GEOLOGICAL SURVEY OF CANADA

OPEN FILE 3093

Hot spots on wood chip insulated slopes, Norman Wells Pipeline, Northwest Territories

M.M. Burgess, D.E. Lawrence, J. MacDonald, D.T. Desrochers

1995

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HOT SPOTS ON WOOD CHIP INSULATED SLOPES, NORMAN WELLS PIPELINE, N.W.T. :

Chronology of 1984 to 1993 observations and summary of 1993 instrumentation program

Burgess, M.M., Lawrence, D.E., MacDonald J., and Desrochers, D.T.

Terrain Sciences Division

Geological Survey of Canada

Geological Survey of Canada

1995

ABSTRACT

The use of wood chip insulation was an innovative concept, introduced in the final design phase of the Norman Wells pipeline, to prevent or retard thaw of permafrost on thaw sensitive slopes. A wood chip layer, 0.5 to 1.8 m thick, was placed on 56 slopes during pipeline construction in 1984-1985. As early as 1986, evidence of continued localized micro-biological heating within the wood chip layer was observed on four slopes. Differential snow melt patterns, particularly in late fall, were a key indicator of the presence of hot spots. By 1993, hot spots ranging in diameter from 1 m to >6 m had been confirmed on 27 of the 56 insulated slopes. Snow melt was extensive, covering more than two thirds of the width of the slope, on about a quarter of the slopes. An instrumentation program was implemented in 1993 on 4 slopes to study the thermal nature and effect of the hot spots on the underlying permafrost soils. Observations made during the 1992 and 1993 field seasons showed temperatures in the hot spots in the 20 to 25°C range, while the surrounding wood chips were 10 to 12 degrees cooler. The warm chips were considerably decomposed and moister than the surrounding chips which showed little evidence of alteration or decomposition. For some hot spots the temperature maximum appears to be near the centre, decreasing towards the edge with a sharp drop in temperature at the edge. Others show heating to be greatest near the margin, indicating perhaps a radial growth of fungal activity.

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1. INTRODUCTION

The Norman Wells Pipeline, owned and operated by the Interprovincial Pipeline Company (IPL), is the first buried oil pipeline operating in the discontinuous permafrost zone of northern Canada. The pipeline was constructed during the winters of 1984-1985 and commenced operation the spring of 1985. Along its 869 km length between Norman Wells, NWT and Zama, Alberta, there are over 165 slopes which required geotechnical evaluation and design (Hanna and McRoberts, 1988; MacInnes et al., 1989; Hanna et al., 1994). Fifty-six permafrost slopes were classified as thaw sensitive and insulated with a layer of wood chips up to 1.8 m thick to retard permafrost thaw.

Heat generation from micro-biological degradation of the wood chips was anticipated and observed in the first year after placement (MacInnes et al. 1990). However, in subsequent years heating persisted in localized areas on several slopes. Several remedial measures were undertaken by IPL to cool the hot spots and reduce their impact. Visual observations in October 1992 indicated that hot spot occurrence was still widespread with 23 of the 56 slopes showing one or more hot spots (Burgess et al., 1993). These observations raised a concern for slope stability due to the potential formation of deeper thaw zones than predicted beneath hot spots. A more detailed thermal study of hot spots was thus implemented in 1993.

This report describes hot spot observations from the time of pipeline construction through to 1993. The observations were recorded in IPL and government field trip reports, data collection sheets and annual reports. An outline of the 1993 hot spot instrumentation program undertaken on four wood chip slopes is provided. Diagrams showing the relative size and location of hot spots on several slopes in October 1992, some preliminary thermal data from October 1992 and 1993, and photographs are also included.

2. BACKGROUND ON THE USE OF WOOD CHIPS

The choice of wood chips as an insulating medium for thaw sensitive permafrost slopes is discussed by McRoberts et al. (1985) and Pick (1987). One of the concerns for using chips on slopes was based on the experience in the pulp and paper industry where piles of wood chips were known to generate heat by micro-biological degradation. Temperature data collected by IPL at a test site near Grand Prairie from July 1983 to July 1984 confirmed this heating phenomena. Wood chips placed on slopes similar in design to those proposed for the Norman Wells Pipeline, generated temperatures of 40 to 50°C the first summer after placement, then cooled to 3 to 4°C the following winter. During the second summer, temperatures increased to 30 to 40°C. A literature search by IPL on thermal behaviour of piles of wood chips concluded that once maximum temperatures are reached, the temperature returns quickly to ambient levels.

Heating in wood chips placed on the pipeline was therefore predicted for the first two thaw seasons following their placement. IPL, recognizing the novelty of the wood chip insulation technique and

the importance of the stability of permafrost slopes, included the assessment of the thermal performance of wood chip slopes as an integral part of their geotechnical monitoring program. Temperature instrumentation was placed by IPL on 18 slopes during construction. These temperature cables were installed generally in two or three locations along each slope to depths of 5 m below mineral soil and placed 3 to 4 m away from the pipe. An additional slope was instrumented by the federal government's Permafrost and Terrain Research and Monitoring (PTRM) program as part of its network of monitoring sites along the pipeline route (Pilon et al., 1989).

3. OBSERVATIONS OF HEAT GENERATION AND HOT SPOTS

3.1. Early Observations

In the first year after placement, temperatures in the centre of the chip layer exceeded 30°C on some slopes (MacInnes et al., 1990). The heating persisted in localized circular or oval spots on some of the wood chip insulated slopes. These areas of localized heating had been visually recognized as early as March of 1986 on slopes 73, 74, 76 and 79 when subsidence and snow melt were observed. Table1 lists all wood chip insulated slopes. (Slopes are numbered from north to south starting at Norman Wells; similarly kilometreposts increase southwards from 0 at Norman Wells). In October and November 1987, hot spots were again noted on slopes 73 and 74 through visual observations of snow melt and wet chips.

Other signs of persistent localized heating were recognized in the data obtained from the ground temperature cables installed on the slopes. For example, a hot spot developed at the location of one of the cables on slope 76. Temperatures within the chips at this location did not drop below 20°C in the first winter after their placement (Figure 1a). Thaw to a depth of about 2.5 m in the mineral soil underlying the chips (Figure 1b) was observed in January 1987 (the second winter). Wood chips were removed from this slope for several weeks during the winter of 1987 to allow the mineral soil to cool. The chips were also spread out to cool and arrest micro-biological activity before being replaced on the slope. Hot spots were once again recognized on the slope in 1992.

Early indications of localized heating were recognized by differences on the surface of the wood chip layer. Some of the observations that suggested micro-biological activity include: 1) Wood chips with more advanced degradation feel spongier to walk across, 2) Localized hot areas in the chips have melted the underlying permafrost, and the chips have settled to conform to the resulting thaw settlement depression, and 3) Localized areas of melted snow or differential snow melt patterns particulary, but not exclusively, in the fall at the time of early snowfall.

Since 1990, particular attention has been paid to snow melt patterns indicative of hot spots. In October 1990, PTRM noted differential snow melt suggesting wood chip heating on 8 slopes (see for example Plate 23 in Appendix A). IPL reported 6 slopes affected by wood chip heating in the fall of 1991. PTRM identified three slopes with hot spots in May 1992. In October 1992, PTRM clearly identified hot spots on 23 slopes, and noted their possible existence on two additional slopes.

TABLE 1. Location of Wood Chip Insulated Slopes

NO.	NAME	kmp	NO.	NAME	kmp
1	Bosworth Ck N	0.3	63	Steep Ck S	194.9
2	Bosworth Ck S	0.4	66	Blackwater Riv N	224.4
3	Canyon Ck N	19.2	66	Blackwater Riv N	224.8
4	Canyon Ck S	19.4	71	Unnamed Ck N	264.2
7	Francis Ck N	23.0	73	Unnamed Ck N	271.4
11	Heleva Ck N	25.6	74	Unnamed Ck S	271.6
12	Heleva Ck S	25.7	75	Unnamed Ck N	273.5
14	Christina Ck S	26.6	76	Unnamed Ck S	273.6
16	Prohibition Ck S	32.3	77	Unnamed Ck N	275.5
28	Great Bear Riv N	78.4	78	Unnamed Ck S	275.6
29A	Great Bear Riv S	78.8	79	Unnamed Ck N	279.0
29B	Great Bear Riv S	79.2	80	Unnamed Ck S	279.3
30	Unnamed Ck N	84.4	82	Ochre River S	286.6
31A	Unnamed Ck S	84.5	84	Unnamed Ck S	311.7
32A	Slope N	93.2	86	Unnamed Ck S	313.1
32B	Slope S	93.3	87	Unnamed Ck N	315.5
33	Unnamed Ck N	94.1	88	Unnamed Ck S	313.6
34	Unnamed Ck S	94.2	89	Unnamed Ck N	317.0
34+	Slope S	96.2	91	Unnamed Ck N	317.9
35	Unnamed Ck N	103.1	92	Unnamed Ck S	318.1
36	Unnamed Ck S	103.2	96	Unnamed Ck S	320.6
44	Unnamed Ck N	133.6	98	Smith Ck N	325.1
45	Unnamed Ck S	133.7	99	Smith Ck S	325.3
47	Little Smith Ck N	159.5	109	Unnamed Ck S	351.9
48B	Little Smith Ck S	160.1	112	Riv Bet 2 Mtns N	352.3
55	Unnamed Ck S	182.2	123	Unnamed Ck N	403.7
61	Unnamed Ck S	191.2	123A	Unnamed Ck S	403.8
62	Steep Ck N	194.4	142	Mackenzie Riv. S	529.6

Figure 1 a) Slope 76, kmp 273.6
Wood chip / Soil Interface Temperatures

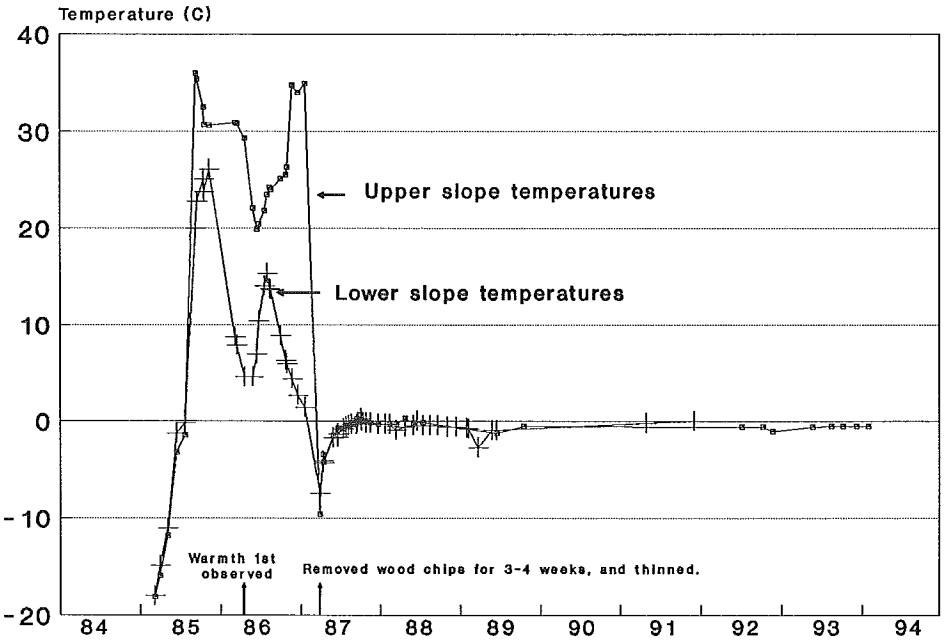
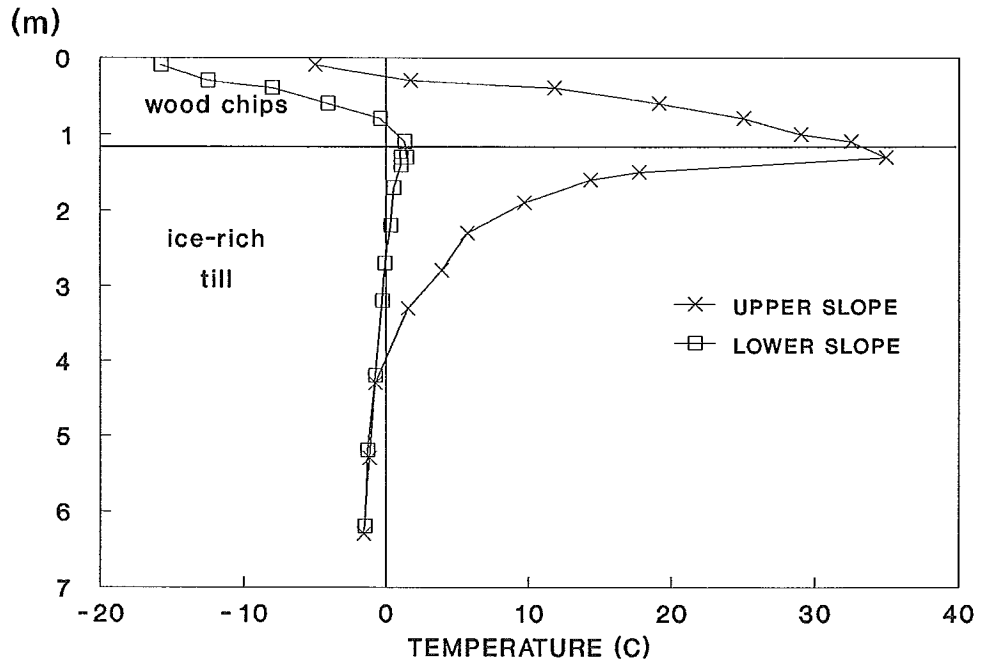


Figure 1 b) Slope 76, kmp 273.6
Temperature-Depth profiles, Jan. 87



3.2. 1992 observations

During the October 1992 PTRM field trip, weather and snow conditions were especially favourable for delineation of hot spots. Details on these observations were presented in Burgess et al. (1993). Table 2, reproduced from that report, summarizes the observations. The 23 slopes with confirmed hot spots were located between Fort Norman and Willowlake River (between kmp 84.5 and 403.7) and represented 56% of the slopes in that section of the pipeline route. Melt areas extended more than two-thirds across the right-of-way on about one-third of the slopes (eg. Plates 18, 24). The shape of the melted area was usually circular with a diameter ranging from 1 to 13 m. Oval and coalescing forms were also observed. Diagrams, outlining the extent and nature of the hot spots on many of these 23 slopes, are presented in Appendix B.

3.3. 1993 observations

Visible snow melt patterns also persisted through the winter of 1992/93, unlike previous winters (Plate 22). In the summer of 1993, the GSC as a component of an Industrial Partnership with IPL, instrumented several hot spots to assess their thermal regime and their potential contribution to thaw of the underlying permafrost. Thermal instrumentation was installed on slopes 31A, 45, 79 and 112. While the details of the instrumentation are presented in section 4, temperature measurements and visual observations are reported here.

Near-surface temperatures were recorded on transects across several hot spots in 1993. The measurements were made using a handheld microprocessor controlled Omega (Model HH22) digital thermometer with a type K thermocouple sensor embedded in the tip of 30 cm probe (eg. Plates 3, 38). Temperatures were recorded with a resolution of 0.1 degree and an accuracy of ±0.6°C.

Figures 2 to 5 are plots of transects across hot spots (or portions thereof) on slopes 31A, 45, 112 and 123. Difference in the temperature between the inside and outside of a hot spot ranged from 4 to 16 degrees. This temperature change occurs over a distance as short as 1 m, as for example at slope 112 in Figure 4. The detailed transect at slope 45 in Figure 2 revealed that there was a zone or halo around the edge of the hot spot where temperatures were warmer than the central region. This suggested the rim was biologically more active than the centre and that micro-organisms formed a ring as the colony grew and radiated outward. Differential snow melt patterns also suggested the hottest temperatures can be found in an outer ring around the hot spot. Some of the larger hot spots expose a ring of bare chips, leaving a circular patch of snow in the centre (Plates 36 and 37).

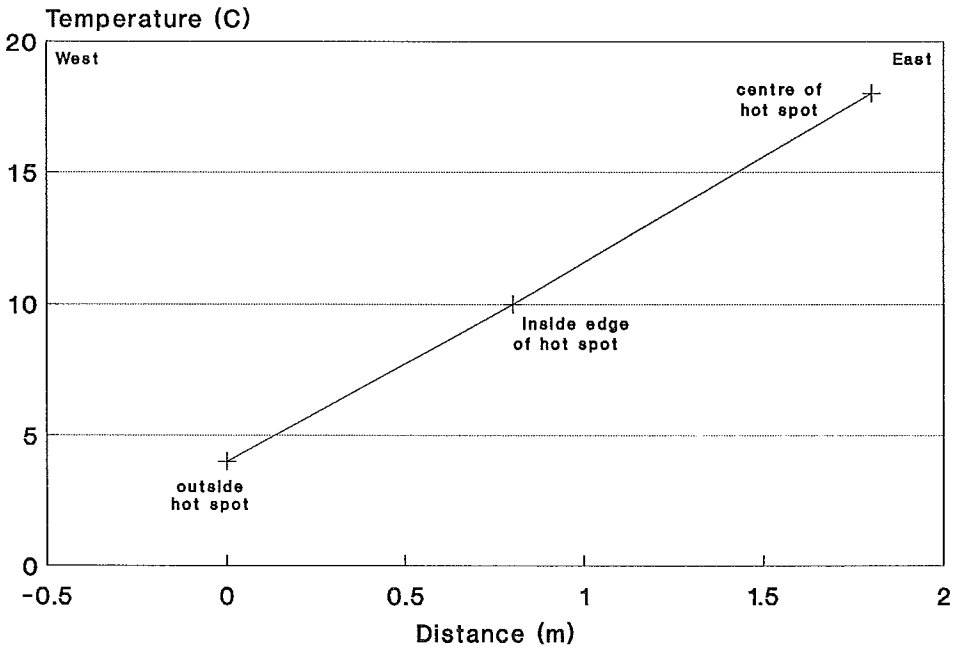
During installation of the instruments in a trench through the hot spot on slope 45 in July 1993 the following observations were noted. The fungi in the wood chips were white in colour and have a soft, dense (shortening-like) consistency in the warmer/active zone around the rim. This dense matrix contained fresh chips and formed a vertical band approximately 20 cm wide (Plate 15). In the centre of the hot spot the wood chips were degraded and appeared wet, slimy, and partially decomposed. Similar conditions were observed during instrumentation on slope 31A in October 1993.

TABLE 2. Summary of Hot Spot Observations, October 1992.

Slope	kmp	Ins	# Hot spots	Size	Temp (°C)	Sample ID
31A	84.5	G		E	12	S7
32A	93.2	G	1	M	12	
33N	94.1	G	1	S		
35	103.1	G	3	S		
36	103.2	G	4	S-L	15	S8
44	133.6	G		E	18	
45	133.7	G	>7	M	15	S9
47	159.5	G	>5	M	18	S10
48B	160.1	G	2			
55	182.2	A	1			
61	191.2	A	1			
63	194.9	G	6	S+M	14	
73	271.4	G		E	18	S6
74	271.6	G	3	S		
75	273.5	G	4	M-L	20	S5
76	273.6	G	1	S		
77	275.5	A	1			
78	275.6	A	4			
79	279.0	G	>9	E		
80	279.3	G	2	S+M	7	
82	286.6	G	6	E	12	S4
112	352.3	G	>5	S+M	6	S2, S3
123	403.7	G	1	E	7	S1

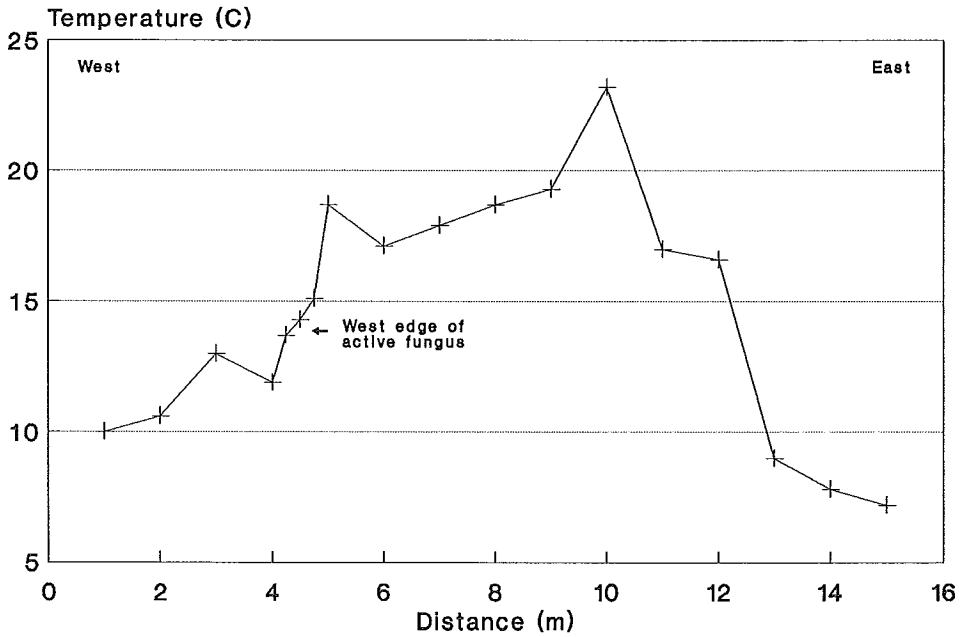
Note: **Size**: S = 1-3m, M = 3-6m, L = +6m, E = extensive
Ins = inspection; G = ground, A = air only
Temp = maximum temperature observed in wood chips

Figure 2. Hot Spot Temperature Transect
Slope 31A, kmp 84.5



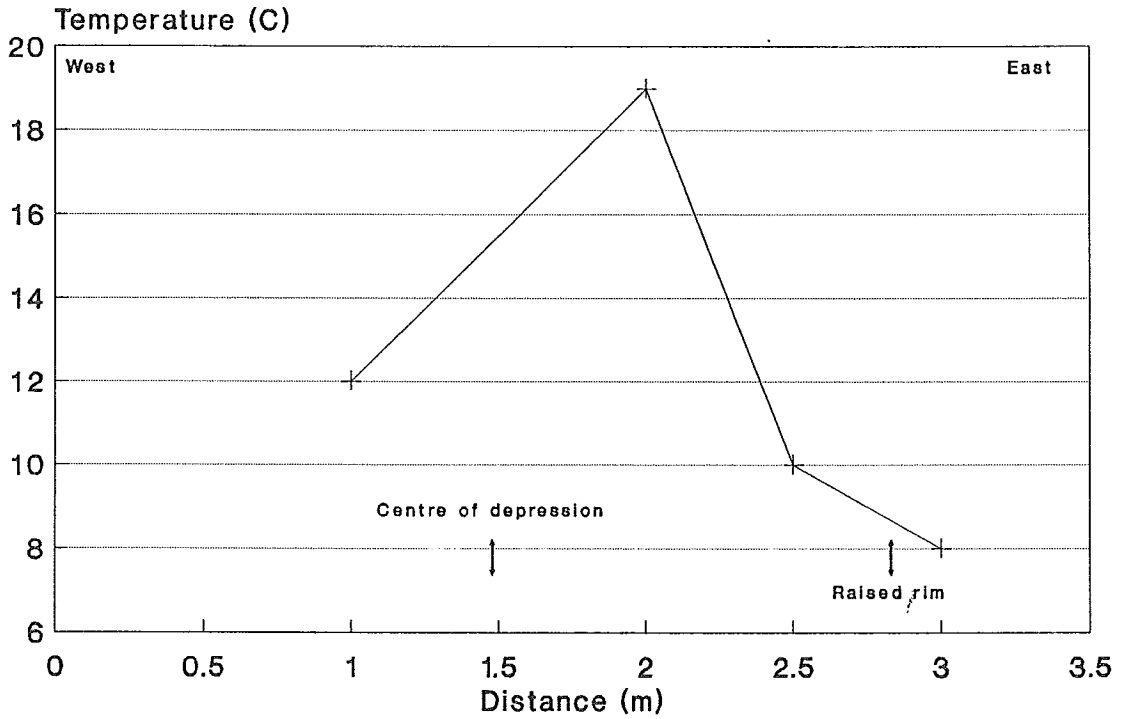
Oct. 7/93 temperatures at 30 cm depth

Figure 3. Hot Spot Temperature Transect
Slope 45, kmp 113.7



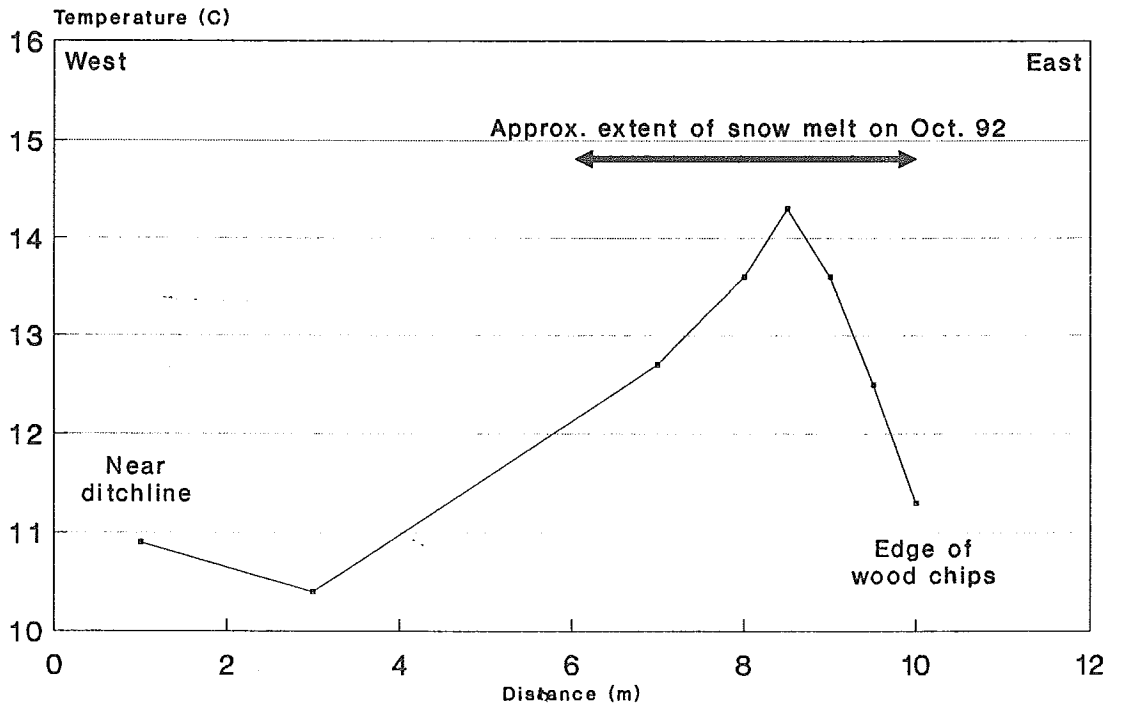
July 28, 1993, temperatures at 30 cm depth, at instrumented area.

Figure 4. Hot Spot Temperature Transect
Slope 112, kmp 352.3



Oct. 6, 1993 temperatures from location
of Hobo-Temp loggers, at 30cm depth.

Figure 5. Hot Spot Temperature Transect
Slope 123, Km 403.7



July 24, 1993, Centreline to west edge.
Temps from hot spot at edge of slope,
30cm depth. Distances are approximate.

3.4. Chronology of observations

A chronology of visual observations has been compiled in Appendix C for each slope where hot spots have been observed. Information for these chronologies has been derived principally from PTRM researcher field data sheets and field trip completion reports. Additional sources include, PTRM annual progress reports to IPL and INAC, and IPL annual reports on monitoring of construction and operation.

3.5. Summary

To the end of 1993, hot spots hade been observed on 27 (48.2%) of the 56 wood chip insulated slopes. This represents 74% of the wood chip slopes between km 78.8 and km 286.6. None of the 10 insulated slopes north of km 78.8, and only 4 of the 15 (26%) insulated slopes south of km 286.6, showed evidence of hot spots.

Table 3 summarizes pertinent hot spot data such as date and depth of maximum temperature recorded in a hot spot, when hot spots were first observed, whether remedial work was done and its nature and date, whether photos (Appendix A) and sketches (Appendix B) are available in this report and whether any instrumentation has been installed.

4. 1993 INSTRUMENTATION PROGRAM

Four large and well developed hot spots located on slopes 31A, 45, 79, and 112, were instrumented in 1993. These slopes were selected to represent a variety of conditions, e.g. different construction years, recently discovered hot spots as well as hot spots observed for several years, and different segments of the pipeline route. In addition, the site selection attempted to avoid slopes where remedial work was planned for the following winter.

4.1 Instrumentation

Temperature instrumentation consisted of i) rigid multisensor probes placed vertically in excavated or augered holes to depths of up to 3.2 m (Plate 5) and ii) small single-channel temperature loggers with an internal sensor. The temperature probes contain eight YSI44033 thermistor sensors (accuracy ±0.1°C) at 20 cm spacing embedded in a PVC tube. The probes were designed so that two could be stacked to give greater depth penetration and observe conditions within the wood chip layer and the underlying mineral soil. Each probe was connected via a 9-pin underwater connector to an 8- channel submersible temperature datalogger (model XL800 manufactured by Richard Brancker Research) and with a resolution of 0.02°C. The loggers were programmed via IBM compatible software to record data every 4 or 6 hours. The single channel logger, HOBO-TEMP (manufactured by Onset Computer Corp), is 3.5 cm in diameter, and 5.5 cm long and housed in a water resistant shell (Plates 6 and 40). The logger has an accuracy of ±0.2 to 0.4°C and a resolution of 0.3°C.

TABLE 3. Summary of hot spot information to December 1993.

SLOPE	KmP	INSTR	SKETCH	PHOTO	MAX. TEMP (°C @ cm)	DATE TEMP MEASURED	FIRST NOTED	REMEDIAL WORK Date	Type
29A	78.8			N.C.			10/92	12/12/84	RpWC
31A	84.5	HS	*	*	12 @ 20 18 @ 30	10/92 10/93	10/92	12/12/84 24/06/85	InBm Berm
32A	93.2		*		12 @ 20	10/92	10/92		
33	94.1						10/92	18/06/85	RxWC
35	103.1						11/89	12/12/84 84/85 W.90 W.91/92	InBm ErC RmS RmS
36	103.2		*		15 @ 20	10/92	89	W.89/90 W.90/91 W.91/92	RmS RmS RmS
44	133.6		*	*	18 @ 20	10/92	10/90	12/12/84 18/06/85 S.88 W.91/92	RpWC RC RC RmS RmWC?
45	133.7	IPL/HS	*	*	15 @ 20 23.2 @ 30	10/92 07/93	05/92	12/12/84 W.85/86 W.89/90	RpWC EC, RC RmWC Fix hole?
47	159.5		*	*	18 @ 20	10/92	10/90		
48B	160.1	IPL					10/90	W.84/85 W.90	Add WC? small RmWC
55	182.2						05/92	W.84/85	repair/RpWC
61	191.2						10/90		
63	194.9		*		14 @ 20	10/92	10/90	W.90/91	RmS
66	224.4			*			10/93	W.86/87	ErC
73	271.4	IPL			18 @ 20	10/92	03/86	07/86 W86/87 10/91	WtWC RmRpWC WtWC
74	271.6	IPL		*	35 @ 90	09/87	03/86	W86/87 02-03/88 10/88 02/89 03/89	RmS, TWC RmRpWC TI shows HS RmWC @HS RpWC @HS
75	273.5	IPL	*		20 @ 20	10/92	09/87	W86/87 02/88 10/91	RmSTWC RmRpWC WtWC
76	273.6	IPL					03/86	03/86 02-03/87	RmS+Ch RmRpWC
77	275.5		*				10/92		
78	275.6		*				10/92		
79	279.0	IPL/HS	*	*	17 @ 30	10/92	03/86	87? 02-03/88 10/88 02-03/89 03/90 03/91	ErC RmRpWC TI RmRpWC RmS RmS
80	279.3		*		7 @ 20	10/92	11/90	W88/89? W90/91?	ErC RmRpWC
82	286.6	IPL	*	*	12 @ 20	10/92	10/86	02-03/87 02/88 10/88 W88/89	RmS+TWC InstV TI shows HS lower slope
109	351.9	IPL		*			10/92	W88/89	ExTB
112	352.3	IPL/HS	*	*	6 @ 20 19 @ 30	10/92 10/93	10/92	W88/89	ExTB
123	403.7		*	*	7 @ 20 14.3 @ 30	10/92	10/92		
142	529.6	IPL		N.C.				02/03/87	RmRpWC

Notes on Table 3:

Listed in Table 3 are the 25 wood chip insulated slopes where hot spots have been observed and the two slopes where their presence is suspected. For a chronology of visual observations on each slope see Appendix A.

1. "Sketch" column: a "*" indicates a sketch of hot spot(s) is available in this report.

