BOP-TOP distances through which these crossings occurred indicated that nearly three-quarters of them involved windows less than 8 feet high (Table 5); less than 10 percent of the crossings occurred where the BOP-TOP distance was 10 feet or more. Fifty-seven percent of all crossings observed occurred through windows between 6 and 8 feet high.

In order to determine whether moose were selecting certain BOP-TOP intervals as crossing sites and to assess the effects of snow depth, adjacent vegetation, and specific location on the tendency of moose to cross the pipeline, data collected in the Tazlina River-Squirrel Creek area (AS 16-21) were analyzed separately. Data on moose crossings during 2 years were available because A/G pipe was installed there earlier than in the rest of the primary study area. Additionally, data from a large sample of crossings (n=565) were collected along this segment of pipeline, and information on asbuilt dimensions, vegetation types, and snow depth was available.

Statistical comparisons of the observed number of moose crossings through various BOP-TOP intervals comprising certain, known proportions of the pipeline segment on AS 16-21 are given in Table 6. These indicate that moose used windows less than 6 feet high in proportion to their occurrence. Windows between 6 and 8 feet high were used disproportionately more than expected, while those more than eight feet high were used less than expected ($P < 0.05$).

Snow depths were less than normal in the Glennallen area during the two winters when the above data were collected. Only 14 of 553 crossings of the pipeline by moose occurred when snow depth under the pipe was 10 inches or more. The mean BOP-TOP distance used by moose for crossing when snow depths were 6 inches or more was not significantly higher than that used when snow depths were less than 6 inches (84.9 vs. 80.2 inches; $t = 1.09$, $P < 0.05$). The shallow snow depths observed during this study were apparently insufficient to cause moose to alter their choice of windows used as pipeline crossing sites.

Statistical comparisons of the occurrence of moose tracks on AS 16-21 crossing the pipeline adjacent to six discrete vegetation types, versus

Table 5. Frequency distribution of BOP-TOP distances at 1068 successful moose crossings of the Trans-Alaska Pipeline. Data for the Fairbanks and Glennallen study areas were combined for the period December 1975 through April 1977.

BOP-TOP (Inches)	Number Observed	Percent Observed	Cumulative Percent
48-59	24	2	2
60-71	163	15	17
72-83	366	34	51
84-95	244	23	74
96-107	138	13	87
108-119	48	5	92
120-131	41	4	96
132-143	15	1	97
144-155	9	1	98
156+	20	2	100
Totals	1,068	100	

Table 6. Occurrence of moose tracks crossing above ground portions of the Trans-Alaska Pipeline at certain BOP-TOP intervals. Data were collected during winters 1975-76 and 1976-77 from the pipeline segment represented by AS 16-AS 21.

BOP-TOP Interval (Inches)	Proportion of Total Pipeline Segment	Observed Number of Crossings	Expected Number of Crossings	Proportion Observed in Each Interval	Confidence Interval on Proportion of Occurrence (95% Family Confidence Coefficient)1/
$\leq$ 72	0.213	127	120	0.225	$0.178 \leq P1 \leq 0.272$
72-95	0.532	346	301	0.612	$0.558 \leq P2 \leq 0.666$
$\geq$ 95	0.255	92	144	0.163	$0.122 \leq P3 \leq 0.204$
Total	1.000	565	565	1.000	

1/ Constructed using the technique of Neu *et al.* 1974.

the proportion of actual occurrence of each type are given in Table 7. Moose used five of the six types in proportion to their occurrence but used the Tall Spruce Type significantly less than expected ($P < 0.05$). This suggests that moose were moving through the area along migratory routes that did not necessarily coincide with the types of vegetation that moose normally select during the winter season. That moose were basically using the area for migration rather than as winter range is further substantiated by an analysis of directional patterns of observed moose tracks. Nearly two-thirds of 542 tracks observed in the area indicated an eastward movement of moose toward the Copper River. The observed number of moose traveling east (345) was significantly greater than that expected if moose had been traveling at random across the pipeline ($z = 6.33$, $P < 0.01$).

