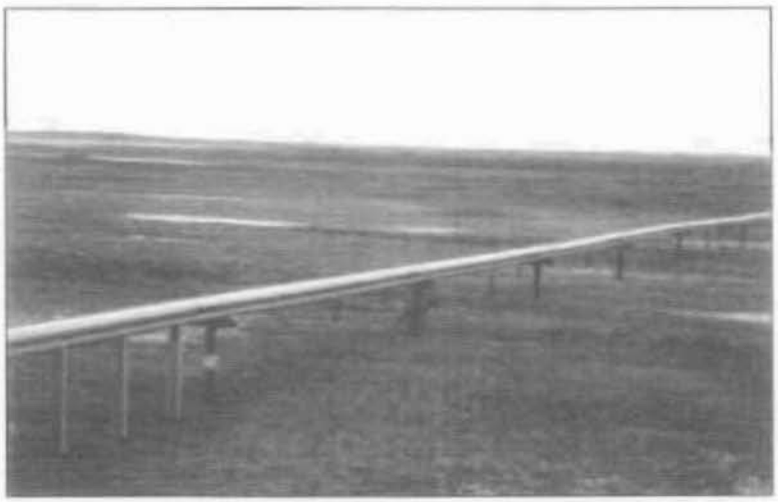
FINAL REPORT
24 July 2001

# The Effect of Pipeline Vibration Dampers on Caribou (*Rangifer tarandus*) Crossing Success Rate Under the Elevated Badami Pipeline, Alaska, 1999



Prepared for

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P462

# The Effect of Pipeline Vibration Dampers on Caribou (*Rangifer tarandus*) Crossing Success Rate Under the Elevated Badami Pipeline, Alaska, 1999

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Cite report as:

Coltrane, J.A., and R.B. Lanctot. 2001. The effect of pipeline vibration dampers on caribou (*Rangifer tarandus*) crossing success rate under the elevated Badami Pipeline, Alaska, 1999. Report for BP Exploration (Alaska) Inc. by LGL Alaska Research Associates, Inc. 20 pp + Appendices.

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**ABSTRACT**

The effect of pipeline vibration dampers (PVDs) on caribou crossing success was examined along the Badami pipeline on Alaska's North Slope, during summer 1999. Observers in towers were used to estimate caribou crossing success near sections of the pipeline with and without PVDs. The numbers of animals, predominant behavior, sex and age class, and crossing success of all caribou groups entering each of two 2,624- x 3,280-ft (799- x 999-m) study areas were recorded. Crossing success (defined as >50% of animals within a group crossing) was not significantly different between caribou groups approaching sections of the pipeline with and without PVDs (37% or 26 of 70 groups for PVDs versus 58% or 14 of 24 groups for non-PVDs). However, there was significantly lower crossing success of individual caribou at pipeline sections with PVDs (27% or 809 of 2,950 individuals) compared to pipeline sections without PVDs (63% or 331 of 524 individuals). There was no effect of group size and composition on caribou crossing success. We also used video cameras to evaluate caribou crossing at several other sites. We were unable to quantitatively assess crossing success, but we observed 813 individuals cross at PVD sites and 639 individuals cross at non-PVD sites. PVDs may have affected crossing success of some caribou, but conclusions from this study are preliminary because of an inadequate study design for quantifying caribou crossing success. Future studies should incorporate multiple replicates and paired comparisons to minimize effects of other variables on caribou crossing success

Key words: Central Arctic Caribou Herd, North Slope, oilfield

# INTRODUCTION

Caribou (*Rangifer tarandus*) of the Central Arctic Herd (CAH) use habitats within the Badami pipeline corridor (Noel 1998, Noel and King 2000). The CAH migrates from the northern foothills of the Brooks Range to the Arctic Coastal Plain including the Prudhoe Bay oilfield and surrounding areas every spring (Cameron and Whitten 1978). Cows generally arrive and calve between late April and early June, while bulls usually arrive in early July (Whitten and Cameron 1980, Jakimchuk et al. 1987). Most calving occurs east of the Badami development facility between Bullen Point and the Canning River (Cameron and Whitten 1978, Gavin 1983, Lawhead and Curatolo 1984, Whitten and Cameron 1985, Cameron et al. 1989), although calving caribou have also been documented between the Sagavanirktok River and Bullen Point (Pollard and Noel 1994, Pollard and Noel 1995, Noel 1998, Noel and Olson 1999, Noel and King 2000). After calving, caribou usually seek coastal and riparian areas, which have higher wind velocities, to escape insect harassment (Cameron and Whitten 1979). Areas along the Badami pipeline frequented by caribou during insect harassment include the deltas of the Sagavanirktok, Kadleroshilik, and Shaviovik rivers (Gavin 1983, Carruthers et al. 1984).

## Study Rationale

The 25-mile (40-km) Badami pipeline, completed during the winter of 1997–1998 by BP Exploration (Alaska) Inc. (BPXA), connects the Badami oilfield facility to the Endicott sales pipeline on the North Slope of Alaska. A review of the pipeline by the Alaska Department of Fish and Game (ADFG) found that three areas totaling about 600 linear ft (182 m) (0.5% of the pipeline length) were elevated less than the 5 ft (1.5 m) required by the North Slope Borough (NSB) Municipal Code and the Alaska Coastal Management Program (1 June 1999 fax from Alvin G. Ott, Regional Supervisor, Habitat and Restoration Division, ADFG, to the North Slope Borough Planning Commission). Additionally, pipeline vibration dampers (PVDs), used to counteract vibrations produced by prevailing northeast winds, have been hung along four sections of the Badami pipeline, totaling 27,179 ft (8,284 m) (21% of the total pipeline length). Two PVDs were placed between pipeline vertical support members (VSM), one at ½-span (27.5 ft or 8.4 m) and one at ¼-span (14 ft or 4.3 m) between VSMs. The ½-span PVDs extended down to 37 in (94 cm) below the pipeline, and PVDs at ¼-span locations extended down to 20 in (51 cm) below the pipeline. ADFG (12 August 1998 letter to BPXA, Appendix A) expressed concern that the "...cumulative effect of mitigating wind-induced vibration with two below-pipe PVDs per span..." may diminish pipeline crossing success by caribou. After review of pipeline height deviations and *Permit NSB 97-028, Conditional Use Permit, Badami Pipeline*, the North Slope Borough Planning Department approved the Conditional Use Permit to BPXA with three stipulations. Stipulation No. 3 reads that "BPXA (shall) work with ADFG and the NSB Wildlife Management Department to develop a monitoring program on the wildlife effects of vibration dampening devices used below the pipeline on crossing success" (letter of 27 August 1998, Appendix A). This study was conducted to address this stipulation, and this report was required by Permit Number ADL 415472.

### Caribou Response To Pipelines

Various studies have examined behavior of caribou encountering elevated pipelines and road systems (Child 1974, Hanson 1981, Smith and Cameron 1985, Dau and Cameron 1986, Murphy and Curatolo 1987, Cronin et al. 1994). Those studies suggest that pipeline crossing success may be affected by group size, group composition, insect activity, and the presence of roads near pipelines. First, individual caribou or small groups of caribou cross roads and pipelines more readily than do larger herds (Child 1974, Smith and Cameron 1985). Second, cows, especially those with calves, tend to avoid structures, including pipes and roads, more than bulls (Whitten and Cameron 1985, Dau and Cameron 1986, Smith et al. 1994). Third, caribou moving to insect relief areas and under insect harassment, cross oilfield pipelines and roads more readily than during periods without insects (Child 1974, Curatolo and Murphy 1986, Dau and Cameron 1986). Fourth, pipes located next to roads with moderate to high levels of traffic may deflect caribou movements (Curatolo and Murphy 1986).

Child (1973) reported a very low crossing rate of caribou under simulated pipelines made of either snow fence covered with burlap or galvanized culverts placed on oil drums. In that study, four underpasses measuring 5 ft or 8 ft high (1.5 or 2.4 m) and 10–150 ft (3–46 m) long beneath a 10,200-ft (3,108-m) snow fence were used by only 5.4% of approaching caribou. Similarly, the 3,600-ft (1,097-m) culvert, which was elevated to only 30 in (76 cm) in most places, was crossed by only 1.5% of the approaching caribou. However, the low crossing rates documented by Child (1973) may have been a result of the short crossing areas, flapping of the burlap that covered the snow fence, and/or the novelty of pipelines to caribou at that time. Caribou may have habituated to pipelines during the past 30 years (i.e., Child's study was done prior to construction of any pipelines; Cronin et al. 1994). Reges and Curatolo (1985) tested pipeline heights ranging from 14 to 43 in (35 to 109 cm) above the ground. Their study indicated that lower pipelines were likely to be jumped, whereas pipelines elevated to 43-in (109-cm) heights formed a nearly total barrier to crossing. Curatolo and Murphy (1986) suggested that caribou will cross beneath pipelines with a clearance of at least 5 ft (1.5 m) unless they are located near moderately or heavily traveled roads. Similar results were reported for pipelines along the Endicott access road (Lawhead and Murphy 1988, Lawhead 1990, Lawhead and Smith 1990). The North Slope Borough's Alaska Coastal Management Program currently mandates all pipelines have a minimum clearance of 5 ft (1.5 m) (North Slope Borough 1984). However, no studies have evaluated the effects of PVDs on caribou crossing success or behavior.

### Study Objectives

Objectives of this study were to: (1) quantify and compare caribou crossing success along Badami pipeline sections with and without PVDs, and (2) determine if group size, group composition, and insect activity affected caribou crossing success and behavior.

## METHODS

Caribou crossing success was monitored along sections of the Badami pipeline with and without PVDs, as well as one buried section of pipeline, using tower-based observers and time-lapse video cameras.

### Study Area

This study was conducted along the Badami pipeline corridor between the west channel of the Sagavanirktok River and Bullen Point on the Arctic Coastal Plain of Alaska (Fig. 1). This area is characterized by a gently rolling thaw-lake plain landscape with elevation rises of 20 to 25 ft (6 to 7 m) above streams and river channels (Walker and Acevedo 1987). Most areas are well drained, with high-centered ice-wedge polygon terrain being most common. However, poorly drained strangmoor, thaw-lakes and ponds, and drained lake basins are also common.

The focus of our study was the Badami pipeline, located within about 1.3 to 3.1 miles (2 to 4.9 km) of the Beaufort Sea coast. This pipeline extends from the Endicott sales pipeline on the west, 25 miles (40 km) east along the Arctic Coastal Plain to the Badami production facility. There is no road adjacent to the Badami pipeline.

### Tower Observations

Tower-based observations were conducted at two 2,624- x 3,280-ft (799- x 999-m) study plots (designated A and B) located along the Badami pipeline 0.45 and 1.77 miles (0.72 and 2.85 km) from the Endicott access road (Fig. 1). The towers were elevated 15 ft (4.6 m) above the ground, with 4- x 4-ft (1.2- x 1.2-m) huts on top. Towers were positioned 82 ft (25 m) south of the pipeline in the middle of each plot. Plot boundaries were marked 1,312 ft (400 m) to the east and west along the length of the pipeline and 1,404 ft (428 m) north and south of the pipeline. Habitat analysis at study locations were based on Walker and Acevedo (1987) Landsat base maps. Vegetation at tower plot A was a mixture of wet herbaceous tundra (35%), moist or dry herbaceous tundra (35%), and sparsely vegetated and barren areas (20%). Plot B vegetation was predominantly wet herbaceous tundra (65%) and shallow ponds (21%).

Caribou activity was monitored daily on plots A and B (Fig. 1) between 0930 and 1530 h, and between 1630 and 2230 h, from 29 June to 26 July 1999. No observations were made between 2230 and 0930 h or between 1530 and 1630 h, when observers were changed. No data were collected on 18 and 26 July due to inclement weather. Tower-based observers documented caribou crossing success and behavioral responses to the pipeline, and monitored weather and mosquito activity. Observations were made with 10x42 binoculars and 15x to 45x spotting scopes. Data were collected using continuous visual monitoring and 10-min interval sampling. Observers recorded group size and composition, predominant activity, and direction of travel for all caribou entering the study plots. Groups were classified according to the predominant (more than 60% of all individuals) sex and age class present. Sex and age classes included bulls, cow/calf pairs, cows without calves, and yearlings. Groups were classified as having a mixed composition if no single age/sex class composed 60% or more of the individuals in the group. We recorded the sex and age class of caribou crossing the pipeline, and whether the location crossed had PVDs or not.

### Insect Activity

Because weather and parasitic insect activity (i.e., mosquitoes and oestrid flies) may influence caribou behavior and movements (Pollard et al. 1996), we recorded weather data and insect abundance at the beginning and middle of each observation period. Weather and insect data collection was postponed when caribou were present in the study area. Wind speed was recorded to the nearest knot using an electronic wind speed indicator (Davis Instruments). Wind direction was recorded in 45° increments using an anemometer and air temperature was recorded using a thermometer to the nearest degree centigrade.

Insect abundance was quantified using systematic sweep net sampling at the tower plots (Pollard and Noel 1994, Pollard et al. 1996). Mosquito sweep counts were averaged over each day (first by tower and then together), and then each day was categorized as having mosquitoes present (>9 mosquitoes) or absent (<9 mosquitoes) (Table C-1, Appendix C). We also calculated a mosquito index (Russell et al. 1993) for camera sites from weather data collected at the Deadhorse airport (Appendix B). We considered any day with at least 4 hourly index scores greater than 0.5 as having mosquitoes present (Appendix B and C). The Deadhorse airport weather data were also used to calculate an oestrid fly index (Mörschel 1999) for each day of observations.

### Camera Observations

Time-lapse video recorders and cameras were set up at 6 sites along the Badami pipeline (Fig. 1). Video cameras were placed in locations to monitor pipeline sections that were buried, sections with PVDs, and sections without PVDs. Locations were chosen based on pipeline configuration, caribou crossing patterns in 1998 (Noel and Olson 1999), and land cover types determined with aerial photography. To document caribou crossing along river corridors where the pipeline was buried, we placed one camera (camera 2) on the east side of the east channel of the Sagavanirktok River and a second camera (camera 6) on the east side of the Kadleroshilik River. The habitat within the camera view on the Kadleroshilik River was predominantly barren (54%) with wet and moist or dry herbaceous tundra (15%). The remaining 4 cameras were paired (one with PVDs and one without PVDs) as closely as possible based on pipeline configuration, topographic and habitat characteristics (i.e., high dry areas with caribou trails).

The view area for camera 1 was predominantly wet herbaceous tundra (76%), and for camera 3, the corresponding paired non-PVD site, was predominantly moist or dry herbaceous tundra (about 75%). Camera site 4 was entirely moist or dry herbaceous tundra (100%) and the paired non-PVD site, camera 5, was predominately moist or dry herbaceous tundra (about 60%) with areas of wet tundra, water and mixed shrub tundra.