2. "Instr" column: indicates whether the slope has thermal instrumentation and which type. Eleven of the hot spot slopes were instrumented. Ten slopes were instrumented with temperature cables by IPL during construction in 1984/85; 3 of the IPL instrumented slopes, plus one other slope (31A) were instrumented (denoted HS) specifically in a known hot spot location in 1993.

3. "Photo": "*" indicates photos showing location or details of hot spot(s) are included in the report.

4. The temperatures listed above are the maximum temperatures recorded in the hot spot when measurements were made in 1992 or 1993. The depth and date (year or month/year) of measurement are indicated.

5. IPL Remedial Work : dates either in yy, mm/yy, or dd/mm/yy; S before the year indicates summer, W=winter

6. Abbreviations:

* = affirmative
N.C. = hot spots not confirmed, but suspected.
HS = Hot spot instrumentation
Rm = Remove
Rp = Replaced
WC = Wood Chips
S = Snow
ErC = Erosion Control
InstV = Installed Ventilation pipes
TI = Thermal Imagery
EC = Extend Crib
T = Temperature

InBm = install berm
RPpEx = Repaired pipe exposure
Ex = Excavate
TWC = Thinned wood chips
ExTB = Excavated Thaw Bulb
Ch = Churned up chips
TB = Thaw Bulb
WtWC = Watered down wood chips
RC = Repair Crib

HOBOS are capable of recording up to 1800 data points, at intervals ranging from 0.5 seconds to 4.8 hrs. The HOBOS were programmed via PC software to record every 4.8 hrs (which allows for a total logging duration of 360 days).

Details on the specific instrumentation layout at each slope are provided in the sections below and illustrated in the sketches in Appendix B and the photos in Appendix A.

4.2 Slope 31A (km 84.5), South Slope:

This slope was insulated with wood chips during the 1984 construction season and did not have any instrumentation installed prior to 1993. Extensive hot spots were first noted during the October 1992 PTRM field trip (see sketch of differential snow melt pattern in Appendix B). Instrumentation was installed in October 1993 at the large hot spot located mid-slope on the western side of the right-of-way. Wood chip thickness at this location ranged from 120 to 145 cm.

Two sets of stacked soil probes and two single soil probes were installed across the western edge of the hot spot. One stack was placed near the centre of the hot spot (probe 5123 on top of 5121), the other stack (probe 5125 on top of 5122) was installed just 30 cm inside the edge of the hot spot. Outside the hot spot, 50 cm from the edge, probe #5120 was placed 75 cm into the mineral soil, and probe 5124 was placed in the wood chips 20 cm further west. The probes were connected to XL800 loggers programmed to take temperature readings every four hours.

Four HOBOs were installed at the wood chip/mineral soil interface: Serial numbers 4423, 4428, 4429, 4482 from near the centre of the hot spot to the outside in a profile as illustrated in Appendix B.

4.3 Slope 45 (km 113.7), Unnamed Creek, South:

This slope was insulated with a 165 cm thick layer of wood chips during the 1984 construction season. Thermal instrumentation was also installed at that time in the wood chip and underlying mineral soil at one borehole located mid-slope; a cable was also placed along the wood chip/mineral soil interface at the side-cut at this location. A hot area was first clearly identified in May 1992 on the upper slope. In October 1992, 7 hot spot areas were noted throughout the slope (see sketch in Appendix B). Instrumentation was installed in the larger hot spot on the upper slope in late July 1993.

Three soil temperature probes were installed across the western edge of the hot spot (see instrumentation figure in Appendix B). All three probes are installed within the wood chip layer above the mineral soil. At the time and location of installation the layer of thawed wood chips ranged from 48 to 67 cm thick. Probe #4704 was placed in the decomposed chips at the edge of the hot spot in the active fungal zone. Probe #4705 was placed approximately one metre to the east near the centre of the hot spot, while probe #4703 was located just outside the hot spot approximately 20 cm

to the west of probe #4704. The probes were connected to XL800 loggers which were programmed to record every 6 hours.

Six HOBO-TEMP loggers were installed across the same transect. These were placed at the frozen/unfrozen interface within the wood chips in a horizontal profile across the hot spot at 25 to 75 cm spacings. Depths below the surface varied between 63 and 82 cm. To aid in retrieval each was tied to flagging tape that extended to the surface.

4.4 Slope 79 (km 279.0), Whitesand North:

This slope was insulated during the 1985 construction season with a layer of wood chips ranging from 100 to 180 cm thick. At that time, shallow thermal instrumentation was installed mainly in the wood chip layer at three locations on the slope. Hot spots were noted in March 1986 and frequently observed thereafter. Wood chips were removed in February 1988 over sections of the slopes to allow cooling of the slope and wood chips, and then replaced in March 1988. Another small area of warm chips, detected by thermal imagery undertaken by IPL in the fall of 1988, was similarly cooled in 1989. Hot spots continued to occur, and snow removal was tried as a remedial measure at select spots in 1990, 1991 and 1992. In October 1992, nine or more extensive coalescing hot spots were identified.

Instrumentation was placed in the large hot spot near the bottom of the slope in October 1993. The hot spot was located using the manual temperature probe. Three HOBO-TEMP loggers were installed in a horizontal profile at a depth of 30 cm below the wood chip surface spaced 50 cm apart (see figure in Appendix B.). One was placed in the centre (serial #767), and one on either side of the hot spot (#746 to the east side and #753 to the west side). Each Hobo was secured to a nylon cord to aid retrieval.

4.5 Slope 109, Unnamed Creek South (km 351.9):

This slope was insulated with 50 cm thick layer of wood chips during the 1984 construction season. There was no thermal instrumentation installed at that time. In 1988, tension cracks mainly parallel to the ditchline, and settlement in the ditchline began to appear over the length of the slope. The tension cracks have since continued to expand laterally and the area of subsidence continued to widen as the thaw bulb around the pipe grows. In the winter of 1991, IPL installed one temperature cable in a borehole adjacent to the pipe, as part of its program to reassess the factor of safety on several slopes with deep thaw bulbs surrounding the pipe. The GSC installed shallow soil probes in the ditch at this location in August 1991.

Hot spots were first suspected in the fall of 1992. In October 1993 numerous hot spots were visible, many over the subsided ditch and snow melt patterns indicated heat loss from tension cracks. HOBO-TEMP logger #4430 was installed at a depth of 20 cm in a 10 cm wide tension crack adjacent

to a hot spot on the west side of the slope. Another HOBO (#4433) was installed at a depth of 30 cm in a 14 cm wide tension crack adjacent to a hot spot on the east side of the slope.

4.6 Slope 112 (km 352.3), River Between Two Mountains, North:

This slope was insulated with a 80 cm thick layer of wood chips during the 1984 construction season. One temperature cable was installed by IPL at that time. An additional cable was installed by IPL in 1991 as part of their program to reassess the factor of safety of select slopes. Hot spots were first noted in October 1992. Five or more small to medium size hot spots were exposed on the slope. One hot spot located below the piezometer, was almost a perfect circle in form. This hot spot appeared to be warmest around its edge where bare wood chips were exposed, and cooler in the middle where snow remained (Plates 36, 37).

Four HOBO-TEMP loggers were installed in a transect across this hot spot in October 1993 (see figure in Appendix B). HOBOS #4427, 768, 1029 are installed at 30 cm depth along a horizontal profile which extends from the centre to just inside the east rim of the hot spot. HOBO #1050 is located at the same depth just outside the hot spot. Each Hobo was attached to orange flagging which was extended to the wood chip surface.

5. SUMMARY

The use of wood chips was an innovative concept, introduced in the final design phase of the Norman Wells pipeline, to prevent or retard the thaw of permafrost on thaw sensitive slopes. Evidence from the pulp industry and tests carried out by IPL indicated that internal heating certainly should be expected in the first year following placement and perhaps to a limited extent in the second season, but heating was not expected to persist in the long term. In general, the technique seems to have been successful in retarding thaw, but the performance has been complicated by the thermal effect of the pipeline itself. The wood chip design thermal model assumed that the pipeline would be thermally neutral; in reality, through to the summer of 1993, it has been operating above the temperature of the surrounding ground on wood chip slopes for almost its entire length except for the first few tens of kilometres.

The appearance of localized snow melt patterns in 1986 on four slopes served as the first evidence of persistent internal heating within the wood chips. Further evidence of localized heating was provided from one of the temperature cables on slope 76. In 1990, differential snow melt patterns were recognized on a total of 8 slopes. By this time, particular attention was being directed to determining the extent and effect of internal heating. In October 1992 hot spots in wood chips as evidenced by snow melt patterns were recognized on 23 wood chip insulated slopes. Melting was extensive, i.e. it extended more than two-thirds across the ROW, on about one-third of these slopes. To date, hot spots have been confirmed on 27 of the 56 wood chip insulated slopes. The phenomena affects about three quarters of the slopes between kmp 78 and 287.

Decline in the factors of safety and the concern about the rates of thaw and possible increases in pore water pressure for a few of the wood chip insulated slopes prompted a closer examination of these slopes and the National Energy Board (the pipeline regulatory authority) requested that the level and frequency of slope monitoring be increased. Because of the persistence and the increase in the number of identified hot spots, several slopes were instrumented in the summer and fall of 1993 with temperature sensors and data loggers in order to establish the amount and extent of heating within the wood chips. The instrumentation program is a component of an Industrial Partnership Program between the GSC and IPL.

Locally wood chip temperatures exceeded 35°C degrees on Norman Wells pipeline slopes in the first two years following placement. More recent data shows hot spots with temperatures in the 20 to 25°C range surrounded by chips 10 to 12 degrees cooler. The warm chips are considerably decomposed and moister than the surrounding chips which show little evidence of alteration or decomposition. White fungal growths are common within the hot spots. For some hot spots, the temperature maximum appears to be near the centre, decreasing toward the edges with a sharp drop in temperature at the edge. Others show heating to be greatest near the margin indicating perhaps a radial growth of bacterial activity.

Data retrieval and analysis in 1994 and 1995 hopefully will provide a better understanding of temperature distribution with time, distance and depth within the hot spots, and the thermal impact on the underlying mineral soil. The hot spot observations and analysis should also help to interpret ground penetrating radar (GPR) surveys undertaken in 1993 and 1994. The GPR surveys form the focus of the IPP between the GSC and IPL and seek to examine in detail the 2D and 3D subsurface thermal and lithologic conditions on several critical wood chip insulated slopes (Moorman, in prep.; Robinson and Moorman in prep.).

6. ACKNOWLEDGEMENTS

The 1993 hot spot instrumentation program was largely funded through the Geological Survey of Canada Industrial Partnership Program (IPP) with IPL. Data and observations collected since 1984 as part of the Permafrost and Terrain Research and Monitoring Program on the Norman Wells Pipeline (PTRM) have been funded through the Northern Affairs Program and Northern Oil and Gas Action Program of the Department of Indian and Northern Affairs (INAC), Natural Resources Canada, the Federal Panel on Energy Research and Development, and IPL. We would like particularly to acknowledge the contributions of Dr. Kaye MacInnes of INAC, PTRM program coordinator and researcher; Dr. Wayne Savigny of UBC, and Harry Baker of the National Research Council.

7. REFERENCES

Burgess, M.M., Lawrence, D.E., and MacInnes, K.L. (1993). Hot spots on wood chip insulated permafrost slopes, Norman Wells pipeline, northwestern Canada. Current Research, Part E, Geological Survey of Canada, Paper 93-1E, p. 133-140.

Hanna, A.J. and McRoberts, E.C. (1988). Permafrost slope design for a buried oil pipeline; in Proceedings of the Fifth International Conference on Permafrost, Volume 2, Norway, August 1998; Tapir publishers, p.1247-1252.

Hanna, A.J., Oswell, J.M., McRoberts, E.C., Smith, J.D., and Fridel, T.W. (1994). Initial performance permafrost slopes: Norman Wells pipeline project, Canada. in Proceedings 7th International Cold Regions Engineering Specialty Conference, Cold Regions Engineering "A Global Perspective", Edmonton, Alberta, p.369-395.

MacInnes, K.L., Burgess, M.M., Harry, D.G., and Baker, T.H.W. (1989). Permafrost and Terrain Research and Monitoring: Norman Wells Pipeline, Volume I Environmental and Engineering Considerations. Environmental Studies Report No. 64. Department of Indian and Northern Affairs Canada, Northern Affairs Program, 132 pp.

MacInnes, K.L., Burgess, M.M., Harry, D.G., and Baker, T.H.W. (1990). Permafrost and Terrain Research and Monitoring: Norman Wells Pipeline, Volume II Research and Monitoring Results: 1983-1988. Environmental Studies Report No. 64. Department of Indian and Northern Affairs Canada, Northern Affairs Program, 204 pp.

McRoberts, E.C., Hanna, A.J., and Smith, J. (1985). Monitoring of thawing permafrost slopes: Interprovincial Pipe line. in Proceedings of Workshops on Subsea Permafrost and pipelines in Permafrost, November 1985. National Research Council of Canada, NRCC Technical Memorandum 139, p.133-151.

Moorman, B.J. (1995). Geotechnical investigations of wood chip slopes along the Norman Wells Pipeline: Analysis of 1993 ground penetrating radar data. Geological Survey of Canada Open File 3024.

Pick, A.R. (1987). Use of wood chips for permafrost stabilization. in Proceedings of the Canadian Society of Civil Engineering Centennial Conference, Montreal, Canada, p.345-365.

Pilon, J.A., Burgess, M.M., Judge, A.S., Allen, V.S., MacInnes, K.L., Harry, D.G., Tarnocai, C., and Baker, H. (1989). Norman Wells to Zama pipeline permafrost and terrain research and monitoring program: site establishment report. Geological Survey of Canada, Open File 2044, 332 pp.

Robinson, S.D. and Moorman, B.J. (1995). Ground penetrating radar surveys along the Norman Wells Pipeline Route, summer 1994. Geological Survey of Canada, Open File 3070.

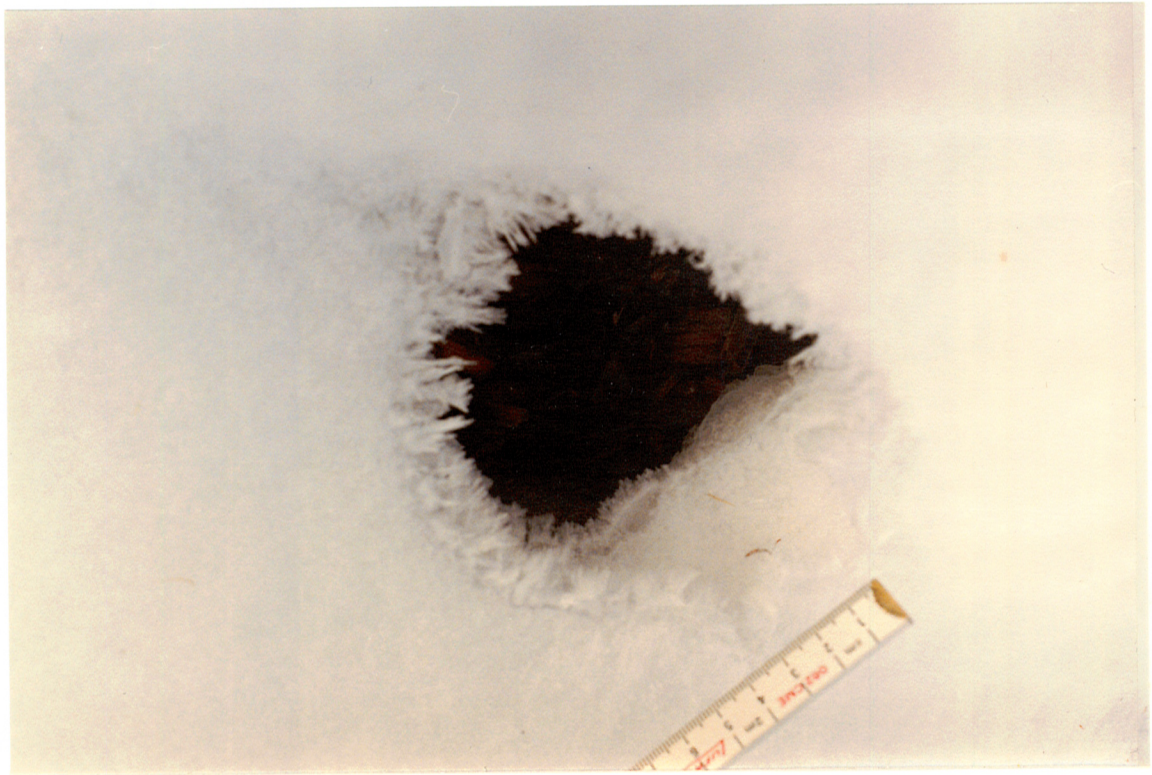
APPENDIX A

Photographic plates

A selection of photos of slopes and instrumentation presented in order of increasing slope number.

Plate 1. Slope 31A, KmP 84.5, Unnamed Creek South, Oct. 1992. Snow covered wood chip insulated slope. Surface inspection indicated hot spots extended across two-thirds of the ROW.

Plates 2,3.
Slope 31A, Unnamed Creek South, KmP 84.5, Oct.1992. Warm air ventilates through the snow from the wood chip layer melting the snow and often exposing wood chips.



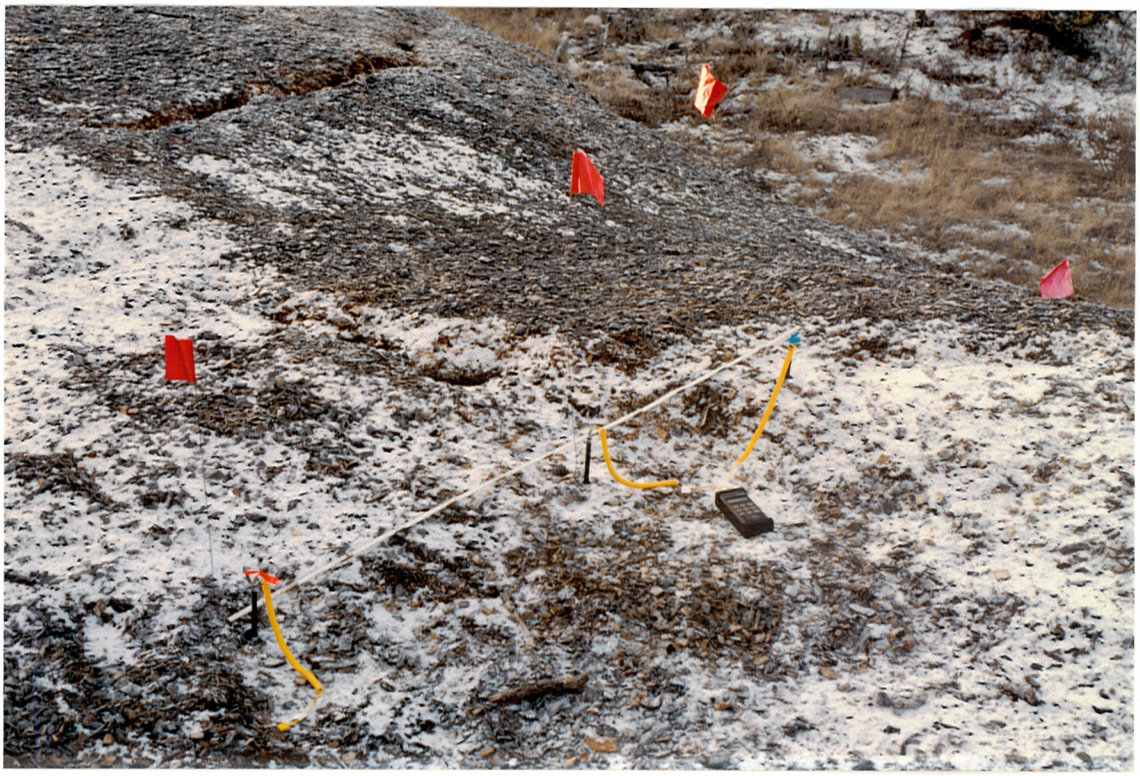


Plate 4. Slope 31A, Unnamed Creek South, KmP 84.5, Oct. 7, 1993. Handheld microprocessor controlled digital thermometer probes are used to measure temperatures in the wood chips to a depth of 30 cm in order to delineate the extent of the hot spot.

Plate 5. Installation of soil probes on slope 31A to instrument a hot spot. Three holes were augered across the area of the hot spot, through the wood chips and into the mineral soil. Soil temperature probes were then installed in each hole to a maximum depth of 3.2 m. Oct. 7, 1993.

Plate 6. Slope 31A, Unnamed Creek South, KmP 84.5, Oct. 7, 1993. Four Hobo-Temp loggers were installed at the base of the wood chip layer between the soil probes in a transect across the hot spot.

Plate 7. Slope 31A, Unnamed Creek South, KmP 84.5. Oct. 7, 1993. Hot spot instrumentation set-up. Subsidence at hot spot location is influenced by the ditchline. Note tension crack which has developed to the west edge of the hot spot.

Plate 8. Slope 31A, Unnamed Creek South, KmP 84.5, Oct. 7, 1993. Northward view of slope with hot spot instrumentation. Note subsided hot area and ditchline, and tension cracks in the wood chips.

Plate 9. Slope 31A, Unnamed Creek South, KmP 84.5, Oct. 7, 1993. Aerial view towards the south of slope 31A with hot spot instrumentation.

Plates 10, 11.

Slope 44, Unnamed Creek North, KmP 133.6, Oct. 92. Aerial photograph of differential snow melt on the wood chips showing the extent and location of hot spots. Areas of most intense heat expose bare wood chips. Partial snow melt over the hot spot forms a hummocky surface.

Plates 12,13.

Slope 45, Unnamed Creek South, KmP 133.7, Oct. 92. Snow melt patterns indicate both local and extensive hot spots in the wood chips. A hummocky and saturated snowpack indicates high surface temperatures in the wood chips.

Plate 14. Slope 45, Unnamed Creek South, KmP 133.7, July 1993. Temperature measurements were recorded at 30 cm depth across an extensive hot spot using a handheld digital thermometer.

Plate 15. Slope 45, Unnamed Creek South, KmP 133.7, July 1993. Vertical zone of active fungus at edge of hot spot is 10 to 15 cm wide.

Plate 16. Slope 45, Unnamed Creek South, Kmp 133.7, July 1993. Trench dug across one edge of hot spot to investigate hot spot and install instrumentation.

Plate 17. Slope 45, Unnamed Creek South, Kmp 133.7, July 1993. New hot spot instrumentation.

Plate 18. Slope 47, Little Smith Creek North, KmP 159.5, Oct. 1992. Aerial view of exposed wood chips due to snow melt from hot spots within the wood chips.

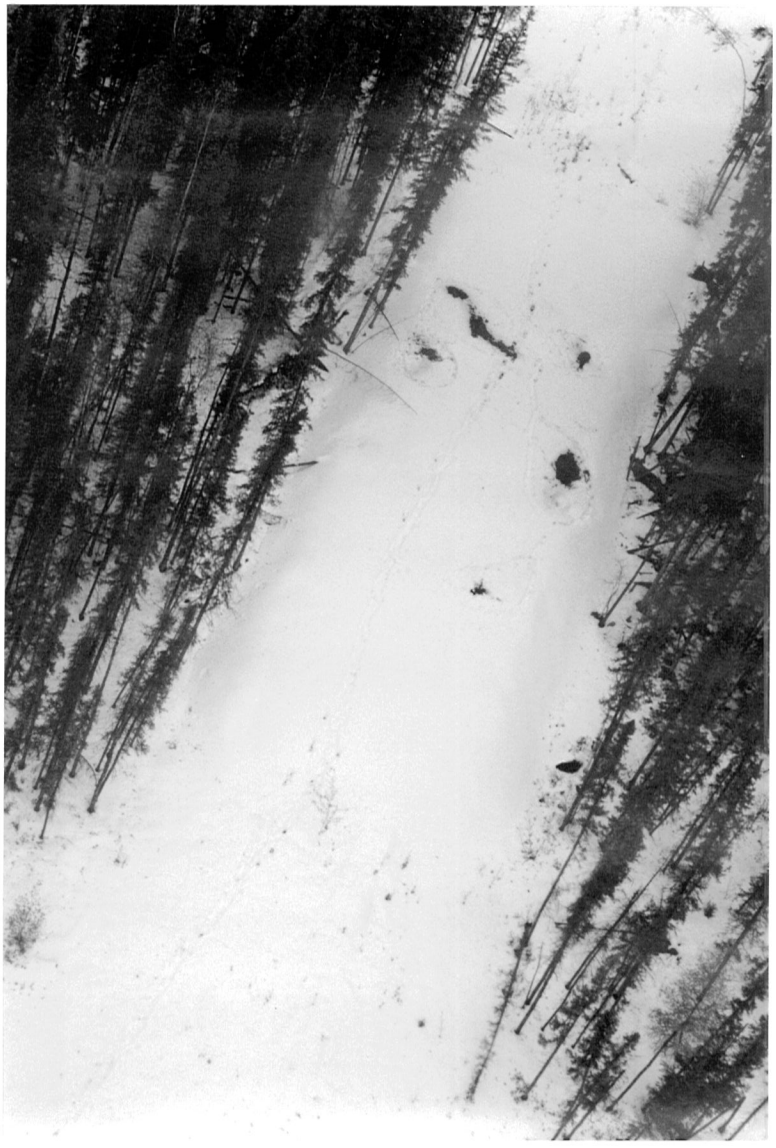


Plate 19. Slope 63, Steep Creek South, KmP 194.9, Oct. 6, 1992. Extensive hot spots were recognized from ground inspection of the slope.

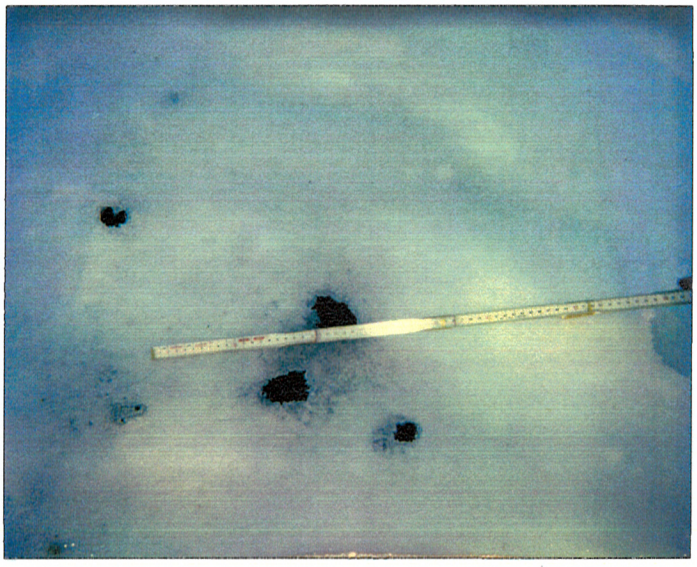


Plate 20. Slope 63, Steep Creek South, Kmp 194.9, Oct. 6, 1992. Hot spot melted through the overlying blanket of snow. Snow depth away from hot areas is 22 to 30 cm.

Plate 21. Slope 66, Blackwater River North, KmP 224.4, Oct. 1993. Aerial photograph of differential snow melt on wood chip slope indicating hot spots.

Plate 22. Slope 76, Unnamed Creek South, KmP 273.6, March 1993. Depressions on the wood chip slope indicate hot spots.

Plates 23, 24.
Slope 79, Whitesand North, KmP 279.0, Oct. 1990. Aerial photographs showing large areas of melted snow due to heat generated in the wood chips.

Plate 25. Slope 79, Whitesand North, KmP 279.0, Oct. 1992. Patches of melted snow over hot areas in the wood chips. Some of the larger hot spots appear to be cooler in the centre since snow has melted in a ring-like pattern.

Plate 26. Slope 79 and 80, Whitesand North and South (in the foreground), KmP 279.0 - 279.3, Oct. 1992. Standing on Slope 80 facing north to Slope 79. Snow melt indicating areas of hot spots on both slopes.

Plate 27. Slope 79, Whitesand North, KmP 279.0, Oct. 3, 1993. Monitoring wood chip temperatures at 30 cm depth with the digital thermometer probe in an attempt to locate the hot spot.

Plate 28. Slope 79, Whitesand North, KmP 279.0, Oct. 6, 1993. Aerial view of hot spot in the wood chip layer.

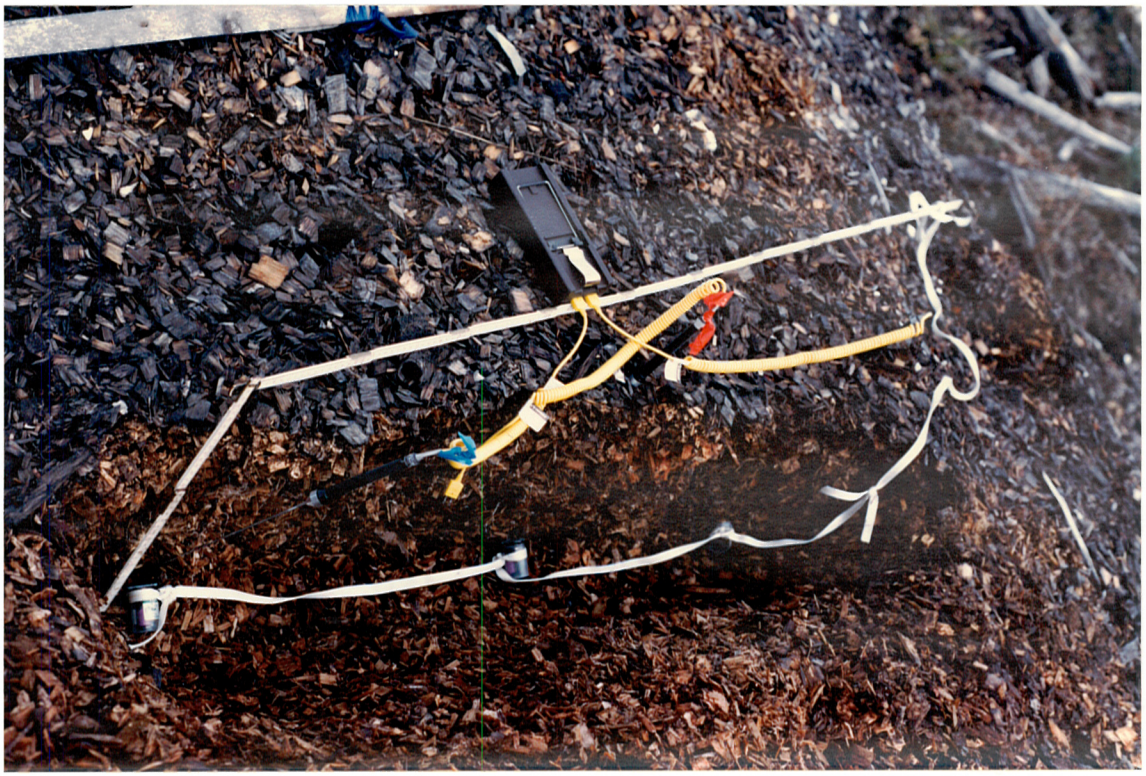


Plate 29. Slope 79, Whitesand North, KmP 279.0, Oct. 3 1993. A 30 cm deep trench was excavated to place three Hobo-Temp loggers in a hot spot located on the lower slope. The Hobo's were attached to a climbing rope which was extended to the surface.

Plate 30. Slope 79, Whitesand North, KmP 279.0, Oct. 3, 1993. Surface conditions after the Hobo's were set-up.

Plate 31. Slope 82. Ochre River South, Kmp 286.6, Oct. 1990. Extensive hot spots at mid-slope.

Plate 32. Slope 82, Ochre River South, KmP 286.6, Oct. 1992. Extensive hot spots at mid-slope.

Plates 33, 34.

Slope 82, Ochre River South, KmP 286.6, Oct. 1993. Aerial view of hot areas on the wood chip slope, recognized by patches of exposed wood chips.

Plate 35. Slope 109, Unnamed Creek South, KmP 351.9, Oct. 6, 1993. Hobo-Temp logger installation at 30 cm depth in a tension crack located near a hot spot. Two tension cracks were instrumented with Hobo's at this slope.

Plates 36, 37.

Slope 112, River Between Two Mountains, KmP 352.3, Oct. 1992. Circular snow melt patterns indicate hot spots in the wood chips.