In order to determine if moose were using certain segments of the pipeline as crossing areas while avoiding certain other segments, the pipeline was divided into seven equilinear segments, each 3.4 miles long, on AS 16-21. The number of moose tracks actually crossing the pipeline in each segment was compared to the expected number (Table 8). Segments 1 and 2 on AS 16 and 17 received significantly less use than expected while Segment 4 on AS 18 received disproportionately heavy use as a crossing area ($P < 0.05$).

Finally, with regard to AS 16-21, an effort was made to evaluate the placement of designated big game crossings and their use during winters 1975-76 and 1976-77. Thirty-two A/G DBGCs were installed in this pipeline segment during construction of the pipeline. Of these, 25 percent were placed in spruce habitats where tree height exceeded 30 feet; this was the only type that moose avoided in their migrations through the area (Table 7). The spacing of the crossings did not conform to the recommended criterion of one crossing each one-half mile. Segment 2 (Table 8) on AS 16 and 17 contained only 1 DBGC, but Segment 3 (AS 17 and 18) contained 6 crossings. Segment 4, which received heavy use as a crossing area by moose (Table 8), contained 5 DBGCs, a rate of placement that was approximately proportionate to the length of pipeline contained in that segment and the total number of DBGCs installed in the Tazlina-Klutina River area.

During both winters of this study, the precise locations of 438 sets of moose tracks crossing the pipeline on AS 16 through 21 were recorded. Of these, 11 passed through DBGCs, a rate of use that did not differ significantly from the expected rate ($z = 1.83$, $P < 0.05$). Moose, therefore, were not seeking out DBGCs as crossing sites during the shallow snow conditions that prevailed during the study period.

A total of 466 detailed drawings of track patterns of moose that approached A/G pipeline and attempted to cross were made during this study. Most data were obtained during 1976-77 in the primary study area but drawings from the Fairbanks area were contributed during both 1975-76 and 1976-77 by A. Townsend and C. Kay. Some of the biologists who contributed observations of moose-pipeline interactions did not record track pattern drawings; those who did made no deliberate effort to seek

Table 7. Occurrence of moose tracks crossing above ground portions of the Trans-Alaska Pipeline adjacent to certain vegetation types. Data were collected during winters 1975-76 and 1976-77 in the pipeline segment represented by AS 16 - AS 21.

Vegetation Type	Proportion of Total Pipeline Segment	Observed Number of Crossings	Expected Number of Crossings	Proportion Observed in Each Type	Confidence Interval on Proportion of Occurrence (95% Family Confidence Coefficient)1/
6-30 ft. *Picea* spp.	0.396	148	144	0.408	$0.336 \leq P1 \leq 0.480$
>30 ft. *Picea* spp.	0.214	57	78	0.157	$0.103 \leq P2 \leq 0.211$
12-30 ft. mixed *Picea* spp.-*Populus* spp.	0.273	101	99	0.278	$0.212 \leq P3 \leq 0.344$
12-30 ft. *Populus* spp.	0.026	13	9	0.036	$0.009 \leq P4 \leq 0.064$
Salix spp.	0.078	41	28	0.113	$0.066 \leq P5 \leq 0.160$
Carex spp.	0.013	3	5	0.008	$0.000 \leq P6 \leq 0.021$
Total	1.000	363	363	1.000	

1/ Constructed using the technique of Neu *et al.* 1974.

Table 8. Occurrence of moose tracks crossing the Trans-Alaska Pipeline in seven equilinear segments of above ground pipeline, AS 16-21. Each segment was 3.4 miles long; data collected during winters 1975-76 and 1976-77.

Segment Number	Proportion of Total Pipeline Segment	Observed Number of Crossings	Expected Number of Crossings	Proportion Observed in Each Segment	Confidence Interval on Proportion of Occurrence (95% Family Confidence Coefficient)[1/]
1	0.143	35	61	0.082	$0.044 \leq P_1 \leq 0.120$
2	0.143	30	61	0.070	$0.035 \leq P_2 \leq 0.105$
3	0.143	78	61	0.182	$0.128 \leq P_3 \leq 0.236$
4	0.143	106	61	0.247	$0.187 \leq P_4 \leq 0.307$
5	0.143	57	61	0.133	$0.086 \leq P_5 \leq 0.180$
6	0.143	58	61	0.135	$0.088 \leq P_6 \leq 0.183$
7	0.143	65	61	0.152	$0.102 \leq P_7 \leq 0.202$

1/ Constructed using the technique of Neu et al. 1974.

out those cases where moose had or had not been deflected in their movements.