Each site had a camera assembly consisting of a GYYR™TLC1800-DC time-lapse videocassette recorder and a Panasonic™ WV-CL 322 color CCTV digital camera equipped with a Computar™ APC auto-iris 8.5 mm semi wide-angle lens (Pollard and Noel 1994, Noel et al. 1998). Each assembly was powered by four 12-volt, 80-amp sealed lead acid batteries, charged by four Solarex™ SX-56 photovoltaic panels. The video recorder, camera, and batteries were housed in insulated aluminum casings to protect them from weather and animals. Each camera assembly was set up about 50 ft (15 m) south of the pipeline, with the solar panels facing south and the cameras aimed down the length of the pipeline. This allowed both the north and south side of the pipeline to be viewed except where hummocks and pipeline VSMs obstructed the view. Each video camera had a 72° field of view and monitored caribou movements along approximately 984 ft (300 m) of the pipeline (a 0.043-$km^2$ area). Video cameras were programmed to record images at 6- to 8-second intervals, 24 hours a day; however, darkness precluded recoding for 4 hours each night. Videotapes were replayed on a GYYR™ time-lapse recorder connected to a color television monitor. Due to the camera's limited field of view, only caribou that crossed the pipeline were recorded. In conjunction with each crossing event, we recorded the date, time, number of individuals crossing, and direction of travel.

Video cameras had a limited field of view, took images at 6- to 8-second intervals making it difficult to accurately estimate the size of large groups, and only recorded caribou that crossed the pipeline. Due to these constraints, no quantitative comparison of crossing success between areas with and without PVDs was possible.

### Statistical Analyses

Data from tower plots were analyzed by treating each caribou group as an independent observation and comparing the number of individual caribou. For group size analyses, we used actual group size (a continuous variable) and 3 categories of group sizes. Categories were determined by plotting frequency of group sizes observed at the tower plots and identifying gaps in their sizes. Using this approach, we defined the following group size categories (1–5, 6–40 and >40 animals). For tower observations, crossing success was defined as when at least 50% of the members of a group crossed the pipeline (Curatolo and Murphy 1986). We also used the percentage of each caribou group that crossed tower plots as a continuous dependent variable to investigate how crossing success was effected by group size (in a one-way, weighted analysis of variance test). We compared the success rate of groups and individuals that crossed sections of pipeline with and without PVDs. For analyses involving continuous variables we used Kruskall-Wallis or Mann-Whitney U tests (Zar 1984). When sample sizes were sufficient, we transformed data (square root for group sizes, and arcsin square root for proportion of caribou crossing) and used parametric analysis of variance and the t-test statistics. Likelihood ratio chi-square and Yates corrected chi-square were used for tests of categorical variables. All analyses were conducted with SYSTAT® ($\alpha$=0.05).

## RESULTS

### Tower Observations

Caribou were recorded from towers on 21 of 26 days between 29 June and 26 July 1999. No caribou were observed on 10, 20, 22, 23, and 25 July. No data were collected on 18 or 26 July due to inclement weather. A total of 94 caribou groups and 3,474 individual caribou were observed, with between 1 and 12 groups observed per day (mean and SE of number of groups = 4.5 ± 0.83 groups; Table C-1, Appendix C).

Thirty-seven percent (26 of 70) of caribou groups observed near the pipeline with PVDs crossed, whereas 58.3% (14 of 24) of the groups in an area without PVDs crossed (Fig. 2 and Table 1). This difference was not significant (Yates corrected $\chi^2$ = 2.47, df = 1, $P$ = 0.12). However, there was a significant difference in crossing success of individual caribou (ANOVA $F_{1,92}$ = 10.1, $P$ = 0.002). Only 27% (809 of 2,950) of individuals observed near pipelines with PVDs successfully crossed versus 63.2% (331 of 524) observed near pipelines without PVDs (Fig. 2).

There was no significant difference in average group size of caribou observed near pipelines with PVDs and without PVDs ($t$-test for unequal variances, $t$ = –1.34, df = 53.8, $P$ = 0.19). Similarly, when group sizes were categorized into 1–5, 6–40, and >40 animals, we found no significant difference in group size between pipeline sections with and without PVDs (Fig. 3, Likelihood ratio $\chi^2$ = 2.48, df = 2, $P$ = 0.29). There also were no significant differences between pipeline sections with and without PVDs regarding sex and age class of animals observed (Table C-2, Appendix C, Likelihood ratio $\chi^2$ = 5.82, df = 4, $P$ = 0.21).

There was no significant effect of group size on crossing success for all pipeline configurations combined (Fig. 4A, Likelihood ratio $\chi^2$ = 2.62, df = 2, $P$ = 0.27), for pipelines without PVDs (Fig. 4B, Likelihood ratio $\chi^2$ = 0.34, df = 2, $P$ = 0.84), or for pipelines with PVDs (Fig. 4C, Likelihood ratio $\chi^2$ = 1.67, df = 2, $P$ = 0.43) (Table C-2, Appendix C). Similarly, we found no effect of group type on caribou crossing success for all pipeline configurations combined (Fig. 5A, $\chi^2$ = 4.52, df = 4, $P$ = 0.34), for pipelines without PVDs (Fig. 5B, $\chi^2$ = 7.65, df = 4, $P$ = 0.11), or for pipelines with PVDs (Fig. 5C, $\chi^2$ = 3.52, df = 4, $P$ = 0.47).

**Insect Activity**

Mosquitoes were classified as being present on 12 days and absent on 14 days during tower observations (Appendix C). Average number of mosquitoes counted/sweep net sample ranged from 17 to 103.3 (mean ± SE = 43.9 ± 9.2, $n$ = 12) on "present" days, and from 0 to 8.5 (mean ± SD = 2.6 ± 0.8, $n$ = 14) on "absent" days. Mosquitoes were present from 2 to 12 July, and on 16 and 23 July. The oestrid fly index (Mörschel 1999) indicated oestrids were likely to be present for 3 hours on 2 July and 1 hour on 9 July (Table B-1). Given that oestrid flies were likely to be active on only 2 of the 26 days in which observations were made, we did not consider them further.

Mosquito presence appeared to significantly decrease the likelihood of caribou crossing the pipeline for all pipeline configurations combined (Table C-1, Appendix C; ANOVA weighted by caribou group size, $F_{1,92}$ = 5.63, $P$ = 0.02) and for pipeline sections with PVDs (ANOVA weighted by caribou group size, $F_{1,68}$ = 4.54, $P$ = 0.04). However, mosquitoes had no significant effect on crossing success across the pipeline section without PVDs (ANOVA weighted by caribou group size, $F_{1,22} = 0.32$, $P = 0.58$).

### Camera Observations

We collected video footage from 5 of the 6 camera sites from 24 June to 26 July 1999 (Fig. 1). The 6th camera, located at the Sagavanirktok River, failed to record shortly after installation. Caribou were observed on at least one camera on all but 4 days (i.e., 30 June and 18-20 July; Appendix C). Mosquitoes were classified as being present on 12 days and absent on 23 days from the 24 June to the 26 July 1999. The Mörschel (1999) index indicated oestrids were likely to be present only on 2 and 9 July, so they were not included in subsequent analyses.

Caribou were recorded at all 5 camera sites. A total of 813 caribou were recorded crossing pipeline sections with PVDs (632 individuals at camera 1 and 181 individuals at camera 4); a total of 639 caribou were recorded crossing pipeline sections without PVDs (529 individuals at camera 3 and 110 individuals at camera 5); 1,034 caribou were recorded crossing at site 5, the river site with buried pipe (Tables C-2 through C-4, Appendix C).

## DISCUSSION

Tower-based observations suggested that caribou may be less likely to cross the Badami pipeline where PVDs were present than in areas where PVDs were not present. While 37% (26 of 70) of the caribou groups near pipeline segments with PVDs crossed the pipeline, and 58.3% (14 of 24) of the groups near pipeline segments without PVDs crossed the pipeline (Table 1), this difference was not statistically significant. In addition, only 27% of individual caribou crossed pipelines with PVDs, while 63% of individuals crossed without PVDs.

However, our results may not reflect the actual effects of PVDs on caribou crossing success given flaws in the study design. Specifically, tower placement eliminated replicates for statistical testing. Perhaps more importantly, placement of towers may have biased crossing rates and success. For example, caribou crossing success in plot B, which had PVDs along its entire length, may have been low because the plot was located near the Sagavanirktok River. Consequently, caribou, which use riparian corridors to access the coast (this study, Child 1971), may have crossed through plot B on the way to the river with no intention of crossing the pipeline. Those caribou may have incorrectly been classified as not having crossed the pipeline. Conversely, plot A was located near the Endicott Sales pipeline and road (Fig. 1). This pipeline intersection and the vehicular traffic along the road may have funneled caribou along the Endicott Sales pipeline into this area, or altered the crossing frequencies.

Secondly, although the use of cameras would have allowed replication, the cameras did not collect caribou observations over a wide enough angle and at a sufficient frequency to make them useful for quantifying caribou crossing success. Camera data were only useful for recording caribou crossing the pipeline. We were able to determine that 813 caribou crossed pipelines with PVDs and 639 crossed pipelines without PVDs during comparable observation periods.

Several other factors may also have affected measurement of crossing success for caribou. The size of the approach zone or the presence of the towers may have affected the observed crossing success. Using a 1,640-ft (500-m) approach zone may have caused observers to record caribou groups passing through the study area (i.e., paralleling the pipeline), but not intending to cross the pipeline, as groups not successfully crossing the pipeline. Logically, smaller approach zones would lead to higher crossing success measurements. Murphy and Curatolo (1987) determined that caribou reacted moderately within 984 ft (300 m) of a pipeline, whereas, they reacted moderately and severely within 1,971–3,280 ft (601–1,000 m) and 0–1,968 ft (0–600 m), respectively, of a pipeline/road complex.

Our analyses suggested that size and classification of caribou groups did not influence whether caribou crossed pipelines with and without PVDs. Other researchers have found that individual or small groups of caribou more readily cross roads and pipelines relative to larger groups (i.e., >100, Child 1974, Smith and Cameron 1985), and that cows and calves are more likely than bulls to avoid pipelines and other oilfield structures (Whitten and Cameron 1985, Dau and Cameron 1986).

## FUTURE STUDIES

Potential effects of PVDs on caribou crossing success could be evaluated by pairing similar stretches of pipeline and habitats both with and without PVDs, however, it may not be possible to adequately account for all confounding variables. Pairs should have similar habitat characteristics. Cameras could be located at paired sites, however, these should focus on measurements of the magnitude of animals crossing, not evaluating crossing success. Ideally, comparisons at the same sites pre- and post-PVD installation should be made.

## ACKNOWLEDGMENTS

This study was conducted for BP Exploration (Alaska) Inc. We thank Dr. Ray Jakubczak, Dave Trudgen, and Conce Rock of BPXA for their support. Dr. Bill Streever, Environmental Studies Group Leader (BPXA), Matthew Cronin and Warren Ballard of LGL Alaska Research Associates, Inc. (LGL), made many constructive comments and revisions on the report. Many thanks to Jamie King of LGL, who helped set up the video cameras and towers, and to our field technicians: Isaak Helmericks, Billy Adams, Shawn Haskell, and Pamela Wolfe. We especially thank Todd Hayes of Air Logistics for piloting the helicopter and assistance with moving and setting up the towers and camera systems.

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Zar, J.H. 1984. Biostatistical analysis. Second edition, Prentice Hall, Englewood Cliffs, NJ. 718 pp.

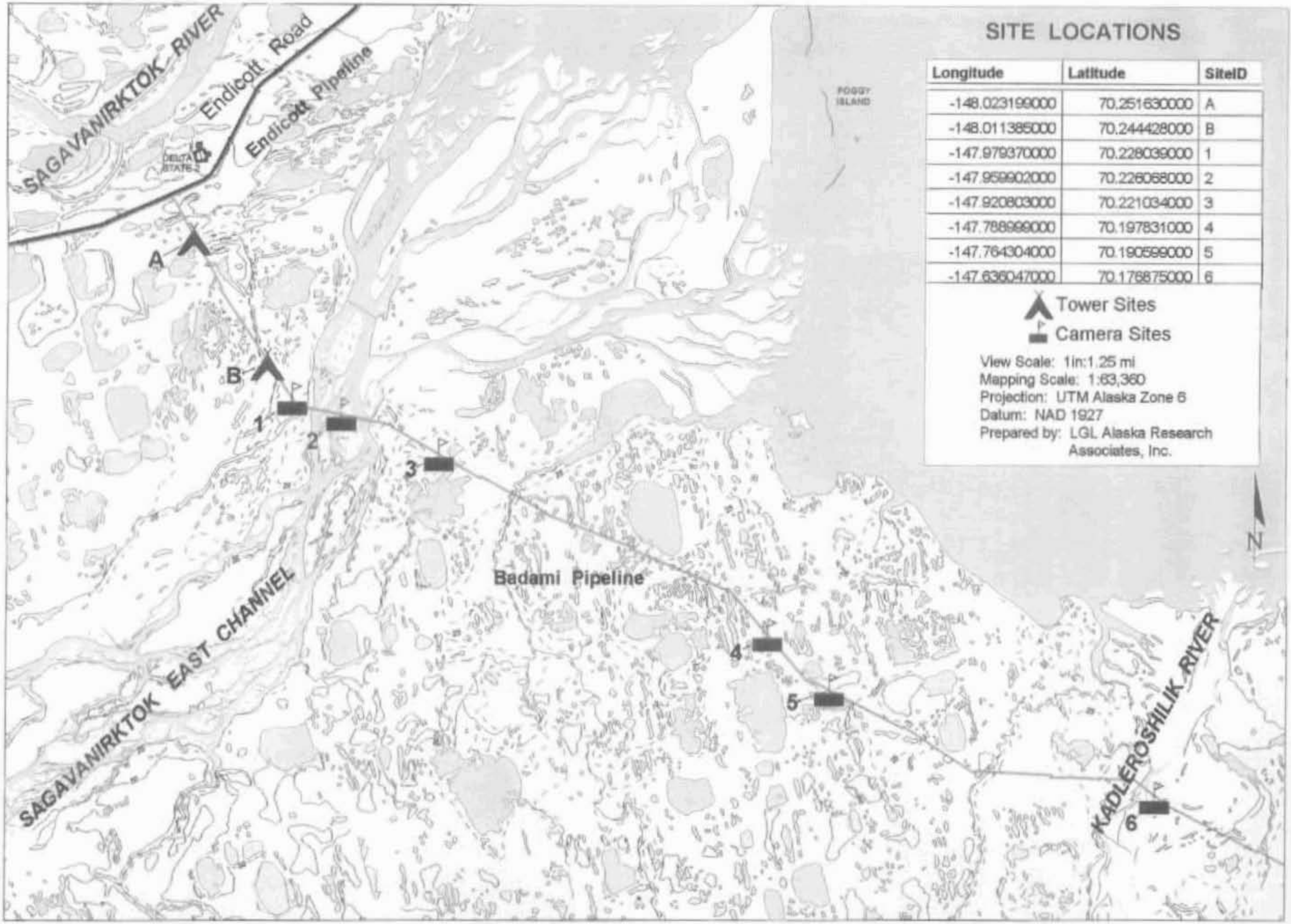


Figure 1. Tower and video camera locations along the Badami pipeline, Sagavanirktok River delta area, Alaska, summer 1999.