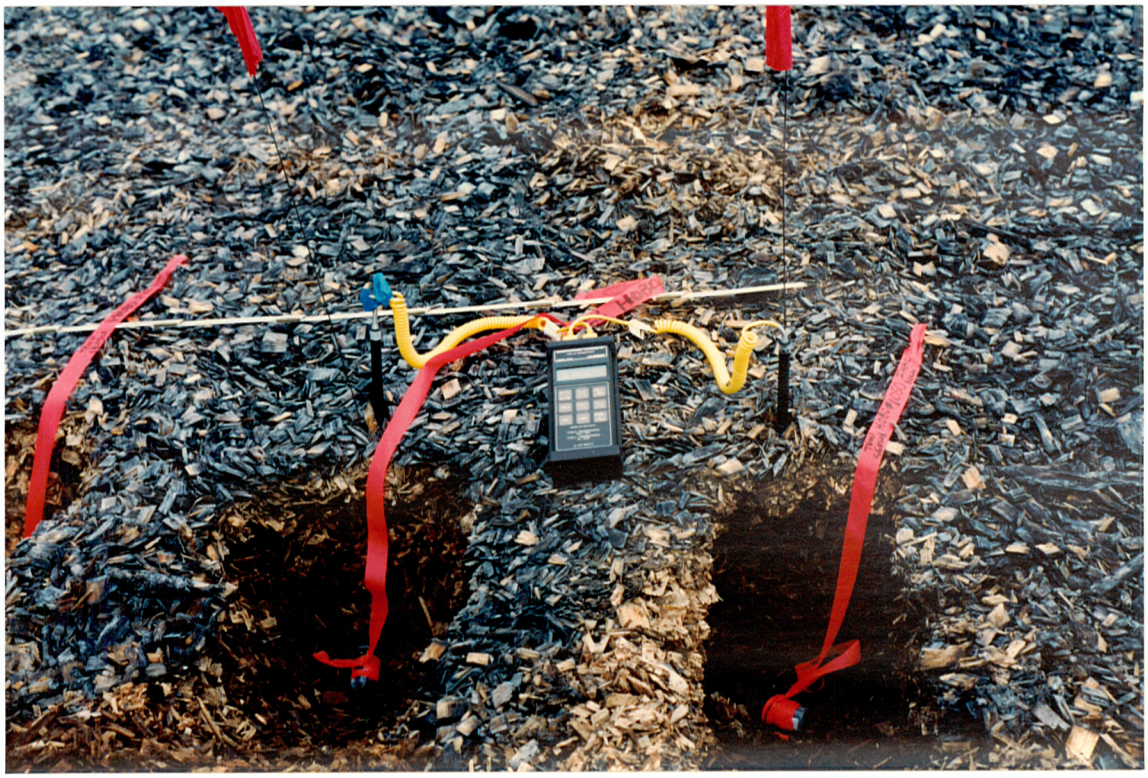


Plate 38. Slope 112, River Between Two Mountains, KmP 352.3, Oct. 6, 1993. 30 cm deep trench was excavated in the wood chip layer to install four Hobo-Temp loggers in a hot spot.

Plate 39. Slope 112, River Between Two Mountains, KmP 352.3, Oct. 6, 1993. Surface conditions after Hobo-Temp logger set-up. Red flagging tape is attached to each logger and extends to the surface.

Plates 40,41.

Slope 112, River Between Two Mountains, KmP 352.3, Oct.6, 1993. Close up view of Hobo-Temp logger installations and wood chip conditions.

Plate 42. Slope 112, River Between Two Mountains, KmP 352.3, Oct.6, 1992. Fungal material in the wood chips.

Plate 43. Slope 112, River Between Two Mountains, KmP 352.3, Oct.6, 1993. Aerial view of circular snow melt patterns indicating several hot spots. A ring-shaped snow melt pattern suggests cooler temperatures in the centre of the hot spot. Hottest temperatures are generated at the rim of the hot spot where active fungus thrives.

APPENDIX B

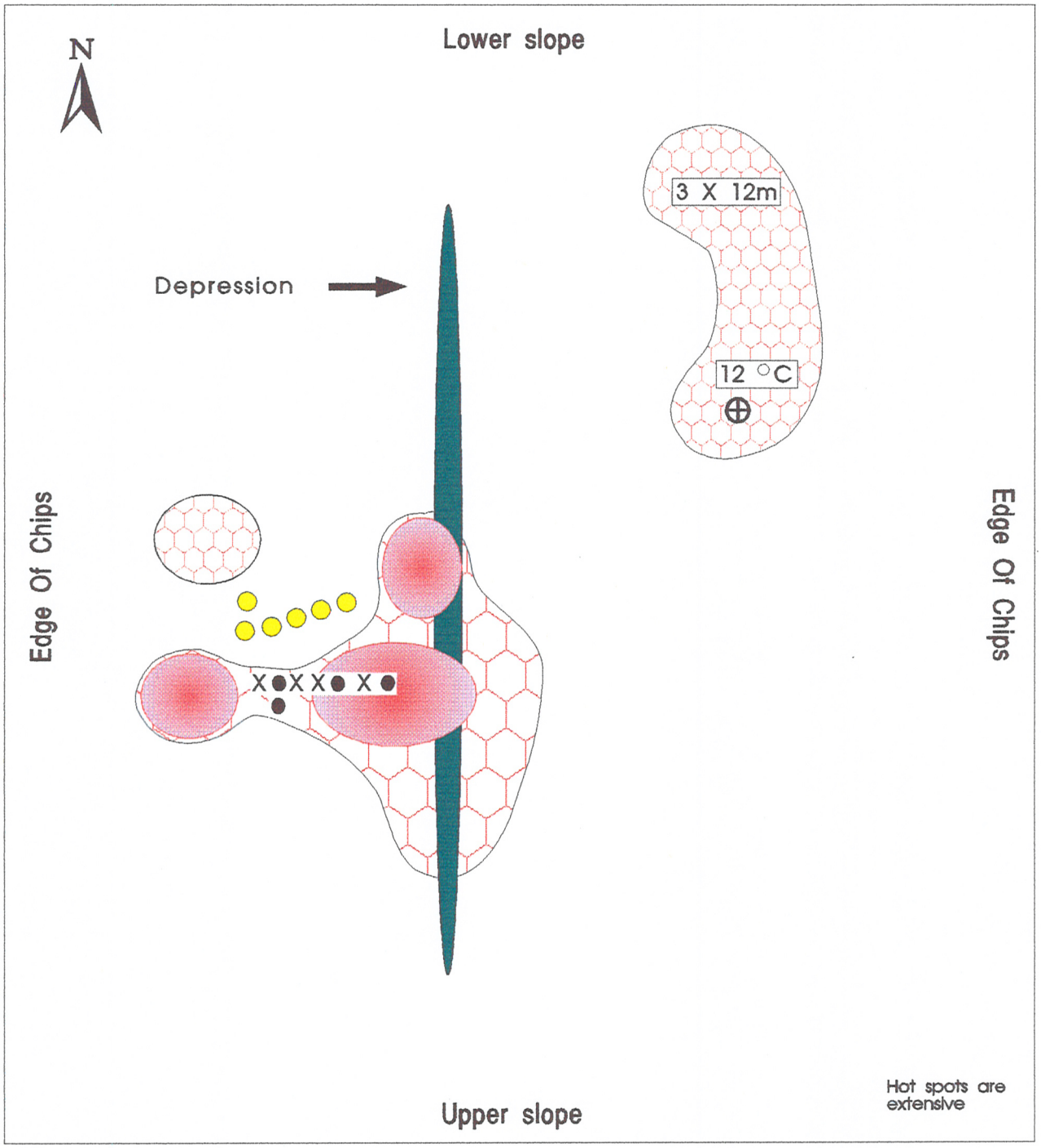
Diagrams of hot spots and instrumentation

Notes:

1. Diagrams are presented in order of increasing slope number. They are not to scale. The north arrow indicates the direction towards the northern end of the pipeline (i.e. towards Norman Wells).

2. Outlines of snow melt and exposed chips refer to conditions observed in October 1992. Instrumentation locations refer to 1993 installations. Slopes were generally snow covered. Exposed chips refers to no snow over the hot spot. Extent of hot spots were determined based on snow melt pattern/thickness and/or temperature measurements. See the legend of the first figure for the patterns used to delineate the area of exposed chips and the area of the hot spot.

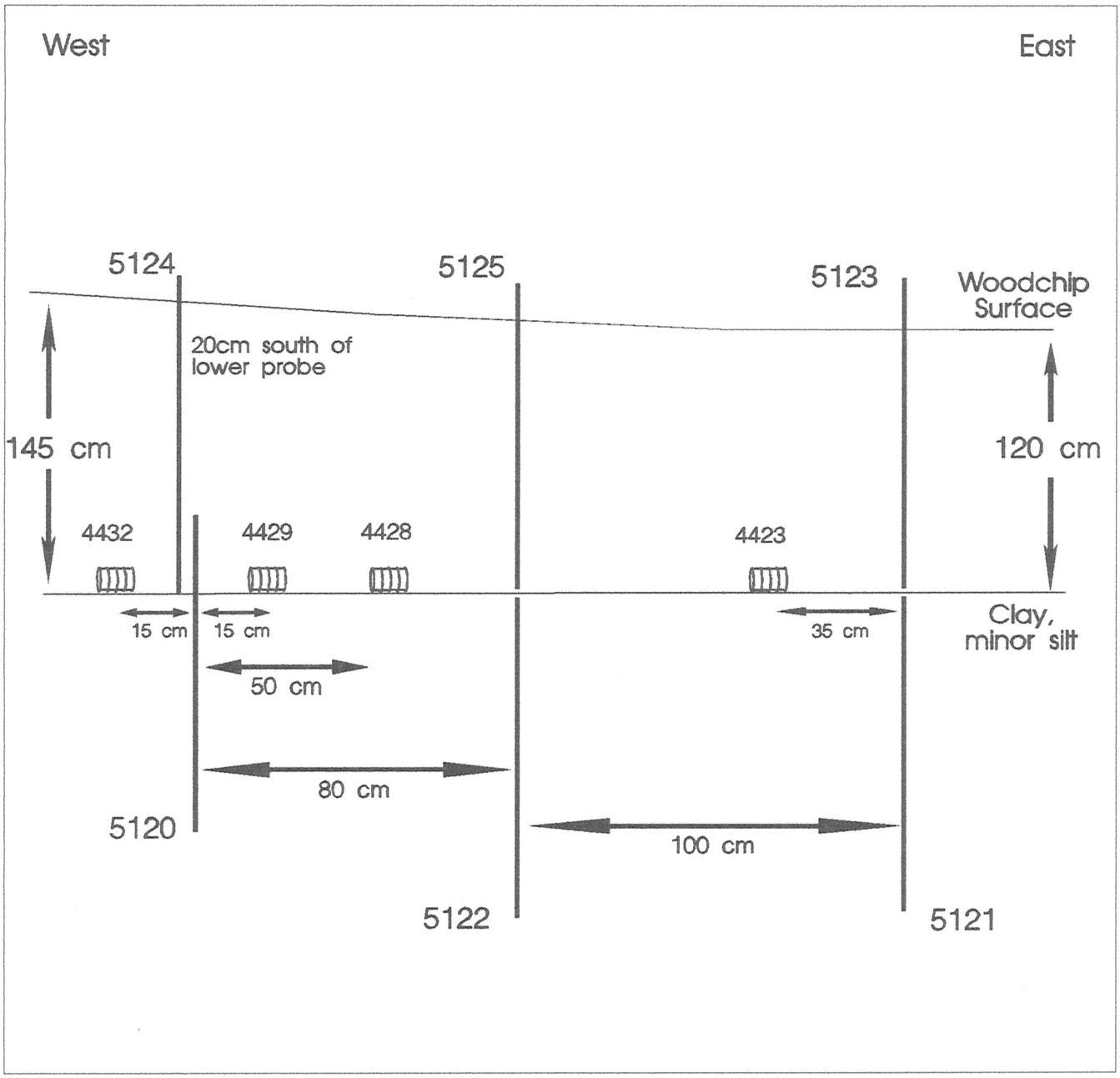
Slope 31A, Kmp 84.5
Location of hot spots, October 1992



Temperature = Max. temp. in hot spot recorded in ° C at approx. 20cm depth.

- Extent of snow melt
- ⊕ Sample # 7
- X HOBO-TEMP Loggers
- Exposed wood chips
- Loggers
- Soil Probes

Slope 31A, Kmp 84.5
Cross-Sectional View of Hot Spot Instrumentation, October 7, 1993

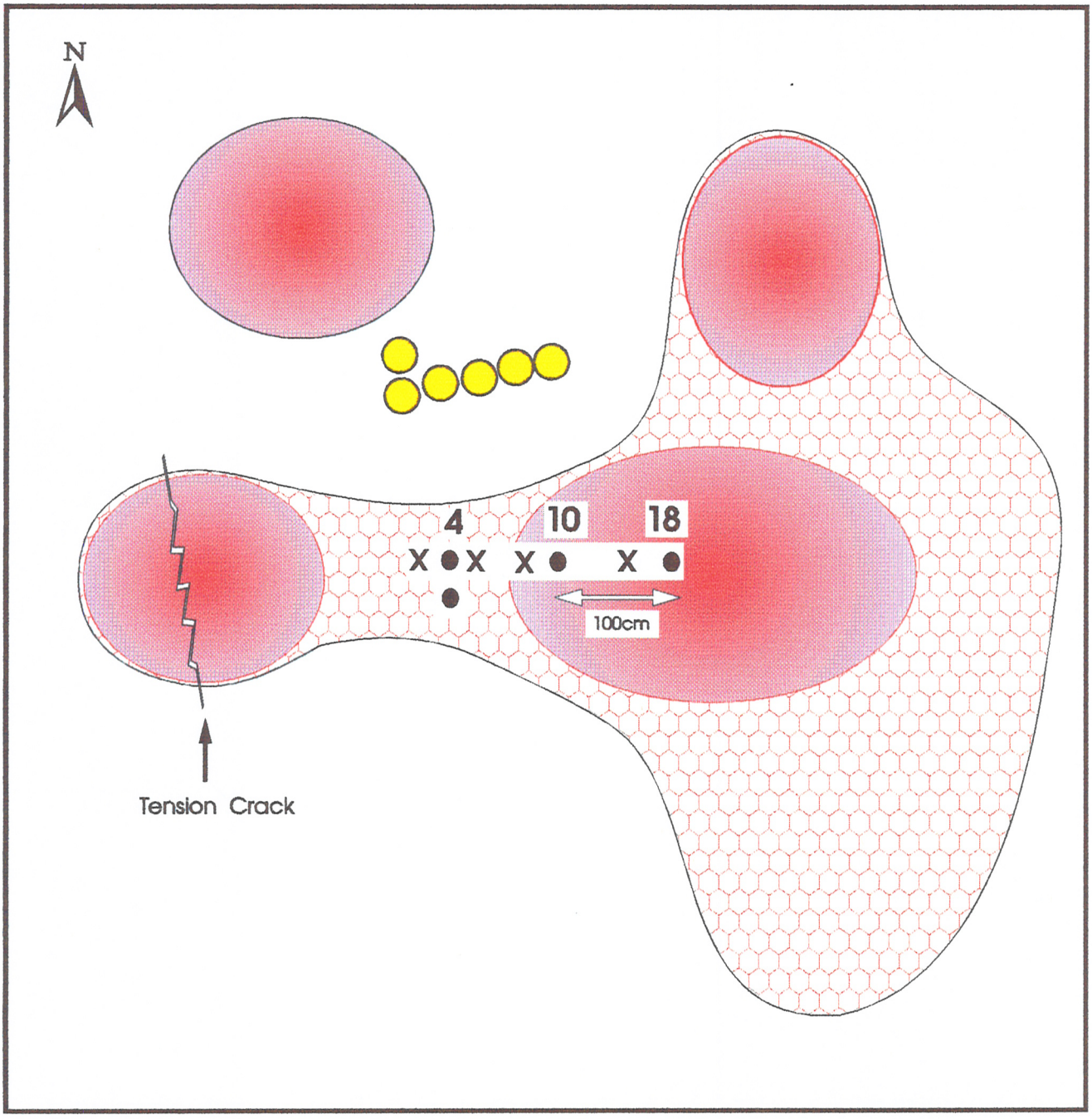


's = Soil probe cable #'s

's = HOBO Serial #'s

| = Soil Probe

Slope 31A, Kmp 84.5
Map View of Hot Spot Transect



#'s = Temperatures at 30cm depth, measured in degrees celsius, recorded at 10:10, October 7, 1993.

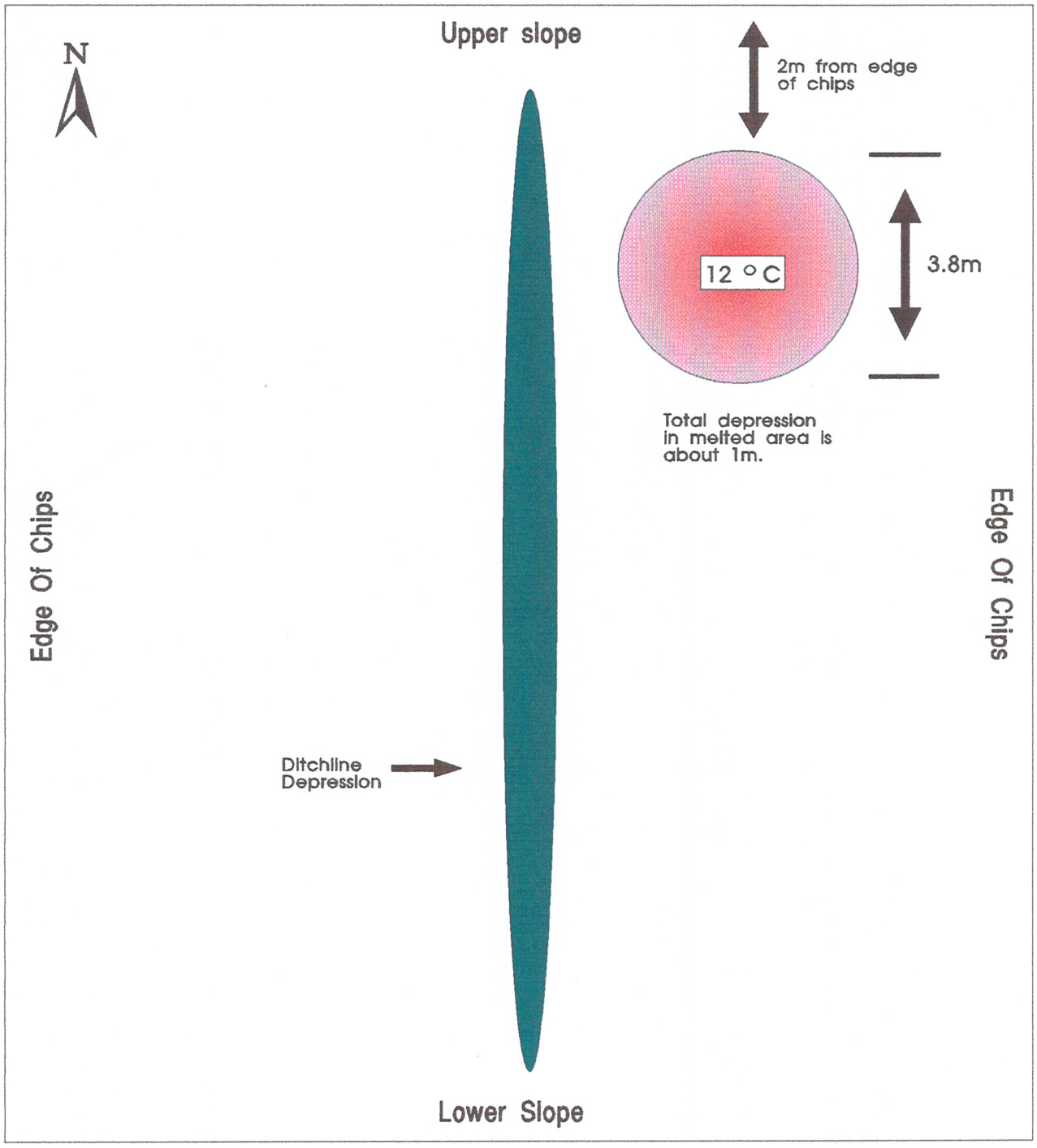
● XL800 data loggers in PVC tubes

● Location of soil probes.

X Location of Hobo-Temp loggers

Diagram is not to scale.

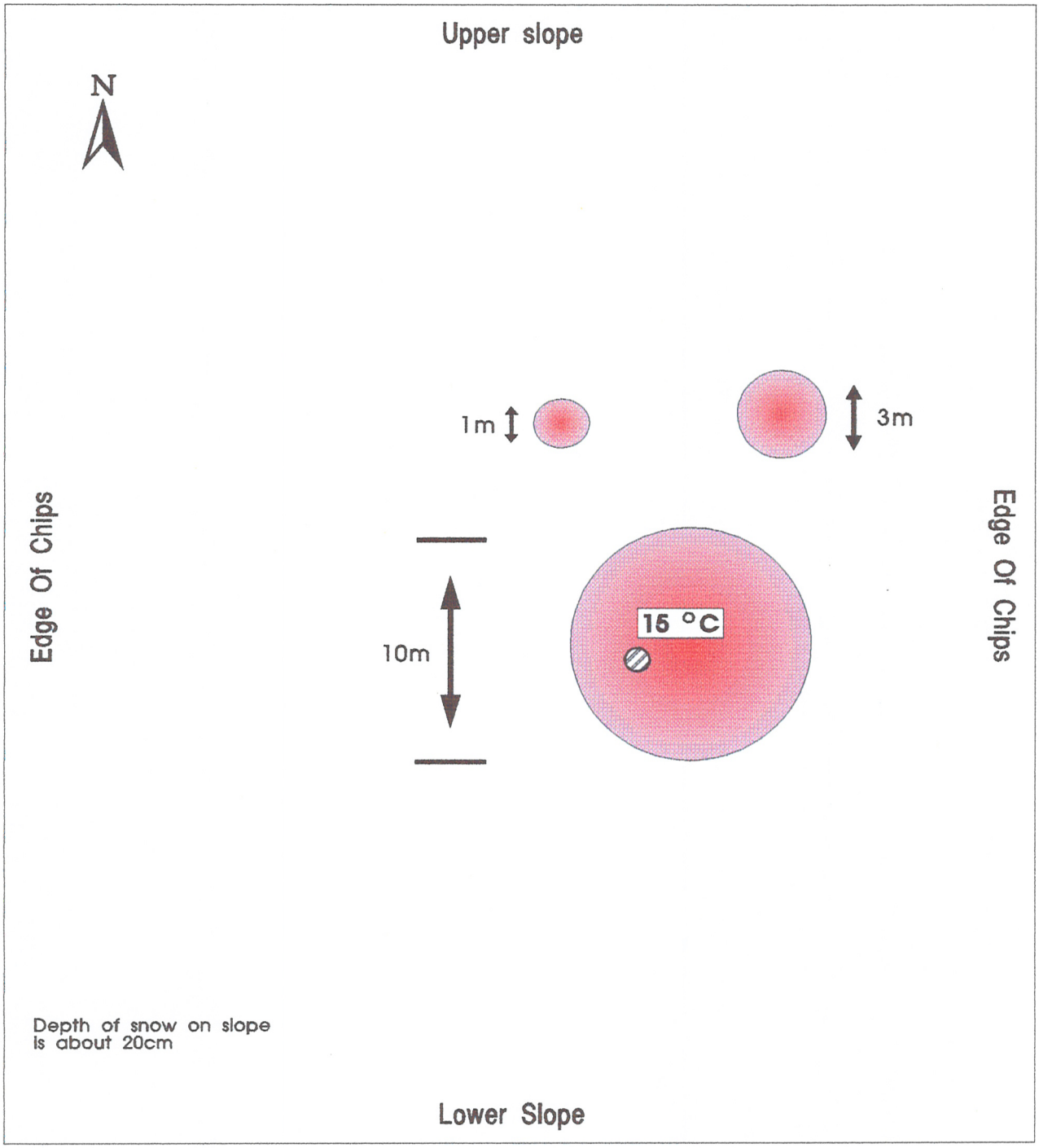
Slope 32A, Kmp 93.2
Location of hot spots, October 1992



Temperature = Max. temp. in hot spot recorded in ° C at approx. 20cm depth.

Extent of snow melt

Slope 36, Kmp 103.2
Location of hot spots, October 1992

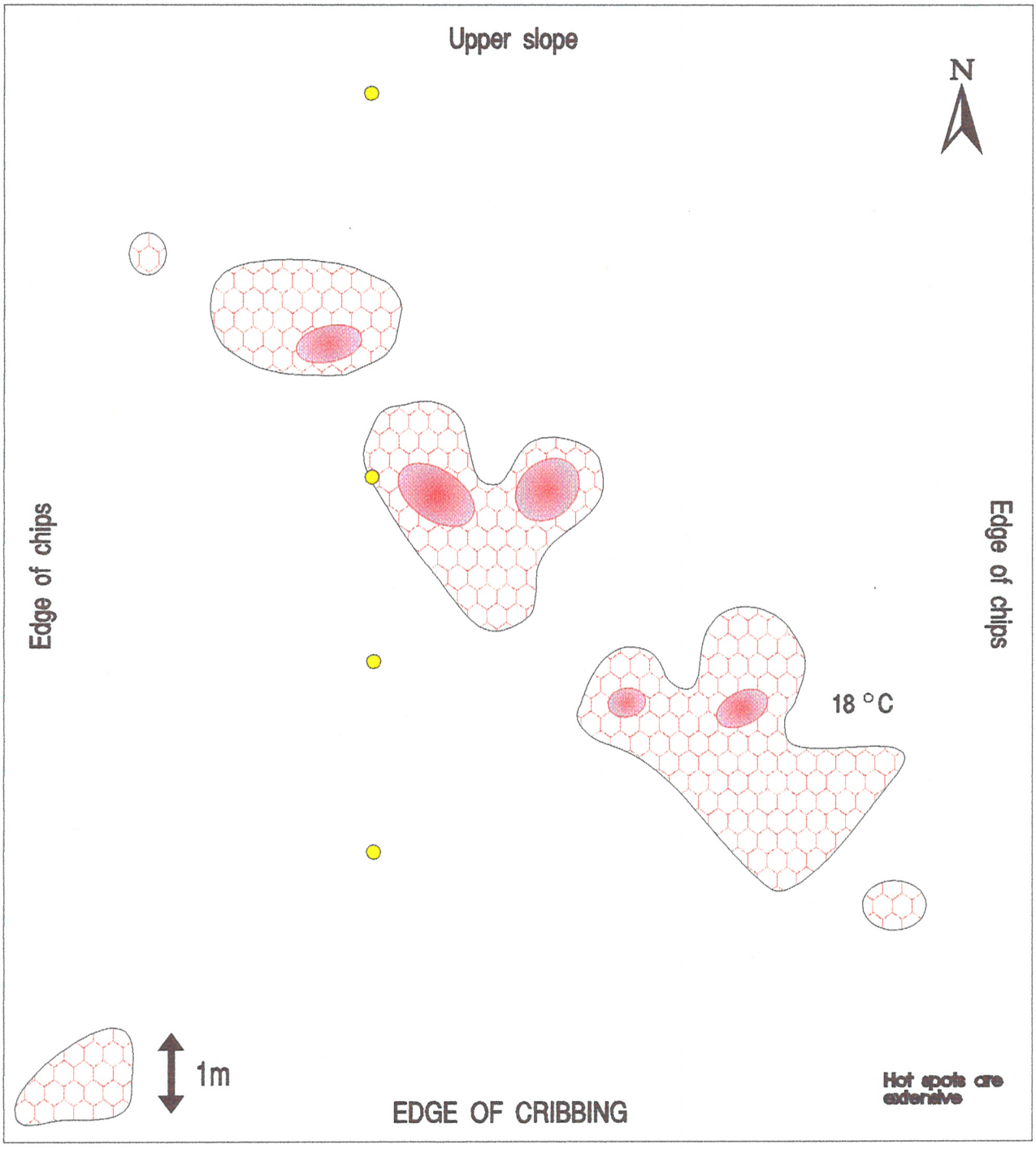


Temperature = Max. temp. in hot spot recorded in ° C at approx. 20cm depth.

Extent of snow melt

Sample # 8

Slope 44, Kmp 133.6
Location of hot spots, October 3, 1992



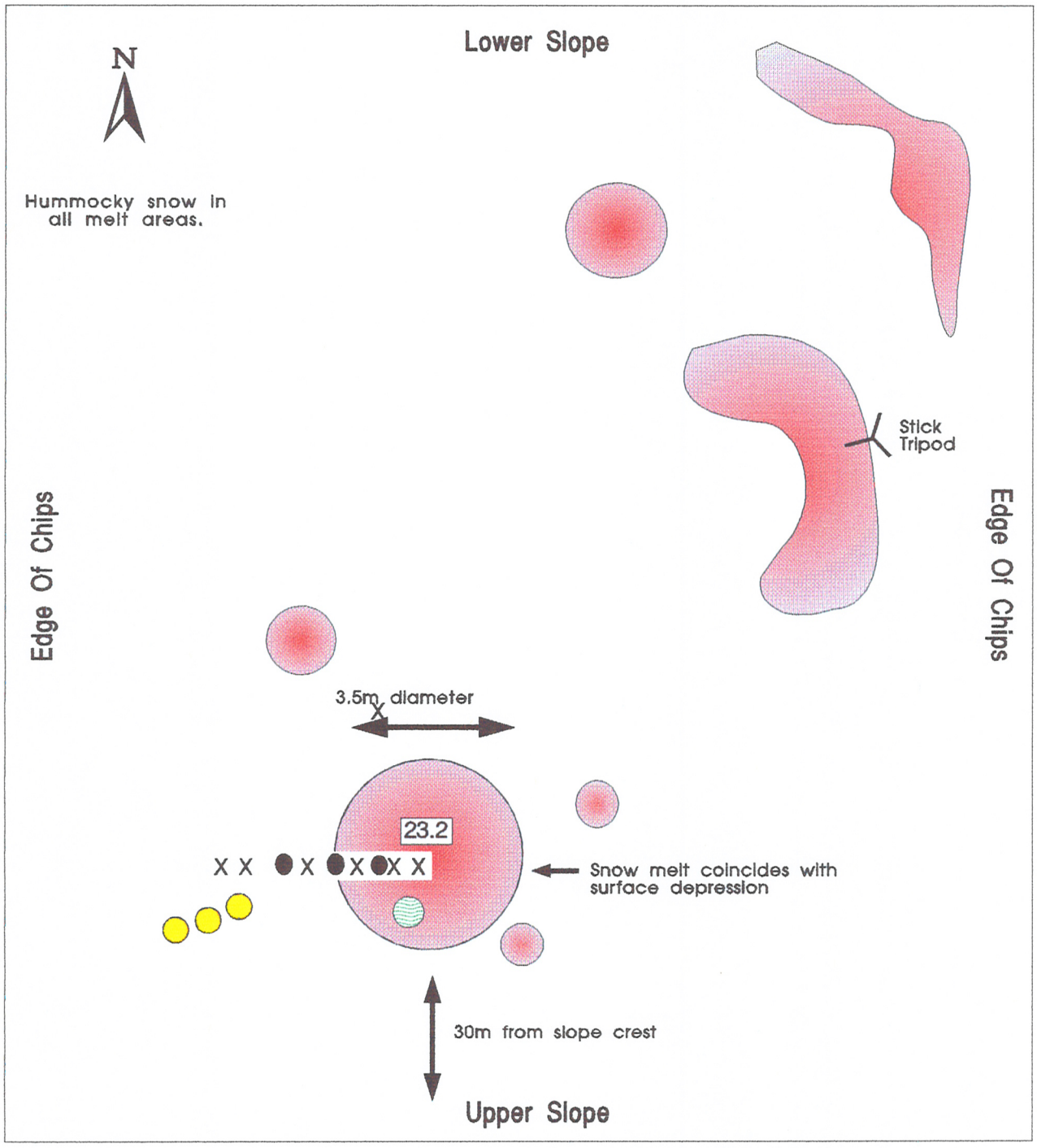
Temperature = Max. temp. in hot spot recorded in ° C at approx. 20cm depth.