A frequency distribution of the different behaviors exhibited by moose attempting to cross A/G pipeline reveals that in nearly two-thirds of all cases observed, moose approached the pipeline perpendicularly, crossed it, and moved directly off the workpad (Table 9). Moose lingered on the workpad, paralleled the pipeline, or recrossed it in only 7 percent of the 466 observations. Deflected movements, in which a moose was either prevented from crossing the pipeline or had to alter its direction of movement in order to cross, were evident for 76 observations (16%). The mean length of deflection was 85 yards and there were 17 observations where the length of deflection exceeded 100 yards. The maximum length of deflection extended for 86 consecutive VSMs, a distance of nearly 1 mile. Snow depths under the pipe ranged from less than 1 inch to 15 inches for the observed deflections.

For those cases where a successful crossing of the pipeline was achieved by moose subsequent to an initial deflection, a one way analysis of variance indicated no significant difference in the mean BOP-TOP distance during the initial encounter versus the mean BOP-TOP distance where the crossing occurred (79.6 vs. 88.5 inches, $F = 3.36$, 114 df; P 0.05). However, BOP-TOP distances initially encountered exceeded those at point of crossing in only four instances. This suggests a biologically significant relationship between a moose's perception of a potential crossing site versus one that will produce a deflected movement. Additionally, other parameters including vegetation type, topography, and orientation of approach may act in combination with BOP-TOP distances to either produce deflections or allow movement across the pipeline. Deflected movements were produced by BOP-TOP distances as low as 57 inches and as high as 188 inches under the complex of conditions observed during this study.

In addition to the instances described above where moose were prevented from crossing the pipeline during construction, the 14 cases where moose did not succeed in crossing A/G pipeline are of particular interest. The mean BOP-TOP distance for the 14 observations where crossings were thwarted was 80 inches (range = 51-122 inches). The length of deflected movement along the pipe was variable; certain moose simply encountered the pipe, refused to cross, and returned in the direction of approach. Others paralleled the pipe for distances up to 680 yards and made several attempts to cross. The mean length of encounter with the pipe was 140 yards. Snow depth under the pipe for 13 of the 14 thwarted crossings was 7 inches or less.

Since most of the observations of moose-pipeline interactions were recorded on the workpad, little was learned about moose that may detect the pipeline at some distance and either decline to enter the right-of-way or decline to cross the workpad berm. During January 1977, A. Townsend recorded moose tracks crossing the pipeline in a one-half mile long section on AS 48 and then counted the tracks crossing an abandoned trail that paralleled the pipeline about 100 yards away.

Table 9. Behavior of moose attempting to cross above ground portions of the Trans-Alaska Pipeline, winters 1975-76 and 1976-77. Data were obtained from interpretation of track patterns in snow.

Behavior of Moose	Number of Observations	Percent of Observations
1. Perpendicular approach to pipe with successful crossing and immediate departure from workpad.	303	65
2. Oblique approach to pipe with successful crossing and immediate departure from workpad.	54	12
3. Successful crossing followed by movement parallel to the pipe or by one or more subsequent crossings.	33	7
4. Moose deflected from direction of travel by pipeline; total deflection 180 feet or less followed by successful crossing.	44	9
5. Moose deflected from direction of travel by pipeline; total deflection greater than 180 feet followed by successful crossing.	18	4
6. Moose deflected from direction of travel; successful crossing not achieved.	14	3

About 20 crossings of the trail were recorded for each crossing of the pipeline. The pipeline bisects a known winter range of moose in this area and the data suggest that moose, during their daily movements, may be actively avoiding contact with the pipe, the workpad, and the associated open space surrounding the pipeline.

Finally, opportunities to actually observe moose as they approached the pipeline were rare. M. Buckley, pipeline surveillance biologist, provided the only visual observation where a moose unsuccessfully attempted to cross the pipeline. Buckley watched a young bull walk along elevated pipeline for three-quarters of a mile on AS 113, a treeless area where vertical clearances of 5-6 feet were typical. The moose made repeated approaches to the pipeline but declined to step up onto the workpad. The date of this observation was 2 October 1976.