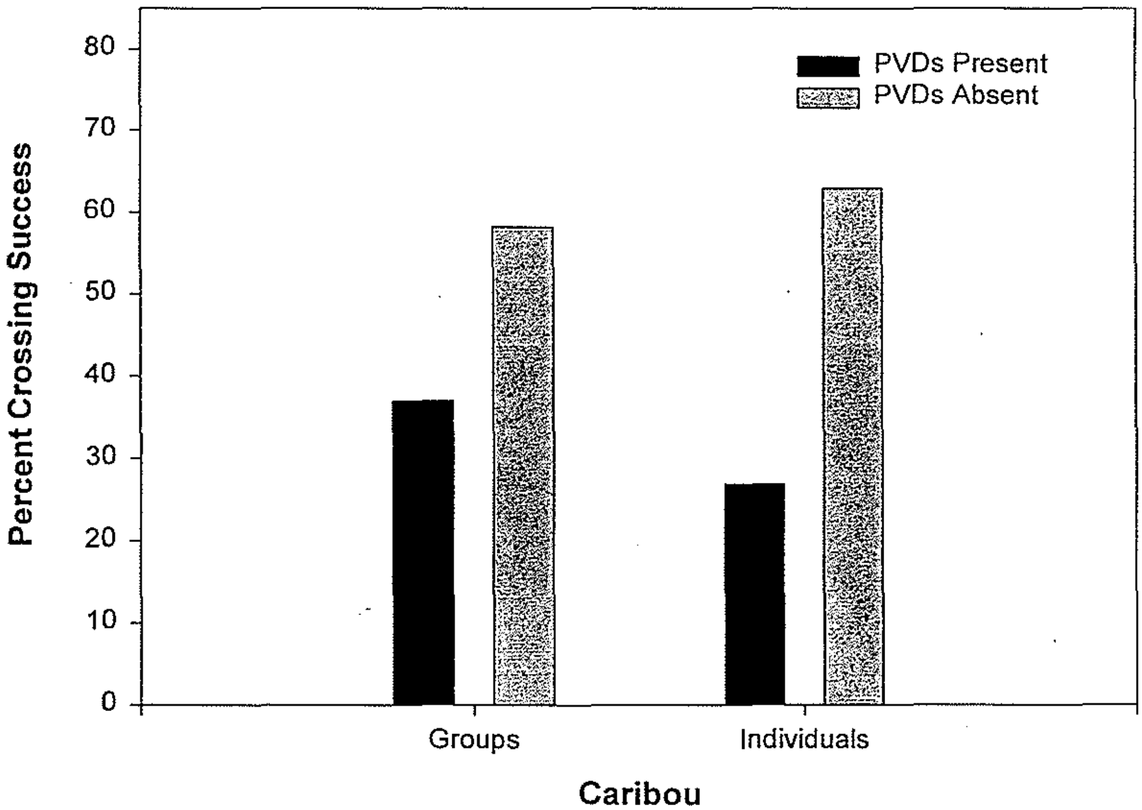


Figure 2. Caribou crossing success for groups and individuals observed from tower plots in relation to the presence and absence of pipeline vibration dampers (PVDs) along the Badami Pipeline, Alaska, between 29 June and 26 July 1999.

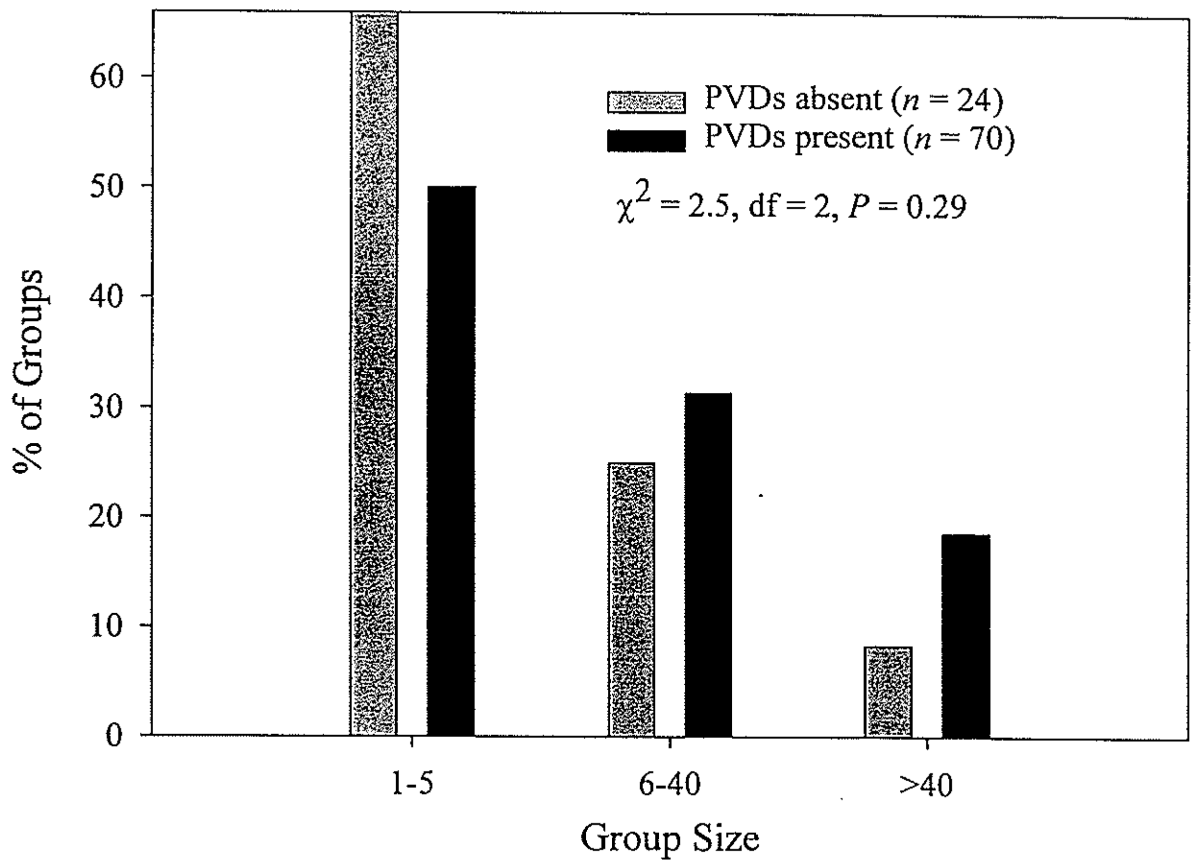


Figure 3. Caribou group size observed from tower plots in relation to the presence and absence of pipeline vibration dampers (PVDs) along the Badami Pipeline, Alaska, between 29 June and 26 July 1999.

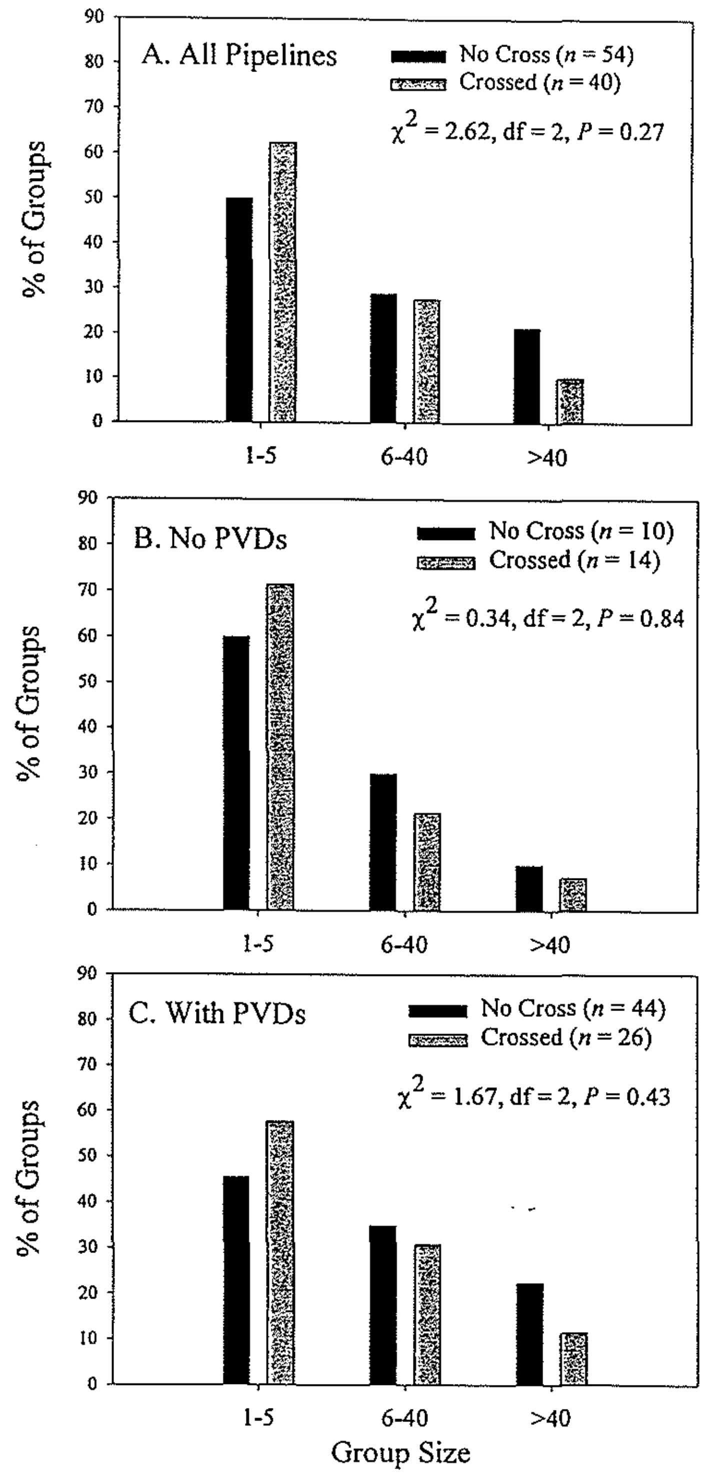


Figure 4. Caribou crossing success at the Badami Pipeline, Alaska, in relation to group size and the presence or absence of pipeline vibration dampers (PVDs). Data were collected at tower plots between 29 June and 26 July 1999.

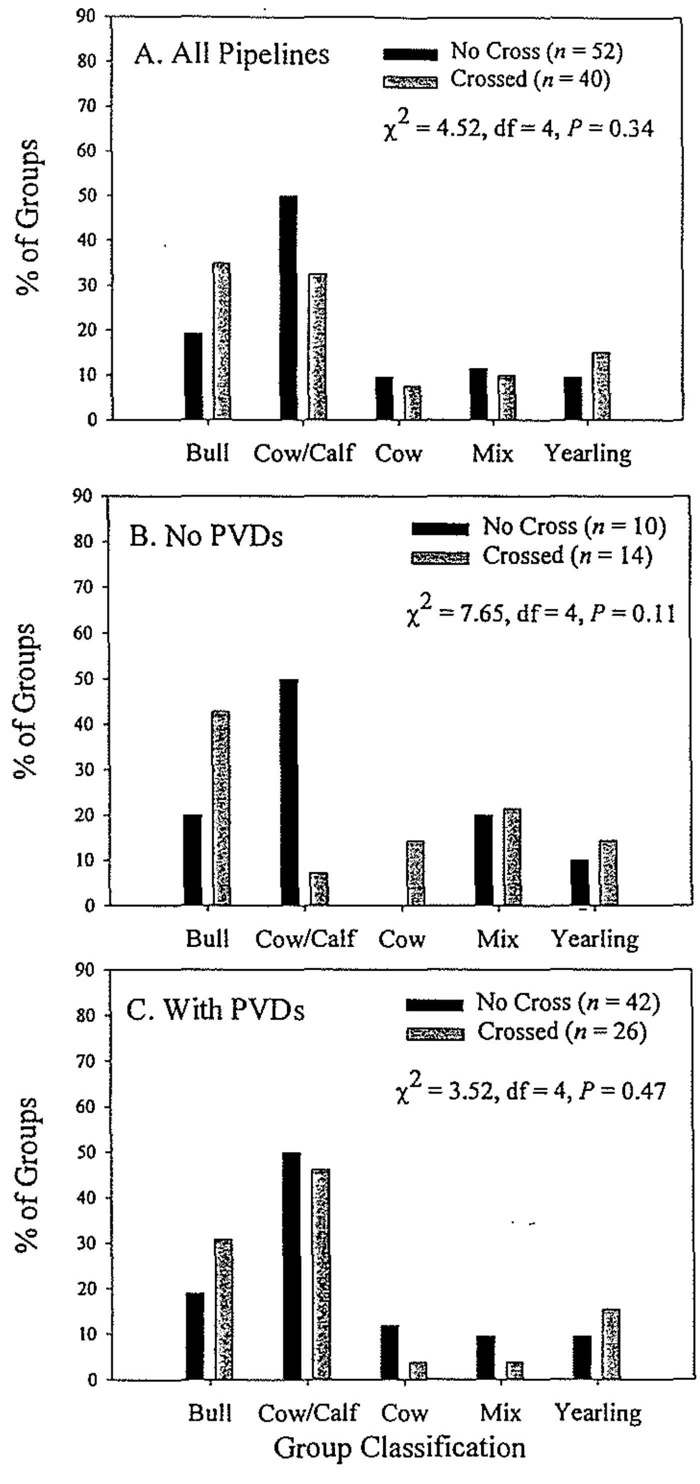


Figure 5. Caribou crossing success at the Badami Pipeline, Alaska, in relation to group type and the presence or absence of pipeline vibration dampers (PVDs). Data were collected at tower plots between 29 June and 26 July 1999.

Table 1. Tower observations of caribou crossing the Badami Pipeline, Alaska, at sites with and without pipeline vibration dampers (PVDs) from 29 June to 26 July 1999. See Figure 1 for location of tower plots.

| | | Groups Observed | | | | Individuals Observed | | | |
|---|---|---|---|---|---|---|---|---|---|
| Study Area | Area ($km^2$) | Total Groups | Total Groups/$km^2$ | # Groups Crossed | % groups Crossed | Total # of Individuals | Total Individuals/ $km^2$ | # Individuals Crossed | % Crossed |
| PVDs | 1.2 | 70 | 58 | 26 | 37.1 | 2950 | 2458 | 809 | 27 |
| Non-PVDs | 0.4 | 24 | 60 | 14 | 58.3 | 524 | 1310 | 331 | 63 |
| Total | 1.6 | 94 | 58.8 | 40 | 42.6 | 3474 | 2171 | 1140 | 32.8 |

# APPENDIX A

# LETTERS OF CORRESPONDENCE

NORTH SLOPE BOROUGH
PLANNING DEPARTMENT
P.O. Box 69
Barrow, Alaska 99723
Phone: 907-852-2611
907-852-0320
Fax: 907-852-0322

Karen Burnell, Director

To: North Slope Borough Planning Commission

Thru: Karen Burnell, Land Management Administrator

From: Jon Dunham, Deputy Director

Date: August 27, 1998

SUBJECT: PERMIT NSB 97-028, CONDITIONAL USE PERMIT, Badami Pipeline

The Badami oil field is being developed by British Petroleum Exploration Alaska (BPXA). The field was originally proposed for development using a buried chilled line, which was the proposal BPXA submitted for the rezoning of the area from Conservation to Resource Development in 1994-95. Normally the action of rezoning along with an administrative approval is the permit from the North Slope Borough for development of a major oilfield. The only time additional permits are needed is when there is a major change in the development proposed. Subsequent plan revisions called for an elevated pipeline, which required a development permit from the North Slope Borough.