Extent of snow melt

Exposed wood chips

Wooden stake

Slope 45, Kmp 133.7
Location of hot spots, October 1992



Temperature = Temp. in hot spot recorded in ° C at approx. 20cm depth. (July 6, 1993)

Extent of snow melt

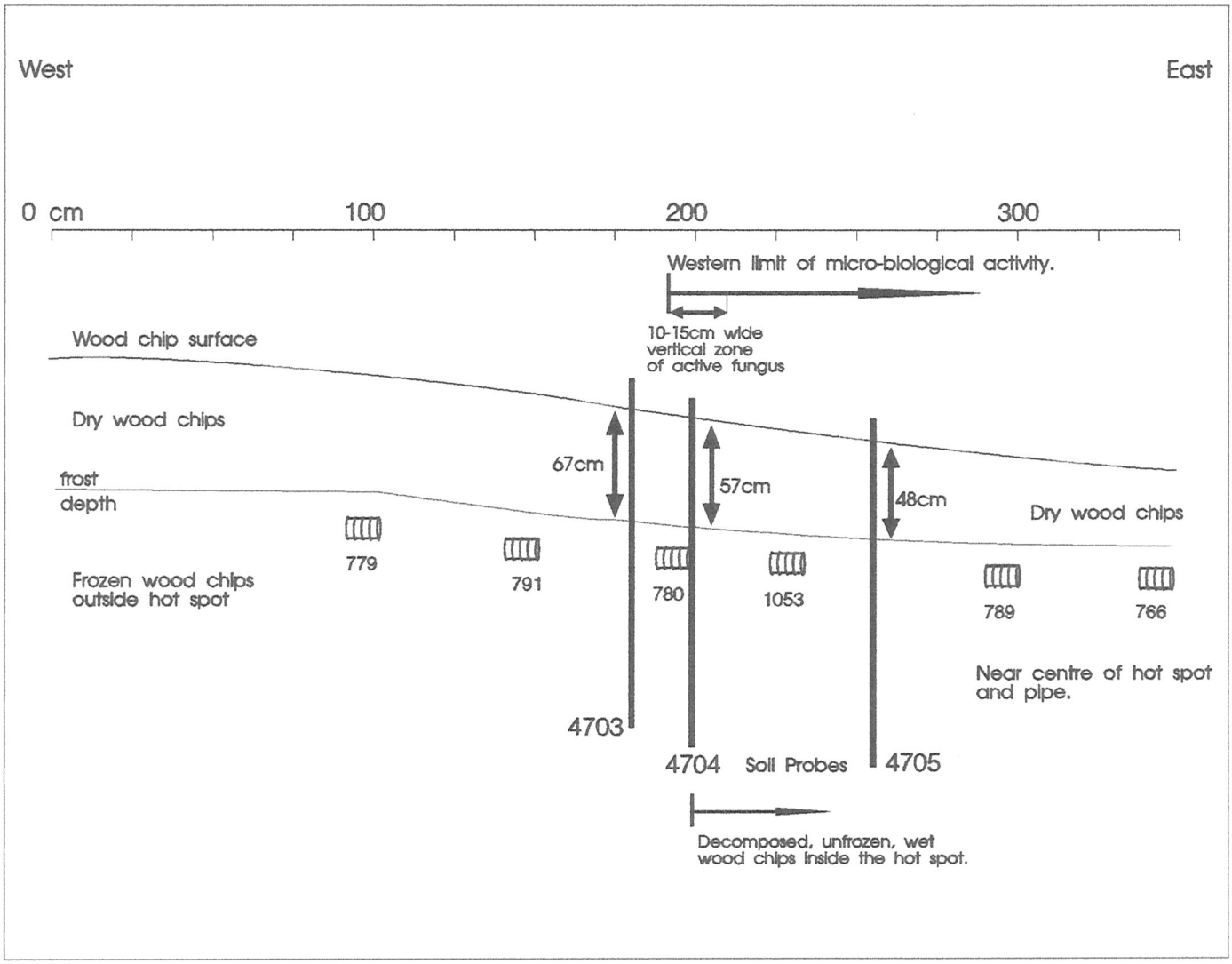
Logger

X HOBO temp. sensors

Sample # 9

Soil temperature probe

Slope 45, Kmp 113.7
Cross-Sectional View of Hot Spot Instrumentation, July 26, 1993



Hobo-Temp Loggers

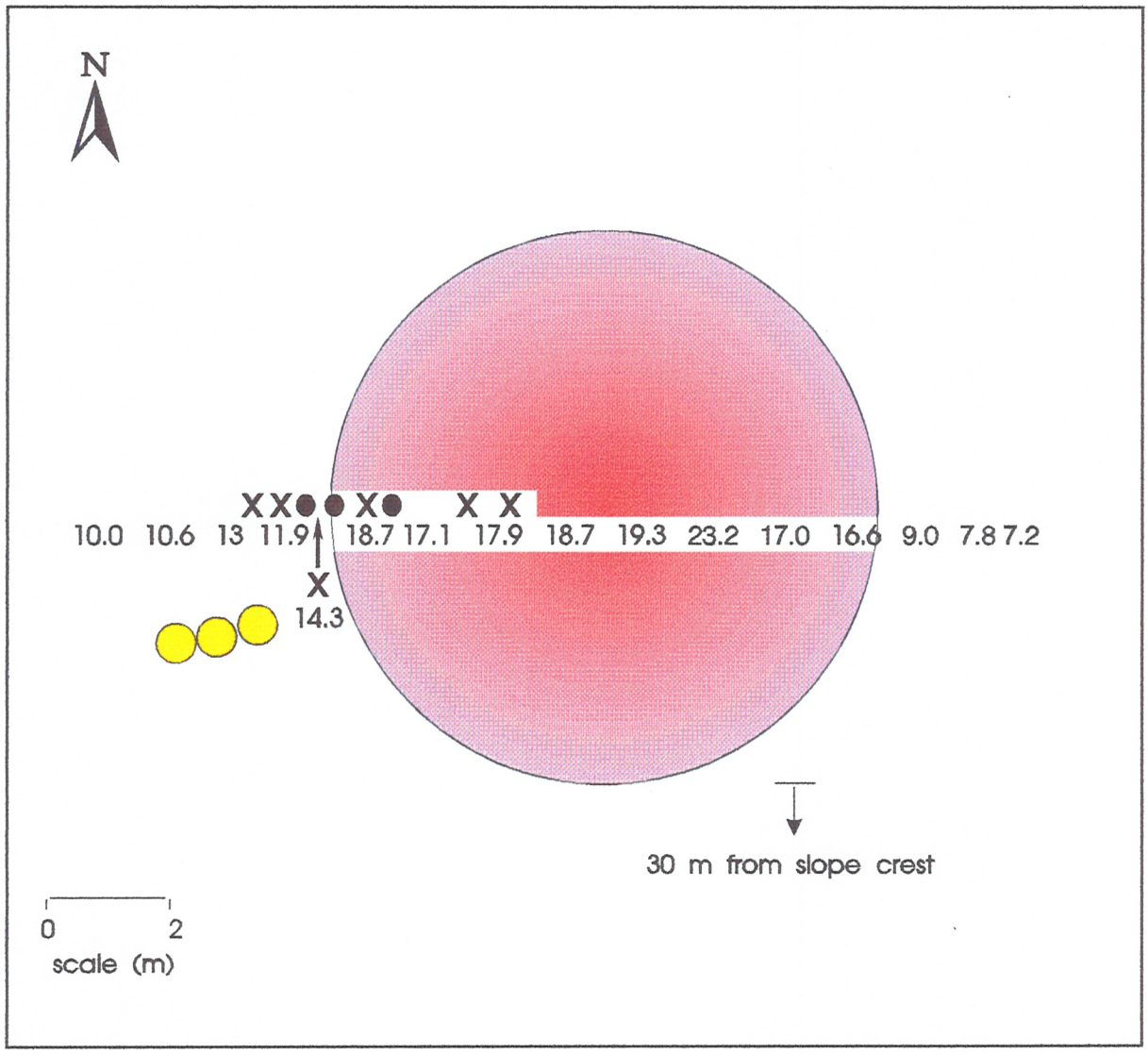
= Soil Probe

's = Soil probe serial numbers

's = Hobo-Temp serial numbers

Note: Hobo's are installed 15 cm into wet woodchips, & attached individually to pink flagging tape. Each flagging tape was extended to the surface.

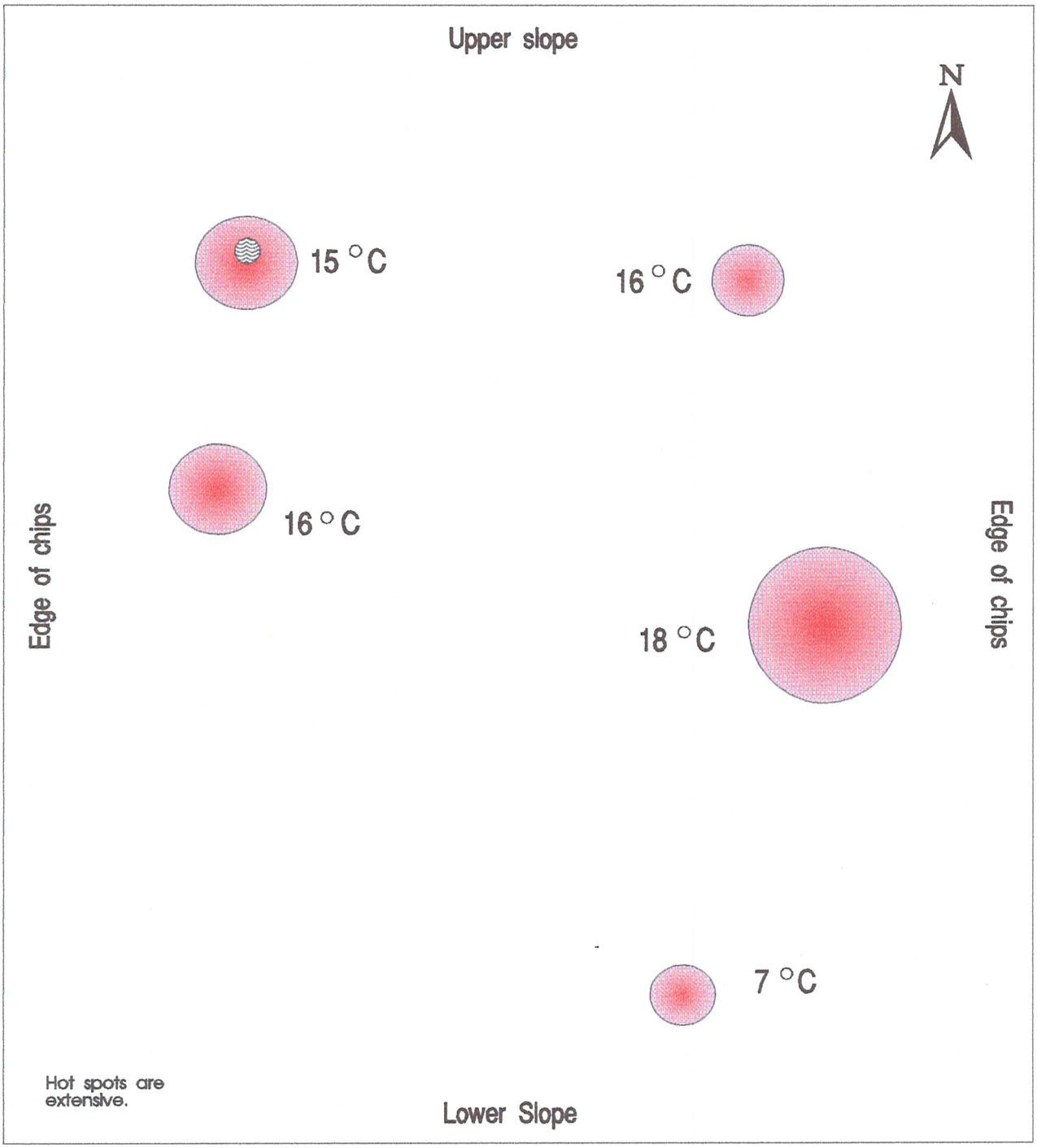
Slope 45, KmP 113.7
Map view of Hot Spot Transect



#'s = Temperatures recorded every 1m, at 30cm depth, measured in degrees celsius, July 26, 1993

- ● Soil Probe
- X Hobo-Temp loggers
- ● XL800 Data loggers

Slope 47, Kmp 160.1
Location of hot spots, October, 1992

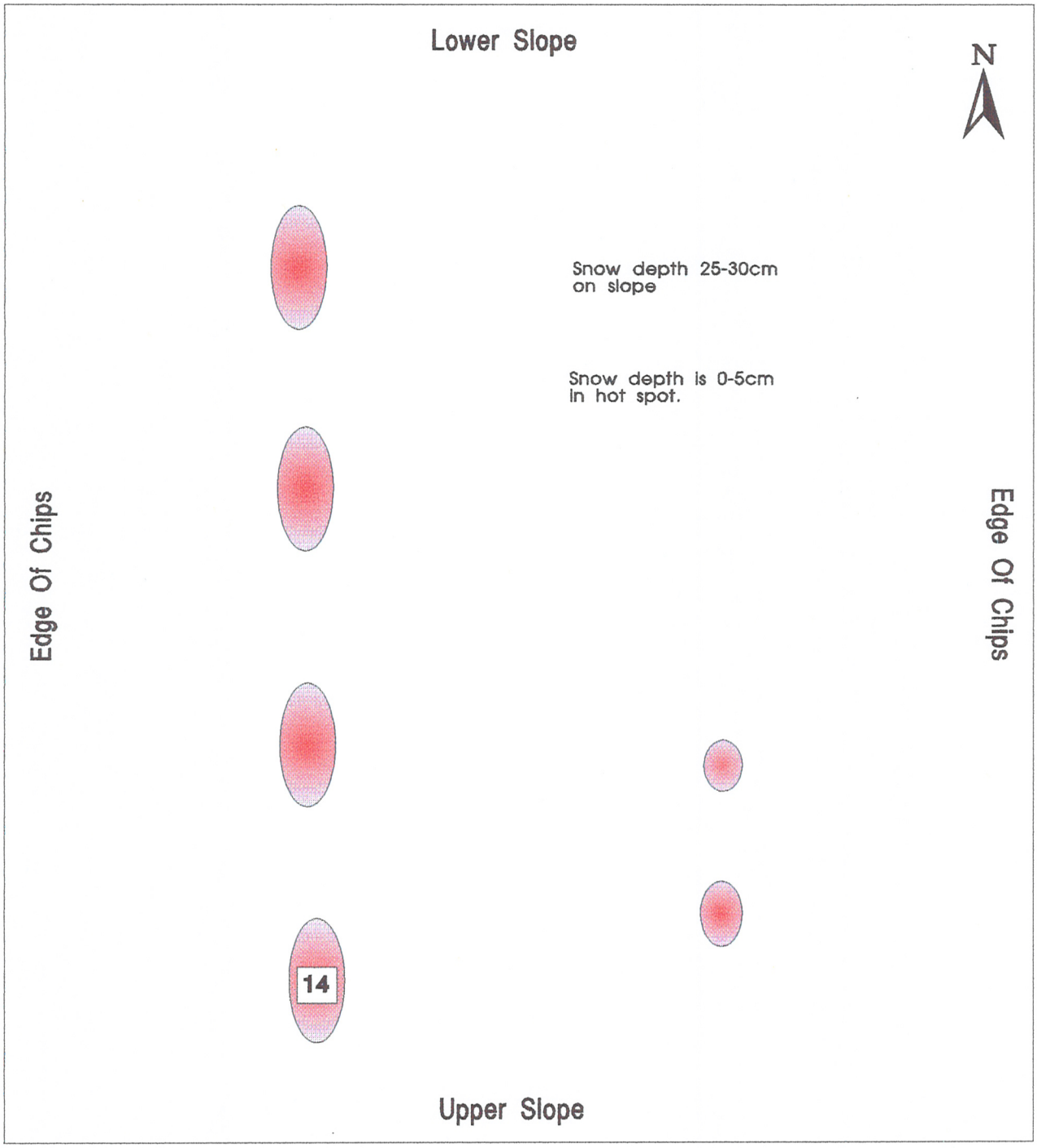


Temperature = Max. Temp. in the hot spot recorded in °C at approx. 20cm depth.

Extent of snow melt

Sample #10

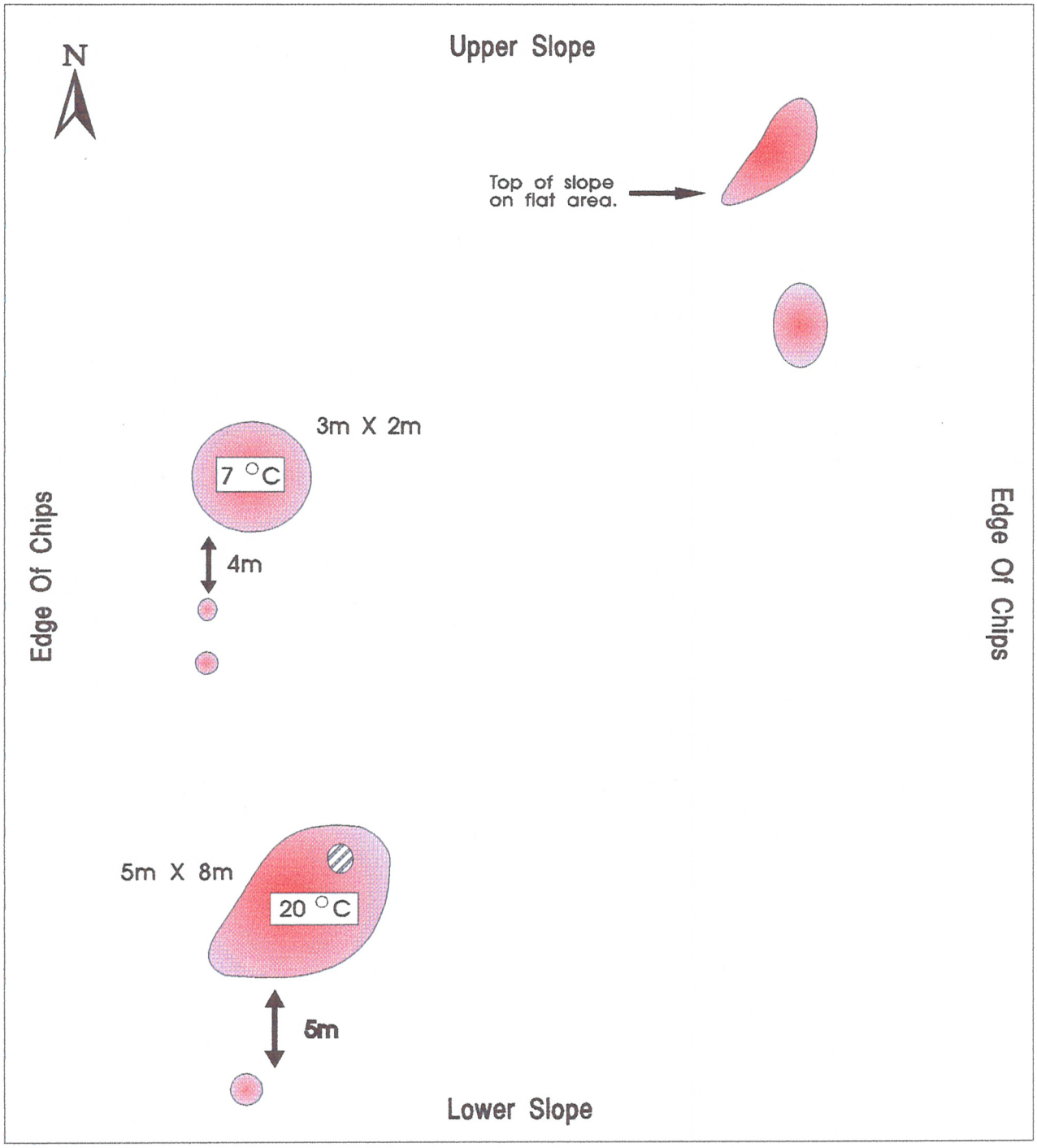
Slope 63, Kmp 194.9
Location of hot spots, October 1992



Temperature = Max. temp. in hot spot recorded in ° C at approx. 20cm depth.
Hot spots are small (1-3m) and medium (3-6m) in diameter.

Extent of snow melt

Slope 75, Kmp 273.5
Location of hot spots, October 1992

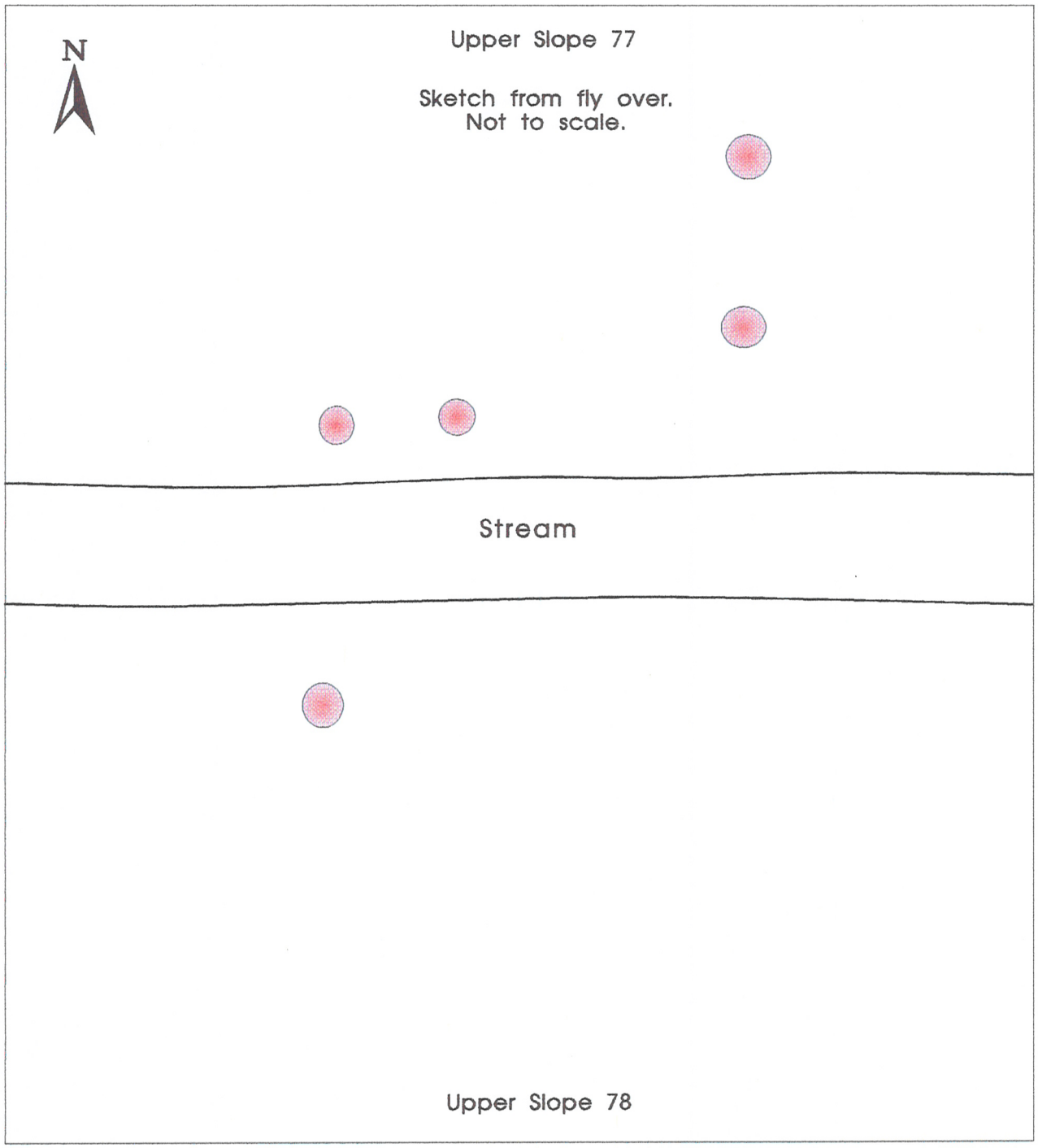


Temperature = Temp. in woodchips recorded in ° C at approx. 20cm depth.

Extent of snow melt

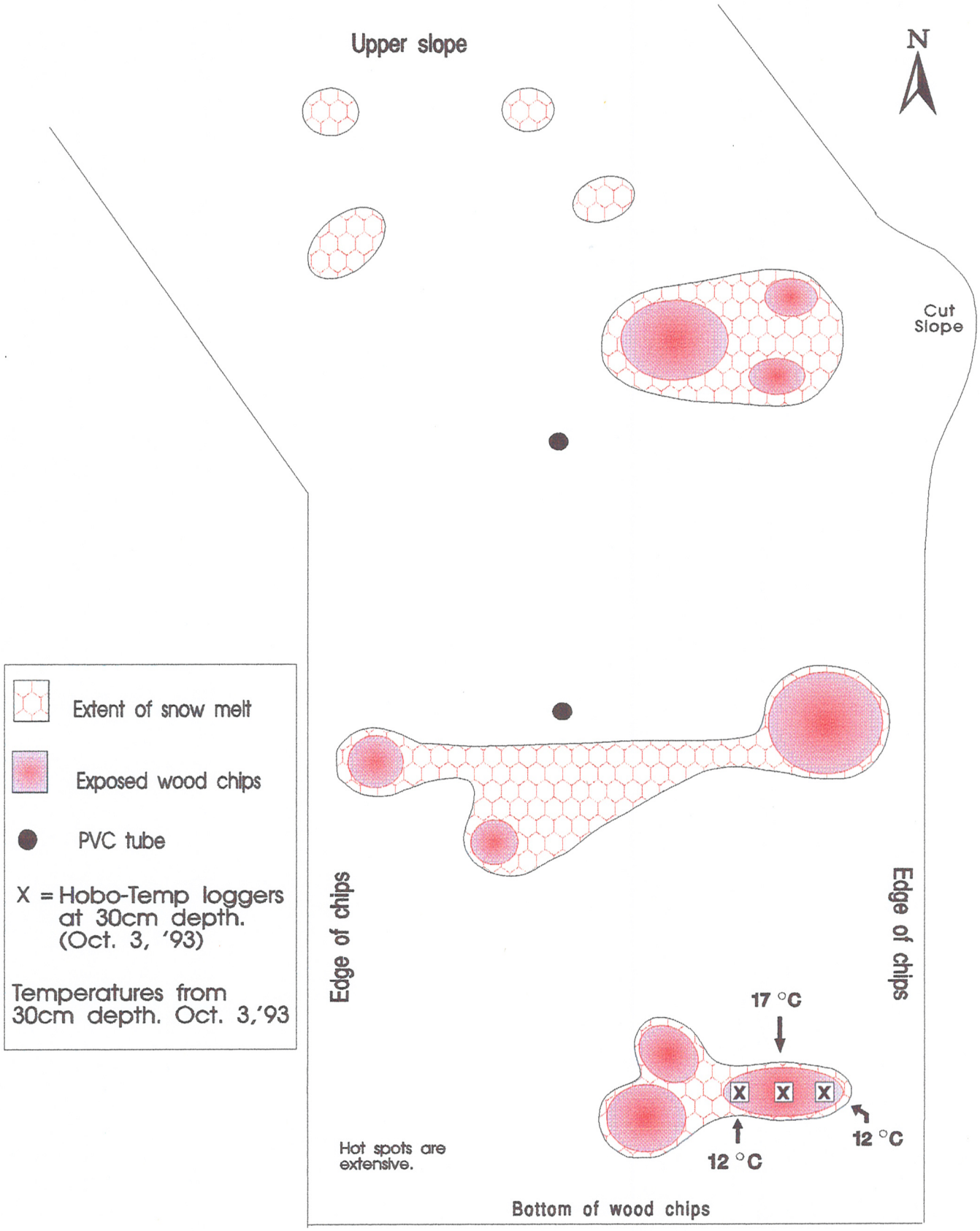
Sample # 5

Slopes 77 and 78, Kmp 275.5-275.6
Location of hot spots, October 1992

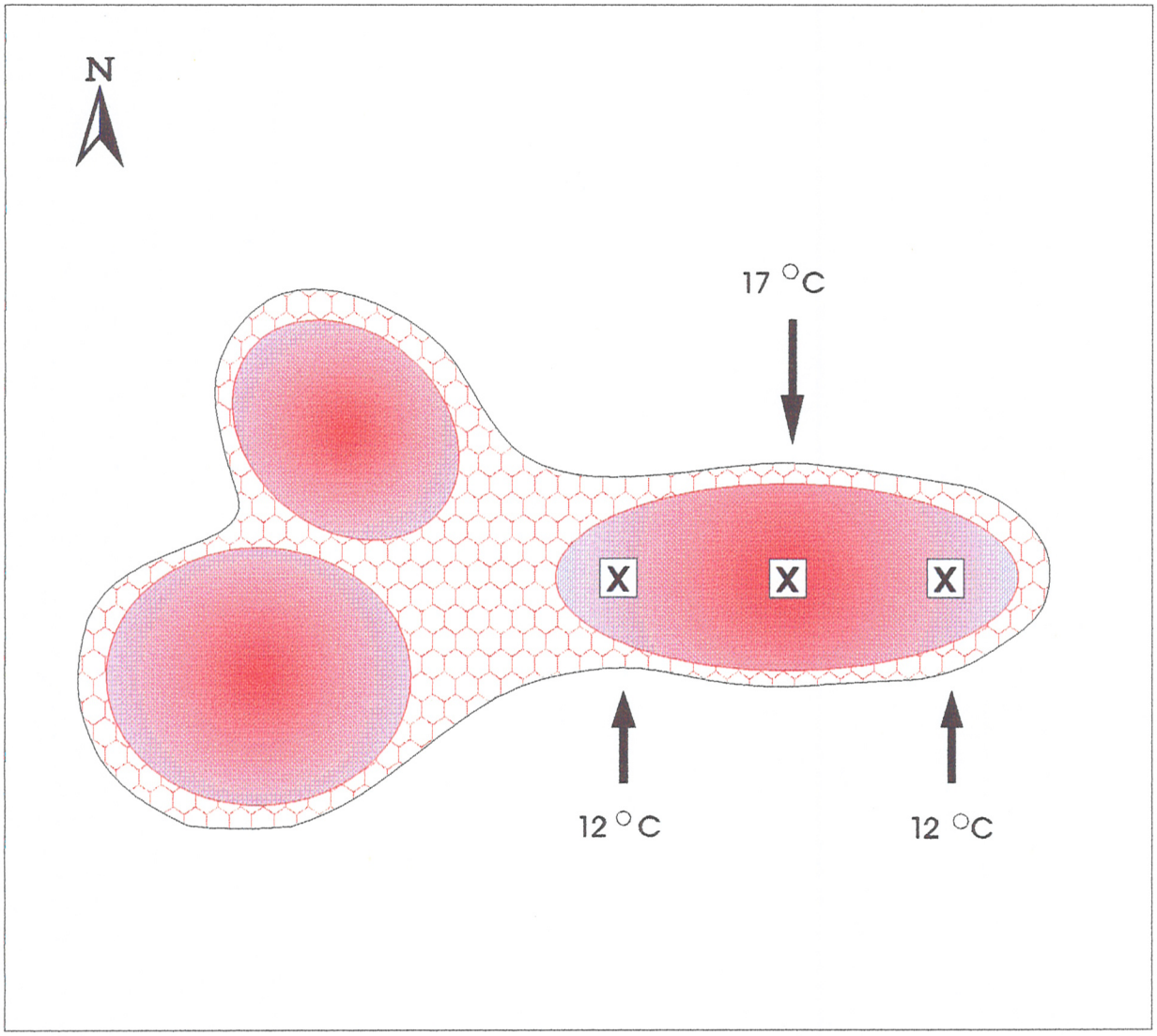


Extent of snow melt

Slope 79, Kmp 279.0
Location of hot spots, October, 1992



Slope 79, Kmp 279.0
Map View of Hot Spot Transect



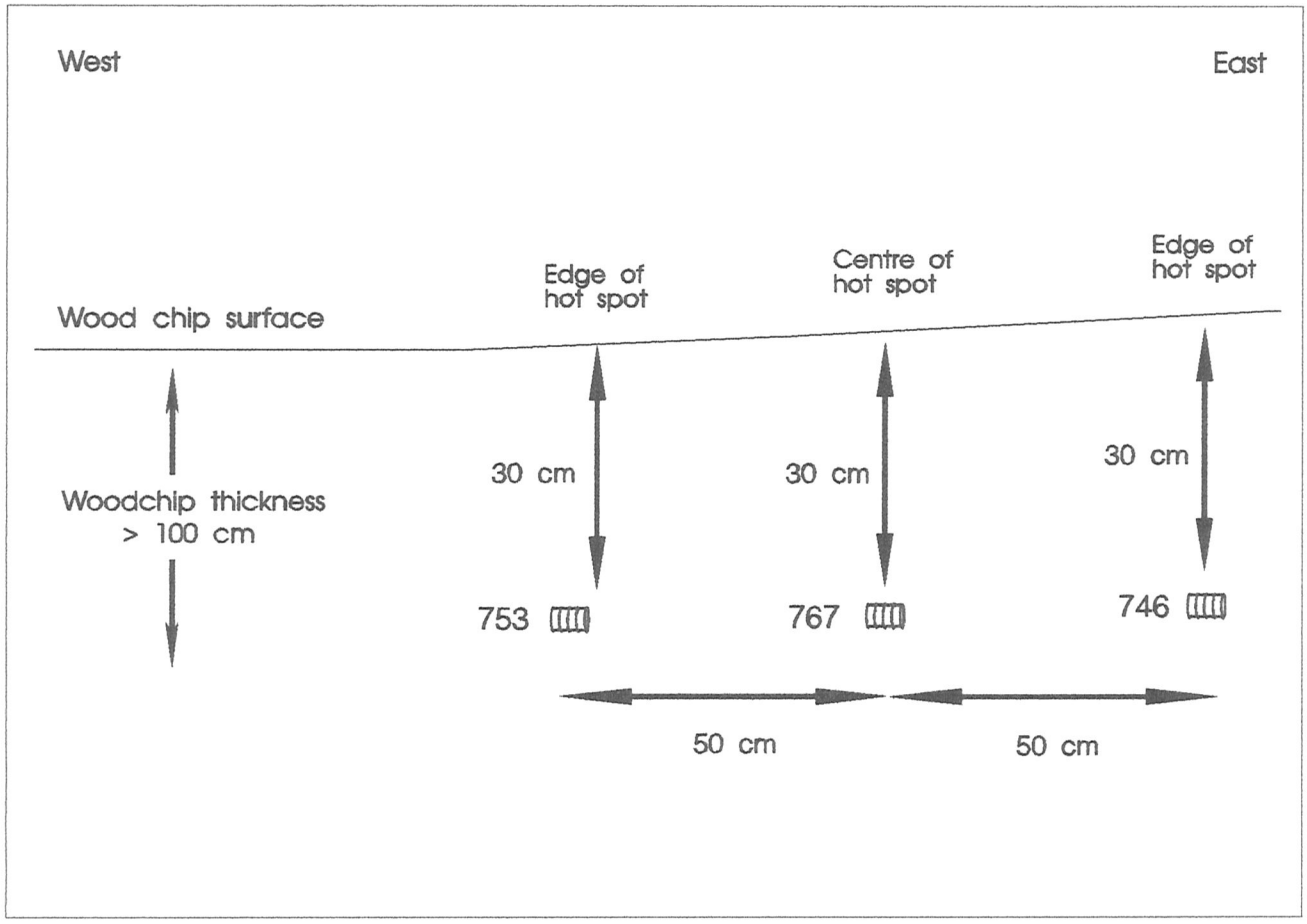
Temperatures recorded at 30cm depth, October 3, 1993, when loggers were installed.