Snow Conditions in the Nelchina Basin Past and Present

Records that are nearly all inclusive on monthly total snowfall and maximum depth of snow on the ground each month for Gulkana, Alaska, date back 34 winters to 1943-44. Similar records that are less complete span the 17 winter period, 1960-61 through 1976-77, for Paxson and Paxson Lake, Alaska, about 75 air miles north of Glennallen. Snow conditions at Paxson and Gulkana typify those occurring on the summer range and winter range, respectively, of the moose whose seasonal migrations are described elsewhere in this report. Paxson, elevation 2750 feet, is on the south side of the Alaska Range and lies midway between the Alphabet Hills and the upper Gakona-upper Chistochina River uplands (Fig. 2). Gulkana, elevation 1570 feet, is in the spruce "flats" on the dissected plateau that forms the floor of the Nelchina Basin.

Mean total snowfall per month at Gulkana varied from 9.4 inches in December to 2.3 inches in April during the 6-month period November through April (Table 10). November and December have mean values about 1.5 times greater than January and February and 2.5 times greater than March and April. The range of monthly total snowfall values observed during the last 26 years (Table 10) indicates that minimum values of less than 1 inch have historically occurred during each month; maximum values exceeding 36 inches have also been recorded. The range of values also clearly indicates that the potential for deep snow conditions exists early in winter during the months of November and December.

Maximum depth of snow on the ground reflects monthly total snowfall minus the effects of wind and temperatures warm enough to produce melting. Data on mean maximum snow depth, November through May, at Gulkana and Paxson show a steady increase in depth for the period November through February with a slight decrease from February through March at both locations (Table 11). Mean values for March and April are similar at Paxson but the effects of warmer spring temperatures and low precipitation during April act to reduce the April mean at Gulkana by over 6 inches from March values.

Table 10 . Mean total snowfall per month at Gulkana, Alaska weather station November through April, 1951-1977.

Month	Mean (Inches)	Standard Error	Range	Years of Record
Nov.	8.3	1.5	0.1-36.2	25
Dec.	9.4	1.5	0.9-30.0	26
Jan.	5.7	0.8	T-17.5	26
Feb.	6.0	0.9	0.9-19.2	26
Mar.	4.6	0.7	0.3-18.6	26
Apr.	2.3	0.4	0.0-6.9	26

Table 11 . Mean maximum snow depth, November through May, at Gulkana and Paxson Lake, Alaska weather stations. Data for Gulkana were from winter 1943-44 through winter 1976-77; Paxson data extended back to 1960 but were incomplete prior to 1968.

	November		December		January		February		March		April		May	
	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson
Mean	9.1	15.3	13.2	24.0	16.7	29.0	19.3	31.0	18.8	28.9	12.2	27.4	1.8	10.4
Range	0-34	4-30	4-32	8-45	2-40	8-51	6-42	9-55	3-55	10-42	1-46	17-50	0-24	0-28
Standard Deviation	7.4	8.9	6.8	11.4	9.2	11.6	9.7	13.0	11.6	9.3	10.7	8.5	4.6	9.5
Years of Record	33	14	34	16	34	15	34	11	34	15	34	11	34	13

The range of monthly maximum snow depth values during the period December through February indicates the potential for far greater snow depths at Paxson (up to 55 inches) compared to Gulkana (Table 11). This potential is realized during most winters; for the entire "winter" period, November through March, there has only been one winter (1971-72) when when the sum of the Gulkana monthly maximum snow depths exceeded that of Paxson. However, the rank orders of these sums for Paxson and Gulkana are not significantly related (Spearman's rs = 0.50; z = 1.57, P 0.05), principally because winters of shallow snow at Gulkana have not necessarily produced similar conditions at Paxson. An analysis of month-by-month comparisons in rank of maximum snow depth at Gulkana and Paxson indicated a significant relationship only for the month of December (Spearman's rs = 0.74; z = 2.87, $P < 0.01$).

At Gulkana the maximum depth of snow on the ground during December has been a good predictor of the degree of winter severity as measured by summing the monthly maximum snow depths for the period November through April. The rank order of the December values for the 34 years of record is significantly related to the rank order of the November-April sum (Spearman's rs = 0.84; z = 4.82, $P < 0.01$). For nine winters having December maximum snow depths of 8 inches or less, the resulting November-April sum has ranked among the seven lowest values on record. For December maximum depths were 18 inches of snow or more; this prediction of winter severity was accurate, but it was not as precise a predictor as were the lower December values.