The Permitting and Zoning Office was informed in May of this year that the Badami Pipeline was less than five feet in height in three specific sites by Gene Pavia, Project Review Coordinator for the Governor's Division of Governmental Coordination at the Joint Pipeline Office (JPO). The call was made to ask if the North Slope Borough knew of this matter and if this was acceptable. The response was that it was not acceptable because North Slope Borough Municipal Code (NSBMC) and the Coastal Management Program (NSBCMP) require a minimum pipeline height of five feet. Such a deviation from the five foot minimum pipeline height standard constituted a violation of local planning and zoning laws. Arrangements were made with BPXA to inspect the sections of the Badami pipeline in question.

The Alaska Department of Fish and Game Habitat Division (ADF&G) reviewed the pipeline survey data for the Badami Project and noted three areas where pipeline height fell below the 5 foot minimum height required by the Alaska Coastal Management Plan (ACMP). This information was outlined in 1 June 1998 fax from Alvin G. Ott, Regional Supervisor, Habitat and Restoration Division, ADF&G.

The JPO pursued an explanation of the height deviation with BPXA and received a reply on May 27, 1998. In a letter from Michael Chang, BP Transportation (Alaska), Inc., which indicated, "Due to undulations in the tundra surface, several VSM's were installed below the five foot elevations....In each of these areas, the height anomalies were the result of hummocks along the right-of-way. Relocation of the VSM's to avoid the peaks could have created pipeline integrity issues or onerous design concerns. All VSM's were installed based on conscious engineering decisions, accounting for many variables at each location." Mr. Chang goes on to say, "BP Transportation (Alaska) Inc. is confident that the VSM's, as installed, meet the agreed design criteria. The engineers and constructors are currently developing "as-built" drawings which will be provided to you as soon as the are available."

BPXA Permitting Supervisor Peter Hanley offered the following explanation,

> *"The length of the pipelines (there are two lines sharing the same Vertical Support Members) that does not meet this requirement is 600 feet out of a total pipeline length of 25 miles (132,000 feet) i.e. 0.5% of the total line length. There are three locations of lower pipeline that comprise this total of 600 feet. There are 14 VSM's out of a total 2400 VSM's that were constructed lower than the 5 foot requirement again at three locations. The reason for the lower segments is that unusual terrain irregularities made it difficult from a design, construction and access (maintenance and repair) criteria to maintain the 5 foot minimum in these three areas. However, it should be noted that there are significant lengths of the Badami pipelines that are over the minimum 5 feet including at some stream crossings (e.g. No Name River). These streams are often caribou migration routes.*
>
> *These pipeline design problems and variance were, we believe, discussed in meetings with Federal and State agencies which the North Slope Borough representatives attended. We believe one of these discussion occurred in an interagency meeting on June 28, 1996 in which Ralph Davis and Susan Atos of your office* (the NSB Permitting & Zoning Office) *attended by teleconference. In addition, we recall that Mr. John Greenslade and I participated in a meeting with Ms. Dee Olin-Hoffman, then Land Management Administrator, during which this design variance was discussed. We also recall Borough representatives did not express any significant concerns with these minor potential variances from the standard. We have researched our permit records but have been unable to locate any documents relating to those discussions. While we believe we had made a good faith effort to discuss this issue with the agencies, we did not, however, formally request a variance from the North Slope Borough. We sincerely regret our failure to submit a formal request and maintain appropriate documentation of the meetings. While the State of Alaska had opportunity to specifically review information on the design elevations in formal design and construction submittals to the State Pipeline Coordinator's Office (SPCO), the same level of information was not provided to the Borough."*

Permit File Review

The North Slope Borough received an application from BPXA for a major amendment to their original rezone plans that were approved by the Borough Assembly in 1994-95. On December 18, 1996, NSB 97-028 was issued to BPXA for the development of the Badami Project. The 5 foot minimum height for elevated pipelines required under NSBMC 19.70.050(L)(5) and NSBCMP 2.4.6(e) was not referenced in the Borough permit since it is law and because BPXA acknowledged this requirement in their documentation that was submitted as permit background information (3.5.2 Elevated Pipelines page 3-7, 4.2.3 Elevated Pipeline page 4-5, BPXA). Additionally, the US Army Corps of Engineers permit for this project (reference number 2-940700, waterway number Mikkelsen Bay 2) specifically states, "...the pipeline system would be elevated at least 5 feet above the tundra surface to allow caribou and other wildlife to pass freely underneath the pipe."

Field Assessment

On June 22, 1998, Craig George, NSB Wildlife Management Biologist and Jon Dunham, Deputy Director for Land Management for the NSB Planning Department flew to Deadhorse to fly the Badami Pipeline route with Dr. Ray Jakubczak, BPXA Supervisor of Environmental Assessment and Dick

Crosby, representing Houston Contracting, builder of the pipeline. A Bell 206 helicopter (ERA, Inc.; chartered by BPXA; piloted by Scott Smith) was used to conduct the inspection.

The people mentioned above departed from the Deadhorse airport and headed for the Endicott pipeline, where the Badami pipeline will tie into the existing pipeline infrastructure. The Badami pipeline is composed of an insulated 12 inch oil pipeline and a 6 inch gas pipeline. Flying West to East, all three of the sites where the pipeline is less than five feet were between the Sagavanirktok River and the Kadleroshilik River. The winter time construction of this pipeline left little sign of equipment damage to the tundra and appeared to be of the lowest impact to the surrounding environment.

The first landing was made at Vertical Support Member (VSM)# 568; the site was in wet tundra interspersed with small ponds. Field measurement of this VSM indicated it was 4.58 feet from grade to the bottom of the 12 inch pipeline (the bottom of the pipeline is actually higher than the top of the steel I-beam). The preliminary as-built information indicated this VSM was about 4.95 feet to the top-of-the-steel (TOS) I-beam supporting the pipelines. Between the VSM 568 and 569, the minimum pipeline height above the ground was 4.6 feet. A few miles west of this site, there appeared to be an area of high historical caribou use based on the presence of numerous north-south trails.

The second landing was made at VSM# 733. The preliminary as-built received from JPO indicated this VSM was approximately 4.88 feet to the TOS. Field measurement indicated this VSM was 4.58 feet to the bottom of the pipeline. The length of pipe out of compliance was about 200 feet. A drained lake area less than 200 feet distance had VSM's approximately 10 feet above ground level (AGL). Thus, it seems likely that caribou could freely move past this potential obstruction.

The lowest pipeline and VSM heights were measured at the third landing at VSM# 975. The preliminary as-built indicated this VSM was approximately 4.27 feet from the grade to TOS. Field measurement indicated this VSM was actually 3.83 feet from the grade to the bottom of the pipeline. Other VSM's were measured at this site as indicated below:

| VSM | As-built Information | Field Measurement |
|---|---|---|
| #976 | 3.65 feet | 3.83 feet |
| #977 | 3.68 feet | 3.33 feet |
| #978 | 4.06 feet | 4.92 feet |

As this pipeline moved East, there were VSM's of 10 feet in height, spanning what appeared to be a dry river channel. There was evidence of caribou passage down in this channel.

At this third landing it was very apparent measurement at the VSM's will not always give an accurate picture of pipeline clearance. In between VSM# 975 and # 976 there is a hummock that is 2.66 feet from the bottom of pipeline, which is about half the height required by NSBMC 19.70.050(L)(5) and NSBCMP 2.4.6(e).

Listed below are the criteria for approving this conditional use permit:

*A.* *Policies*. NSBMC 19.70.050., "Coastal Management and Area Wide Policies," subsection L(5)(a) & (b) states,

(a) A means of providing for unimpeded wildlife crossing shall be included in the design and construction of structures such as roads and pipelines that are located in areas used by wildlife. Pipeline design shall be based on the best available information and include adequate pipeline elevation, ramping, or burial to minimize disruptions of migratory patterns and other major movements of wildlife. Aboveground pipelines shall be elevated a minimum of 5 feet from the ground to the bottom of the pipe, except at those points where the pipeline intersects a road, pad, or caribou ramp, or is constructed within 100 feet of an existing pipeline that is elevated less than 5 feet. Temporary pipelines (not to exceed 6 months) are exempt from this policy. NSBCMP 2.4.6(e)

(b) Intent: In areas used by wildlife, this policy establishes a five-foot minimum pipeline elevation where elevation is the preferred means of providing for unimpeded wildlife crossings. Best available information will be evaluated during project review to determine if pipeline burial, ramping, elevation, or a combination thereof, will be employed.

This policy clearly mandates a minimum standard that is required to be maintained at every location along a pipeline. This standard will become increasing important as these pipelines approached the villages of the North Slope to ensure an abundance of subsistence resources for Borough residents.

*B.* *Reviewing Parties.* Comments to be provided at public hearing.

*C.* *Villages.* For approvals within the villages or their areas of influence, due deference has been given to the opinions of residents of the village and the proposal is in conformance with adopted village plan policies. Concerns or comments received from village residents will be provided at the public hearing.

*D.* *Dimensional Standards.* For residential buildings separated by ten or less feet, or less than five feet from a property line, all interior walls, partitions and ceilings must be one-hour construction or a sprinkler system must be installed throughout the building. N/A

*E.* *Density.* The proposal as submitted does not unduly increase the number of people or buildings per lot above that of the surrounding neighborhood. N/A

*F.* *Appearance & Solar Access.* The proposal as submitted does blend in with the general neighborhood appearance and does not excessively deprive the neighbors of solar access. N/A

*G.* *Traffic.* The proposal shall be shown by the developer not to overload the street system with traffic or result in unsafe streets or dangers to pedestrians. N/A

*H.* *Parking.* The parking and loading spaces for the proposal shall be adequate, safe and properly designed to prevent excessive noise, lack of parking for occupants or neighbors or danger to pedestrians. N/A

*I.* *Utilities & Drainage.* The proposal shall be adequately served by water, sewer, electricity and other utilities and shall be properly drained to prevent additional drainage problems for surrounding area. N/A

*J.* *Peak Use.* The proposal shall not have significantly different peak use or occupancy characteristics than the surrounding neighborhood. N/A

*K.* *Historic & Cultural Resources.* Proposals shall not disturb traditional activities or values at historic or cultural sites identified in published studies or by the Commission on Inupiat History, Language and Culture. N/A

*L. Watershed Protection.* The proposal shall provide for the conservation of natural features such as drainage basins and watersheds, permafrost stability and the general environment of the area. The proposal shall provide for the protection of watershed areas during and after construction. Conditions of approval shall be designed to minimize or eliminate siltation, road and surface runoff, and pollution of the water supply. No raw sewage shall be dumped in the Middle Salt Lagoon. N/A

*M. Fire Safety & Emergency Access.* The proposal shall not pose a fire danger as determined by the Barrow fire chief or the State Fire Marshal. The proposal shall have clear and easy accessibility for fire and emergency apparatus and police protection. N/A

*N. Noise & Nuisance.* The proposal shall not significantly impact surrounding properties with excessive noise, fumes, odors, glare, smoke, light, vibration, dust, litter, or interference in any radio or television receivers off the premises, or cause significant line voltage fluctuation off the premises. N/A

*O. Tundra Travel.* Vehicles shall be operated in a manner such that the vegetative mat of the tundra is not disturbed and blading or removal of the tundra vegetative cover is prohibited. Snow ramps, snow/ice bridges or cribbing shall be used to cross frozen water bodies to preclude cutting, eroding or degrading or their banks. Snow ramps and snow/ice bridges be substantially free of soil and debris and of sufficient thickness to support vehicles. Snow/ice bridges must be removed or breached, and cribbing removed after final use or prior to breakup, whichever occurs first. Frozen water courses shall be crossed at shallow riffle areas, if such areas exist. Where such areas do not exist, an environmentally preferred location will be identified. Vehicles shall not be abandoned. N/A

STAFF RECOMMENDATION: It appears to be clear that BPXA intended to comply with all applicable codes and policies, however due to the change in NSB personnel and to some lesser degree the evolving nature of the Badami project construction, the North Slope Borough did not have complete information on this project. Staff recommends approval of this conditional use be given provided the conditions listed below are met:

1. A final as-built of the pipeline height, including areas between VSMs, be submitted to the Permitting & Zoning Division to be a part of the record of the Badami Pipeline construction;

2. An annual report be provided to the NSB Wildlife Management Department on any animal fatalities associated with the lower sections of this pipeline; and

3. BPXA work with ADF&G and the NSB Wildlife Management Department to develop a monitoring program on the wildlife effects of vibration dampening devises used below the pipeline on crossing success.

Cc: NSB Planning Commission
Benjamin P. Nageak, Mayor
Marie Carroll, Chief Administrative Officer
Charles D.N. Brower, Director, Wildlife Management
Taqulik Hepa, Deputy Director, Wildlife Management

Gene Pavia, Governor's Office, Division of Governmental Coordination/Joint Pipeline Office, SOA
William Britt, State Pipeline Coordinator/Joint Pipeline Office, SOA
Al Ott, Regional Supervisor, Habitat and Restoration Division, ADF&G, SOA
Mary Weger, Project Manager, U.S. Army Corps of Engineers
Peter Hanley, Permitting Supervisor, BPXA
Dr. Ray Jakubczak, Supervisor of Environmental Assessment, BPXA

STATE OF ALASKA

TONY KNOWLES, GOVERNOR

**DEPARTMENT OF FISH AND GAME**

*HABITAT & RESTORATION DIVISION*

*1300 COLLEGE ROAD*
*FAIRBANKS, ALASKA 99701-1599*
*PHONE: (907) 459-7289*
*FAX: (907) 456-3091*

August 12, 1998

Mr. Peter T. Hanley
Permitting Supervisor
HSE - Alaska
BP Exploration (Alaska) Inc.
P.O. Box 196612
Anchorage, AK 99519-6612

Dear Mr. Hanley:

The Alaska Department of Fish and Game (ADF&G) participated in an August 6, 1998, meeting between BP Exploration (Alaska) Inc. (BPXA), BP Transportation (Alaska) Inc.(BPTA), Colt Engineering (Colt), and the State Pipeline Coordinator's Office (SPCO). The meeting primarily focused on engineering concerns related to mitigation of wind-induced vibration on the Badami utility pipeline. Colt's contractor, SSD, determined that pipeline vibration dampers (PVDs), which are elastomer-suspended weights mounted beneath pipelines, are the most readily available and proven devices among methods constituting best available technology for mitigating wind-induced vibration. Because the Badami utility pipeline experiences two modes of vibration, two PVDs would be required on each mitigated span of pipe. For the portion of the utility line east of the Endicott Pipeline, span length is 55 feet; therefore PVDs would be placed at approximately 14 feet (1/4 span) and 27.5 feet (1/2 span) from the adjacent vertical support member (VSM). The PVDs used at 1/2-span locations can extend up to 37 inches below the pipe, and PVDs at 1/4-span locations can extend up to 20 inches below the pipe.