Hobo-Temp logger installed at 30cm into the wood chips.

Exposed wood chips

Extent of snow melt

Slope 79, Kmp 279.0
Cross-Sectional View of Hot Spot Instrumentation, October 3, 1993

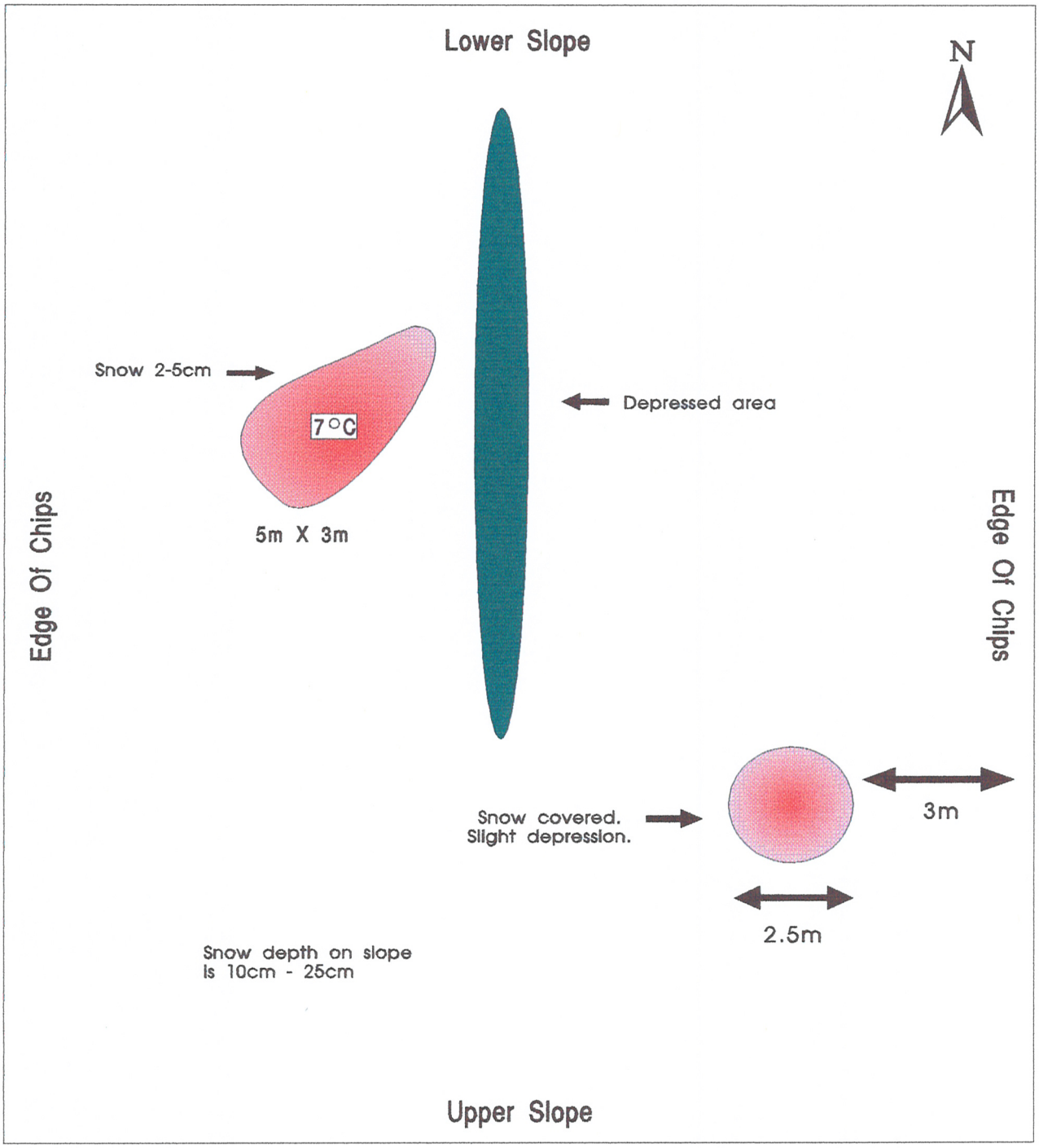


Hobo-Temp logger with serial number

Note: The area of melted snow over the instrumented hot spot coalesces with snow melt from other hot spots to the west. There will be a thermal influence on Hobo-Temp logger #753 from the adjacent hot spots.

Hobo's were attached to tight climbing rope and may all be pulled at once. The rope was tied to stake at edge of ROW.

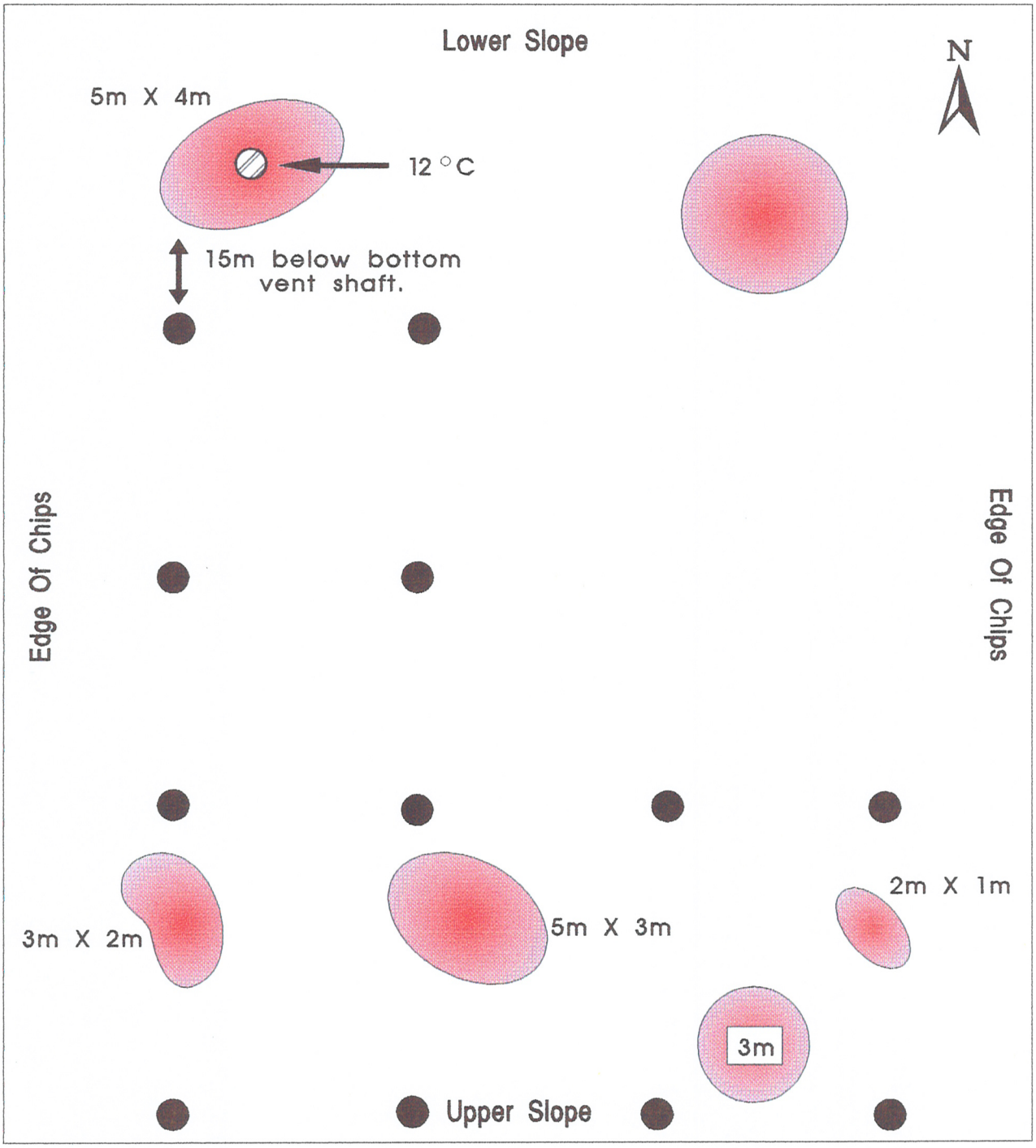
Slope 80, Kmp 279.3
Location of hot spots, October 1992



Temperature = Max. temp. in hot spot recorded in ° C at approx. 20cm depth.

Extent of snow melt

Slope 82, Kmp 286.6
Location of hot spots, October 1992



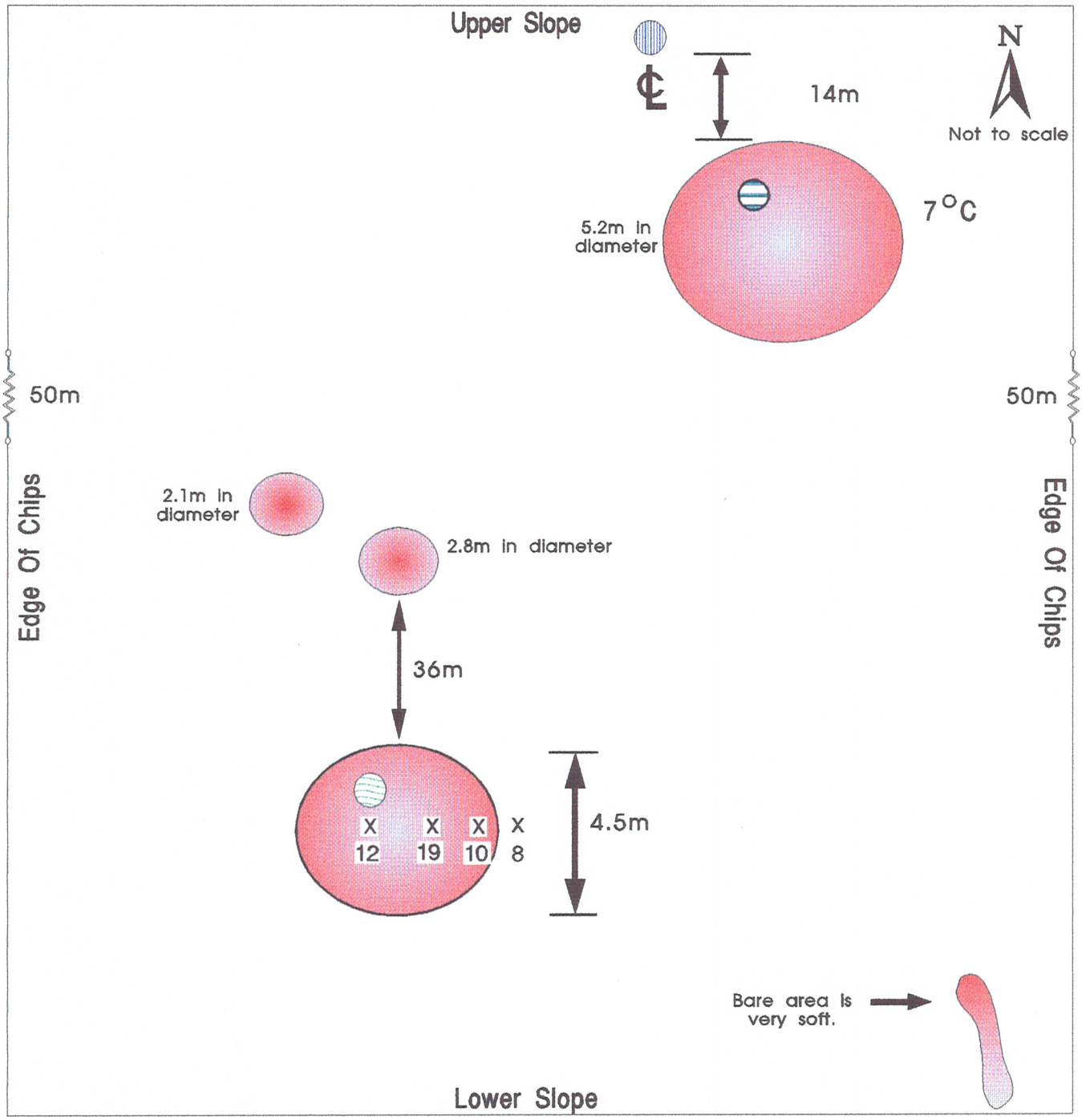
Temperature = Max. temp. in hot spot recorded in °C at approx. 20cm depth.

Extent of snow melt

Sample #4

Vent Shaft

Slope 112, Kmp 352.3
Location of hot spots, October 1992



Temperature = Max. temp. in hot spot recorded in °C at approx. 20cm depth.

Extent of snow melt

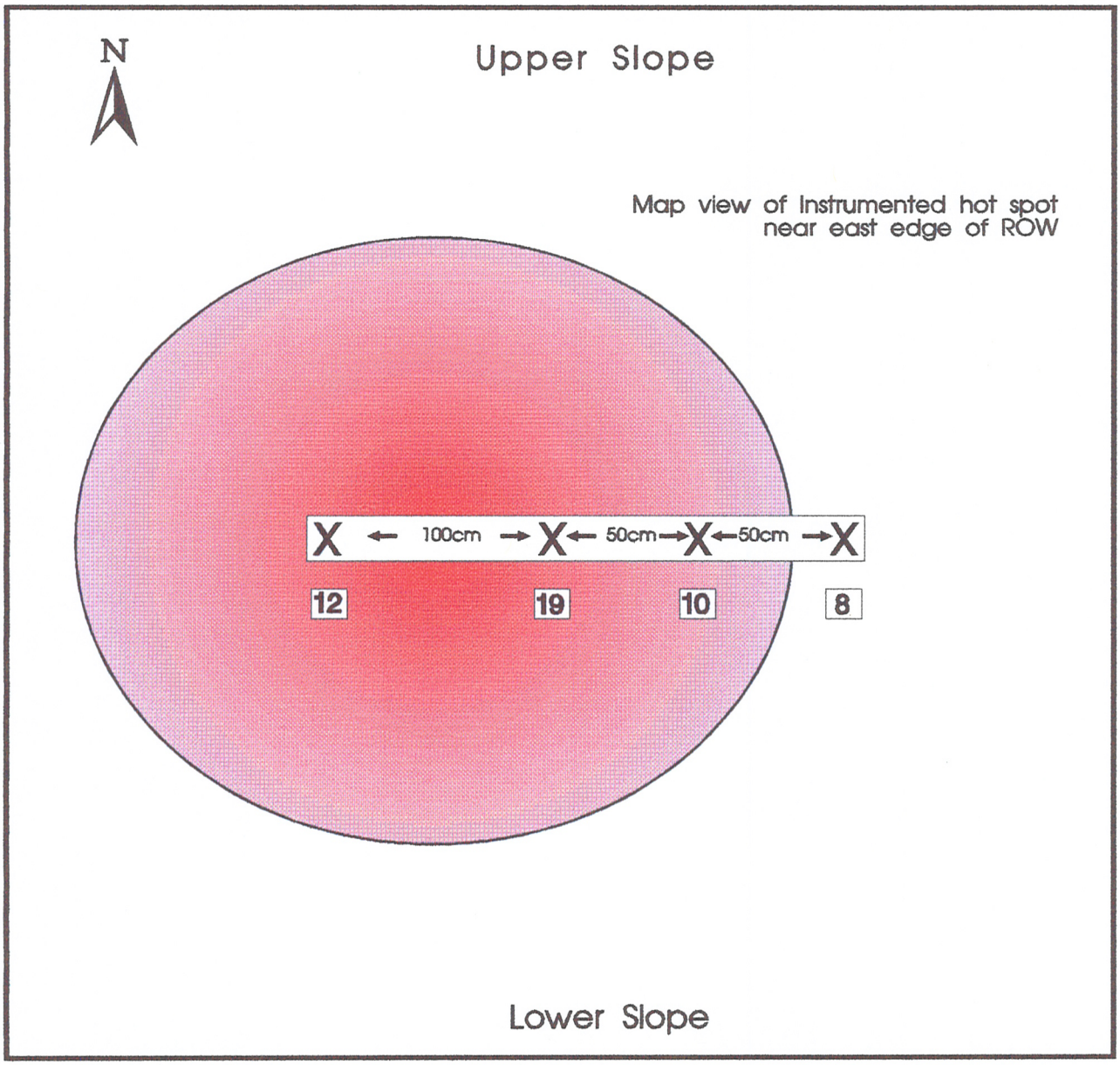
IPL Piezometer

X Location of hobos; and temperatures at time of installation (Oct. 6, 1993).

Sample #2

Sample #3

Slope 112, Kmp 352.3
Map View of Hot Spot Transect
October 6, 1993

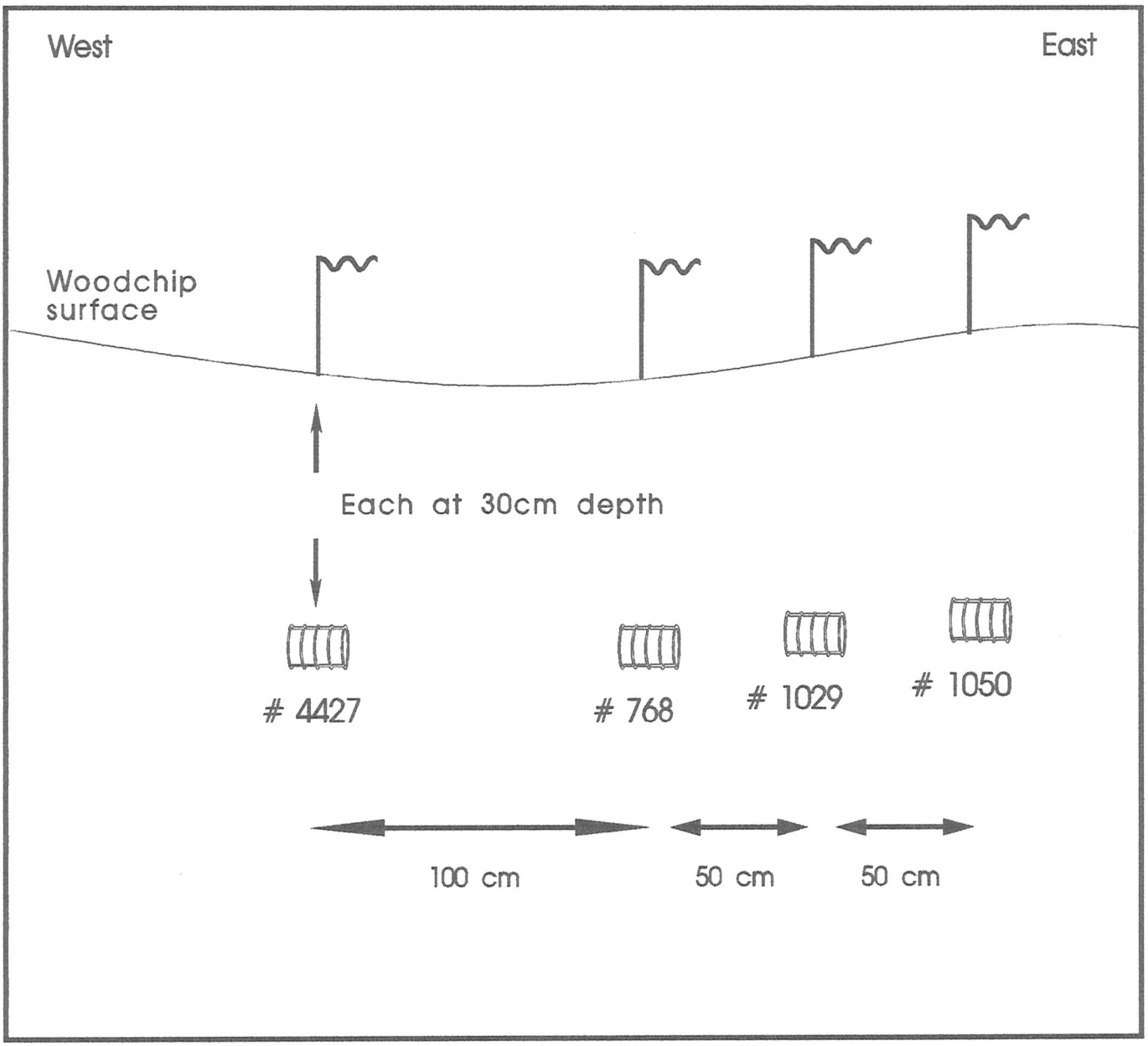


X = Aerial distribution of Hobo-Temp loggers across hot spot. Each logger is positioned 30cm into the wood chips.

#'s = Temperatures at 30cm into wood chips, measured in degrees celsius. Recorded at 10:05, October 6, 1993.

Diagram is not to scale.

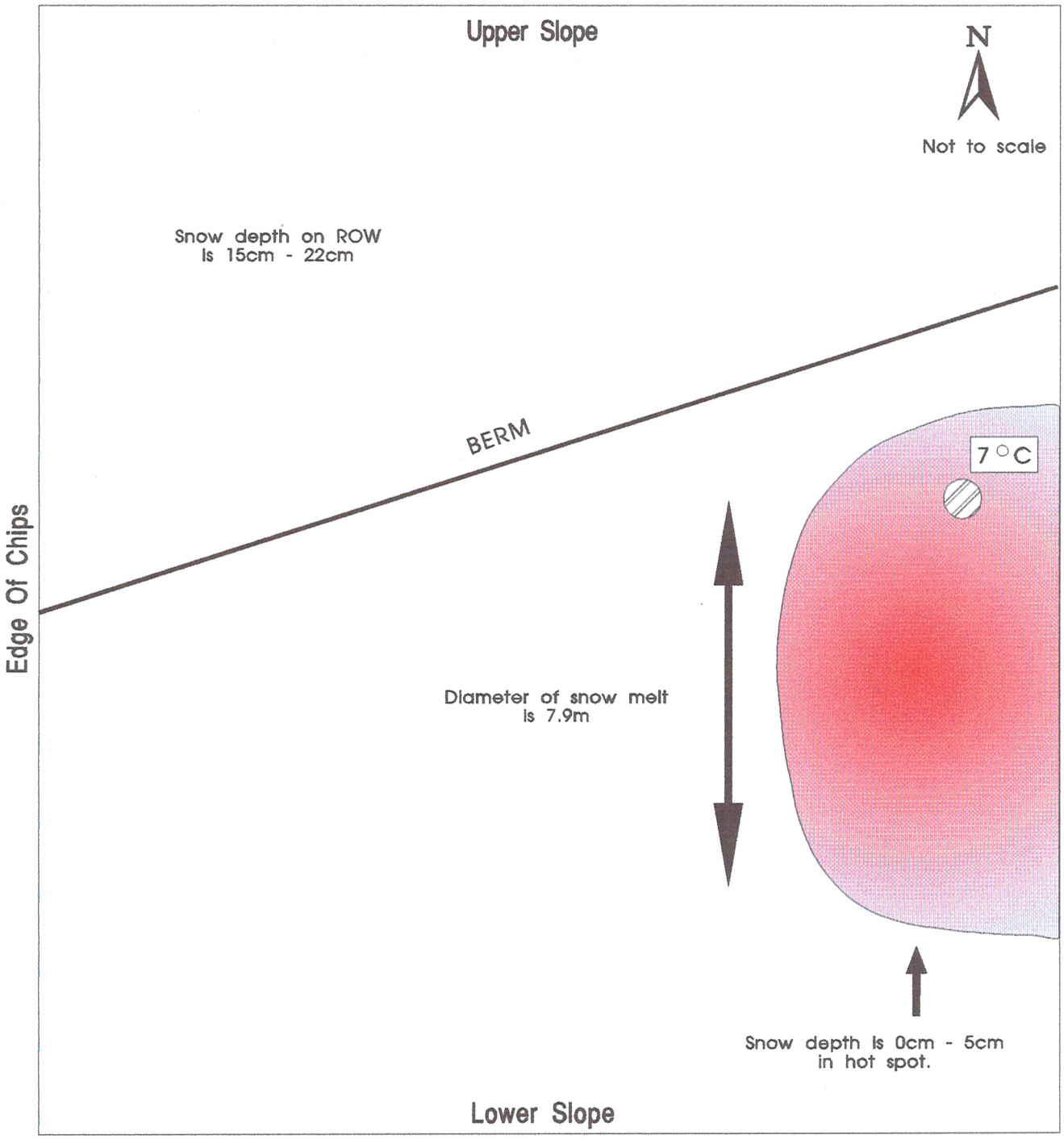
Slope 112, Kmp 352.3
Cross-Sectional View of Hot Spot Instrumentation, October 6, 1993



Hobo's are individually attached to flagging tape.
Each flagging tape is tied to small red survey flag & labeled.

#'s = Hobo-Temp serial numbers

Slope 123, Kmp 403.7
Location of hot spots, October 1992



Temperature = Temp. in hot spot recorded in ° C at approx. 20cm depth.

Sample #1

Extent of snow melt

APPENDIX C

Chronology of observers comments on all hot spot slopes

Notes:

1. Comments have not been edited and may occasionally be short and cryptic. Initials in brackets at the end of an entry are those of the observers/authors.

2. Dates typed in bold italic font have comments related to hot spots.

3. w/c or w.c. refers to wood chips; ROW refers to right-of-way.

SOURCES:

1. Internal completion reports filed after each government field data collection trip.

2. Data sheets from each government field trip.

3. Annual government progress reports (these are available by contacting K.L. MacInnes, Land Resources, INAC, P.O. 1500, Yellowknife, N.W.T., X1A 2R3):

INAC, EMR, NRC and AG-CAN. (1987). Annual progress report to INAC and IPL, November 1987 - Norman Wells to Zama Pipeline Permafrost and Terrain Research and Monitoring Program. 24 pp.

INAC, EMR, NRC and AG-CAN. (1988). Annual progress report to INAC and IPL, November 1988 - Norman Wells to Zama Pipeline Permafrost and Terrain Research and Monitoring Program. 43 pp.

INAC, EMR, NRC and AG-CAN. (1989). Annual progress report to INAC and IPL, November 1989 - Norman Wells to Zama Pipeline Permafrost and Terrain Research and Monitoring Program. 77 pp.

INAC, EMR, NRC, AG-CAN and UBC. (1990). Annual progress report to INAC and IPL, November 1990 - Norman Wells to Zama Pipeline Permafrost and Terrain Research and Monitoring Program. 99 pp.

INAC, EMR, NRC, AG-CAN and UBC. (1991). Annual progress report to INAC and IPL, November 1991 - Norman Wells to Zama Pipeline Permafrost and Terrain Research and Monitoring Program. xx pp.

INAC, EMR, AG-CAN and UBC. (1992). Annual progress report to INAC and IPL, December 1992 - Norman Wells to Zama Pipeline Permafrost and Terrain Research and Monitoring Program. xx pp.

INAC, NRCan, AG-CAN and UBC. (1993). Annual progress report to INAC and IPL, November 1993 - Norman Wells to Zama Pipeline permafrost and Terrain Research and Monitoring Program. xx pp.

4. IPL annual reports to the national Energy Board:

Interprovincial Pipe Line (NW) Ltd. (1984). Norman Wells Pipeline Project - 1984 report on monitoring of construction and operation. Report to National Energy Board of Canada, 43 pp. + appendices.

Interprovincial Pipe Line (NW) Ltd. (1985). Norman Wells Pipeline Project - 1985 report on monitoring of construction and operation. Report to National Energy Board of Canada, 43 pp. + appendices.

Interprovincial Pipe Line (NW) Ltd. (1986). Norman Wells Pipeline Project - 1986 report on monitoring of construction and operation. Report to National Energy Board of Canada, 50 pp. + appendices.

Interprovincial Pipe Line (NW) Ltd. (1987). Norman Wells Pipeline Project - 1987 report on monitoring of construction and operation. Report to the National Energy Board of Canada, 59 pp. + appendices.

Interprovincial Pipe Line (NW) Ltd. (1988). Norman Wells Pipeline Project - 1988 report on monitoring of construction and operation. Report to the National Energy Board of Canada, 48 pp.

Interprovincial Pipe Line (NW) Ltd. (1989). Norman Wells Pipeline Project - 1988 report on monitoring of construction and operation. Report to the National Energy Board of Canada, 47 pp.

Interprovincial Pipe Line (NW) Ltd. (1990). Norman Wells Pipeline Project - 1988 report on monitoring of construction and operation. Report to the National Energy Board of Canada, 48 pp.

Interprovincial Pipe Line (NW) Ltd. (1991). Norman Wells Pipeline Project - 1988 report on monitoring of construction and operation. Report to the National Energy Board of Canada, 57 pp.

Interprovincial Pipe Line (NW) Ltd. (1992). Norman Wells Pipeline Project - 1988 report on monitoring of construction and operation. Report to the National Energy Board of Canada, 40 pp.

Interprovincial Pipe Line (NW) Ltd. (1993). Norman Wells Pipeline Project - 1988 report on monitoring of construction and operation. Report to the National Energy Board of Canada, 22 pp.