During the 10-winter period, 1967-68 through 1976-77, 6 "unusual" winters have occurred at Gulkana (Table 12). The five winters of shallowest snow depths on record have occurred during this period along with the winter of greatest snow depth, 1971-72. A ten-fold difference in the November through April sum of maximum snow depths (snow depth index) is apparent between the mildest winter and the most severe (Table 12). During the mildest winters on record, the snow depth index was only about one-half or less of the 34-year mean; the index of the most severe winter on record was 2.5 times greater than the long-term mean. During winter 1971-72, the average maximum depth of snow for the period November through April at Gulkana was 39 inches per month.

Finally, maximum monthly snow depth data for Gulkana and Paxson during the three winters of this study appear in Table 13. Winter 1974-75 ranked in the upper one-third of record severe winters at Gulkana (Table 12) and depths approaching 40 inches occurred at Paxson during December and January. Shallow snow depths at Paxson that were among the shallowest recorded since 1960 were characteristic of winter 1975-76. Winter 1976-77 was the fourth mildest on record for Gulkana (Table 12), but deep snow occurred at Paxson with a January maximum depth of 37 inches. These data help explain the movement patterns of marked moose and the data on moose-pipeline interactions presented elsewhere in this report.

Table 12 . Indices of winter severity as indicated by monthly maximum snow depths at the Gulkana, Alaska weather station, winter 1967-68 through winter 1976-77.

Winter	Snow Depth Index1/	Rank of Winter Severity2/	Mean Snow Depth Per Month3/	Snow Depth Index Expressed as a Percentage of 34 Year Mean4/
1967-68	24	1	4	27
1968-69	46	5	8	52
1969-70	31	2	5	35
1970-71	58	11	10	65
1971-72	235	34	39	264
1972-73	43	3	7	48
1973-74	77	17	13	87
1974-75	106	24	18	119
1975-76	51	10	9	57
1976-77	45	4	8	51

1/ Computed by summing maximum depth of snow on the ground, November through April each year.

2/ Based on 34 winters of record, 1943-44 through 1976-77. Rank 1 represents the shallowest snow depths on record.

3/ Computed by dividing the snow depth index by six, or the number of months in the interval November through April.

4/ Mean snow depth index for 34 winters of record equals 89 inches.

Table 13. Maximum depth of snow on the ground at Gulkana and Paxson Lake, Alaska weather stations during the three winters of this study, 1974-75 through 1976-77.

	November		December		January		February		March		April		May	
Year	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxson	Gulkana	Paxs
1974 -75	7	14	22	38	24	38	21	37	18	26	14	31	T	12
1975 -76	2	5	8	8	11	16	16	16	14	24	T	17	T	0
1976 -77	6	24	15	33	2	37	6	30	8	40	8	50	4	25

DISCUSSION

Population Identity and Migratory Movements of Moose

The movement patterns of visual-collared and radio-collared moose in the primary study area suggest that three basic populations of moose occur there and members of each have varying potential for interacting with the pipeline. These populations include moose that spend the late summer to early winter period each year in: 1) the Alphabet Hills and surrounding areas; 2) the upper Gakona River; and 3) the spruce-dominated lowlands covering a vast area on the Crosswind Lake-Ewan Lake flats and the lower drainages of the Gulkana, Gakona and Chistochina Rivers. Movement data for members of the lowland population are few and the seasonal movements that these moose undergo are not well defined.

Data on seasonal movements of the Alphabet Hills and upper Gakona River moose indicate that during summer they exploit habitats occurring at about 2500-3000 feet elevation and certain individuals may be found near the limits of subalpine vegetation at about 3800 feet. During winters of average or above average snowfall, moose from these areas use a complex of habitat types at 1800-2200 feet elevation including plant communities dominated by spruce, riparian willows, or balsam poplar. Two large burns, one northeast of Sourdough, the other near Tulsona Creek, have supported large numbers of moose from December through April during many years. Occasionally, during winters of below normal snowfall, moose migrate only short distances and may spend the entire winter in areas normally classified as summer range.