The ADF&G has expressed concern that the life-of-pipeline, cumulative effect of mitigating wind-induced vibration with two below-pipe PVDs per span over more than half the pipeline length will be diminished caribou-crossing success. During the referenced meeting, participants discussed the possibility of conducting a study with the objective of measuring the effect, if any, of multiple PVDs on caribou-crossing success. The ADF&G cautioned that quantifying a potential decrement in crossing success at treated spans, which may only be significant when integrated over the length and lifetime of the pipeline, would be difficult. We stated that broad-scale surveys would be unlikely to detect the integrated decrement, given natural variation in caribou movements and populations.

The ADF&G recommends that, should a study of caribou response to PVDs occur, the following preliminary considerations be incorporated in study design.

- The study should examine crossing frequencies of caribou groups, stratified by group size, group composition, encountered pipe height, and season (e.g., insect harassment), on matched treatment and control sections of the Badami utility pipeline.
- Treatment and control sections should have matched frequency distributions of pipe heights above tundra grade (i.e., pipe height is another variable affecting crossing success and therefore needs to be comparable).
- Treatment and control sections should incorporate similar habitat types, and especially similar proportions of riparian versus nonriparian habitat, because caribou often move to or from the coast along river floodplains during periods of high insect harassment.

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- Treatment and control sections should have an adequate number of spans with pipe heights as low as 5 feet above tundra grade to test the situation where PVDs would essentially subdivide the big game clearance zone under a span into three smaller zones. We suspect PVDs used on pipe heights ≥ 7 feet would be less likely to affect crossing success of caribou groups than PVDs used on lower pipes.
- Study location should be selected on current caribou use data such that there is a high probability of caribou groups using the study sections at a rate sufficient to yield statistically significant results. Large sample sizes would be necessary to meaningfully test crossing success stratified by group size, group composition, pipe height, and season, although significant results for pooled group sizes encountering matched treatment and control sections might be obtained with lower sample sizes.
- Treatment and control sections should be sufficiently long to maximize sample size of observed caribou groups. In the past, manned observation towers have been used to conduct this type of study. Current technology may permit use of remotely operated, telescopic video equipment to enable observation of longer lengths of treatment and control pipeline with minimal personnel, permanent data record (videotape), and no need to set up field camps or use daily helicopter access for remote sites.

In the context of the engineering discussions that occurred at the referenced August 6, 1998, meeting on PVDs, our understanding is that BPXA will engage in a 3-year monitoring study of "below-pipe" PVDs, V-blocks, and one "above-pipe" vibration-damping method (e.g., "elevated" PVD or Stockbridge damper). According to our notes, Colt stated that they could have initial results on alternative vibration-damping designs after the first winter of monitoring. We believe the SPCO, in consultation with the ADF&G and BPXA/BPTA, may be in a position to consider a permanent mitigation method (or methods) for the Badami utility line based on engineering considerations prior to results being available from a caribou study. For this reason, we recommend that a caribou study not be directly tied to the Badami project but be viewed more as research to assist BPXA and government agencies with future decisions related to vibration damping methods for North Slope pipelines.

Questions on these recommendations may be directed to Roger Post at 459-7287 or by E-mail at rpost@fishgame.state.ak.us.

Sincerely,

Alvin G. Ott
Regional Supervisor

cc: Ray Jakubczak, BPXA, Anchorage
John Ennis, BPXA, Anchorage
Les Owen, BPTA, Anchorage
Greg Swank, SPCO, Anchorage
Jon Dunham, NSB, Barrow
Craig George, NSB, Barrow
Ken Whitten, ADF&G, Fairbanks
Roger Post, ADF&G, Fairbanks

# APPENDIX B

# MOSQUITO AND OESTRID ACTIVITY INDICES

Table B-1. Daily average temperature and wind velocity recorded at the Deadhorse Weather Station (ASCC 1999), with tabulations of hourly mosquito (Russell et al. 1993) and oestrid activity indices (Mörschel 1999).

| | | | | | Mosquito Index | | | Oestrid Index | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Mean Temperature (°C) | *n* | Mean Wind Speed (mps) | *n* | No. of Records <0.5 | No. of Records ≥0.5 | Mosq. No. | No. of Records <0.4 | No. of Records ≥0.4 |
| 1-May-99 | -7.56 | 27 | 4.05 | 34 | 27 | 0 | N/A | 27 | 0 |
| 2-May-99 | -8.75 | 12 | 9.12 | 12 | 12 | 0 | N/A | 12 | 0 |
| 3-May-99 | -12.69 | 26 | 9.88 | 26 | 26 | 0 | N/A | 26 | 0 |
| 4-May-99 | -14.29 | 24 | 7.88 | 24 | 24 | 0 | N/A | 24 | 0 |
| 5-May-99 | -10.73 | 30 | 4.83 | 32 | 30 | 0 | N/A | 30 | 0 |
| 6-May-99 | -9.13 | 30 | 2.86 | 32 | 30 | 0 | N/A | 30 | 0 |
| 7-May-99 | -7.75 | 28 | 3.60 | 28 | 28 | 0 | N/A | 28 | 0 |
| 8-May-99 | -6.14 | 29 | 3.30 | 31 | 29 | 0 | N/A | 29 | 0 |
| 9-May-99 | -5.56 | 25 | 3.15 | 30 | 25 | 0 | N/A | 25 | 0 |
| 10-May-99 | -5.91 | 35 | 8.03 | 37 | 35 | 0 | N/A | 35 | 0 |
| 11-May 99 | -2.48 | 27 | 7.75 | 27 | 27 | 0 | N/A | 27 | 0 |
| 12-May-99 | -2.07 | 29 | 9.98 | 29 | 29 | 0 | N/A | 29 | 0 |
| 13-May-99 | -2.93 | 29 | 4.71 | 29 | 29 | 0 | N/A | 29 | 0 |
| 14-May-99 | -0.81 | 21 | 3.66 | 23 | 21 | 0 | N/A | 21 | 0 |
| 15-May-99 | -1.04 | 24 | 3.24 | 24 | 24 | 0 | N/A | 24 | 0 |
| 16-May-99 | -2.04 | 24 | 3.81 | 24 | 24 | 0 | N/A | 24 | 0 |
| 17-May 99 | -7.00 | 27 | 5.65 | 29 | 27 | 0 | N/A | 27 | 0 |
| 18-May-99 | -7.73 | 26 | 9.23 | 26 | 26 | 0 | N/A | 26 | 0 |
| 19-May-99 | -6.42 | 26 | 10.81 | 26 | 26 | 0 | N/A | 26 | 0 |
| 20-May-99 | -5.74 | 27 | 9.52 | 27 | 27 | 0 | N/A | 27 | 0 |
| 21-May-99 | -5.52 | 25 | 6.70 | 25 | 25 | 0 | N/A | 25 | 0 |
| 22-May-99 | -4.23 | 21 | 4.13 | 26 | 20 | 0 | N/A | 20 | 0 |
| 23-May-99 | -4.12 | 25 | 2.61 | 29 | 25 | 0 | N/A | 25 | 0 |
| 24-May-99 | -3.52 | 27 | 8.57 | 27 | 27 | 0 | N/A | 27 | 0 |
| 25-May-99 | -4.36 | 25 | 9.52 | 25 | 25 | 0 | N/A | 25 | 0 |
| 26-May-99 | -4.23 | 26 | 11.01 | 26 | 26 | 0 | N/A | 26 | 0 |
| 27-May-99 | -2.00 | 29 | 7.67 | 29 | 29 | 0 | N/A | 29 | 0 |
| 28-May-99 | -0.36 | 25 | 3.56 | 29 | 25 | 0 | N/A | 25 | 0 |
| 29-May-99 | -1.34 | 29 | 5.11 | 30 | 29 | 0 | N/A | 29 | 0 |
| 30-May-99 | -2.08 | 24 | 7.73 | 24 | 24 | 0 | N/A | 24 | 0 |
| 31-May-99 | -0.61 | 31 | 2.77 | 34 | 31 | 0 | N/A | 31 | 0 |

Table B-1 *(cont.)*

| Date | Mean Temperature (°C) | *n* | Mean Wind Speed (mps) | *n* | Mosquito Index: No. of Records <0.5 | Mosquito Index: No. of Records ≥0.5 | Mosq. No. | Oestrid Index: No. of Records <0.4 | Oestrid Index: No. of Records ≥0.4 |
|---|---|---|---|---|---|---|---|---|---|
| 1-Jun-99 | -0.58 | 31 | 7.56 | 32 | 31 | 0 | N/A | 31 | 0 |
| 2-Jun-99 | -0.53 | 17 | 6.29 | 27 | 17 | 0 | N/A | 17 | 0 |
| 3-Jun-99 | 0.06 | 33 | 3.59 | 34 | 33 | 0 | N/A | 33 | 0 |
| 4-Jun-99 | -0.07 | 29 | 5.84 | 29 | 29 | 0 | N/A | 29 | 0 |
| 5-Jun-99 | -0.32 | 28 | 4.98 | 28 | 28 | 0 | N/A | 28 | 0 |
| 6-Jun-99 | -0.07 | 27 | 4.69 | 29 | 27 | 0 | N/A | 27 | 0 |
| 7-Jun-99 | -2.07 | 30 | 7.29 | 30 | 28 | 0 | N/A | 28 | 0 |
| 8-Jun-99 | -0.52 | 25 | 8.30 | 25 | 25 | 0 | N/A | 25 | 0 |
| 9-Jun-99 | 1.63 | 35 | 6.83 | 35 | 35 | 0 | N/A | 35 | 0 |
| 10-Jun-99 | 1.32 | 37 | 7.47 | 37 | 37 | 0 | N/A | 37 | 0 |
| 11-Jun-99 | 2.37 | 41 | 3.89 | 41 | 41 | 0 | N/A | 41 | 0 |
| 12-Jun-99 | 5.84 | 25 | 5.39 | 25 | 25 | 0 | N/A | 25 | 0 |
| 13-Jun-99 | 7.54 | 26 | 4.12 | 26 | 26 | 0 | N/A | 26 | 0 |
| 14-Jun-99 | 4.66 | 29 | 3.62 | 29 | 29 | 0 | N/A | 29 | 0 |
| 15-Jun-99 | 5.04 | 26 | 5.05 | 26 | 26 | 0 | N/A | 26 | 0 |
| 16-Jun-99 | 4.25 | 28 | 10.17 | 28 | 28 | 0 | N/A | 28 | 0 |
| 17-Jun-99 | 3.58 | 36 | 4.15 | 36 | 36 | 0 | N/A | 36 | 0 |
| 18-Jun-99 | 1.82 | 38 | 3.91 | 38 | 38 | 0 | N/A | 38 | 0 |
| 19-Jun-99 | 2.09 | 33 | 3.79 | 33 | 33 | 0 | N/A | 33 | 0 |
| 20-Jun-99 | 1.18 | 34 | 6.48 | 34 | 34 | 0 | N/A | 34 | 0 |
| 21-Jun-99 | 0.47 | 36 | 12.67 | 36 | 36 | 0 | N/A | 36 | 0 |
| 22-Jun-99 | 2.22 | 37 | 8.36 | 37 | 37 | 0 | N/A | 37 | 0 |
| 23-Jun-99 | 3.53 | 32 | 3.88 | 32 | 32 | 0 | N/A | 32 | 0 |
| 24-Jun-99 | 2.00 | 38 | 5.42 | 38 | 38 | 0 | N/A | 38 | 0 |
| 25-Jun-99 | 5.25 | 24 | 5.04 | 24 | 24 | 0 | N/A | 24 | 0 |
| 26-Jun-99 | 6.92 | 24 | 3.77 | 24 | 24 | 0 | N/A | 24 | 0 |
| 27-Jun-99 | 1.14 | 35 | 3.83 | 36 | 35 | 0 | N/A | 35 | 0 |
| 28-Jun-99 | 3.59 | 29 | 3.21 | 29 | 29 | 0 | N/A | 29 | 0 |
| 29-Jun-99 | 4.83 | 24 | 6.35 | 24 | 24 | 0 | 0 | 24 | 0 |
| 30-Jun-99 | 6.38 | 24 | 4.53 | 24 | 24 | 0 | 0.5 | 24 | 0 |

Table B-1 *(cont.)*

| Date | Mean Temperature (°C) | *n* | Mean Wind Speed (mps) | *n* | Mosquito Index: No. of Records <0.5 | Mosquito Index: No. of Records ≥0.5 | Mosq. No. | Oestrid Index: No. of Records <0.4 | Oestrid Index: No. of Records ≥0.4 |
|---|---|---|---|---|---|---|---|---|---|
| 1-Jul-99 | 10.79 | 24 | 4.31 | 24 | 23 | 1 | 1.5 | 24 | 0 |
| 2-Jul-99 | 15.91 | 23 | 3.80 | 23 | 20 | 3 | 103.3 | 20 | 3 |
| 3-Jul-99 | 14.21 | 24 | 3.97 | 24 | 24 | 0 | 38.5 | 24 | 0 |
| 4-Jul-99 | 14.63 | 24 | 5.234 | 24 | 24 | 0 | 5.62 | 24 | 0 |
| 5-Jul-99 | 15.17 | 24 | 4.46 | 24 | 23 | 1 | 92.9 | 24 | 0 |
| 6-Jul-99 | 8.83 | 42 | 5.11 | 42 | 42 | 0 | 40.0 | 42 | 0 |
| 7-Jul-99 | 8.30 | 37 | 2.40 | 38 | 37 | 0 | 17.6 | 37 | 0 |
| 8-Jul-99 | 9.16 | 32 | 2.38 | 32 | 32 | 0 | 26.9 | 32 | 0 |
| 9-Jul-99 | 12.00 | 26 | 3.039 | 26 | 23 | 3 | 83.1 | 25 | 1 |
| 10-Jul-99 | 9.20 | 30 | 4.29 | 30 | 30 | 0 | 26.5 | 30 | 0 |
| 11-Jul-99 | 6.92 | 24 | 3.75 | 24 | 24 | 0 | 22.1 | 24 | 0 |
| 12-Jul-99 | 6.91 | 23 | 4.29 | 24 | 23 | 0 | 20 | 23 | 0 |
| 13-Jul-99 | 8.65 | 23 | 5.55 | 23 | 23 | 0 | 8.5 | 23 | 0 |
| 14-Jul-99 | 8.63 | 24 | 7.21 | 24 | 24 | 0 | 5 | 24 | 0 |
| 15-Jul-99 | 10.21 | 24 | 4.76 | 24 | 21 | 3 | 7.3 | 24 | 0 |
| 16-Jul-99 | 10.17 | 29 | 3.09 | 29 | 28 | 1 | 29.5 | 29 | 0 |
| 17-Jul-99 | 5.97 | 36 | 4.71 | 36 | 36 | 0 | 3.4 | 36 | 0 |
| 18-Jul-99 | 4.26 | 27 | 5.70 | 27 | 27 | 0 | 1.9 | 27 | 0 |
| 19-Jul-99 | 3.88 | 34 | 3.42 | 34 | 34 | 0 | 0 | 34 | 0 |
| 20-Jul-99 | 2.54 | 26 | 8.99 | 26 | 26 | 0 | 0 | 26 | 0 |
| 21-Jul-99 | 1.83 | 36 | 6.31 | 36 | 36 | 0 | 0 | 36 | 0 |
| 22-Jul-99 | 2.97 | 34 | 5.01 | 34 | 34 | 0 | 26.3 | 34 | 0 |
| 23-Jul-99 | 2.50 | 34 | 1.89 | 34 | 34 | 0 | 2.2 | 34 | 0 |
| 24-Jul-99 | 3.0 | 38 | 2.94 | 38 | 38 | 0 | 0 | 38 | 0 |
| 25-Jul-99 | 1.52 | 42 | 5.85 | 42 | 42 | 0 | N/A | 42 | 0 |
| 26-Jul-99 | 1.71 | 35 | 8.95 | 36 | 35 | 0 | N/A | 35 | 0 |
| 27-Jul-99 | 2.03 | 36 | 7.52 | 36 | 36 | 0 | N/A | 36 | 0 |
| 28-Jul-99 | 2.03 | 30 | 3.04 | 30 | 30 | 0 | N/A | 30 | 0 |
| 29-Jul-99 | 2.46 | 41 | 6.25 | 42 | 41 | 0 | N/A | 41 | 0 |
| 30-Jul-99 | 7.92 | 24 | 3.62 | 24 | 24 | 0 | N/A | 24 | 0 |
| 31-Jul-99 | 12.00 | 24 | 4.63 | 24 | 23 | 1 | N/A | 23 | 1 |