OBSERVERS - NWZ PIPELINE PTRM PROGRAM

MA	M. Adamson
FA	F. Adlem
VA	V. Allen
HB	H. Baker
KB	K. Beraska
JB	J. Bowen
AB	A. Boyer
DB	D. Boyle
JB	J. Broadbent
MB	M. Burgess
BD	B. Davidge
SDa	S. Davidson
SDe	S. Deschene
DD	D. Desrochers
SD	S. Dupras
DE	D. Elliott
KE	K. Etherington
PE	P. Egginton
JG	J. Ginter
LG	L. Goodrich
KH	K. Halvorson
DH	D. Harry
JH	J. Hayes
KH	K. Hennebury
BH	B. Hoover
AJ	A. Judge
LK	L. Korzenowski
DK	D. Kroetsch
WL	W. Lafleur
TL or DEL	T. Lawrence
JM	J. MacDonald
KLM or KM	K. MacInnes
FM	F. McCowan
AM	A. McRobert
MM	M. Mitchell
DM	D. Mulock
AN	A. Nixon
JP	J. Pilon
WP	W. Pollard
PR	P. Rivard
AR	A. Robertson
NS	N. Sancartier
KWS	W. Savigny
LS	L. Schmidt
DS	D. Sego
WS	W. Stephen
MS	M. Swyripa
AT	A. Taylor
CT	C. Tarnocai
DT	D. Trudeau
JU	J. Umpherson
DU	D. Unrau
LW	L. Walker
AW	A. Wilkinson

Slope 29A, km 78.8
GREAT BEAR SOUTH

12.12.84	Wood chip remedial Work at slopes constructed in 1984. Comments: Place missing chips on slope. (1984 Report on Monitoring of Construction and Operation)
02.85	Additional woodchips not yet placed on slope. (KLM)
06.89	Chips settled, water flowing out of slope onto chips. (KLM)
09.91	Seepage (wet wood chips) present at centre of slope. No tension cracks observed from limited aerial and ground observations. (KLM)
06.92	Wood chips damp but water flow as observed in May was not present. Small tension cracks present across the top of the slope (above the wood chips) at sand bag berm. Vegetation is colonizing where wood chips are shallow and/or moist (native horsetails and legumes). (KLM)
10.92	There may be hot spots on slope but a ground check was not made to confirm. (KLM/DEL)

SLOPE 31A KP 84.5
UNNAMED SOUTH

12.12.84	Wood chip remedial work at slopes constructed in 1984: Comments: Install cutoff berm. (1984 Report on Monitoring of Construction and Operation)
24.06.85	Erosion between berm and woodchips. New berms constructed. (1985 Report on Monitoring of Construction and Operation)
09.91	Tension cracks visible at top east side. (KLM)
10.92	Areas of hot spots, extending two-thirds across the ROW. Extensive. Maximum temperature recorded in degrees celsius at about 20 cm depth in wood chips is 12 degrees. Sample #7. Cracks present. (KLM/DEL)
07.10.92	Sample #7 from lower east hot spot, 5cm-15cm depth, 12 degrees celsius at 20cm depth, white mycel, odour. 2cm of snow cover. (KLM- to Forintek)
25.07.93	Tension crack. (KLM)
02.10.93	Monitored wood chip temperatures with a needle probe. Temperatures taken at a 30cm depth at 16:40. (DD)
07.10.93	Set-up hot spot instrumentation. Double-checked delineation and extent of hot spot with needle probe temperature sensors and wood chip temperatures were taken at 10:10. Dug through 120cm to 145cm of wood chips before getting to mineral soil. Augured three holes in mineral soil (clay/silt) and inserted the lower section of the ditch probe temperature cable in each hole. Installed upper sections to each lower section except for cable #5124 (upper section) that was installed 20cm south of cable #5120. Installed four Hobo's at the surface of the mineral soil and between each ditch probe. Each HOBO was secured with a tight rope and inserted at the bottom of the wood chip layer at depths stated above. (to remove HOBO's - 2 options: (i)pull hard on rope to attempt to recover all four HOBO's at once; or (ii) carefully dig down to mineral soil via near ditch probes and cables. Option 1 is recommended). Listing of probe and logger serial #'s were given to Vic Allen on return. (DD)

Slope 32A, North
Km 93.2

05.90	Especially conspicuous subsided ditchline. (KLM)
10.92	One hot spot. 3-6 meters in diameter or max. dimension. Maximum temperature recorded in degrees celsius at about 20cm depth in the wood chips is 12 C. (KLM/DEL)

Slope 33, North
km 94.1

18.06.85	Rock scattered on chips. Clean rock off of wood chips. (1985 Report on Monitoring of Construction and Operation)
10.92	One hot spot, 1-3 meters in diameter or maximum dimension. (KLM/DEL)

Slope 35, North
km 103.1

12.12.84	Wood chip remedial Work At Slopes Constructed in 1984: Comments: Install cut off Berm. (1984 Report on Monitoring of Construction and Operation)
11.89	Winter 1990 description: heating of wood chips. Proposed remedial measure: Remove snow and monitor during winter of 1990. (1989 Report on Monitoring of Construction and Operation)
09.90	Tension cracks in wood chips were visible at side and centre. (KLM)
09.91	Tension cracks visible across lower slope - recheck. (KLM)
11.91	Removal of snow to cool wood chip slope. Erosion and subsidence have occurred along and adjacent to the ditch line near the non-insulated crest of the slope. This is an area of previous erosion which occurred in 1984/1985. This minor subsidence area was restored by filling this area above the wood chip insulated slope with 40 cubic metres of granular material as part of the 1991 ROW maintenance program. (1991 Report on Monitoring of Construction and Operation)
06.92	New tension crack across the slope (not observed in May) (KLM)
10.92	Three hot spots, maximum dimension or diameter is 1-3 meters. (KLM/DEL)

Slope 36, South
km 103.2

89	Warm zone reported. (1990 IPL maintenance and monitoring report)
11.89	Hot wood chips will be removed and replaced in the winter as done in previous years at other slopes. (1989 Report on Monitoring of Construction and Operation)
90	Snow removed. Further snow removal planned for winter 1991. (1990 IPL maintenance and monitoring report)
10.90	Clear patches in snow visible from air (MB)
11.90	"Warm" zone reported last year. Slope 36 is a new observation. Snow was removed in 1990 causing some cooling. Further snow removal is planned during the ROW maintenance program in 1991. (1990 Report on Monitoring of Construction and Operation)
03.91	Snow removal from this slope from which hot spots were identified last fall. (MB/KLM)
06.91	New tension crack in the wood chip slope. Not observed in May. Located in the lower west corner. (KLM)
11.91	Slope 36, which has been warm for two previous years was cooler than 10 degrees celsius in October 1991 and appears to be no longer a problem. (1991 Report on Monitoring of Construction and Operation)
10.92	Four hot spots, small to large in size, 1 is over 6 meters. Maximum temperature recorded at 20cm depth is 15 degrees celsius. Sample #8 (KLM/DEL)
07.10.92	Sample 8 taken from hot spot on mid-slope. Sampled at 5cm - 10cm depth. 15 degrees celsius at 20cm depth. Slight odour. (KLM)
11.92	Maintenance carried out between Dec. 91 to Mar 92 included snow removal to enable wood chips to cool on slope 36. (1992 Report on Monitoring of Construction and Operation)

Slope 44
Unnamed South - North Slope
KmP 113.6

12.12.84	Wood chip remedial work at slopes constructed in 1984. Comments: Increase thickness to design. (1984 Report on Construction and Operation)
18.06.85	Wood chips at water edge. Level wood chips, fix crib, completed. Wood chips sliding into creek. Recommendation: extension to crib required. (1985 Report on Monitoring of Construction and Operation)
21.06.86	North side centre two sections of cribbing partly collapsed downward, water flowing under cribbing. Many chips gone and more collapsing downward as soil beneath cracks away from slope. Chips on bank downstream at 2m-3m above current water level. Chips also washed from top of pile above cribbing. (KM/DH)
17.07.86	Remedial work since June 21 visit: creek straightened and edge sandbagged and riprapped in front of cribbing eliminating water flow under cribbing; sandbags also inside cribbing (KM)
27.09.86	Continued collapse of wood chips above cribbing on slope. (KM/HB)
03.87	Woodchips lost due to flooding replaced. (KLM)
25.05.87	Collapse hole. (MB/AW)
17.06.87	Slope looks good. Did not appear to experience flooding at break up like last year. Water clear, no sediment. (KM/HB)
14.09.88	Slight tension crack on the opposite slope, east side, where former collapse, high water. (KM/PK/DH/CT)
88	Cribbing repaired as part of summer 1988 ROW maintenance. (1988 Report on Monitoring of Construction and Operation)
08.05.90	1 log down on North side wood chip crib. Surface smooth. (KM/HB)
10.90	Possibly differential snow melt most likely due to hot spots. (MB)
05.91	Wood chip slope surface is smooth. Tension cracks are present. (May 8-12 Field Trip)
11.91	-This slope contains the most extensive and hottest wood chips (up to 33 degrees C). As a part of the 1992 right-of-way maintenance program, the wood chips will be removed from this slope to facilitate cooling and freezeback of the ground. Winter 1991 discription: Heating of wood chips. Slight ditch line subsidence. Proposed remedial measure, 1992: Remove wood chips. Recontour wood chips. (IPL- 1991 Report on Monitoring Of Construction And Operation)
05.92	This slope was clear of snow because of a winter maintenance program to control biological heating. (WS) Wood chip surface is smooth. (May 20-24 Field Trip)
02.08.92	Tension cracks subparallel slope at toe. Upper cracks delineate upper boundary of collapse area, lower cracks parallel cribbing and set of cracks on West side of collapse area at toe. Cracks coincide with area of chip removal last winter. (MB, JM)
03.10.92	+/- five hot spots +/- extending two-thirds across slope Photo in field trip report. Very extensive. Maximum temperature recorded in degrees celsius at 20 cm depth in wood chips is 18 C. Cracks present. (KM/TL)
11.92	Maintenance activities from Dec. 91 to Mar. 92: Wood chips were spread around on slope 44 to enhance cooling and 20 cubic metres of granular material was placed in a sunken ditch line at the top of the slope. A prelininary parametric study indicated that for thaw bulbs with certain depth and width ratios, there could be a significant reduction in factor of safty. Portions of six slopes indicated potential safty factors of less than 1.3, including slope 44. (1992 Report on Monitoring of Construction and Operation)
28.07.93	Tension cracks parallel to slope near toe of slope and also around collapse area. (DEL)
02.10.93	Snow cover on 2/3rd of 45 and < 1/3 of slope 44. (KM/DD/KE)

Slope 45
Unnamed South - South Slope
KmP 113.76

31.08.83	Proposed slope monitoring instrumentation. Design:cut to 16 degrees with 1100m of wood chips. Comment: significant ice rich clay, cut and insulate slope. Proposed instrumentation: 1 thermister string, 1 piezometer (shallow), 1 thermister string for side cuts. (Outline of Procedures and Schedules for post-construction monitoring of the Norman Wells to Zama Pipeline)
02.04.84	1st readings from CT2.
05.06.84	1st readings from T13.
07.84	Design: 1200 mm w/c. Comments: significant ice rich clay, cut and insulate slope. Instrumentation: 1T, 1P, 1CT, 1SP. (1984- IPL Post Construction Monitoring Programs for the Norman Wells Pipeline)
12.12.84	Wood chip remedial work at slopes constructed in 1984. Comments: Make up length and side cut. (1984 Report on Construction and Operation)
26.10.84	1st readings from TA2.
08.06.85	New chips on west side of slope to PVC tubes, not on east side. Top of PVC T13 broken but cable intact. Toe of cribbing on south side is partly fallen away, west end is gone. Woodchips fallen to creek, visible snow layer under old chips at toe of slope. Large block of ice at foot of cribbing. New chips only on parts of North and South slope cut thermistors (CT) mostly above zero on South side without new chips. (KM/DH)
24.06.85	Wood chip movement. Recommendation: Extend crib. Strip chips from surface up side cut and 3m east of ditchline feather crest to 1' depth over 15m. (1985 Report on Monitoring of Construction and Operation)
16.07.85	SW cribbing down and woodchips still in creek area no sign of maintenance to adjust woodchip positions (see June notes) ice has melted from toe of slope. Clayey silt, silty sand. (KM/SD)
06.09.85	No sign of recent maintenance or change to woodchip distribution. Cribbing on south side starting to tilt. (KM/DH)
19.12.85	Thermal monitoring of this slope had 0.5m - 1.5m of thaw beneath the wood chips that did not freeze back. (IPL- 1985 Report on monitoring...)
25.05.86	Wood chips down centre of slope seem to have been bulldozed, ploughed up on sides (to allow cold penetration over winter). Switch boxes exposed. One PVC pipe smashed. Some chips slightly upstream. (MB/WP)
21.06.86	Cribbing on west side of south slope repaired since last fall. (Note PVC tubes on south side in same conditions as last summer. North side centre two sections of cribbing partly collapse downward, water flowing under cribbing - many chips gone and more collapsing downward, as soil beneath cracks away from slope. Chips on bank downstream at 2-3m above current water level. Chips also washed from top of pile above cribbing. (Noted PVC tubes on South side in about the same condition as last summer) (KM/DH)
27.09.86	Snow depth: on ROW: 6cm-10cm (KM/HB)
29.10.86	Slide at bottom of slope - cribbing damaged - circular area collapse 5cm-10cm wide - chips exposed and half frozen. Collapse hole at base. Snow depth: on ROW: 10cm (MB/VA)
11.86	A washout of the crib, wood chips and backfill has occurred caused by stream blockage. During the winter, the crib will be renovated; the lower portion of the washout will be backfilled with coarse gravel and chips will be redistributed to restore the toe of the slope. (1986 IPl Report on Monitoring of Construction and Operation)
08.02.87	T13 and PT is snow buried. (JP)
10.03.87	TA2 is buried in greater than 30cm of snow. Couldn't find T2 and T3 in snow. (JP)
25.05.87	Some patches of snow on slope still. (MB/AW)
12.07.87	CT2 barely readable on the box. (KM/AM)
10.03.88	Rocks and poles here. Snow density measured. Later remedial work on North slope. Couldn't find pipe thermistor cable, under snow. Could find adjacent Temperature cable in the snow. (KM/DT)
26.05.88	Some collapse in wood chips over pipe at top of slope. (KM/CT/DK)
10.07.88	Water low. Crib OK. (MB/KM)

28.06.89	Cut slope cable CT2. Sorry didn't read pipe thermistors. (KM/PE/TL)
11.89	Hole in top of wood chips, south slope, IPL proposed to excavate hole, investigate, and repair as necessary. (1988 Report on Monitoring of Construction and Operation)
08.05.90	Water level mark up. Other equip.-piezometer. Melting to 30cm at TA2. Smooth surface. (KM/HB)
16.06.90	1 red tail hawk patrolling area. Water low. CT2 clicks on sequence. (KM/DK)
15.09.90	T13 needs cap on tube. (KM/WSt/CT)
09.03.91	Snow east of TA2 cable 81cm, 81cm, 84cm, 74cm. Several unfrozen sensors on the CT cable laid across the slope at the mineral soil - wood chip contact. (MB/VA)
10.05.91	Some ice at edge of creek. Flooding did not remove any new woodchip, tension cracks across North West corner of slope extending off ROW. Tension cracks top East side off ROW. Missing caps at T13. (KM/MS)
05.91	Wood chip surface is smooth. (May 8-12 Field Trip)
19.06.91	Didn't notice any change to tension cracks at top west slope; tension crack at east side of wood chips at cut location of slope. Missed PT's. Tension crack in sand above cable CT2, parallel to slope. (KM/CT)
30.07.91	Water relatively low. Didn't read pt. (AM/AR)
06.09.91	T13 cable's tube laying on ground, will be covered by snow soon. Repair for winter. Note iron stain in water and rocks at base of slopes. Doesn't seem to be upstream of slope. Water low, clear. (KM/CT/DK)
05.10.91	T13 needs cap on tube. CT clicks - in sequence. (KM/DS) The cracks noted in May,'91 are less conspicuous. Summer vegetation growth and suspected ranking of wood chips have covered most evidence of cracking. No evidence of progressive movement across cracks (since May '91) was found. (WS- Oct. Reconnaissance and Monitoring Report)
11.91	Considerable old evidence of instability was found in a burn area immediately upstream and downstream of the crossing. Outside of the burn area, beginning 1km downstream and continuing to Mackenzie River, there is widespread evidence of recent, shallow instability that caused blockage of the creek and small, short-lived lakes in several places. Tension cracks were found in backslopes on the east and west sides of the ROW during the May visit. Those on the east side were traced as far as the ditch where they were orientated approximately perpendicular to the pipe. Vertical displacement was evident across successive cracks in both backslopes, but none was detected near the ditch. The tension cracks were barely detectable in Oct. Careful visual monitoring will be continued at the crossing and down stream along the creek as far as Mackenzie River. (UBC, GSC, INAC - Slopes and Wood Chip insulation, PTRM 1991 Annual Progress report)
21.05.92	Water flowing over ice. Tension crack across part of upper slope above low area, cracks in cut mineral soil and parallel to ROW. Unfrozen hot spot area greater than probe length of 152cm, temp. at 55cm=17C, air temp. at wood chip surface =16C. Hot spot visible due to snow melt. Full of fungal hyphe (light color top 25cm, also wet and slimy layer sampled 25 to 55cm.). Box needs repair, only one reading available at pt1-11. -Hot spot on upper slope which caused snow melt from bottom upward. Temperature at 55cm was 17C. (air T. at w.c. surface 16C). No resistance to probe for length of probe (150cm). Sampled surface (0-25cm) and below surface (25-45cm) wood chips for possible analysis of microflora. Surface layer conspicuous with white growth (fungal hyphe, etc.) and lower layer was sticky with gelatinous material on the wood chips. On May 20 and 24, water was flowing over the tops of the cribbing on both slopes. Snow depth at T13 is 30cm, TA2 30cm, CT 30-50cm. -Wood chip surface uneven. Tension cracks. (KM/KWS)
05.92	The slope was snow covered. The stream was flowing over ice and the thalweg was at the approximate level of the top of the wood chips. A new tension crack was noted on the west side of the ROW trending at high angle to the ditchline. The location of this crack makes it contiguous with a similar one noted in 1991 on the opposite side of the ditch and continuing into the east backslope. A hot spot on slope 45 was recognized from the pattern of snow melt. Probing confirmed that frost was absent from a circular-shaped area 3 to 3.5 m in diameter and centred over the pipeline. Wood chips were found to be 1.2m thick and overlying a minimum thickness of 0.3m of unfrozen mineral soil consisting of sandy to clayey silt. Based on the minimal penetration resistance of the probe, examination of the material brought up the probe, and the way in which our movement over the hot spot caused

vibrations which almost certainly involved transient displacement of mineral soil, the soil can be described as very soft to soft with a uniaxial compressive strength ranging from <25 kPa to as much as 50 kPa.

A white fungus and pale amber-coloured gelatinous material were present in void spaces on at least the top 25cm of the wood chips, which was the maximum depth of test pits. These materials were warm to touch and fetid. Samples were taken on May 21 and again on May 24, 1992. (May Recc. and monit. report, KWS)

06.92 Re-sampled microorganisms in the wood chip hot spot at the slope. There appears to have been some change in predominant organisms and their characteristics since the May sampling. The "white layer" of predominantly white basiomycete fungi is still conspicuous near the surface. Samples are currently being cultured at Forintek in Ottawa for preliminary identification of predominant and \ or thermophilic fungi. It may also be necessary to check for other thermophilic organisms such as bacteria. (KM,AM,DK- June 16-20 1992 Completion Report)

02.08.92 Tension cracks at edge of chips on side cut of west side of ROW, slumping. Uneven chips, ditchline subsidence. (MB/JM)

03.10.92 Noted two lathe stakes indicating borehole and probe line. Hot spot - west of CT and 2 lower down plus upper hotspot where sampled earlier in year. Borehole + probe line just above cable location + an upper probe line at bottom of upper hot spot. Snow depth at TA2 20,23,22cm, T13 23,24,27cm, CT2 15,20,20cm.

Three hot spots, Medium size, 3-6 meters. Max. temp. recorded in degree C at 20cm depth in wood chips is 15 C. Sample #9. Cracks present. (KM/TL)

07.10.92 Sample 9 taken at 5-10cm depth, white hyphe odour, 12-14 degrees C at 20cm, air temp 1 degrees C. 2cm snow cover. (KLM)

11.92 The data from temperature and piezometer instrumentation does indicate potential instability. (1992 Report on Monitoring of Construction and Operation)

25.11.92 78/63cm +/-5m upslope of TA2. CT2 no markings to distinguish 1-9 on dial or box. Snow depth at TA2 is 40, 43,44cm, CT2 52,40,38cm. Unstable line conditions. (JB/PG)

13.03.93 At CT2, no marks on box. Cable PT1-11 not found. Snow depth at T13 is 95cm, TA2 125cm, CT2 82cm. (BM/VA)

11.06.93 Toe of slope- east- collapsed. Black tube in sun =27 degrees. CT-2 Numbers in sequence -unsure of position, creek low. Tension cracks N and E sides. Log jam in creek just above slope 45 may cause increased bank under cutting adjacent to SE corner of crib, appears to be causing some deepening of creek on E side of ROW between insulated slopes. No new tension cracks. Part of DPW initial access was across spoil pile. (KM,CT,AM)

25.07.93 Tension crack at the NW corner at toe of slope. Installed 3 soil probes with loggers at hot spot and 6 hobos.Wood chip temperature in hot spots as high as 23 degrees, out side hot spots as low as 7 degrees C. (JM)

09.09.93 Air smoky, (didn't check slope thoroughly for tension cracks). TA2 orange paint. Line conditions unstable. (KM/CT)

02.10.93 Snow cover on 2/3rd of 45 and <1/3 of slope 44. Desrochers repairing cable to EMR logger in hotspot. Circle of snow melt also on left side. Shutdown since 8 a.m. Trace snow at TA2/T13/PT. (KM/DD/KE)

02.12.93 T13 erratic / woodchips windblown bare on top. Snow depth at TA2 is 15-15-15cm, T13 15-15-14cm, CT2 13-15-21cm. Stable line conditions. (JB)

Little Smith North
Slope 47
km 159.5

09.86 Woodchip movement on east side of slope. (KLM)

10.90 Differential snow melt most likely due to hot spots.(MB)

10.91 The north slope was found to be in good condition, however approximately 300 meters north of the crossing (kp 159.2) a meander on the right bank of Little Smith Creek is encroaching on the southwest side of the ROW. Evidence of shallow, thaw related instability near the elevation of the ROW appeared to be more widespread than in 1987 aerial photographs, and more than was remembered from previous trips by the writer. (KWS)

05.92 Wood chip insulation on the north slope was found to be in good condition.

Evidence of instability was noted from air photos and aerial reconnaissance in Oct. 1991 approximately 300m north of the insulated section (kp 159.2) where a meander on the right bank of Little Smith Creek is encroaching on the southwest side of the ROW. This area was inspected on the ground on May 21, 1992. Three distinct mechanisms of instability are interpreted based on the brief site visit.

Mechanism #1 affects the top of the slope adjacent to the ROW. It is an active, shallow form of instability, in order of 1.0 to 1.5m deep, with detached landslide blocks measuring 3 to 5m wide (in the direction of movement) and 5 to 8m long. Typically a width of ground comprised of 3 to 6 of these blocks extends from the right (southwest)edge of the ROW in a downslope direction to where the effects of the second mechanism become dominant. Instability appears to be seated in a thin silty loess (Unified Classification of ML-SM) unit which is believed to be ice rich. This unit rests on silty and sandy gravel (GP). Degradation of ground ice and related excess pore pressures are the most likely causes of the shallow instability. Assuming that ground ice has already degraded on the ROW, the retrogressing pattern of instability can be expected to stop after encroaching a few meters onto the southwest side of the ROW. Orange flagging was placed at the location where cracking has already reached the southwest side.

Mechanism #2 involves the gravel (GP) described above. Numerous springs were observed where this unit is exposed beneath the silty landslide debris and large icings indicate discharge occurs throughout the winter. The groundwater is washing fines out of the slope and contributing to mud floes in the silty landslide debris and in a fissured clay which underlies the gravel. Groundwater discharge may have increased as the effects of construction and operation of the pipeline created a window in the frozen silt aquitard.

Mechanism #3: A medium to high plastic, grey, fissured, lake clay (CI to CH) outcrops along the lower portion of the slope. This material is almost certainly what the insulation at slope 47 was placed to protect and so it is assumed to be ice rich. Its low strength contributes to shallow mud flows. The same properties would make it susceptible to deep-seated landslides (both frozen and frozen) although no evidence of active deep-seated instability was identified nearby.

None of these mechanisms is considered a short term threat to the pipeline ROW and the area is considered to be a low priority. Regular aerial inspection by IPL and PTRM is recommended and an annual on-ground inspection should be carried out to look for any evidence of change in the mechanisms and rate of instability. (May recc. and mon. report, KWS)

06.92 Tension cracks on slope west of the ROW are continuing to open, noted from changes on flagging spruce split across a tension crack in May. NOTE: Fresh landslides conspicuous on Mackenzie River bank west of kp 156 and also in the Old Fort Point area. (KLM)

10.92 More than five hotspots, extending two thirds across the slope. Extensive. Max. temperature recorded in degrees C at 20 cm depth in wood chips is 18 C. Sample #10. (KLM/DEL)

07.10.92 Sample #10 taken at 5-15cm depth, 15 degrees C at 15 cm. White mycel odour, Hot spot on upper slope. (KLM)

Slope 48B
Little Smith South
KmP 160.1

12.12.84	Wood chip remedial work at slopes constructed in 1984. Comments: Make up deficiency of depth. (1984 Report on Monitoring of Construction and Operation)
06.07.89	Conspicuous subsidence on east side of slope and large tension cracks in wood chips parallel to ditchline. Considerable water coming from beneath wood chips and some water flow adjacent to wood chips on east side of wood chips. The small drainage channel 20 - 30m east of the right-of-way continues to down cut, leaving more sediment deposited across the slope below wood chips (Water flow appears to be more conspicuous again in the old Hagglund's track area on winter road access to creek, east of ROW and north of Remote Maintenance Base). (KM)
05.90	W.c. surface smooth. Subsided ditchline. Water flow from below wood chips. (May 7-10 Field trip)
08.90	Tension cracks. (Aug. 1-2 Field trip)
09.90	Tension cracks visible in ditch area. (KLM)
10.90	Differential snow melt most likely due to hot spots.(MB)
11.90	Operation and Maintenance Activities: removal of wood chips at bottom of slope to investigate subsurface drainage. (IPL- 1990 Report On Monitoring of Construction and Operation)
09.03.91	1st readings from 91-3. There seems to be a lower factor of safety at this slope, IPL plans more detailed analysis. (MB/VA)
05.91	Wood chip surface is uneven. Subsided ditch line. Water flow from below wood chips, usually in ditch line. (May 8-12 Field Trip)
06.91	Water flow from below wood chips. (June 29-Aug.2 field trip)
30.07.91	Thermistors in lower cable of two new PVC tubes, unlike most '91 sites with thermistor cable up slope from piezometer. (AM/AR)
10.91	The performance of this slope is considered poor. 1) A large volume of ground water flow is believed to enter the ditch from an upland gravel aquifer. Some ground water is controlled out of the ditch at mid slope subdrain and natural discharge is evident from the ditch at the bottom of the slope. 2)Extensive settlement has occurred on the insulated slope and it is associated with an array of tension cracks. Comparative study of May and Oct. '91 photographs indicates the settlement is visibly progressive in the mid slope area where the subdrain system is located. 3)Considerable silt has been deposited over organic soil in both groundwater discharge areas, but particularly at the bottom. 4) Silt is reported in test hole logs at the site. Wide spread shallow instability is developing along a tributary to Little Smith Creek situated immediately west of the right-of-way. It is restricted to the west of the tributary and is not an immediate threat. The extent of instability has increased since '87 areal photographs were taken however. The area will be monitored in 1992. (WS- Oct. Reconnaissance and Monitoring Report)
11.91	There is more thaw adjacent to the pipe due to the influence of the pipe, and in some cases, this deeper thaw is probably reducing the safety factor against failure to less than the design target of 1.5. This slope may be considered more serious. Where the width of the thaw bulb is greater, the contrast in settlement across the ditchline is less noticeable based on visual observation. Installation of Monitoring equipment on wood chip slope between Jan. to Mar. (IPL- 1991 Report on Monitoring of Construction and Operation)
21.05.92	Probed tension cracks on east side between wood chip drainage ditch and piezo, full 152cm length of probe, also in snow patch below. Water diverted east from V berm above wood chips goes off ROW at north end - upper helipad, under moss, and surfaces near south side of next lower helipad. River open at crossing, full of sediment, ice pile in river downstream. Erosion and icings on north river banks downstream of crossing. -"V" berm at top of slope is directing surface water above wood chips off ROW well. On east side of ROW water flows below vegetative cover and resurfaces near second helipad clearing down slope (flowing in gravel layer). -Wood chip surface uneven. Subsided ditchline. Tension cracks. Hot spots. (KM/WS)
21.05.92	Clear surface water was moving along the west side of the ROW over the crest of this slope and as far as the 'V' berm. The berm diverted flow off the east side of the ROW where it infiltrated below the

03.10.93	Water flow E. of w.c. slope coming out ground E. of piezo. above 91 temp. cable, slow flow from ditchline with temp. ~+5C, water flow in ditch to east of wood chips and coming from wood chips - upper slope. 91-3 cable not working. Thin snow cover on slope (discharge water unfrozen). (KM/DD/KE)
02.12.93	Snow depth at 92-3 is 7-7-12cm. Stable line conditions. (JB)
25.01.94	Snow bladed off slope - just a skiff of snow on chips. Connector wires broke on cable 91-3. (JB)

SLOPE 55
KM 181.9, Unnamed Creek South

12.12.84 This design slope required extensive cross slope grading resulting in vertical ice rich side cuts. The insulation was brought up to but not over the top of the cut. Degradation of this cut has resulted in fallen trees and uprooted top soil. The remaining trees contained in the area bounded by the fall line (intersecting edge of the ROW 2/3 up slope, the cut line at crest of the slope, and the edge of ROW will be cut and sectioned in place. This area will be covered with a nominal thickness of wood chips .

Wood chip remedial work at slopes constructed in 1984. Comments: Make up shortage at crest. Chip repair area to west. (1984 Report on Monitoring of Construction and Operation)

05.92 A hot spot was found over the ditch very close to the bottom of the slope. (WS,KLM)

A hot spot was found centred about 10m upslope (measured on the slope) from the bottom of the wood chip insulation. It was centred over the ditch, circular in shape, and about 5m in diameter. Probing was possible to the full depth of the probe, 1.5m. (May Recc. Mon. Rep., WS)

10.92 One hot spot, inspected from air. (KLM/DEL)

SLOPE 61, South
km 191.2

28.06.89 First wood chip slope south of 1984 staging area (kp 190) and DPW winter road crossing (1989 debris over snow not removed). More conspicuous tension cracks. (KLM)

05.90 Especially conspicuous subsided ditchline. (KLM)

09.90 EMR used ground probing radar to examine subsurface more extensively for thaw below the wood chips. (KLM)

10.90 Differential snow melt most likely due to hot spots.(MB)

05.92 The winter road obstructed natural drainage and a large area encompassing the entire valley bottom and including the toe of the insulated slope was flooded. (WS,KLM)

The winter road obstructed a stream crossing of the pipeline ROW about 250m north of the toe of this wood chip slope. Spring runoff ponded behind the obstruction flooded an estimated 150m section of the pipeline ROW and was within approximately 100m of the toe of the wood chips on May 22, 1992. Strandline evidence indicated the water had been higher a few days earlier, possibly as close as 50m to the toe of the wood chips. (May Recc. Mon. Report, KWS)

10.92 One hot spot, inspected by air. Near toe of slope. (KLM/DEL)

10.06.93 Tension cracks. (KLM)

25.07.93 Tension cracks at east side, parallel to ditch. (KLM)

Steep Creek South
Slope 63
km 194.9

10.90 Differential snow melt most likely due to hot spots.(MB)

11.90 Winter 1990 description: heating of wood chips. Proposed remedial measure: remove wood chips and monitor during winter 1991. (1990 Report on Monitoring of Construction and Operation)

03.91 Snow removal where hot spots were identified last fall. (MB/KLM)

10.91 Deep-seated, old landslides are present on the south slope of Steep Creek. On the basis of airphoto interpretation, the area of deep-seated instability appears to begin at least 500 metres east of the ROW, crosses the ROW, and continues downstream about 800m to the Mackenzie R, extending from valley bottom to near upland level. The mechanism is interpreted to be deep-seated, retrogressive, rotational slumping through frozen soil. There is no evidence of recent activity on the ROW although a slide scarp up to 1.4m high was identified within 5m west of the ROW. Large slides centred 300m upstream and 450m downstream cut off poorly vegetated channel in the flood plain, indicating substantial movement. These slides will be ground checked in more detail in May.

This slope was identified by IPL in early 1991 for re-analysis while the slope on the north side of Steep Creek, Slope 62, was identified for further investigation instrumentation and re-analysis. It is recommended that Slope 63 be given equal attention because of field evidence of large deep-seated instability. The presence of these large landslides indicates that the design approach of avoiding areas of deep-seated instability in frozen soils is not well founded. The writer is studying this mode of failure and its possible effect on the pipeline, and will report on it in the future. (KWS)

11.91 Maintenance activity undertaken between Jan. to Mar. 1991 includes removal of snow to cool wood chip slope.

A preliminary parametric study indicated indicated that for thaw bulbs with certain depth to width ratios, there could be a significant reduction in factor of safety. Portions of six slopes indicated potential safety factors of less than 1.3, including slope 63. (1991 Report on Monitoring of Construction and Operation)

05.92 Deep-seated, old landslides were reported on the south slope of Steep Creek in my Oct. 1991 monitoring report. Airphoto evidence of progressive movement was cited around the eastern headscarp of a slide centred 300m upstream of the pipeline ROW. This area was ground checked on May 22, 1992. The route taken is shown in figure 10. I followed the head scarp outlined on Figures 9 and 10. After about 150 to 200m the scarp curved toward the valley and at least two other overlapping but not continuous scarps were confirmed farther upslope. The total relief over each scarp was 3 to 6m. Below these scarps I found a large icing which I followed to the floodplain level. After reaching the floodplain I followed the toe of the slope west toward the ROW confirming evidence of recent slope movement in the form of trees pushed over and overridden by a 10 to 12m high toe which is moving laterally into the floodplain.

As a result of this traverse it can be said with a high degree of certainty that this landslide area is active. The evidence at the toe is unequivocal and on the basis of both live and dead trees being overridden velocities are estimated to be between 10 to 100 cm/year. Evidence of active movement in the eastern headscarp area is less reliable. There are several prominent scarps with sharp relief where mineral soil is exposed and dead and weathered root systems are stretched across the overlying torn organic mat. I am satisfied that this evidence indicates progressive movement with velocities estimated to be between 1 and 10 cm/year.