The migratory movements that moose undertake return them seasonally to traditionally used areas and data exist to demonstrate that moose use traditional routes during their travels. Moose were observed to return to winter ranges used in previous years despite a one-year interval when migration was incomplete. In the primary study area, that portion of the pipeline between Sourdough and Round Top Mountain is crossed by many members of the Alphabet Hills moose population during seasonal migrations in the period late November to late January and again during early May through late June. Certain moose spend both winter and summer adjacent to the pipeline in this area and some moose traffic across the workpad can be expected during all months.

The available data on the timing and duration of migratory movements indicate that during any given year much variation exists between the dates of initiation of migration by different individuals. Certain individuals may leave their summer-fall ranges as early as 1 November. Some moose arrive on their winter range as much as six weeks earlier than others. This variation acts to lengthen the period that moose may be in contact with the pipeline, but the movement data obtained for the radio-collared moose indicated that by late January contact with the pipeline had ceased, even during those years when snow conditions caused migration to begin relatively late. Few data exist that relate the observed variability in initiation of migratory movements to the various sex and age classes in the population, but a preliminary conclusion is that cows with calves tend to begin their migratory movements earlier than cows without calves, and bulls are among the last to leave upland areas.

Much year-to-year variation in migratory movements was observed during this study. Snowfall or lack thereof triggers behavioral responses in moose during early winter and to a large extent the timing of the fall migration is related to weather patterns in late autumn and early winter. During certain years of low snowfall, many moose that would normally migrate long distances fail to do so and thus may not contact the pipeline. During spring, most movement occurs during breakup when snow depths are generally decreasing. By May, when many moose contact the pipeline during their spring migration in the Nelchina Basin, snow depths are sufficiently low that few problems arising from moose trying to cross A/G pipeline are anticipated. However, sun crusted snow or densely packed berms may exist during part of the spring migration and dense snow sufficient to support or partially support moose may act to effectively lower BOP-TOP distances. Such conditions were not observed during this study.

Moose-Pipeline Interactions

The observations obtained during this study on the effects of pipeline construction on moose movements suggest that moose are physically prevented from crossing welded pipe resting on cribbing when BOP-TOP distances are less than 4 feet. Observations of moose being deflected by open ditches 10 or more feet deep during installation of below-ground (B/G) pipe were also reported to me, and it seems clear that such features also block moose movements. The significance of blocked movements as a result of these construction practices would depend upon the length of the cribbed pipe or ditch, the length of time that the feature existed, and the time of year. Since many moose appear reluctant to be deflected around potential barriers when the length of the barrier is one-half mile or more, such barriers should be shorter than one-half mile, should be removed as rapidly as possible, and should not be in place during the migratory season of moose in order to minimize undesirable impacts.

Data on successful crossings of A/G pipeline by moose indicated that during shallow snow conditions nearly 60 percent of all crossings occurred through windows with BOP-TOP distances between 6 and 8 feet high. Three-quarters of all crossings occurred where the BOP-TOP distance was 8 feet or less, and more than 90 percent of all moose used windows less than 10 feet high as crossing sites. Only 2 percent of the observed crossings occurred through windows between 4 and 5 feet high. BOP-TOP distances of 60 inches represent a practical lower limit for potential moose crossing sites when snow depths do not exceed 10 inches.

The intensive studies done on the pipeline segment corresponding to AS 16 through AS 21 revealed that moose crossed the pipeline at BOP-TOP distances less than 6 feet in proportion to their occurrence, used BOP-TOPs between 6 and 8 feet more than statistically expected, and used those distances greater than 8 feet less than expected. The pipeline segment where these crossings occurred was used primarily as a migratory corridor by moose. Moose apparently crossed the pipeline as they encountered it adjacent to the vegetation types and migratory routes that were followed, rather than trying to seek out specific sites as crossing areas. Snow depth during the two winters when these observations were made was subnormal in that area. No significant relationship was observed between the mean BOP-TOP distances used as crossings with snow depths of 6 or more inches versus those used when snow was less than 6 inches deep. The tendency of moose to use low BOP-TOP distances as crossing sites rather than seek higher pipe during shallow snow conditions was further substantiated by analyzing the use of designated big game crossings on AS 16 through 21. Use of the DBGCs, where BOP-TOP distances equalled or exceeded 10 feet, was not significantly greater than expected.