Table B-1 *(cont.)*

| Date | Mean Temperature (°C) | *n* | Mean Wind Speed (mps) | *n* | Mosquito Index: No. of Records <0.5 | Mosquito Index: No. of Records ≥0.5 | Mosq. No. | Oestrid Index: No. of Records <0.4 | Oestrid Index: No. of Records ≥0.4 |
|---|---|---|---|---|---|---|---|---|---|
| 1-Aug-99 | 12.86 | 21 | 4.01 | 21 | 19 | 2 | N/A | 21 | 0 |
| 2-Aug-99 | 11.00 | 21 | 3.45 | 21 | 21 | 0 | N/A | 21 | 0 |
| 3-Aug-99 | 7.63 | 32 | 8.05 | 32 | 32 | 0 | N/A | 32 | 0 |
| 4-Aug-99 | 9.97 | 29 | 5.76 | 29 | 29 | 0 | N/A | 29 | 0 |
| 5-Aug-99 | 17.42 | 24 | 4.07 | 24 | 20 | 4 | N/A | 14 | 10 |
| 6-Aug-99 | 15.73 | 30 | 3.07 | 32 | 28 | 2 | N/A | 20 | 10 |
| 7-Aug-99 | 9.52 | 27 | 5.79 | 27 | 27 | 0 | N/A | 27 | 0 |
| 8-Aug-99 | 7.10 | 41 | 5.30 | 41 | 41 | 0 | N/A | 41 | 0 |
| 9-Aug-99 | 9.72 | 43 | 1.91 | 45 | 43 | 0 | N/A | 43 | 0 |
| 10-Aug-99 | 7.22 | 37 | 3.26 | 39 | 37 | 0 | N/A | 37 | 0 |
| 11-Aug-99 | 12.63 | 24 | 3.02 | 24 | 18 | 6 | N/A | 22 | 2 |
| 12-Aug-99 | 7.24 | 34 | 4.04 | 43 | 34 | 0 | N/A | 34 | 0 |
| 13-Aug-99 | 7.13 | 39 | 2.93 | 39 | 39 | 0 | N/A | 39 | 0 |
| 14-Aug-99 | 9.41 | 29 | 3.48 | 30 | 29 | 0 | N/A | 29 | 0 |
| 15-Aug-99 | 7.18 | 39 | 2.00 | 39 | 39 | 0 | N/A | 39 | 0 |
| 16-Aug-99 | 10.38 | 26 | 3.06 | 26 | 26 | 0 | N/A | 26 | 0 |
| 17-Aug-99 | 10.98 | 40 | 6.72 | 41 | 40 | 0 | N/A | 40 | 0 |
| 18-Aug-99 | 5.11 | 57 | 3.00 | 57 | 57 | 0 | N/A | 57 | 0 |
| 19-Aug-99 | 3.32 | 34 | 11.91 | 34 | 34 | 0 | N/A | 34 | 0 |
| 20-Aug-99 | 4.10 | 29 | 10.85 | 29 | 29 | 0 | N/A | 29 | 0 |
| 21-Aug-99 | 3.18 | 39 | 8.84 | 44 | 39 | 0 | N/A | 39 | 0 |
| 22-Aug-99 | 3.07 | 46 | 3.50 | 54 | 46 | 0 | N/A | 46 | 0 |
| 23-Aug-99 | 3.02 | 44 | 9.74 | 44 | 44 | 0 | N/A | 44 | 0 |
| 24-Aug-99 | 2.83 | 36 | 9.52 | 36 | 36 | 0 | N/A | 36 | 0 |
| 25-Aug-99 | 2.55 | 31 | 4.59 | 31 | 31 | 0 | N/A | 31 | 0 |
| 26-Aug-99 | 5.92 | 24 | 5.23 | 24 | 24 | 0 | N/A | 24 | 0 |
| 27-Aug-99 | 2.34 | 41 | 5.58 | 41 | 41 | 0 | N/A | 41 | 0 |
| 28-Aug-99 | -0.19 | 31 | 3.73 | 31 | 31 | 0 | N/A | 31 | 0 |
| 29-Aug-99 | 0.69 | 35 | 8.39 | 35 | 35 | 0 | N/A | 35 | 0 |
| 30-Aug-99 | 2.25 | 40 | 6.94 | 40 | 40 | 0 | N/A | 40 | 0 |
| 31-Aug-99 | 1.16 | 19 | 3.22 | 27 | 19 | 0 | N/A | 19 | 0 |

# Mosquito and Oestrid Activity Indices

## Mosquito Activity Index (Russell 1993)

IF temperature >18°C THEN $TI_m = 1$
IF temperature <6°C THEN $TI_m = 0$
$TI_m$ = 1-((18-temperature)/13)
IF wind >6 mps then $WI_m = 0$
$WI_m$ = (6-wind)/6
$I_m = TI_m \times WI_m$

where:

$TI_m$ = Temperature Index for Mosquitoes
$WI_m$ = Wind Index for Mosquitoes
$I_m$ = Mosquito Activity Index

These parameters were translated into IF statements for $TI_m$ and $WI_m$ with inputs as follows:

$T_h$ = Temperature in °C recorded hourly at Deadhorse Weather Station
$V_h$ = Wind velocity in mps recorded hourly at Deadhorse Weather Station

Syntax is IF (logical test, value if true, value if false)

$TI_m$ = IF ($T_h$ <6, 0, IF($T_h$ >18, 1, (1-((18-$T_h$)/13))))
$WI_m$ = IF ($V_h$ >6, 0, ((6-$V_h$)/6))
then $I_m = TI_m \times WI_m$

## Oestrid Activity Index (Mörschel 1999)

Predicts presence/absence of oestrid flies with 83% reliability

$$y = \frac{e^{(-2.9646+0.166xTemp-0.1951xWind)}}{1+e^{(-2.9646+0.166xTemp-0.1951xWind)}}$$

where:

$y$ = estimated probability of oestrid fly presence (between 0 and 1)
Temp = Temperature in °C recorded hourly at Deadhorse Weather Station
Wind = Wind speed in mps recorded hourly at Deadhorse Weather Station

Oestrid flies were considered present when $y$ was ≥ 0.4

# APPENDIX C

# 1999 CARIBOU DATA

Table C-1. Daily summaries of caribou data collected at tower plots A and B between 29 June and 25 July 1999.

| Date | Observation Hours | Mosquito Count | Total Caribou Groups | No. of Caribou Individuals | No. of Individuals Crossed Pipeline |
|---|---|---|---|---|---|
| **Plot A** | | | | | |
| 6/29/99 | 12 | 0 | 1 | 2 | 2 |
| 6/30/99 | 13 | 0 | 4 | 9 | 2 |
| 7/1/99 | 12 | 12 | 9 | 74 | 25 |
| 7/2/99 | 12 | 327 | 4 | 13 | 13 |
| 7/3/99 | 11.5 | 138 | 7 | 406 | 12 |
| 7/4/99 | 12.5 | 20 | 8 | 460 | 28 |
| 7/5/99 | 12 | 280 | 2 | 2 | 1 |
| 7/6/99 | 12 | 33 | 1 | 6 | 6 |
| 7/7/99 | 12.5 | 89 | 0 | 0 | 0 |
| 7/8/99 | 12.5 | 100 | 3 | 136 | 136 |
| 7/9/99 | 12 | 152 | 1 | 1 | 0 |
| 7/10/99 | 6.5 | 30 | 0 | 0 | 0 |
| 7/11/99 | 12.5 | 90 | 2 | 291 | 275 |
| 7/12/99 | 12.5 | 100 | 3 | 14 | 7 |
| 7/13/99 | 12 | 26 | 1 | 3 | 0 |
| 7/14/99 | 12 | 22 | 2 | 10 | 10 |
| 7/15/99 | 12.5 | 31 | 0 | 0 | 0 |
| 7/16/99 | 11.5 | 136 | 1 | 2 | 0 |
| 7/17/99 | 13 | 18 | 1 | 2 | 0 |
| 7/18/99 | 0 | No Count | | | |
| 7/19/99 | 13.5 | 3 | 1 | 2 | 2 |
| 7/20/99 | 2 | 0 | 0 | 0 | 0 |
| 7/21/99 | 1.5 | 0 | 2 | 7 | 5 |
| 7/22/99 | 10 | 0 | 1 | 1 | 1 |
| 7/23/99 | 9 | 79 | 0 | 0 | 0 |
| 7/24/99 | 9 | 13 | 1 | 1 | 1 |
| 7/25/99 | 3 | 0 | 0 | 0 | 0 |
| **Plot B** | | | | | |
| 6/29/99 | 12 | 0 | 1 | 1 | 1 |
| 6/30/99 | 12 | 4 | 0 | 0 | 0 |
| 7/1/99 | 12 | 2 | 3 | 19 | 2 |
| 7/2/99 | 12 | 499 | 4 | 4 | 1 |
| 7/3/99 | 12 | 170 | 4 | 454 | 450 |
| 7/4/99 | 12 | 25 | 1 | 81 | 0 |
| 7/5/99 | 11.5 | 463 | 0 | 0 | 0 |
| 7/6/99 | 11.5 | 215 | 3 | 30 | 0 |
| 7/7/99 | 11.5 | 52 | 1 | 2 | 2 |
| 7/8/99 | 12 | 115 | 3 | 393 | 2 |
| 7/9/99 | 11.5 | 513 | 2 | 201 | 0 |
| 7/10/99 | 6 | 76 | 0 | 0 | 0 |
| 7/11/99 | 12 | 87 | 3 | 403 | 98 |
| 7/12/99 | 11.5 | 60 | 5 | 147 | 13 |
| 7/13/99 | 11.5 | 21 | 2 | 106 | 16 |

Table C-1 *(cont.)*

| Date | Observation Hours | Mosquito Count | Total Caribou Groups | No. of Caribou Individuals | No. of Individuals Crossed Pipeline |
|---|---|---|---|---|---|
| 7/14/99 | 12 | 18 | 1 | 9 | 9 |
| 7/15/99 | 12 | 27 | 1 | 5 | 2 |
| 7/16/99 | 11.5 | 100 | 2 | 19 | 0 |
| 7/17/99 | 11.5 | 9 | 0 | 0 | 0 |
| 7/18/99 | 0 | No Count | | | |
| 7/19/99 | 12.5 | 9 | 3 | 7 | 7 |
| 7/20/99 | 0 | 0 | 0 | 0 | 0 |
| 7/21/99 | 4 | 0 | 0 | 0 | 0 |
| 7/22/99 | 10 | 0 | 0 | 0 | 0 |
| 7/23/99 | 7.5 | No Count | 0 | 0 | 0 |
| 7/24/99 | 9 | 0 | 1 | 15 | 15 |
| 7/25/99 | 2 | 0 | 0 | 0 | 0 |

Table C-2. Data collected at tower plots A and B by caribou group along the Badami pipeline between 29 June and 25 July 1999. PVDs refers to caribou observed in areas of the pipeline with and without pipeline vibration dampers. Mosquito level is defined as follows: present = >9 mosquitos per count and absent = <9 mosquitos per count. Size categories are defined as: A = 1-10, B = 11-50, C = >50 caribou. Group types are defined by the dominant sex and age, including: B = bull, CO = cow, Y = yearling, MIX = mixed composition, and UN = unclassified. Side of pipeline indicates whether a group was first observed north or south of the pipeline.

| Date | Group # | PVDs | Mosquito Level | Group Size | Size Category | Group Type | Side of Pipeline | No. of Individuals Crossed | Proportion Crossed |
|---|---|---|---|---|---|---|---|---|---|
| **Plot A** | | | | | | | | | |
| 6/29/1999 | 1 | no | 0 | 2 | A | B | S | 2 | 100 |
| 6/30/1999 | 1 | yes | 0 | 2 | A | B | S | 2 | 100 |
| 6/30/1999 | 2 | no | 0 | 3 | A | MIX | S | 0 | 0 |
| 6/30/1999 | 3 | no | 0 | 2 | A | MIX | S | 0 | 0 |
| 6/30/1999 | 4 | no | 0 | 2 | A | CO | S | 0 | 0 |
| 7/1/1999 | 1 | no | 0 | 8 | A | B | N | 0 | 0 |
| 7/1/1999 | 2 | yes | 0 | 22 | B | MIX | S | 12 | 55 |
| 7/1/1999 | 3 | yes | 1 | 7 | A | CO | S | 1 | 14 |
| 7/1/1999 | 4 | no | 1 | 18 | B | B | S | 0 | 0 |
| 7/1/1999 | 5 | no | 1 | 5 | A | B | S | 5 | 100 |
| 7/1/1999 | 6 | no | 1 | 1 | A | B | N | 1 | 100 |
| 7/1/1999 | 7 | yes | 1 | 9 | A | B | N | 0 | 0 |
| 7/1/1999 | 2a | yes | 1 | 9 | A | UN | S | 1 | 11 |
| 7/1/1999 | 2B | no | 1 | 10 | A | Y | S | 5 | 50 |
| 7/2/1999 | 1 | no | 8 | 1 | A | Y | S | 1 | 100 |
| 7/2/1999 | 2 | yes | 8 | 2 | A | B | S | 2 | 100 |
| 7/2/1999 | 3 | yes | 4 | 9 | A | B | N | 9 | 100 |
| 7/2/1999 | 4 | no | 0 | 1 | A | CO | S | 1 | 100 |
| 7/3/1999 | 1 | yes | 72 | 214 | C | CO | N | 0 | 0 |
| 7/3/1999 | 5 | yes | 11 | 32 | B | CO | N | 0 | 0 |
| 7/3/1999 | 6 | no | 11 | 130 | C | CO | N | 0 | 0 |
| 7/3/1999 | 7 | yes | 11 | 1 | A | Y | N | 0 | 0 |
| 7/3/1999 | 2/3/ | no | 11 | 17 | B | CO | S | 4 | 24 |
| 7/3/1999 | 2/3/ | yes | 11 | 17 | B | CO | S | 3 | 18 |
| 7/3/1999 | 2/3/B | yes | 11 | 6 | A | Y | S | 3 | 50 |
| 7/3/1999 | 2/3B | no | 11 | 7 | A | Y | S | 1 | 14 |
| 7/3/1999 | 4 | yes | 11 | 12 | B | CO | N | 0 | 0 |
| 7/4/1999 | 1 | yes | 0 | 147 | C | CO | N | 0 | 0 |
| 7/4/1999 | 2 | no | 0 | 21 | B | MIX | S | 21 | 100 |
| 7/4/1999 | 3 | no | 0 | 2 | A | MIX | S | 2 | 100 |
| 7/4/1999 | 4 | yes | 0 | 2 | A | Y | S | 2 | 100 |
| 7/4/1999 | 5 | no | 2 | 3 | A | B | S | 3 | 100 |
| 7/4/1999 | 6 | yes | 2 | 25 | B | CO | N | 0 | 0 |
| 7/4/1999 | 7 | yes | 2 | 168 | C | CO | N | 0 | 0 |
| 7/4/1999 | 8 | yes | 2 | 92 | C | CO | N | 0 | 0 |
| 7/5/1999 | 1 | yes | 12 | 1 | A | B | S | 1 | 100 |
| 7/5/1999 | 2 | yes | 2 | 1 | A | CO | N | 0 | 0 |
| 7/6/1999 | 1 | yes | 22 | 6 | A | CO | S | 6 | 100 |