The mechanism of instability is interpreted to be retrogressive earth slumping. What is not clear is whether the failure surfaces controlling the headscarp and toe areas are interconnected and hence deep-seated (maximum depth of the failure surfaces would be 12 to 18m). Alternatively, they may be shallow (max. depth would be 5 to 10m) and the surfaces not necessarily interconnected. It is also possible that both shallow and deep-seated mechanisms are active. It should be noted on Fig. 10 that there are two ponds above the toe area. This interpreted to indicate that the toe area is affected by a relatively more active slumping mechanism including backward rotation of the slump block.

This slope was identified by IPL in early 1991 for re-analysis while the slope on the north side of Steep Creek, Slope 62, was identified for further investigation, instrumentation and re-analysis. The foregoing confirmation of active and possibly deep-seated instability in association with large landslides immediately adjacent to the ROW underscores the importance of further study of slope 63. (May recc.

and mon. rep., KWS)

10.92 6 hot spots, small and medium size, 1-3m, 3-6m. Max. temp. recorded in degrees C at about 20cm depth in wood chips is 14 degrees. Two east side, 4 west side. (KLM/DEL)

Slope 66
Blackwater River North
Kmp 224.4

06.85	Sediment and woodchips moved several hundred meters SE of ROW from mid-slope. Maintenance underway. (KLM)
06.86	Noted new rip-rap on woodchip upper slope and west side slope. Evidence continued erosion and mass movement on west side slope (newest by lower woodchip section). Water by-passing rip-rap by upper and lower section. (KLM)
09.86	Continued collapse of soil and woodchips on west side of slope. (KLM)
11.86	Thermal erosion has continued at this location. During winter 1987, the drainage ditch will be excavated and erosion protection will be installed. (IPL 1986 Report on Monitoring of Construction and Operation)
06.87	Blackwater N. slope remedial work/design survived spring melt OK. Will continue to check cross drainage area at mid-slope after rainstorms. (NOTE: Eagle Tower near Blackwater (km 205) will be operational all summer for local precipitation data.) (KLM)
08.90	Blackwater river was clear and there was no sign of water in the drainage ditches along the insulated north slope. (KLM)
07.91	The slope survived the high precipitation over the previous weekend (assuming rain storm actually hit ROW here) and there was no surface sign of flow in the rip-rapped drainage ditch west of the upper wood chips on July 30 or August 1. When we checked the slope on the ground there was some water flow across the mid-slope under the rip--rap (i.e. you could hear it but not see it) and some visible flow down the west side of the lower wood chip section (August 1). (KLM)
06.10.93	Locations of hot spots observed from air. Photo taken at 3:10. (DD)

Slope 73
Unnamed North
KmP 271.44 - 271.54

31.08.83	Proposed slopes monitoring Instrumentation. Design: 1000mm of wood chips. Comment: "prevent thaw" slope. Instrumentation: 3 shallow thermister strings, 1 shallow piezometer. (Outline of Procedures and Scedules for post-construction Monitoring of the Norman Wells to Zama Pipeline)
07.84	Kmp 270.93- Design: 1000 mm w/c. Comments: "prevent thaw" slope. Instrumentation: 3T, 1P. EMR: KmP 271- Comments: high sensitive lacustrine plain massive ice in ice rich clay. Instrumentation: 12 cables. (IPL- Post Construction Monitoring Programs for the Norman Wells Pipeline)
02.03.85	1st readings from TA16, T6, T1, TA18, T3, and TA3.
06.03.85	1st readings from CT1, and CT2.
28.03.85	Oil present but probably not flowing. T6 at top of slope in woodchips. TA16 is centre top slope in woodchips. TA3, CT1, and CT2 are mid-slope in woodchips, TA18, and T1 are in lower slope, in woodchips. (KM/MM)
10.04.85	On ROW: new clearing. (JH)
06.06.85	New woodchip slope; initial design 1000mm w/c chips appear to include more fines than '84 Bosworth or Canyon Creek. chips etc. Need data on depths of woodchips and positions of thermistors. Potential major erosion on camp 73-ROW access: Now gulling started where hoggland use observed last summer (also winter road). (KM/DH)
16.07.85	Creek is much drier than July 1984, mostly a 'boulderfield'. Need specs on site. (KM/SD)
19.12.85	Beakers settled and eroded. Fix beakers. (L.Perrier, 18.06.85) (IPL- Report On Monitoring of Construction and Operation)
06.03.86	Deep loose snow. Lower slope T1 thawed 70cm, below woodchips. CT thermistors - mid slope were missed. Snow depth: on ROW: 45-65cm, off ROW: 49-66cm. (WP)
03.86	Noted snow melt patterns in the snow.(IPL 1986 Maintenance and Monitoring Report)
21.06.86	Water level in creek very low. Small gullying above woodchip on west side of ROW. (KM/DH)
17.07.86	Minor erosion gulleys - travel side - above wood chips have gone from about 5-10cm deep to 15-20cm deep. (no evidence of remedial work). Out on east side collapsing, trees falling into shoofly. (KM)
07.86	Sprayed water for 2 hours. (IPL 1986 Maintenance and Monitoring Report)
08.86	Minor gullying at top of slope 73 deepened further however water diverted off the ROW by sand bag berm above woodchips. (KLM)
10.08.86	1st readings from HA119. Addition of new ipl thermistors at the base of the slope, connector box under a rock. Wood chips watered using pump. Minor gullying at top of slope deepened further however water diverted off the ROW by sand bag berm above wood chips. Pump used to water slope, Pump removed (after floods of Aug. 5) either by flood or helicopter. Reported condition to ipl Aug.5am when did initial work at 7a and 7b in rain Aug.5. Pilot pulled pump to slightly higher ground. (KM/DM)
29.09.86	Minor gully erosion continuing above woodchips. (has been deepening about 5-10cm/month; now up to 30cm-40cm). (KLM/HB)
26.10.86	Two tension cracks in lower slope, at least 1m deep - snow cover thin, melting over warmer wood chips - cracks visible in aerial shots. Hung cable HA119 from stick propped up with rock. Snow depth: on ROW:5cm, off ROW:5cm. (MB/VA)
11.86	Residual heat from exothermic wood decomposition has been observed at certain spots. It is planned to cool these "hot" areas during winter 1986-1987. Vane shear tests conducted in 1986 suggest that the unfrozen areas on these slopes should be refrozen to ensure stability. (IPL 1986 Report on Monitoring of Construction and Operation)
17.12.86	3 large tension cracks at bottom of slope (looks like snow has been cleared off area). Warmest temperature is on new cable #119 (DT/BH)
86/87	Removed wood chips and exposed soil surface to winter air for periods ranging from 19 to 30 days. (1987 IPL Maintenance and Monitoring Report)
07.02.87	Snow cleared with cat (JP)
10.03.87	Snow and chips removed and replaced? Need new depth info. (KM/AM/LS)
22.05.87	Bit of erosion gulling at top of slope before chips. Bear and 2 cubs on slope. (MB/AW)
17.06.87	Slightly muddy. (KM/HB)

12.07.87	Little water in Whitesand- similar to July '85 also no sign of any new sediment from last nights rain. Removed chips and snow. (KM/AM)
16.08.87	Water seepage to surface from beneath wood chips on bottom west side of slope. (KM/CT)
15.09.87	Wet at bottom SW corner of slope below woodchips. Water very low in creek. Problem with readings - connector at T6. Red connector problem at T3. (KM/DH)
11.87	-Station:45M, Pipe settlement monitoring data at this location with measurable pipe strain: maximum % = 0.30. -The thinning and removal techniques for cooling the wood chips were not as effective on the three slopes where these techniques were tested. Small isolated patches of wood chips on these slopes warmed again in the summer 1987. It is proposed that wood chips be removed and replaced from the "hot" patches on this slope. (1987 IPL Report On Monitoring Of Construction and Operation)
18.12.87	Missed 2 cables. (AB/DT)
18.01.88	Snow depth: on ROW:45cm, off ROW:45cm. (AM/DE)
08.02.88	Snow depth: on ROW:40cm, off ROW:40cm. (DT/AB)
09.03.88	No snow removed on slope. (KM/DT)
26.05.88	Low water. (KM/DK/CT)
08.07.88	Crib OK. Flooding doesn't appear to have affected island in crossing. (KM)
11.08.88	Creek very low. (KM)
14.09.88	Water muddy and still to high to walk across. (KM/CT)
24.01.89	Snow depth at TA16 is 37cm, TA3 31cm, CT1 31cm, T1 32cm, TA18 32cm. (AB/JG)
28.06.89	Creek very low. (KM/PE/TL)
10.08.89	Little water in creek. (AM/JN)
13.09.89	Water in creek very low. 119 lying on wood chips. TA16 needs repair. (KM/PK)
27.10.89	Snow depth: on ROW: 15cm, off ROW: 15cm. (DT)
27.12.89	Remainder of cables missed or not found in the snow. TA16 maybe not working. 57cm of snow. (JG/DT)
08.02.90	CT1 and CT2 were not found (both not found last trip). Found T6 and TA16,(not found last trip). 119 not in use. TA16 is bear damaged. (JG/SDa)
21.03.90	Deep snow. Hard to move missed CT cable at edge of slope. Snow depths at T6 are 53cm,53cm,54cm, T3 are 52cm,53cm,53cm, TA3 are same as T3, TA18 are 62cm,60cm,61cm, T1 are same. (KM/JB)
08.05.90	Mosquitos are out! Water relatively low for this time of year, islands not flooded. TA cable damaged, box missing. Smooth surface. (KM/HB)
16.06.90	River up from May, and considerable sediment - brown. TA cable severed. (KM)
03.08.90	Water low, clear. (TA missing). Holes. (KM/TL/WS)
15.09.90	Water low. TA cut. Tension cracks. Erosion, sediment deposition. (KM/WSt)
13.10.90	No differential snow melt but in some areas chips are spongier than others. Woodchips smooth except for toe. Can't find HA119. Snow Depth: on ROW: 2cm, off ROW:2cm. (MB/AW)
28.01.91	Unable to locate missing stations (buried in snow). (MS/JG/SD)
09.03.91	New equipment installed in Feb.'91 (3 new tubes). lowest slope- 2 new cables- closer to center line than old cables. Didn't read new cable (didn't have right connector for new '91 cable). Partial snow packing etc.- Hagglund. Missed connectors buried in snow. Connector box loose at TA18 and TA3. Snow depths at T6 are 50cm,54cm,52cm, TA3: 55cm,52cm,54cm, T3: 55cm,52cm,54cm, T1:62cm,64cm,65cm, TA18 is same as T1. There seems to be a lower factor of safety at this slope, IPL plans more detailed analysis. (KLM)
10.05.91	Considerable ice left, waters muddy. TA16 needs repair. (KM/MS/WS)
05.91	Wood chip surface is smooth. (May 8-12 Field Trip)
06.06.91	1st readings from 91-2.
19.06.91	Missed cable at top edge of w.c.. Water low. TA cable damaged needs box. (KM)
01.08.91	Water levels down from Tue. July 30. Still considerable sediment in water. Note variable readings, thermistor problems. (AM/RS)
27.08.91	New temperature probes installed in ditch 25cm and 50cm from C/L to depths of 1.4m beneath mineral soil surface- located opposite cable T1. Probes connected to XL800 loggers. Dug hole through chips opposite cable 91-2. Chips very different from those exposed when digging at slope 29B. Lots of signs of fungus/mold, i.e. of more heating. Could not locate pipe since was section of deeper burial so moved

	upslope and tried a new hole opposite T1. Successfully located pipe and installed probes. (MB)
05.10.91	Water low in creek. (DS)
	The warm/hot spots were watered down this month, this should allow freezeback to occur in the wood chips. (IPL- Nov. 1991 Report on Monitoring of Construction and Operation)
14.11.91	Unable to locate missing stations. TA16 cable may have been damaged by a bear. (MS/SD)
11.91	There is more thaw adjacent to the pipe due to the influence of the pipe, and in some cases, this deeper thaw is probably reducing the safety factor against failure to less than the designed target of 1.5. This slope may be considered more serious.
	Installation of Monitoring equipment undertaken between Jan. to Mar. 1991.
	Dispersal of water on wood chip slope to cool hot spot. (IPL- 1991 Report on Monitoring of Construction and Operations)
27.01.92	Unable to locate missing stations. (snow?). Snow depth at T1 is 51cm, T3 54cm, T6 54cm. (MS/BD)
04.03.92	Cable 91-2, thawed. (KLM)
22.05.92	River open with ice at edges TA cable top of slope broken by bear.
	Wood chip surface uneven. (KM/WS)
03.08.92	Hummocky micro relief: small collapse pockets (not present last year). Two small collapse holes about 1m wide down slope from ditch probes on west side of ROW with tension crack about 50cm deep on uphill side of one - put stake and flagging to mark. Woodchips over all slope seem soft, spongy when walking (don't recall this being noted last summer). Subsided ditchline at toe. (MB/JM)
05.10.92	Hot spots - area across whole lower slope from above ditch probes and T1 cable location to bottom. T1 in tall tube by new piezo and ditch loggers. TA3 midslope by spruce pole; 2 tubes together (low). Snow depth at T6 18,16,17cm, T3 15,19,18cm, T1 3,9,13cm, 91-2 5,7,9cm. (KM/KH/TL)
05.10.92	Extensive. Max. temp. recorded in degrees C at about 20cm depth in woodchips is 18 C. Sample #6 taken. Entire lower slope included (check photos). (DEL/KLM)
06.10.92	White mycel, odour strong, 10-15cm depth. 18 degrees C at 20cm. (KLM)
18.11.92	Snow depth at T6 is 36cm, TA3 36cm, CT1 34cm, T1 30cm, 91-2 36cm. (KH/SD)
11.92	A preliminary parametric study indicated that for thaw bulbs with certain depth to width ratios, there could be a significant reduction in factor of safty. Portions of six slopes indicated potential safty factors of less than 1.3, including slope 73. ..Additional; piezometers and thermistors were installed in Feb. 1991.
	The data from temperature and piezometer instrumentation does indicate potential instability. (1992 Report on Monitoring of Construction and Operation)
18.01.93	Added T9 and T11 data on data sheet to T6 and T1 cables, respectively.
25.01.93	Old hotspots are not evident - no new ones noted as snow conditions have covered everything recently. Drifting + new snow make identification hard. Snow depth at T6 is 50cm, T3/TA3/CT1/CT2 56cm, T1 49cm, 91-2 51cm.
	Snow depth: on ROW: 52 cm, off ROW: 48 cm (KH/SD)
11.06.93	Water low, wood chips uneven. (KM,AM)
03.10.93	Creek very low, reading EMR loggers. Snow depth at T3 is 0. (KM/KE)

Slope 74 - Table Mountain
km 271.6

31.08.83	Proposed slopes monitoring instrumentation. Design: 1200mm of wood chips. Comment: "prevent thaw" slope Proposed Instrumentation: 3 shallow thermister strings, 1 piezometer. (Outline of Procedures and Schedules for post-construction monitoring of the Norman Wells to Zama Pipeline)
07.84	Unnamed Creek South. 1200mm w/c. "prevent thaw slope" instrumentation 3T, 1P. (Post Construction Monitoring Programs for the Norman Wells to Zama Pipeline)
06.06.85	Initial design 1200mm woodchips, "prevent thaw slope" (KLM/DH)
16.07.85	IPL automatic data logger on upper slope tubes: not able to read TA5 +T2, TA-16 + T11 need specs. for cables. (KLM/SD)
10.08.85	4 cables mid-slope - data logger removed - but not possible to read as connected together. (KLM)
06.09.85	4 upper slope cables: unable to read (data logger gone but 4 cables interconnected) (KLM/DH)
12.10.85	+4 upper slope cables (no connectors, were on a logger) -not read in Sept. -see next sheet for Oct. (VA)
03.03.86	Deep snow. (WP)
03.86	Noted snow melt patterns in the snow. (IPL 1986 Maintenance and Monitoring Report)
21.06.86	Water level low. Tracked vehicle travel on slope evident from wood chips. (KLM/DH)
26.10.86	No obvious spots with thinner or melting snow. (MB/VA)
86/87	Snow removed and wood chips thinned where thickness exceeded 1.4m. (IPL 1987 Maintenance and Monitoring Report)
10.03.87	Snow removed and some wood chips. (KLM/AM/TS)
22.05.87	Less chips put back on lower slope? Hence mound at lower cables, T9 and TA13. (MB/AW)
12.06.87	Anomalous readings at T2 on slope 74. (KLM/AM)
16.08.87	Creek extremely low (KLM/CT)
09.87	Two hot zones noted in Sept. 1987. Temperatures recorded were 25 to 35 degrees celsius at a depth of 0.9m in the wood chips. (IPL 1987 Maintenance and Monitoring Report)
29.09.87	IPL Temperature Probing at 0.9m depth along slopes. Diagrams are included in text. Two hot areas, Maximum temperature in upper hot area, located between the upper and lower instrumentation, is 29 degrees celsius. Maximum temperature in lower hot area below lower instrumentationn is 35 degrees celsius. (Info from sketch in 1987 Report on Monitoring of Construction and Operation)
13.10.87	Some spots on mid slope are low with snow and chips are wet. (DT/DB)
11.87	The thinning and snow removal techniques for cooling the wood chips were not as effective on the slopes where these techniques were tested. Small isolated patches of wood chips on these slopes warmed again in summer 1987. It is proposed that wood chips be removed and replaced from the "hot" patches on the slopes at Kp 271.6 and Kp 273.6. (1987 Report on Monitoring of Construction and Operation)
18.12.87	Signs of melting at midslope 5m X 5m depression, about 2cm of snow in melted area, about 40cm adjacent. (DT/AB)
18.01.88	Two areas are melting - one on middle slope and the other on the lower slope. (KLM/AM)
02.88	Removed wood chips. (IPl 1988 Maintenance and Monitoring Report)
09.03.88	Ploughed down to excavation with piezometer - Woodchips about 2.5m deep. (KLM/DT)
26.05.88	Woodchips replaced from removal in Feb.-Mar. piezometer on lower slope. Water in river low. (KLM)
08.07.88	Good flow in river, muddy, not high now. (KLM)
11.08.88	Creek very low, hardly any flow. (KLM)
14.09.88	Relatively high muddy water. (KLM/PK)
10.88	Thermal imagery showed a 8m dia. hot zone in mid. slope. (IPL 1988 Maintenance and Monitoring Report)
07.12.88	Area mid-slope hot spot 4m X 5m (has been staked) (AB/JG)
.89	Removal and replacement of wood chips in a hot zone at top of slope. (IPl 1989 Maintenance and Monitoring Report)
15.03.89	Hagglund closing up hole made to cool hot spot in wood chips just below cables in middle slope. Opened several weeks ago. Shovelling out snow first. (KM/MB/AT)
21.05.89	Hole that was made to cool off hot spot in mid slope last winter and refilled in March looks in good shape. (MB/VA)
02.07.89	T2 at upper wood chips, above hot spot opened last winter, heating. (KLM,DEL)

11.89	During the 1988 slope monitoring programs, a small hot zone remained at the top of Slope 74. The larger, lower zone showed no evidence of regeneration of heat. (1989 Report on Monitoring of Construction and Operation)
08.09.89	Creek drier than earlier August. (KLM/PK)
15.09.90	Piezometer at bottom broken. (KLM/WS)
13.10.90	Snow cover about 5cm. even texture (MB/AW)
19.06.91	Water very low in creek (KLM)
01.08.91	Water lower than on tue., still considerable sediment; piezometer broken by bear. (AM/RS)
05.10.91	Abrupt changes in woodchip level midway between top two boreholes. (KLM/WS)
11.91	The warm/hot areas on the slope remained either very isolated or not too warm and no special measures are required. (1991 Report on Monitoring of Construction and Operation)
07.03.92	Snowmobiles- trails to read cables. Snow depth TA13= 58, 60, 62. T13= 67, 69, 70. T2= 50, 53, 51. (KLM)
22.05.92	Snow in depressions on wood chips and snow in bush. (WS,KLM)
03.08.92	Very uneven. Large collapse areas, the biggest being where they removed snow and chips from the hot spot a few winters ago (89?) (MB/JM)
04.10.92	13,18,14,19,20,18,17,18,18,20,19,20 down from upper hot spots - lower slope borehole Note: top tube has 4 boxes. Lower cable tube (red/white) 2 boxes. Depression below upper cables - center ROW. Snow depth at TA5 15,17,15cm, T11 same as TA, T2 same as TA5, TA13 20,21,20cm. - 3 hot spots, small size, 1-3m, lower slope several small. (KLM/DEL)
18.11.92	Two hot spots were found on slopes 75 and 74, these are new ones and are small with a 12cm layer of snow on them - all marked hotspots were not too bad and may have cooled down a bit although they are still visible with depressions in the snow. Hot spot on upper east area of slope 2.5m in diameter. Snow depth at T9/TA13 is 40cm, T2/TA16/TA5 36cm. (KH/SDa)
25.01.93	No hotspots visible from bottom - one in middle of slope not very prominent - slight depression, small hotspot at top east side of slope. Hotspot diagram on data sheet. Snow depth at TA5/TA16/T11 is 46cm, T2 47cm, TA13/T9 43cm. Snow depth: on ROW: 45 cm, off ROW: 42 cm (KH/SDa)
13.03.93	Hot spot observed. (BM/VA)
11.06.93	Creek low. Depression in wood chips above TA-13 subsided ditch at toe of wood chips. Mineral soil above slope. Contact wire jack to switch needs solder. Tension cracks at toe over pipe and on west side of wood chips. (KM)
24.07.93	Creek very low, slope uneven, thaw bulb area seems to be settling more. (KLM)
03.10.93	Tension crack and more settlement in "hot spot" between TA13 etc (lower cables) and upper w.c. cable location (snow on Oct. 6 - hot spot areas visible). T13 switch box needs repair? Trace snow at TA13/T9/T13. T13 mineral soil top of w.c. (KM/KE/DD)

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Prepared A.J.H Date 87-09-29 Checked ____ Date ____

SLOPE 74 UNNAMED S.

TEMPERATURE AT 0.9m DEPTH (°C)

		DISTANCE ALONG SLOPE, m
	1.0	50
	0.5	40
	3.3	30
	4.9	20
	0.5	10
	0	0
5.4	3.0	5
5.6	2.5	10
7.4	3.0	15
21	0.4	20
6.3	1.6	25
1.9	0.4	30
5.2	1.6	35
5.4		40
4.0	1.8	45
2.4	0.2	50
4.1	0.0	55
26	0.7	60
28	5.1	65
25	4.9	70
6.7	6.4	75
	2.4	85
	3.8	95

UPPER INSTRUMENTS

29

35

LOWER INSTRUMENTS

Slope 75 - Table Mountain
km 273.5

31.08.83	Proposed slopes monitoring Instrumentation. Design: cut to 16 degrees with 1200mm of wood chips. Comments: major ice rich clay, cut and insulate. Proposed Instrumentation: 2 shallow piezometers, 1 shallow piezometer, 1 thermister string for side cuts. (Outline of procedures and schedules for monitoring of the Norman Wells to Zama Pipeline)
07.84	Unnamed Creek North. C16 degrees + 1200. major ice rich clay, cut and insulate. Instrumentation 2P, 1P, 1CT (Post Construction Monitoring Programs for the Norman Wells to Zama Pipeline)
19.07.85	At 16 degrees = 1200, major IRC. (KLM,SD)
03.03.86	Deep loose snow, in places with a surface crust underlain by powder. (WP)
21.06.86	Woodchips and cribbing OK. (KLM/DH)
17.07.86	Shoofly adjacent to slope 75. Major gully 2 to 3m. Deep, out on east side collapsing, trees falling into shoofly. Eroded to 3m deep. (KLM)
10.08.86	Deeply eroded shoofly gully now contained flowing creek that was further eroding lower slope (Highest water level that I have observed in main creek during summer). Trees collapsing as erosion and thaw continues on east side of access. (KLM)
27.09.86	Note erosion on adjacent shoofly. Erosion continuing downward and eastward. (KLM/HB)
26.10.86	Even snow cover. (MB/VA)
86/87	Snow removed and wood chips thinned where thickness exceeded 1.4m. (IPL 1987 Maintenance and Monitoring Report)
06.02.87	Snow removed from slope. (JP)
11.03.87	Most snow cover removed, some light new snow. (KLM/AM/TS)
25.05.87	30-50cm less chips put back on; based on mounds around PVC pipes and spread to side of previous woodchip pile. (MB/AW)
12.06.87	Anomalous readings at T16. (KLM)
17.06.87	Impressive restoration of adjacent shoofly!
29.09.87	Hot zone located in Sept. 1987. Temperatures recorded were 31-35 degrees celsius at a depth of 0.9m in the wood chips. Hot spot located above upper instramentation as shown in text. (1987 IPL Maintenance and Monitoring Report)
02.88	Removed wood chips. (IPL 1988 Maintenance and monitoring report)
03.88	Replaced wood chips. (IPL 1988 Maintenance and Monitoring Report)
09.03.88	Hot spot excavated, snow plowed down center to below lowest cables. (KLM/DT)
11.08.88	T16 unstable almost no flow in creek. (KLM/AM/JN)
14.09.88	Chips out of corner on # 76. High muddy water in creek. (KLM/PK)
02.07.89	Collapse in wood chips, south slope, east corner at cribbing. (KLM/DEL)
08.09.89	Creek almost dry. (KLM/PK)
16.06.90	Water fast flow, moderately high. (KLM/CT)
15.09.90	Few tension cracks at top parallel to ditchline. (KLM/WS)
15.10.90	Differential snow melt most likely due to hot spots. Thin snow cover on upper slope, windswept. Woodchips uneven, bit of differential snowmelt. (MB/AW)
19.06.91	Stream low (KLM/CT)
05.10.91	Tension crack- west side, downslope of lower tube TA5. (KLM/DS)
10.91	Dispersal of water on wood chip slope in Oct. to cool hot spot. (1991 Report on Monitoring of Construction and Operation)
27.01.92	Snow Depth: T12 60cm, TA5 60cm, T16 55cm, TA4 60cm, CT3A 65cm. (MS,BD)
07.03.92	Didn't read cable at edge of slope. Snow Depth TA5 50, 46, 52, TA4= 62,63,58.(upper slope) (KLM)
05.92	Concerning slopes 75 and 76: Solution karst appears to be pervasive in the mountain slopes situated north east of the ROW along this section. Mountain top cracking and one suspect ancient rock avalanche deposit may indicate a landslide hazard from these slopes. I attempted to check for recent movement across cracks in the mountain ridge but snow cover was too extensive. I checked the depositional area of a suspect ancient, small rock avalanche believed to have crossed the ROW at approximately kp 275. This was also inconclusive because seasonal frost prevented any digging. I will be sending Dr. Derek Ford of McMaster University what limited information and air photos we have in the hope that he will have an opportunity to inspect the site as part of his research studies in the area. (KWS)

22.05.92	Snow gone on woodchips, Snow off ROW (KLM,WS)
03.08.92	Very uneven, collapse areas. no tension cracks. Subsided ditchline at toe. (MB/JM)
06.10.92	Several large Hot spots, with a maximum temperature of 20 degrees C at 20 cm depth (air temp. at surface 0 degrees C). Snow depth at TA4 16,14,15cm, T16 same, TA5 16,14cm, T12 same. (KM/KH/TL)
	Four hot spots, med.-large, 3-6m-plus 6m diameter or max. dimension. Max. temp. in degrees C at 20cm depth into woodchips is 20. Sample #5. (KLM/DEL)
	Sample 5 at Lower hot spot, air = 0 degrees at surface, 5-15cm depth. (KLM)
18.11.92	Two hotspots were found on slopes 75 and 74, these are new ones and are small with a 12cm layer of snow on them - all marked hotspots were not to bad and may have cooled down a bit although they are still visible with depressions in the snow. Hot spot on center of slope between two thermistor poles. 3 meters in diameter. Snow depth at TA4/T16 is 24cm, TA5/T12 31cm. (KH/SDa)
25.01.93	Hotspot between tubes approx. 2.5m dia. Snow depth at TA4/T16 is 50cm, TA5/T12 51cm. Snow depth: on ROW: 52 cm, off ROW: 50 cm (KH/SDa)
18.05.93	Evidence of creek bank instability west of pipe crossing toward the main creek. Potential for downstream damming of creek. (KLM)
24.07.93	Creek very low, clear, small depressions at hot spot marked in October. (KLM)
03.10.93	Tension cracks - vertical E. and W. sides. Stable line conditions. (Note Oct. 6 - new snow - hot spots melted on both slopes). (DD/KE)
05.12.93	Two hot spots, small. Diagram available with data sheets. (KM/KH)
26.01.94	Two hot spots on slope. (JB) (Diagram with data sheets: #1) hot spot, centre of ROW, 2m in diameter, snow depth is 20cm. #2) hot spot, Slightly off to one side of ROW, 4m in diameter, Snow depth is 12cm.)
14.03.94	65, 68, 65cm across upper slope. 5m X 8m hot spot above lower cables, snow shallower. 45, 52, 48cm at TA4 and T16. 40, 40, 42cm at TA5 and T12. (KLM,DD)

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Prepared AJH Date 87-09-29 Checked ____ Date ____

SLOPE 75, UNNAMED N.