Unsuccessful attempts by moose to cross the pipeline, or cases where moose had to alter their direction of travel in order to achieve a successful crossing, were of particular interest during this study. Deflected movements that resulted in either of these two behaviors occurred in 16 percent of 466 cases where detailed responses to the pipeline by moose were recorded. Many of the deflected movements were followed by a successful crossing after an average length of deflection of 85 yards. In all but 4 of 62 instances, moose chose a window of higher BOP-TOP dimensions as a crossing site after rejecting one with less clearance.

It is noteworthy that certain moose displayed a fear response to the pipeline at windows that other moose used as crossing sites with no apparent hesitancy. While certain moose were observed to pass underneath pipeline that was only 49 inches above the workpad, other individuals were deflected by pipe as high as 168 inches. The ultimate fate of a moose that is deflected and does not cross cannot be determined by short-term observation of tracks. Presumably, the moose may return and attempt to cross again if the pipeline bisects its migratory route. During migration, moose are highly motivated to cross the pipeline and may make repeated attempts to do so. In those areas where radio-collared moose are not present it is difficult to interpret the data obtained from tracks seen on the workpad. The observed crossings may represent the repeated activities on the part of resident moose that have become habituated to the pipeline after frequent contact with it. It is likely that moose with winter and summer ranges far removed would behave differently when approaching the pipeline compared to moose that live adjacent to the right-of-way throughout the year.

Limited data gathered in the Fairbanks area suggest that certain moose that have winter ranges near the pipeline may actively avoid contact with the pipeline, the workpad, or the open space surrounding the workpad-pipeline complex.

Moose, Snow, and Pipelines in the Nelchina Basin

Monthly total snowfall and maximum depth of snow on the ground each month are two parameters available from NOAA records that may be useful in predicting the difficulty moose may have in coping with pipelines that could impede their migrations or interfere with daily movements. The importance of snow density, as well as depth, has long been recognized as essential in understanding ungulate-snow relationships (cf. Coady 1974). However, density data are not readily available from the weather records. In the Nelchina Basin during most winters, temperatures remain below 25°F from November through March and wind conditions in the spruce forests that comprise the floor of the Basin do not produce densely compacted snow. Deep, dense snow that would act to provide partial support for moose would occur only under very unusual weather conditions during the period mid-November through late January when most migrating moose have contact with the pipeline during their extensive early-winter movements. Snow, as a critical factor determining the impact of the pipeline on the welfare of moose, would therefore have to act primarily through sheer depth, blocking some pipeline windows and reducing the visual appeal of others as potential crossing sites.

The builders of dams that impound large quantities of water use design criteria to insure dam integrity during the maximum probable flood likely to occur during the life of the structure. So it should be with builders of pipelines that cross through moose habitat; they must consider the maximum probable snowfall likely to occur. To plan for less than the maximum conditions demonstrates a narrow perspective at best and invites disaster at worst.

The potential effects on moose of even the deepest of snows depend on the amount of A/G pipeline in a given area, its height above ground, the timing of moose movements through the area in relation to the period of maximum snow depth, winter maintenance practices along the pipeline, and the length of time that deep snow conditions persist. Evaluation of the potential impact that the Trans-Alaska Pipeline may have on moose during deep snow conditions must, therefore, be area specific and be based on knowledge of both pipeline characteristics and moose behavior.

On the floor of the Nelchina Basin where the pipeline crosses extensive, level areas of spruce forest, B/G pipeline is mainly confined to areas immediately adjacent to the Gulkana, Tazlina and Klutina Rivers. Lengthy, unbroken segments of A/G pipeline, many in excess of 5 miles, are typical in this portion of the Basin. Such segments are characteristic of that portion of the primary study area between Squirrel Creek and the Gulkana River, AS 16 through 26. In the southern portion of this area, where intensive studies on moose-pipeline interactions were made, 21 percent of the pipeline was constructed with BOP-TOP distances less than 6 feet. With 36 inches of snow underneath the pipe, nearly one-half of the pipeline in that area would have bottom-of-pipe to top-of-snow distances of 4 feet or less and some of the windows would be completely blocked. I offer the hypothesis that under these conditions, with 30 to

40 inches of snow, moose would have to undertake extensive deflected movements in order to find suitable crossing sites. Increased depths above that threshold may cause some moose to refrain from crossing at all.