Table C-2 *(cont.)*

| Date | Group # | PVDs | Mosquito Level | Group Size | Size Category | Group Type | Side of Pipeline | No. of Individuals Crossed | Proportion Crossed |
|---|---|---|---|---|---|---|---|---|---|
| 7/8/1999 | 1 | no | 27 | 7 | A | CO | S | 7 | 100 |
| 7/8/1999 | 2 | yes | 38 | 128 | C | CO | S | 128 | 100 |
| 7/8/1999 | 3 | yes | 20 | 1 | A | B | N | 0 | 0 |
| 7/9/1999 | 1 | yes | 21 | 1 | A | B | N | 0 | 0 |
| 7/11/1999 | 1 | no | 11 | 275 | C | MIX | S | 275 | 100 |
| 7/11/1999 | 2 | yes | 36 | 16 | B | B | N | 0 | 0 |
| 7/12/1999 | 1 | no | 44 | 4 | A | CO | N | 0 | 0 |
| 7/12/1999 | 2 | yes | 23 | 9 | A | B | N | 4 | 44 |
| 7/12/1999 | 3 | no | 23 | 1 | A | B | N | 1 | 100 |
| 7/13/1999 | 1 | yes | 9 | 3 | A | MIX | N | 0 | 0 |
| 7/14/1999 | 1 | yes | 10 | 9 | A | CO | S | 9 | 100 |
| 7/14/1999 | 2 | no | 0 | 1 | A | B | S | 1 | 100 |
| 7/16/1999 | 1 | no | 5 | 2 | A | CO | S | 0 | 0 |
| 7/17/1999 | 1 | yes | 10 | 2 | A | CO | S | 0 | 0 |
| 7/19/1999 | 1 | yes | 3 | 2 | A | CO | S | 2 | 100 |
| 7/21/1999 | 1 | yes | 0 | 5 | A | B | S | 5 | 100 |
| 7/24/1999 | 1 | no | 5 | 1 | A | CO | N | 1 | 100 |
| **Plot B** | | | | | | | | | |
| 6/29/1999 | 1 | yes | 0 | 1 | A | Y | S | 1 | 100 |
| 7/1/1999 | 1 | yes | 1 | 2 | A | B | N | 0 | 0 |
| 7/1/1999 | 2 | yes | 0 | 2 | A | CO | N | 2 | 100 |
| 7/2/1999 | 1 | yes | 56 | 1 | A | CO | S | 1 | 100 |
| 7/2/1999 | 2 | yes | 16 | 1 | A | Y | S | 0 | 0 |
| 7/2/1999 | 3 | yes | 8 | 1 | A | CO | N | 0 | 0 |
| 7/2/1999 | 4 | yes | 8 | 1 | A | CO | S | 0 | 0 |
| 7/3/1999 | 1 | yes | 20 | 450 | C | CO | S | 225 | 50 |
| 7/3/1999 | 2 | yes | 15 | 2 | A | CO | S | 0 | 0 |
| 7/3/1999 | 3 | yes | 15 | 1 | A | CO | N | 0 | 0 |
| 7/3/1999 | 4 | yes | 15 | 1 | A | Y | S | 0 | 0 |
| 7/3/1999 | 1/2/ | yes | 20 | 225 | C | CO | S | 225 | 100 |
| 7/4/1999 | 1 | yes | 2 | 81 | C | MIX | N | 0 | 0 |
| 7/6/1999 | 1 | yes | 211 | 4 | A | CO | S | 0 | 0 |
| 7/6/1999 | 2 | yes | 211 | 20 | B | CO | S | 0 | 0 |
| 7/6/1999 | 3 | yes | 211 | 6 | A | CO | N | 0 | 0 |
| 7/7/1999 | 1 | yes | 3 | 2 | A | MIX | S | 0 | 0 |
| 7/8/1999 | 2 | yes | 57 | 1 | A | Y | S | 0 | 0 |
| 7/8/1999 | 3 | yes | 57 | 2 | A | B | S | 2 | 100 |
| 7/8/1999 | 4 | yes | 22 | 375 | C | CO | N | 0 | 0 |
| 7/9/1999 | 2 | yes | 228 | 150 | C | CO | N | 0 | 0 |
| 7/9/1999 | 3 | yes | 228 | 1 | A | CO | S | 0 | 0 |
| 7/11/1999 | 1 | yes | 27 | 2 | A | CO | S | 0 | 0 |
| 7/11/1999 | 3/2/ | yes | 26 | 350 | C | MIX | N | 98 | 28 |
| 7/12/1999 | 1 | yes | 11 | 13 | B | CO | S | 13 | 100 |
| 7/12/1999 | 2 | yes | 27 | 3 | A | CO | S | 0 | 0 |
| 7/12/1999 | 3 | yes | 27 | 40 | B | CO | S | 0 | 0 |
| 7/12/1999 | 4 | yes | 27 | 90 | C | B | S | 0 | 0 |
| 7/12/1999 | 5 | yes | 12 | 1 | A | B | S | 0 | 0 |
| 7/13/1999 | 1 | yes | 13 | 105 | C | CO | S | 15 | 14 |

Table C-2 *(cont.)*

| Date | Group # | PVDs | Mosquito Level | Group Size | Size Category | Group Type | Side of Pipeline | No. of Individuals Crossed | Proportion Crossed |
|---|---|---|---|---|---|---|---|---|---|
| 7/13/1999 | 2 | yes | 13 | 1 | A | Y | S | 1 | 100 |
| 7/14/1999 | 1 | yes | 0 | 9 | A | CO | N | 9 | 100 |
| 7/15/1999 | 1 | yes | 1 | 5 | A | B | N | 5 | 100 |
| 7/16/1999 | 1 | yes | 2 | 12 | B | UN | S | 0 | 0 |
| 7/16/1999 | 2 | yes | 2 | 7 | A | CO | S | 0 | 0 |
| 7/19/1999 | 1 | yes | 5 | 4 | A | CO | S | 4 | 100 |
| 7/19/1999 | 2 | yes | 5 | 2 | A | CO | S | 2 | 100 |
| 7/19/1999 | 3 | yes | 5 | 1 | A | B | S | 1 | 100 |
| 7/24/1999 | 1 | yes | 0 | 15 | B | CO | S | 15 | 100 |

Table C-3. Daily summaries of time-lapse video camera data collected at 5 remote camera sites along the Badami pipeline, Arctic Coastal Plain, Alaska between 24 June and 26 July 1999.

| Date | Observation Hours | Total Groups | No. of Individuals | Date | Observation Hours | Total Groups | No. of Individuals |
|---|---|---|---|---|---|---|---|
| **Camera 1 (PVDs)** | | | | **Camera 3 (No PVDs)** | | | |
| 6/24/1999 | 20 | 0 | 0 | 6/24/1999 | 20 | 0 | 0 |
| 6/25/1999 | 20 | 0 | 0 | 6/25/1999 | 20 | 0 | 0 |
| 6/26/1999 | 20 | 0 | 0 | 6/26/1999 | 20 | 0 | 0 |
| 6/27/1999 | 20 | 0 | 0 | 6/27/1999 | 20 | 0 | 0 |
| 6/28/1999 | 20 | 0 | 0 | 6/28/1999 | 20 | 1 | 2 |
| 6/29/1999 | 20 | 0 | 0 | 6/29/1999 | 20 | 0 | 0 |
| 6/30/1999 | 20 | 0 | 0 | 6/30/1999 | 20 | 0 | 0 |
| 7/1/1999 | 20 | 1 | 2 | 7/1/1999 | 20 | 1 | 5 |
| 7/2/1999 | 20 | 2 | 3 | 7/2/1999 | 20 | 1 | 1 |
| 7/3/1999 | 20 | 1 | 200 | 7/3/1999 | 20 | 0 | 0 |
| 7/4/1999 | 20 | 1 | 2 | 7/4/1999 | 20 | 3 | 190 |
| 7/5/1999 | 20 | 1 | 3 | 7/5/1999 | 20 | 1 | 1 |
| 7/6/1999 | 20 | 1 | 4 | 7/6/1999 | 20 | 0 | 0 |
| 7/7/1999 | 20 | 0 | 0 | 7/7/1999 | 20 | 1 | 2 |
| 7/8/1999 | 20 | 1 | 2 | 7/8/1999 | 20 | 2 | 19 |
| 7/9/1999 | 20 | 2 | 230 | 7/9/1999 | 20 | 1 | 2 |
| 7/10/1999 | 20 | 1 | 10 | 7/10/1999 | 20 | 0 | 0 |
| 7/11/1999 | 20 | 3 | 32 | 7/11/1999 | 20 | 2 | 12 |
| 7/12/1999 | 20 | 1 | 1 | 7/12/1999 | 20 | 0 | 0 |
| 7/13/1999 | 20 | 5 | 149 | 7/13/1999 | 20 | 1 | 14 |
| 7/14/1999 | 20 | 0 | 0 | 7/14/1999 | 20 | 0 | 0 |
| 7/15/1999 | 20 | 0 | 0 | 7/15/1999 | 20 | 5 | 259 |
| 7/16/1999 | 20 | 0 | 0 | 7/16/1999 | 20 | 2 | 2 |
| 7/17/1999 | 20 | 0 | 0 | 7/17/1999 | 20 | 0 | 0 |
| 7/18/1999 | 20 | 0 | 0 | 7/18/1999 | 20 | 0 | 0 |
| 7/19/1999 | 20 | 0 | 0 | 7/19/1999 | 20 | 0 | 0 |
| 7/20/1999 | 20 | 0 | 0 | 7/20/1999 | 20 | 0 | 0 |
| 7/21/1999 | 20 | 0 | 0 | 7/21/1999 | 20 | 0 | 0 |
| 7/22/1999 | 20 | 0 | 0 | 7/22/1999 | 20 | 0 | 0 |
| 7/23/1999 | 20 | 0 | 0 | 7/23/1999 | 20 | 1 | 12 |
| 7/24/1999 | 20 | 0 | 0 | 7/24/1999 | 20 | 1 | 8 |
| 7/25/1999 | 20 | 0 | 0 | 7/25/1999 | 20 | 0 | 0 |
| 7/26/1999 | 20 | 0 | 0 | 7/26/1999 | 20 | 0 | 0 |

Table C-3 *(cont.)*

| Date | Observation Hours | Total Groups | No. of Individuals | Date | Observation Hours | Total Groups | No. of Individuals |
|---|---|---|---|---|---|---|---|
| **Camera 4 (PVDs)** | | | | **Camera 5 (No PVDs)** | | | |
| 6/24/1999 | 20 | 0 | 0 | 6/24/1999 | 20 | 1 | 1 |
| 6/25/1999 | 20 | 0 | 0 | 6/25/1999 | 20 | 1 | 3 |
| 6/26/1999 | 20 | 0 | 0 | 6/26/1999 | 20 | 1 | 3 |
| 6/27/1999 | 20 | 0 | 0 | 6/27/1999 | 20 | 3 | 4 |
| 6/28/1999 | 20 | 5 | 15 | 6/28/1999 | 20 | 1 | 2 |
| 6/29/1999 | 20 | 1 | 1 | 6/29/1999 | 20 | 0 | 0 |
| 6/30/1999 | 20 | 0 | 0 | 6/30/1999 | 20 | 0 | 0 |
| 7/1/1999 | 20 | 9 | 25 | 7/1/1999 | 20 | 1 | 1 |
| 7/2/1999 | 20 | 0 | 0 | 7/2/1999 | 20 | 2 | 15 |
| 7/3/1999 | 20 | 1 | 1 | 7/3/1999 | 20 | 0 | 0 |
| 7/4/1999 | 20 | 0 | 0 | 7/4/1999 | 20 | 0 | 0 |
| 7/5/1999 | 20 | 2 | 4 | 7/5/1999 | 20 | 0 | 0 |
| 7/6/1999 | 20 | 1 | 1 | 7/6/1999 | 20 | 0 | 0 |
| 7/7/1999 | 20 | 0 | 0 | 7/7/1999 | 20 | 0 | 0 |
| 7/8/1999 | 20 | 0 | 0 | 7/8/1999 | 20 | 1 | 1 |
| 7/9/1999 | 20 | 1 | 2 | 7/9/1999 | 20 | 0 | 0 |
| 7/10/1999 | 20 | 0 | 0 | 7/10/1999 | 20 | 2 | 101 |
| 7/11/1999 | 20 | 2 | 9 | 7/11/1999 | 20 | 1 | 18 |
| 7/12/1999 | 20 | 0 | 0 | 7/12/1999 | 20 | 0 | 0 |
| 7/13/1999 | 20 | 2 | 3 | 7/13/1999 | 20 | 0 | 0 |
| 7/14/1999 | 20 | 3 | 4 | 7/14/1999 | 20 | 0 | 0 |
| 7/15/1999 | 20 | 1 | 82 | 7/15/1999 | 20 | 0 | 0 |
| 7/16/1999 | 20 | 1 | 6 | 7/16/1999 | 20 | 0 | 0 |
| 7/17/1999 | 20 | 0 | 0 | 7/17/1999 | 20 | 0 | 0 |
| 7/18/1999 | 20 | 0 | 0 | 7/18/1999 | 20 | 0 | 0 |
| 7/19/1999 | 20 | 0 | 0 | 7/19/1999 | 20 | 0 | 0 |
| 7/20/1999 | 20 | 0 | 0 | 7/20/1999 | 20 | 0 | 0 |
| 7/21/1999 | 20 | 0 | 0 | 7/21/1999 | 20 | 1 | 2 |
| 7/22/1999 | 20 | 0 | 0 | 7/22/1999 | 20 | 0 | 0 |
| 7/23/1999 | 20 | 2 | 4 | 7/23/1999 | 20 | 0 | 0 |
| 7/24/1999 | 20 | 8 | 39 | 7/24/1999 | 20 | 2 | 29 |
| 7/25/1999 | 20 | 0 | 0 | 7/25/1999 | 20 | 2 | 7 |
| 7/26/1999 | 20 | 0 | 0 | 7/26/1999 | 20 | 0 | 0 |

Table C-3 *(cont.)*

| Date | Observation Hours | Total Groups | No. of Individuals | Date | Observation Hours | Total Groups | No. of Individuals |
|---|---|---|---|---|---|---|---|
| **Camera 6 (Buried Pipeline/River Crossing)** | | | | | | | |
| 6/24/1999 | 20 | 0 | 0 | | | | |
| 6/25/1999 | 20 | 0 | 0 | | | | |
| 6/26/1999 | 20 | 0 | 0 | | | | |
| 6/27/1999 | 20 | 1 | 4 | | | | |
| 6/28/1999 | 20 | 4 | 31 | | | | |
| 6/29/1999 | 20 | 2 | 16 | | | | |
| 6/30/1999 | 20 | 0 | 0 | | | | |
| 7/1/1999 | 20 | 2 | 17 | | | | |
| 7/2/1999 | 20 | 2 | 5 | | | | |
| 7/3/1999 | 20 | 7 | 123 | | | | |
| 7/4/1999 | 20 | 0 | 0 | | | | |
| 7/5/1999 | 20 | 0 | 0 | | | | |
| 7/6/1999 | 20 | 1 | 1 | | | | |
| 7/7/1999 | 20 | 1 | 1 | | | | |
| 7/8/1999 | 20 | 1 | 50 | | | | |
| 7/9/1999 | 20 | 0 | 0 | | | | |
| 7/10/1999 | 20 | 2 | 281 | | | | |
| 7/11/1999 | 20 | 1 | 42 | | | | |
| 7/12/1999 | 20 | 3 | 60 | | | | |
| 7/13/1999 | 20 | 2 | 4 | | | | |
| 7/14/1999 | 20 | 2 | 2 | | | | |
| 7/15/1999 | 20 | 1 | 1 | | | | |
| 7/16/1999 | 20 | 2 | 10 | | | | |
| 7/17/1999 | 20 | 2 | 3 | | | | |
| 7/18/1999 | 20 | 0 | 0 | | | | |
| 7/19/1999 | 20 | 0 | 0 | | | | |
| 7/20/1999 | 20 | 0 | 0 | | | | |
| 7/21/1999 | 20 | 0 | 0 | | | | |
| 7/22/1999 | 20 | 1 | 10 | | | | |
| 7/23/1999 | 20 | 2 | 3 | | | | |
| 7/24/1999 | 20 | 3 | 369 | | | | |
| 7/25/1999 | 20 | 0 | 0 | | | | |
| 7/26/1999 | 20 | 0 | 0 | | | | |

Table C-4. Time-lapse video camera data collected at 5 remote camera sites by caribou groups along the Badami pipeline between 28 June and 25 July 1999. Mosquitoes were considered present or absent based on a mosquito index (see Appendix B). See Table C-2 for definitions of PVDs, size category, and side of pipeline.

| Date | Group # | Mosquito Level | PVDs | Group Size | Size Category | Crossed Pipe | Side of Pipeline |
|---|---|---|---|---|---|---|---|
| **Camera 1 (PVDs)** | | | | | | | |
| 7/1/1999 | 1 | absent | yes | 2 | A | yes | S |
| 7/2/1999 | 2 | present | yes | 2 | A | no | S |
| 7/2/1999 | 3 | present | yes | 1 | A | yes | S |
| 7/3/1999 | 4 | present | yes | 200 | C | yes | N |
| 7/4/1999 | 5 | absent | yes | 2 | A | yes | S |
| 7/5/1999 | 6 | present | yes | 3 | A | yes | N |
| 7/6/1999 | 7 | present | yes | 4 | A | no | S |
| 7/8/1999 | 8 | present | yes | 2 | A | yes | S |
| 7/9/1999 | 9 | present | yes | 80 | C | yes | N |
| 7/9/1999 | 10 | present | yes | 150 | C | yes | N |
| 7/10/1999 | 11 | present | yes | 10 | A | yes | N |
| 7/11/1999 | 12 | present | yes | 1 | A | no | not recorded |
| 7/11/1999 | 13 | present | yes | 19 | B | yes | N |
| 7/11/1999 | 14 | present | yes | 12 | B | yes | N |
| 7/12/1999 | 15 | present | yes | 1 | A | yes | S |
| 7/13/1999 | 16 | absent | yes | 25 | B | yes | N |
| 7/13/1999 | 17 | absent | yes | 50 | B | yes | S |
| 7/13/1999 | 18 | absent | yes | 70 | C | yes | S |
| 7/13/1999 | 19 | absent | yes | 2 | A | yes | N |
| 7/13/1999 | 20 | absent | yes | 2 | A | yes | N |
| 7/24/1999 | 21 | absent | yes | 1 | A | yes | S |
| 7/24/1999 | 22 | absent | yes | 12 | B | yes | S |
| **Camera 3 (No PVDs)** | | | | | | | |
| 6/28/1999 | 1 | absent | no | 2 | A | yes | S |
| 7/1/1999 | 2 | absent | no | 5 | A | yes | S |
| 7/2/1999 | 3 | present | no | 1 | A | yes | N |
| 7/4/1999 | 4 | absent | no | 150 | C | yes | N |
| 7/4/1999 | 5 | absent | no | 26 | B | yes | S |
| 7/4/1999 | 6 | absent | no | 14 | B | yes | N |
| 7/5/1999 | 7 | present | no | 1 | A | yes | S |
| 7/7/1999 | 8 | present | no | 2 | A | yes | N |
| 7/8/1999 | 9 | present | no | 12 | B | yes | S |
| 7/8/1999 | 10 | present | no | 7 | A | yes | N |
| 7/9/1999 | 11 | present | no | 2 | A | yes | N |
| 7/11/1999 | 12 | present | no | 5 | A | yes | N |
| 7/11/1999 | 13 | present | no | 7 | A | yes | S |
| 7/13/1999 | 14 | absent | no | 14 | B | yes | N |
| 7/15/1999 | 15 | absent | no | 150 | C | yes | S |
| 7/15/1999 | 16 | absent | no | 25 | B | yes | S |
| 7/15/1999 | 17 | absent | no | 20 | B | yes | N |

Table C-4 *(cont.)*

| Date | Group # | Mosquito Level | PVDs | Group Size | Size Category | Crossed Pipe | Side of Pipeline |
|---|---|---|---|---|---|---|---|
| 7/15/1999 | 18 | absent | no | 44 | B | yes | S |
| 7/15/1999 | 19 | absent | no | 20 | B | yes | S |
| 7/16/1999 | 20 | present | no | 1 | A | yes | S |
| 7/16/1999 | 21 | present | no | 1 | A | yes | N |
| 7/23/1999 | 22 | present | no | 12 | B | yes | S |
| 7/24/1999 | 23 | absent | no | 8 | A | yes | N |
| **Camera 4 (PVDs)** | | | | | | | |
| 6/28/1999 | 1 | absent | yes | 2 | A | yes | S |
| 6/28/1999 | 2 | absent | yes | 2 | A | no | S |
| 6/28/1999 | 3 | absent | yes | 1 | A | yes | S |
| 6/28/1999 | 4 | absent | yes | 9 | A | yes | S |
| 6/28/1999 | 5 | absent | yes | 1 | A | yes | N |
| 6/29/1999 | 6 | absent | yes | 1 | A | no | S |
| 7/1/1999 | 7 | absent | yes | 6 | A | yes | S |
| 7/1/1999 | 8 | absent | yes | 3 | A | yes | N |
| 7/1/1999 | 9 | absent | yes | 7 | A | yes | S |
| 7/1/1999 | 10 | absent | yes | 1 | A | yes | S |
| 7/1/1999 | 11 | absent | yes | 1 | A | yes | N |
| 7/1/1999 | 12 | absent | yes | 3 | A | yes | S |
| 7/1/1999 | 13 | absent | yes | 1 | A | yes | N |
| 7/1/1999 | 14 | absent | yes | 1 | A | yes | S |
| 7/1/1999 | 15 | absent | yes | 2 | A | yes | N |
| 7/3/1999 | 16 | present | yes | 1 | A | yes | S |
| 7/5/1999 | 17 | present | yes | 1 | A | yes | S |
| 7/5/1999 | 18 | present | yes | 3 | A | yes | S |
| 7/6/1999 | 19 | present | yes | 1 | A | yes | S |
| 7/9/1999 | 20 | present | yes | 2 | A | yes | S |
| 7/11/1999 | 21 | present | yes | 5 | A | yes | N |
| 7/11/1999 | 22 | present | yes | 4 | A | yes | S |
| 7/13/1999 | 23 | absent | yes | 2 | A | yes | S |
| 7/13/1999 | 24 | absent | yes | 1 | A | no | N |
| 7/14/1999 | 25 | absent | yes | 2 | A | yes | S |
| 7/14/1999 | 26 | absent | yes | 1 | A | no | N |
| 7/14/1999 | 27 | absent | yes | 1 | A | yes | N |
| 7/15/1999 | 28 | absent | yes | 82 | C | yes | S |
| 7/16/1999 | 29 | present | yes | 5 | A | yes | N |
| 7/16/1999 | 30 | present | yes | 1 | A | yes | S |
| 7/23/1999 | 31 | present | yes | 2 | A | yes | S |
| 7/23/1999 | 32 | present | yes | 2 | A | yes | S |
| 7/24/1999 | 33 | absent | yes | 4 | A | yes | N |
| 7/24/1999 | 34 | absent | yes | 1 | A | no | S |
| 7/24/1999 | 35 | absent | yes | 3 | A | yes | S |
| 7/24/1999 | 36 | absent | yes | 3 | A | yes | N |
| 7/24/1999 | 37 | absent | yes | 9 | A | no | S |
| 7/24/1999 | 38 | absent | yes | 4 | A | yes | S |
| 7/24/1999 | 39 | absent | yes | 3 | A | yes | N |
| 7/24/1999 | 40 | absent | yes | 12 | B | yes | N |

Table C-4 *(cont.)*

| Date | Group # | Mosquito Level | PVDs | Group Size | Size Category | Crossed Pipe | Side of Pipeline |
|---|---|---|---|---|---|---|---|
| **Camera 5 (No PVDs)** | | | | | | | |
| 6/24/1999 | 1 | absent | no | 1 | A | yes | S |
| 6/25/1999 | 2 | absent | no | 3 | A | yes | S |
| 6/26/1999 | 3 | absent | no | 3 | A | no | S |
| 6/27/1999 | 4 | absent | no | 2 | A | yes | S |
| 6/27/1999 | 5 | absent | no | 1 | A | yes | N |
| 6/27/1999 | 6 | absent | no | 1 | A | yes | S |
| 6/28/1999 | 7 | absent | no | 2 | A | yes | S |
| 7/1/1999 | 8 | absent | no | 1 | A | yes | S |
| 7/2/1999 | 9 | present | no | 13 | B | no | S |
| 7/2/1999 | 10 | present | no | 2 | A | yes | N |
| 7/8/1999 | 11 | present | no | 1 | A | yes | N |
| 7/10/1999 | 12 | present | no | 40 | B | yes | S |
| 7/10/1999 | 14 | present | no | 61 | C | yes | N |
| 7/11/1999 | 13 | present | no | 18 | B | yes | N |
| 7/21/1999 | 15 | absent | no | 2 | A | yes | S |
| 7/24/1999 | 16 | absent | no | 4 | A | yes | N |
| 7/24/1999 | 17 | absent | no | 25 | B | yes | N |
| 7/25/1999 | 18 | absent | no | 3 | A | yes | N |
| 7/25/1999 | 19 | absent | no | 4 | A | yes | N |
| **Camera 6 (Buried Pipeline/River Crossing)** | | | | | | | |
| 6/27/1999 | 1 | absent | river | 4 | A | yes | N |
| 6/28/1999 | 2 | absent | river | 5 | A | yes | N |
| 6/28/1999 | 3 | absent | river | 7 | A | yes | N |
| 6/28/1999 | 4 | absent | river | 17 | B | yes | S |
| 6/28/1999 | 5 | absent | river | 2 | A | yes | S |
| 6/29/1999 | 6 | absent | river | 10 | A | yes | N |
| 6/29/1999 | 7 | absent | river | 6 | A | yes | S |
| 7/1/1999 | 8 | absent | river | 13 | B | yes | S |
| 7/1/1999 | 9 | absent | river | 4 | A | yes | S |
| 7/2/1999 | 10 | present | river | 4 | A | yes | S |
| 7/2/1999 | 11 | present | river | 1 | A | no | S |
| 7/3/1999 | 12 | present | river | 3 | A | yes | N |
| 7/3/1999 | 13 | present | river | 58 | C | yes | N |
| 7/3/1999 | 14 | present | river | 56 | C | yes | N |
| 7/3/1999 | 15 | present | river | 3 | A | yes | N |
| 7/3/1999 | 16 | present | river | 1 | A | yes | S |
| 7/3/1999 | 17 | present | river | 1 | A | no | S |
| 7/3/1999 | 18 | present | river | 1 | A | yes | N |
| 7/6/1999 | 19 | present | river | 1 | A | yes | S |
| 7/7/1999 | 20 | present | river | 1 | A | yes | N |
| 7/8/1999 | 21 | present | river | 50 | B | yes | B |
| 7/10/1999 | 22 | present | river | 280 | C | yes | N |
| 7/10/1999 | 23 | present | river | 1 | A | yes | N |
| 7/11/1999 | 24 | present | river | 42 | B | yes | N |
| 7/12/1999 | 25 | present | river | 2 | A | yes | N |
| 7/12/1999 | 26 | present | river | 5 | A | yes | S |

Table C-4 *(cont.)*

| Date | Group # | Mosquito Level | PVDs | Group Size | Size Category | Crossed Pipe | Side of Pipeline |
|---|---|---|---|---|---|---|---|
| 7/12/1999 | 27 | present | river | 56 | C | yes | B |
| 7/13/1999 | 28 | absent | river | 3 | A | yes | S |
| 7/13/1999 | 29 | absent | river | 1 | A | yes | S |
| 7/14/1999 | 30 | absent | river | 1 | A | yes | N |
| 7/14/1999 | 31 | absent | river | 1 | A | yes | S |
| 7/15/1999 | 32 | absent | river | 1 | A | yes | N |
| 7/16/1999 | 33 | present | river | 9 | A | yes | N |
| 7/16/1999 | 34 | present | river | 1 | A | yes | S |
| 7/17/1999 | 35 | absent | river | 1 | A | yes | N |
| 7/17/1999 | 36 | absent | river | 2 | A | yes | S |
| 7/22/1999 | 37 | absent | river | 10 | A | yes | S |
| 7/23/1999 | 38 | present | river | 1 | A | yes | N |
| 7/23/1999 | 39 | present | river | 2 | A | yes | S |
| 7/24/1999 | 40 | absent | river | 2 | A | yes | S |
| 7/24/1999 | 41 | absent | river | 366 | C | yes | S |
| 7/24/1999 | 42 | absent | river | 1 | A | yes | S |