Over the past 34 years, 30 to 40-inch snow depths or more have occurred during one November, one December, and five Januaries at Gulkana. Later in winter, during February and March, these conditions have occurred during six and seven different years, respectively, with a maximum record depth of 55 inches in March 1972. Deep snow late in winter would mainly act to prevent those moose that winter adjacent to the pipeline from getting to various parts of their home range since most migrants have reached their destination by late January. During the past 34 years, two winters, 1965-66 and 1971-72, stand out as meeting the criteria of 30- to 40-inch snow depths that occurred as early as November or December and persisted until late spring. If winters of this nature occur during the life of the Trans-Alaska Pipeline, I foresee many moose having difficulty achieving free passage and movement across the pipeline in southern portions of the primary study area.

In northern portions of the primary study area where the radio-collared moose of the Alphabet Hills crossed the pipeline, a fortuitous arrangement of ice-free soils allowed B/G pipeline to be liberally installed. On AS 27, 28 and part of AS 29, generally the area between Sourdough and Round Top Mountain, 9.9 miles of B/G pipeline in five segments ranging from 0.3 to 4.4 miles occurs in a total pipeline segment 16.8 miles long. Additionally, topographic features frequently allowed the A/G pipe in this area to be installed at BOP-TOP heights exceeding 8 feet. It seems unlikely that migrating moose would be seriously hampered in their efforts to cross the pipeline in this particular area even with snow depths exceeding the record maximum at Gulkana.

Industry's Compliance with Stipulation 2.5.4.1

The concept of free passage and movement of big game animals as contained in Stipulation 2.5.4.1 of the right-of-way lease agreement was not defined or expanded upon when the lease was signed. In the broadest sense, a stipulation as all encompassing as this would be impossible to satisfy since it has been shown that certain animals under certain conditions have failed to achieve free passage. A reasonable definition of the stipulation would require that the welfare of moose populations not be compromised during construction and operation of the pipeline. If significant numbers of moose from a given population failed to reach their traditional seasonal ranges, or if the residents of an area adjacent to the pipeline failed to exploit the energy sources within their home range due to interference of the pipeline, the stipulation clearly would not have been satisfied. Because of the open-ended nature of the stipulation, and because environmental conditions necessary to fully appraise the impact of the pipeline have not yet occurred, a deferred evaluation of industry's compliance with this stipulation is necessary. If, during future winters of deep snow, serious moose-pipeline problems are identified, it is possible that stipulation compliance could be assured by snow removal at certain key sites.

Additional Data Needs

The following represent additional data that could not be collected during this study:

1. The ability of moose to cross the pipeline while it is operational: since field aspects of this study terminated prior to oil flow in June 1977, the effects of radiated heat on snow beneath the pipeline and other possible effects of hot oil flowing through the pipeline remain to be investigated.

2. The ability of moose to achieve free passage when snow depths exceed 30-40 inches: since these conditions occur rarely in the Nelchina Basin it will be necessary to defer this aspect of the study until environmental conditions are suitable.

3. The behavior of certain moose that display a fear response to the pipeline-workpad complex or that are deflected by BOP-TOP distances that other moose use freely: these moose are largely undetected by studies confined to the workpad, but they may be the key animals to study if stipulation compliance is to be fully evaluated.

4. The behavior of moose that encounter the pipeline in tundra environments: few data are available on moose-pipeline interactions on the tundra or in areas of sparse tree cover. The pipeline traverses these habitats commonly in northern segments of its length, and moose, although sparse, are known to inhabit these areas.

5. Evaluation of the spacing, design criteria, revegetation, and remedial actions performed on certain designated big game crossings: an adequate evaluation of the use of DBGCs will require data collected during deep snow conditions. Since much alteration and revegetation of the crossings occurred after the field phase of this study terminated, an assessment of the success or failure of these measures is not yet possible.

6. The relationship of snow depth underneath the pipeline to snow depth away from the pipeline: observations made during this study suggest that A/G pipeline acts much the same as trees do in shielding the area below it from snow. Wind has the potential of altering snow conditions underneath the pipeline. Since snow depth and quality under the pipeline may affect the ability of moose to cross, these areas warrant further study.

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