TEMPERATURES AT 0.9m DEPTH (°C)

			DISTANCE ALONG SLOPE, m
3.1		6.3	15
6.3		3.7	5
		0 (LOWER INSTRUMENTS)	0
3.7		4.1	5
5.2		5.4	15
	UPPER INSTRUMENTS	0	2.1
5.7		3.8	25
6.3		4.5	30
7.4		2.1	35
15	32 35 34 31	14	40
5.7		1.2	45
	0.8		55
	1.4		65

Slope 76 - Unnamed South
km 273.6

21.08.83	Proposed slopes monitoring Instrumentation. Design: 1200mm of wood chips. Comments: "prevent thaw" slope. Proposed Instrumentation: 2 shallow thermister strings, 1 piezometer. (Outline of Procedures and sehedules for post-construction monitoring of the Norman Wells Pipeline)
07.84	Unnamed Creek South. 1200mm w/c. "prevent thaw" slope Instrumentation 2T, 1P. (Post Construction Monitoring Programs for the Norman Wells Pipeline)
28.03.85	New site. (KLM/MM)
19.07.85	"Prevent thaw" slope. 1200mm woodchips. (KLM/SD)
11.85	Thaw has progressed to approximately 0.5m below the wood chips. This location will be subjected to shear vane strength tests in late 1985. (1985 Report on Monitoring of Construction and Operation)
03.03.86	Considerable warmth noted on upper slope. (HB/BG) Deep snow; 44cm-60cm on ROW 50-74cm off. (WP/JP)
03.86	Snow removed and the wood chips churned up. (IPL 1986 maintenance and monitoring report)
25.05.86	Signs of lots of activity (human). Surface drilling, ruts, ploughing / dosing? warm temperatures. (MP/WP)
21.06.86	Cribbing OK, noted rough wood chips from remedial work / snow removal Mar. 1986. (KLM/DH)
17.07.86	This slope has slightly warmer internal wood chip temperatures, but lower than in 1986, reversal - upper wood chips warmer than lower ones. Highest wood chip temperatures 25 degrees celsius. (KLM)
10.08.86	Considerable sediment laden water flowing in creek. Most water that I've seen in creek. (KLM)
26.10.86	Ground warmer at upper cables, some at lower cables surface frozen, no give when walking. Surface still uneven, messed up from last winter.. (MB/VA)
11.86	Residual heat from exothermic wood decomposition has been observed at certain spots. It is planned to cool these "hot" areas during the winter 1986-1987. Vane shear tests conducted in 1986 suggest that the unfrozen areas on these slopes should be refrozen to ensure stability. (IPL 1986 Report on Monitoring of Construction and Operation)
17.12.86	warmest wood chips are at the top of slope 76 at bottom thermistor #9 on cable TA7 now +31 degrees C. Up about 9 degrees since sept 27th. (KLM)
86/87	removed wood chips and exposed soil surface to winter air for periods ranging from 19 to 30 days. (1987 IPL maintenance and monitoring report)
11.03.87	Woodchips were placed back on slope. (KLM/AM/TS)
25.05.87	About 30cm less chips were put back on? (MB/AW)
12.06.87	PVC cap missing at TA7, T5. (KLM/AM)
11.87	The thinning and snow removal techniques for cooling the wood chips were not as effective on the slopes where these techniques were tested. Small isolated patches of wood chips on these slopes warmed again in summer 1987. It is proposed that wood chips be removed and replaced from the "hot" patches on the slope. (IPL 1987 Report on Monitoring of Construction and Operation)
09.03.88	Snow not plowed. (KLM/DT)
08.07.88	Considerable flow level below cribs. (KLM)
11.08.88	Chips collapsing at cribbing. (KLM/AM/JN)
14.09.88	High muddy water. Chips missing NW corner of crib. Highest water I have seen in creek, strong flow. TA7 dead, no readings. (KLM)
21.03.90	Deeper snow, lower slope. (KLM/JB/DR)
16.06.90	Cable TA7 needs repair. (KLM/CT/DK)
03.08.90	Water flow from bottom of the wood chips and settlement of about 50cm, lowest center crib has dropped down. (KLM/DEL)
15.09.90	Moisture from SW corner of crib. Tension crack in woodchips at top of slope. (KLM/WS)
15.10.90	Snow cover over all of slope. (MB/AW)
19.06.91	Tension crack parallel to west side of ditch below T4 cable area; damp at bottom of crib transverse cracks across top of woodchips. TA7 needs repair. (KLM)
01.08.91	Toe of slope and crib repaired since Tuesday. Woodchips undercut by water at cribbing on south slope (west side) (AM/AR)
08.91	High water undercut the lower west cribbing resulting in loss of woodchips (observed July 30). This site was repaired the following day. (KLM)

10.91	A small crack trending across the ROW was discovered near the bottom of the insulated slope. Thaw subsidence in front of the log retaining crib is suspected as the cause. This will be monitored in 1992. A small old rock avalanche track is believed to cross the ROW at approximately kp 275. The depositional zone was inspected briefly from the air but heavy vegetation prevented confirmation of rockslide debris. This will be ground checked in May of 1992. Aerial photographs of the mountains immediately east of the ROW were checked to identify possible source areas. Two arrays of mountain top cracking were identified, one adjacent to the ROW at kp 275 and the other at 273. These will be checked in 1992 to determine if there is any evidence of fresh movement. (KWS)
27.01.92	Snow Depth: T4 50cm, TA12 50cm, T5 50cm, TA7 not working, not working last time. (MS,BD)
07.03.92	Slight crust of dense snow at surface at top and along upper slope. Upper TA cable not working. Snow depth T5 48,52,56. T4 50,50,51. (KLM)
22.05.92	Snow patches in depressions only. TA7 doesn't work. (KLM)
05.92	Several areas of instability on the left bank of this creek began about 350m downstream of the crossing. These areas should be monitored on an annual basis and after any long return period precipitation events. Accelerated movement could cause blockage of the creek and, possibility, flooding of the ROW. (KWS)
03.08.92	Subsided ditchline at toe with collapse area. Tension crack on west edge with slumping. (MB/JM)
04.10.92	TA7 open box but reads. Snow depth at TA7 same as T5, T5 17,18,19cm, TA12 20,18,19cm, T4 same. (KLM/DEL) Areas of hot spots (in field trip report by Kaye)
18.11.92	Snow depth at TA7/T5/T4/TA12 is 39cm. (KH/SDa)
25.01.93	Cable TA7 wires broke off inside box - box is also broken - requires new box; soldering required. Snow depth at TA7/T5 is 47cm, TA12/T4 51cm. (KH/SDa)
18.05.93	Evidence of creek bank instability west of pipe crossing toward the main creek. Potential for downstream damming of creek. (KM)
24.07.93	Chips collapsed at crib, bottom, west corner of South slope (new since June monitoring). Tension cracks on West edge. (KLM)
03.10.93	Collapsed w.c. at crib, transverse cracks at top and toe (E. side wide) horizontal rows of tension cracks all the way up W. side. (Note Oct. 6 - new snow - hot spots melted on both slopes). Stable line conditions. (DD/KE) One ? small hot spot.
03.12.93	The only hot spots we found were on slope 76 where there were two small patches that had less snow cover than the surrounding area and the wood chips were not frozen. (KE)
14.03.94	Hot spot behind flagged tension cracks at bottom. 38,38,42cm at TA12 and T4. 39, 40, 41, 42cm of snow at T5. (KLM/DD)

Slope 77, North
km 275.5

10.92 One hot spot. (KLM/DEL)

Slope 78, South
km 275.6

10.92 Four hot spots, two east upper, two bottom west.(KLM/DEL)

Slope 79 - Whitesand North
Km 279.13

03.86	Noted melt patterns in the snow. (1986 IPL Maintenance and monitoring report)
17.07.86	Whitesand North - toe of wood chips missing. Water flowing from under woodchips. (KLM)
10.08.86	Small gully eroded in wooden peg monitoring east side slope. Water flowing from bottom of wood chip slope. Considerable water in river - sediment laden. Water back in main channel. (KLM)
09.86	Water stopped from under woodchips. (KLM)
29.10.86	Snow covered. Chips soft and snow melting in patch on west side between two boreholes. Chip surface uneven and somewhat soft when walking down from top hole. (MB/VA)
11.86	The east side cut slope has been subjected to erosion. The cut will be seeded, fertilized and covered with an erosion control mat. Residual heat from exothermic wood decompostion has been observed at certain spots. It is planned to cool these "hot" areas during the winter 1986-1987. Vane shear tests conducted in 1986 suggest that the unfrozen areas on these slopes should be refrozen to ensure stability. (IPL 1986 Report on Monitoring of Construction and Operation)
06.87	Two cross drainages were partially blocked by woodchips spread out in winter at the top of Whitesand North slope (km 279). North of spoil disposal area. Drainage ditch on west (top) side of slope enlarging. May need to be rip-rapped. (KLM)
17.08.87	Three new cables, attached to stakes would appreciate new position details of thermistors, please no observed moisture seeping from under wood chips at bottom of slope as occurred last Aug. etc. water in creek very low. (KLM/CT)
15.09.87	PVC tubes now in place. Creek very low. (KLM/DH)
13.10.87	Couldn't reach down tube at HT147, will have to bring coat hanger next time. (DT/DB)
18.12.87	Melting below cable TA13 5m X 3m. HT147 switch box too far down inside PVC tube. (DT/AB)
02.88	Removed wood chips. (1988 IPL maintenance and monitoring report)
09.03.88	Middle cable frozen in bottom of tube. Snow removed. (KLM/DT)
03.88	Wood chips replaced. (1988 IPL maintenance and monitoring report)
19.04.88	Water running swiftly. (AB/FM)
26.05.88	River very low. (KLM/CT/DK)
07.88	High water has cut under wood chips at toe of slope, depositing some wood chips plus sediment on flood plain and into Whitesand Creek. (KLM)
10.07.88	Chips at base of slope have been washed out by flooding of creek which rose about 1m. Straight fresh face of expose chips rather than tapered edge. Lots of sediments freshly deposited. Chips washed into creek. (KLM/MB)
11.08.88	Water low, clear. (KLM/AM/JN)
10.88	Thermal imagery showed a 3m diameter, previously known warm zone (ie. previously 10-15 degrees celsius) now that had heated up to almost 30 degrees celsius. Wood chips will be removed and replaced again during winter 88/89. (1988 IPL maintenance and monitoring report)
89	Removal and replacement of wood chips in a hot zone. Noted a small 2m hot zone still remaining. (1989 IPL maintenance and monitoring report)
07.89	Soil from exposed cut on east side above wood chips has eroded down on to wood chips, moving markers on cut slope. This is first conspicuous soil movement I have seen here since 1985 construction. (KLM)
11.89	A very isolated hot zone remained on Slope 79. Wood chips were removed at these locations as part of the 1989 ROW maintenance program. This program appears successful, however a small 2m hot zone still remains at Slope 79. (1989 Report on Monitoring of Construction and Operation)
90	Reoccurence of warm zone since wood chip removal/replacement program carried out in 1987. Snow removed in 1990. Further snow removal planned winter 1991. (1990 IPL maintenance and monitoring report)
10.90	Differential snow melt most likely due to hot spots.(MB)
11.90	Winter 1990 description: heating of wood chips. Proposed remedial measure: removal of snow and possible excavation of wood chips. (1990 Report on Monitoring of Construction and Operation)
03.91	Snow removal from slope which hot spots were identified last fall. (MB/VA)
19.06.91	Creek low; tension crack on east side of ditch. Tension crack parallel to lower ditch. (KLM)

11.91	Removal of snow to cool wood chip slopes. The warm/hot areas on this slope remain either very isolated or not not too warm and no special measures were required. (1991 Report on monitoring of construction and operation)
22.05.92	Hot spot depression below lowest cable peizo near hotspot damaged. HT147 needs new casing (WS,KLM)
03.08.92	**Very uneven; large collapse area below broken piezo (below lower cable TA13). Small tension cracks perpendicular slope at downslope end of collapse area. Erosion on side cut on east side of ROW with fines deposited on top of chips. (MB/JM)**
04.10.92	Hot spots, second downslope tube (broken), especially around and below TA13 tube, lower slope 15cm snow, HS at to????. TA14 good snow cover around tube. TA13 hot spot area? Hot spots present - lower slope. Snow depth at TA14 17,14,15cm, TA13 5,7,5cm. Areas extending two-thirds across the slope. Photo in report. (KM/TL) Nine or more. Extensive coalescing circles.
11.92	Maintenance activities from Dec. 91 to Mar. 92 included: Snow was cleared from the wood chips on slope 79 to enhance cooling of a hot spot. (1992 Report on Monitoring of Construction and Operation)
15.03.93	Hot spots - lower one 10cm hole 15cm deep; diagram on data sheet. Snow depth at TA13 is 50cm, TA14 55cm. (BM/VA)
19.05.93	Pneumatic piezometer down slope from TA-13 is cut. Tension cracks with hot spot area go across the slope. Above cable TA-14, upper slope, tension cracks are parallel to ditch. (KM)
03.10.93	Tension crack middle of ROW - top slope - vertical. Lower piezometer damaged. Row of Hobo-Temp recorders at bottom E. side of wood chips. Picked up old HBT replacement cable - left it at Norman Wells P.S. Stable line conditions. Snow on Oct. 6 - hot spots visible. Snow depth at TA14/TA13 is 0. (KM/DD)
03.10.93	Hobo transect installation. Located hot spot with needle probe temperature sensors and wood chip temperatures were taken. Installed three Hobo's along a transect on a hot spot selected by Ted Lawrence. Each Hobo was secured with a tight rope and inserted in the wood chip layer at a depth of 30cm and a distance of 50cm. (simply pull on rope to recover all three hobo's at once) (photos were taken). (DD)

Slope 80, South
km 279.3, Whitesand

11.88	Wood chip erosion. IPL's proposed action is to collect chips and return to slope. Install reinforcement (sandbags) to hold chips in place during the winter of 1989. (IPL 1988 Report on Monitoring of Construction and Operation)
11.90	Winter 1990 description: heating of wood chips. Proposed remedial measure: remove wood chips. (1990 Report on Monitoring of Construction and Operation)
10.92	Two hot spots, small and medium, 1-3m to 3-6m. Max. Temp. recorded in degrees Celsius at about 20cm depth in wood chip is 7 degrees. (KLM/DEL)

Ochre South, Slope 82
kp 286.7

31.08.83	Proposed slopes monitoring Instrumentation. Design: 1100mm of wood chips. Comments: major ice rich clay. Proposed Instrumentation: 3 shallow thermister strings, 1 piezometer. (Outline of Procedures and Schedules for post-construction monitoring of the Norman Wells to Zama Pipeline)
07.84	Ochre South. Typical design. Very steep unfrozen till. Instrumentation 3DP (Post Construction Monitoring Programs for the Norman Wells Pipeline)
21.06.86	Some bear diggings in chips? or IPL? (KLM/DH)
17.07.86	Collapse in woodchips now very conspicuous in center of slope between mid. and upper slope cable levels. (orange stain and froth on water coming from trench area and flowing off to west side of ROW, slight sheen just below sand bag berm below chips. (KLM)
10.08.86	River - sediment laden and high, full width of river bed. (KLM)
29.09.86	Subsidence in chips. More tension cracks and subsidence over trench at bottom of slope. No evidence of remedial work on Ochre N. (KLM/HB)
29.10.86	Chip surface +_ even at top of slope. Chips softer (warmer) between mid and lower boreholes. Small crack below lower hole, 45 degrees to trench. Some snow melt in lower half, snow thinner, chips more uneven. Subsidence for a few metres on either side of trench. (MB/VA)
06.02.87	Chips blown bare, wide crack in snow 10", crack in chips 6", crack depth is 3 ft. (JB)
11.03.87	Snow removed from slope (KLM/TS)
25.05.87	Cracks in lower slope parallel trench and collapse in trench. (MB/AW)
11.06.87	Animals digging in woodchips in midslope. Tension crack diagonal on slope near TA8 and T7. lower. (KLM/AM)
17.06.87	Transverse tension crack below lowest cables, nearer toe of slope, tension cracks parallel to pipe on both sides of trench area, water flowing from trench area at toe of slope. (HB/KLM)
07.87	No surface water flowing from beneath wood chips. (KLM)
17.08.87	No apparent change since July surface undulated, collapse in wood chips over lower trench / pipe. (KLM/CT)
09.87	Two hot zones located in Sept. 1987. Temperatures recorded were 31-35 degrees celsius at a depth of 0.9m in the wood chips. (1987 IPL maintenance and monitoring report)
15.09.87	Checked top three thermistors T7 (KLM) Pronounced heating (to 12 C) was noted near the bottom of the woodchips at the lower cable on Slope 82 (Ochre S.), a north facing slope. Thermistors 1 and 2 on Cable T-7 were at 3 C on August 17, on September 15 they were 12 C and 9 C respectively. (KLM)
29.09.87	Temperature probing at 0.9m depth Large hot spot located between T1and T2, with a maximum temperature of 35 degrees celsius. Second hot spot located around T1, with a maximum temperature of 13.3 degrees. Sketches available in text. (1987 Report on Monitoring of Construction and Operation
13.11.87	Mid-slope signs of snow melting. (DT/DB)
11.87	The thinning and snow removal techniques for cooling the wood chips were not as effective on the slopes where these techniques were tested. Small isolated patches of wood chips on these slopes warmed again in summer 1987. A design for venting the base of the wood chips is proposed to be tested at Ochre River South. (IPL 1987 Report on Monitoring of Construction and Operation)
18.01.88	Melting mid slope. (AB/DT)
02.88	Installed ventilation pipes Feb. 19-22, 1988. Surface settlement of wood chips along ditch line on the lower slope are in the order of 0.5m. (1988 IPL maintenance and monitoring report) Since the system was installed in late winter the ventilation pipes did not have time to overcome continuing heat generation. Some significant cooling did occur until the summer period when the ventilation pipes were closed. (1988 Report on Monitoring of Construction and Operation, IPL, Nov.1988)
09.03.88	82-11 along pipe 300 upper east. Note new ventilation pipes and cables. (KLM/DT)
26.05.88	About 50cm depression over pipe on lower slope. (KLM/CT/DK)
07.88	North slope survived well. New undercuts and slides on south river bank east and west of pipe crossing and extending into pipe crossing. Wood chip slope: depression and small gully in wood chips, with water

flow over pipe at bottom of the slope. Thermistor in ventilation pipe now gave lower reading than in May. Ventilation pipes open. (KLM)

08.07.88 Undercutting and sliding on south bank of Ochre both upstream and downstream of pipeline crossing. Selection of new cables read. Many sensors/ cables showing variability, drifting. (MB/KLM)

11.08.88 Plastic has been put over tops of ventilation pipes. Pipe exposed July 25 at creek crossing - South side. Rip-rapped temporarily. Remedial work done at base of slope over pipe - chips smooth over trench. Creek low. Cut into South side of ROW. (KLM/AM/JN)

08.88 On July 8 and 10 monitoring, major undercutting and slumping of the high river bank up river from the south side of the pipe crossing was underway. Some bank had started to erode on the east side of the ROW at the crossing. There were riffles at the pipe crossing but water was too deep and muddy to see anything. On July 25 INAC Land Use Inspector Alvin Boyer found about 30m of exposed pipe. Exposed pipe was also observed on July 25 by IPL Environmental Co-ordinator John Hayes.

A crew was taken to the site by helicopter and temporary rip rapping of the exposed pipe was completed July 28. (IPL plans to conduct pipe and river profile survey in the fall and developed plans for winter remedial work and lowering of the pipe).

The nearest weather data is from the Mt. Gaudet fire tower north of Wrigley (near Km 305) and 15 km south of the Ochre River crossing. The June 29 to July 7 rain storm totalled 132.7mm with 80% of that falling June 30 (43.2mm, 1300 hrs) and July 1 (62.8mm, 1300 hrs). Between July 10 and July 25, an additional 11.6 mm was recorded at Mt. Gaudet; 80% of this (9.2mm) fell between July 19 and 22.

During low water in August 1987, the river flowed toward the south side of the low river bank at the pipe crossing. (In August 1986, during high water, flow covered all boulders for the full width of the pipe crossing.) On July 8 and 10, 1988, flow was across about 2/3rds of the south side of the channel and against 11 all flow occurred over about a 20m width on the river bed. Small sections of the riverbank adjacent to the pipe were continuing to fail, especially west of the center line.

Between August 10 and 22, there has been an addition 30mm of precipitation at Mt. gaudet, 70% of this fell August 14 (17.3mm/0 and 15 (3.6mm). No report yet on how this storm may have affected the crossing area. (KLM)

14.09.88 Remedial work underway at crossing. (Bags for sand being moved to site.) Water higher than Aug. 11, covering about 1/2 of crossing width. Adjacent slopes, especially upriver, continuing to fail. Water muddy. Some collapse developing again at bottom of slope, water flowing from under wood chips, muddy cross drainage in small streams between slope bottom and river bank. (KLM/CT/PK/DH)

10.88 Parallel tension cracks noted in fall of 1988. October 1988 thermal imagery showed up previously known hot spots. These will be left to cool through the ventilation pipes.

10.88 In previous years, identification and delineation of "hot" wood chips has been accomplished by sampling wood chip temperature in a grid fashion with a portible thermister rod, by observing differential snow melt in the spring and autmnn, and by observing differential settlement of the wood chip surface. In order to enhance detection capabilities, IPL undertook a program to thermally map wood chip slopes. Attempts in the autumn of 1987 were of limited success due to a high proportion of reflected infra-red radiation. In reconducted. By using a known hot spot as a reference (ie. Slope 82) and through computer enhanced analysis, results were more successful. (1988 IPL Report on Monitoring of Construction and Operation)

11.89 At Slope 82, the ventilation pipes to cool wood chips appear to have cooled the small hot zone on the lower slope. The system has noow had one full winter of operation. The main hot area on the east side of the wood chips still remains warm. The system will be re-assessed in 1990.

Identification and delineation of "hot" wood chips has been accomplished by sampling wood chip temperature in a grid fashion using a portable thermister rod, by observing differential snow melt in thte spring and autumn, and by observing differential settlement of the wood chip surface. Slope 82 will be left to cool through the ventilation pipes.

Beneath the small hot area on Slope 82, 1m of thaw is still present. While this is in excess of the design thaw for an ice rich slope, the area is very localized and the wood chips have been cooled successfully as discussed above with the exception of one hot area. This thaw is therefore not considered critical. Thaw beneath other hot zones is probably in the order of 1 to 2m, however, being quite local, the impact on overall stability is neglilible. The site will be closely monitored in 1990.

A shift in the Ocher River (Kp 286.2) and exposure of approximately thirty (30) metres of pipeline within the south flood plain. Temporary repairs were implimented by IPL during the summer of 1988 to protect the exposed sections of pipe at thte Ochre River. However , due to the nature of the

	remedial neasures required, accessibility, and remote location, permanent repairs could not take place until the winter of 1989. (1989 Report on Monitoring of Construction and Operation)
07.12.88	Read only cables in grey PVC tubes. Visual sign of heating mid slope about 1m X 2m in size. (AB/JG)
16.03.89	Remedial work at bottom slope, up to lower vent pipes. (KM/MB/AT)
02.07.89	Noted 2 new cable at upper vent pipes, pipes sealed with plastic, depression at mid slope larger. (KLM,DEL)
07.89	Watercrossing: Current main channel is on the south side, where the river bank eroded in July 1988 and pipe was replaced and reburied in March 1989. High south river bank just up-river from pipe crossing shows very recent signs of additional breaking up and slumping into river with new fans of sediment and clumps of live vegetation extending into the river -- perhaps a consequence of June 15 - 16 or even July 1 - 2 rainstorms. More changes to riverbanks downstream since September. Wood chip slope S.: Noted winter remedial work on lower slope. No current drainage observed from ditchline and woodchips are now more or less level across the ditchline. Also noted are new cables in wood chips. Major depression mid slope but no new tension cracks were currently evident. (KLM)
11.08.89	It looks fairly warm in the "hot spot" of Ocher S. Water low, low flow all at south side, black sandbags placed last summer now partly out of water. (KLM)
89	Vent pipes appear to have cooled wood chips in small hot zone on lower slope. Beneath small hot zone 1m of thaw present. Main hot zone still remains warm - expect 1 to 2m of thaw present beneath wood chips. Settlement along ditchline on lower slope fixed by removing wood chips and placing select backfill to bring up to grade. (1989 IPL maintenance and monitoring report)
21.03.90	50-60cm snow on the lower slopes where hot spots are (KLM/JB/DR)
05.90	The largest overall depression occurs at Ochre S. slope between the lower two original cable positions/boreholes and in the area where ventilation pipes have been placed. The depression area has been marked with a stick grid. A tension crack is present on the west side of the marked grid. (KLM)
16.06.90	Vents not closed river high, very muddy, water running from below wood chips in 2 locations. (KLM/CT/DK)
03.08.90	Muddy river, med. high, abrupt collapse area now in center. (KLM/WS/DEL)
15.09.90	Water low, all S. side. Small visible water flow, ditch area at base of wood chips. EMR used ground probing radar to examine the slope more extensively for thaw below the wood chips. (KLM/WSt)
15.10.90	Differential snow melt most likely due to hot spots. Differential snow melt over big hot spot depression.(MB)
11.90	Main hot zone approximately 12m across has been further cooled and constrained by ventilation pipes. Complete cooling may not be possible under present conditions, as wood chip decomposition continues. Ventilation pipes will remain operational in the winter of 1990/91 to determine if further cooling can be accomplished. (1990 Report on Monitoring of Construction and Operation)
19.06.91	Water low, more pronounced pockets of settlement in stick grid area of woodchips. Appear to be numerous small settlement or collapse areas developing within the larger settled area marked by the stick grid. (KLM)
30.07.91	Water high and full of sediment. Across 2/3rds of channel- from south water flow from ditch below wood chips. (AM/AR)
08.91	High muddy water covered about two-thirds of the currently active channel (post July 1988) with main water flow on the south side of the crossing. Water was high enough on July 30 to back into the subsided ditch area several meters (south side). Settlement, tension crack widening, and water flow from below the wood chips were evident on Slope 82. (KLM)
05.10.91	Water in river low, truck drove down slope east of T9 cable location then west to edge of stick farm "big hot area" more settlement and pockets of settlement at big hot. (KLM/DS)
11.91	Slope remain either very isolated or not too warm and no special measures are required. (1991 Report on Monitoring of Construction and Operation)
27.01.92	Grey PVC tubes only. Snow depth T7 39cm, TA2 39cm, T9 27cm, T18 18.5cm. (MS,BD)
22.05.92	Sediment in river, snow depressions, water coming out of ditch at bottom of woodchip slope. (KM,WS)
03.08.92	Tension cracks parallel slope over top of buried ventilation pipes in the main hot spot / collapse area. As chips collapse and slump to the sides of the vent pipes, cracks appear over top of pipes. Tension cracks also parallel slope along east edge of chips on lower slope; these are about 1m deep, with chips slumping towards center of ROW (not away from). Subsided ditchline on lower slope. (MB/JM)

06.10.92	Snow melted to wood chips in big hot area above TA8? Hot spots below TA8 location. Covers (garbage bags) still on vent tubes. Snow depth at T18/TA6 10,10,10cm, TA8 12,13, 13cm, T7 some. Hot spots extend two-thirds across the ROW. (KM/KH) 6 hot spots. Extensive. Max. temp. recorded in degrees C about 20cm depth in wood chips is 12. Sample #4. (KLM/DEL) Sample 4 lower hot spot, white mycel, odour, 12 degrees at 20cm, sampled 5-10cm depth (KLM)
11.92	Isolated warm wood chip areas are not considered a threat to overall slope stability as proven on the Ochre Slope. However, it is recommended that plans be formulated to water these areas next fall prior to freeze up or some other means be employed to cool off any hotter or extensive warm areas. (1992 Report on Monitoring of Construction and Operation)
18.11.92	Old hotspots are still showing as depressions in ....Snow depth at T18 is 25cm, TA15/T9/TA6 30cm, TA2 36cm. (KH/SDa)
25.01.93	Cold. Windy. No visible hotspot. Wind has kept snow levels down on top of slope. Snow depth at T18/TA15 is 20cm, T9/TA6/T7/TA2/TA8 21cm. Snow depth: on ROW: 20 cm, off ROW: 36 cm (KH/SDa)
15.03.93	Cable TA6 - no knob. Snow depth at TA15/T18 is 20cm, TA6/T9 27cm, TA2/T7/TA8 43cm. (BM/VA)
19.05.93	More tension cracks in "big hot" area. The center oval depression is conspicuous. Low volume ground water discharge in ditch at bottom of wood chips. We read original cables only. It would appear that the plastic covers over the air tube tubes were in place all winter -however I didn't visit this slope in March to verify this. If not, then summer covers (garbage bags) have been placed on tubes early this year). (KLM)
11.06.93	River low. (AM,CT)
11.06.93	Tension cracks. Water discharge from ditch, wood chip insulated slopes. (KLM)
25.07.93	Tension cracks, primarily in big hot area. Temperature of wood chips at approx. 30cm depth varied from 9 degrees outside hot spots to 20 degrees C within the hot spots. (KLM)
03.10.93	Settlement continuing - ditch + big hot and other areas, tension cracks on E. and W. of ditch/hot areas. (Snow cover on Oct. 6 - hot spots observed).(KM/KE/DD) Read IPL multi-thermistor cables with Ken Etherington at Ocher River South. (photos were taken) (DD)
06.10.93	Photos of hot spots were taken at 3:10. (DD)
05.12.93	Hot spot diagram available with data sheets. Below thermal fence, 7 ft in diameter. (KM/KH)

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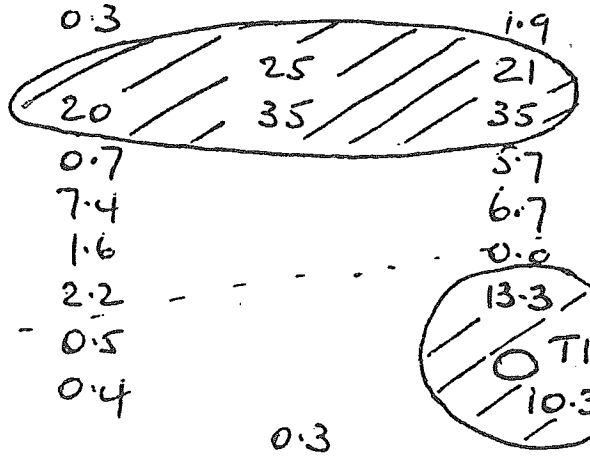
File CG14119 Subject TEMPERATURE PROBING Page No. ____ of ____

Prepared AJH Date 87-09-29 Checked ____ Date ____

SLOPE 82 OCHRE SOUTH

TEMPERATURES AT 0.9m DEPTH (°C)



DISTANCE ALONG SLOPE, m

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85

1987 Ipl Report

For final copies

Slope 109
Unnamed Creek South
KmP 351.9

15.09.88	Tension cracks appear to be more conspicuous along ditch in wood chips. (KLM/PK/CT/DH)
11.88	Excavated to observe narrow thaw bulb beneath wood chips. (1989 IPL maintenance and monitoring report)
11.89	-The extra thaw around the pipe (a thaw bulb), being constrained laterally, is not expected to result in a significant reduction in overall slope stability that might impact on the pipeline. An excavation on 11.88 confirmed this theory. (IPL- 1989 Report on Monitoring of Construction and Operation)
11.89	Tension cracks and surface depressions extensive. Probably the most uneven wood chip slope that has developed since construction. A pipe thermistor and logger were installed just north of this slope in September 1989 (see report of C.Tarnocai). (D.E.Lawrence - Annual Progress Report To INAC and IPL Nov.1989)
05.90	Uneven surface. Subsided ditch line. The depression ranges up to 50cm deep and to 3.5m wide. Tension cracks. (May 7-10 Field trip)
09.90	EMR used ground probing radar to examine the slope more extensively for thaw below the wood chips. (KLM)
11.90	-Ditch line and tension cracking will be assessed in 1991 to determine if remedial actions are necessary. -Further investigation in 10/90 at this most prominent wood chip settlement site, indicates the cause as settlement within the thaw bulb around the pipe in contrast to very shallow thaw away from the ditchline. The extra thaw around the pipe being constrained laterally, is not expected to result in a significant reduction in overall slope stability that might impact on the pipeline. (IPL- 1990 Report On Monitoring Of Construction And Operation)
10.03.91	1st readings from 91-6.
11.05.91	New PVC tube lying on ground, broken off, tried to set upright again. Probably will blow over. Piez. about 5m down slope. (KLM/MS)
05.91	Wood chip surface is uneven. Subsided ditch line. Tension cracks. (May 8-12 Field trip)
20.06.91	(tension cracks) thaw bulb appears to be widening, but hard to tell without markers and with surface disturbance. Note variation between readings. (KLM/CT)
06.91	Water flow from below wood chips. (June 14-21 field trip)
30.07.91	Chips dark and wet. Water high and sediment high.(AM/AR)
24.08.91	New temperature probes installed in ditch 25cm and 50cm from C/L- opposite cable 91-6 (which is 1.5m from C/L). Chips are 45cm thick, then sandy backfill for 1m then stiff clay. Tension cracks parallel to ditch appear - widened across slope. (MB)
09.91	Tension cracks. (Sept. 4-9 field trip)
04.10.91	Tension cracks widening, and sharp change in settlement at ditch blocks. (KM/DS)
11.91	This slope has the most dramatic wood chip settlement. There has been significant thaw in the immediate vicinity of the pipe. In contrast to the sides of the ditch line, the insulating effect of the wood chips have restrained the thaw bulb very effectively causing a high contrast in settlement across the ditch line. Installation of Monitoring equipment on wood chip slope undertaken Jan. to Mar. 1991 (IPL-1991 Report on Monitoring of Construction and Operation)
07.03.92	XL800's (#3627, 3645, 3483) connected to ditch probes serviced. All worked O.K. since installation last August. Snow depth: on ROW: 49cm,50cm,39cm. (MB/VA)
24.05.92	New small tension cracks in already subsided ditch area below new piezometer, also east side of ROW above thermistor cable. Tension cracks in ditch further up ditch above w.c. Potential to put more water in ditch. May want a berm etc. across top of wood chips to divert water from going under w.c. New ditch probes (EMR) look undisturbed. About 30cm to frost in new tension cracks. Sediment in small stream. -Wood chip ditchline subsidence above the top of the wood chips is also increasing: this increases the possibility of precipitation to collect in the ditchline above the slope. -Wood chip surface uneven. Subsided ditch line. Tension cracks. (KM/WS)
05.92	Numerous locations on the slope were probed. Frost was found at a depth of 10 to 12cm except at tension cracks which could be probed to depths of up to 45cm. A new set of tension cracks was found 1 to 1.3m

outside the prominent ones noted on previous trips. The original tension crack system has an average width of about 5m. The total width of the new set is at least 7m
and reaches highs of 7.5 to 8m. It is centered on the pipe.
I found one tension crack on the east side of the ROW which trends perpendicular to the pipeline axis. It is located 25m from the creek bank, or 5m vertically above the creek. I searched for a continuation on the west side of the centreline but found none. I encourage Mr. Lawrence to inspect this area carefully during the Oct. PTRM trip. (May Recc. and Mon. Rep, KWS)

31.07.92 1 to 2 tension cracks parallel ditchline as more material collapses in to subsided area, extend for most of slope. Transverse crack at bottom of slope. Very uneven. Large collapse areas. Cracking and slumping exposes fresher chips. Cracks and subsidence suggest width of thaw bulb increasing. Overall slope is very uneven with many sinkholes. (MB/JM)

04.10.92 Snow depth at MB 14,16,17cm at probes. Snow depth at 91-6 13,16,15cm. May have hot spots but not carefully re-checked. (KM/DEL)

15.03.93 Snow depth at 91-6 is 37cm. (BM/VA)

11.06.93 Small creek muddy. Tension cracks. (AM,KM)

24.07.93 91-6 PVC tube broken. Tension cracks parallel to ditchline. Wider and more tension cracks, and the suggestion that thaw bulb probably wider and deeper (now 5-7m across) and that seepage and flow from across the thaw bulb at base of wood chips (judging from the sedge vegetation seepage isn't new -I (Kaye) just havn't gone to bottom to check it). Cracks have been flagged. Transverse crack across toe of slope. (JM/DEL/KLM)

09.09.93 Note: more tension cracks E and W of ditch line (V) and old tension cracks wider; horizontal tension crack across toe of slope is disturbed. 91-6 tube knocked over. Soil probes west=7cm 0 ref to w.c., east probe=8.5cm 0 ref to w.c. (lowest point of surface). Line conditions unstable. (KLM)

06.10.93 Numerous hot spots visible, many over subsided ditch; EMR loggers down loaded. 2 Hobo temps. in tension cracks; 1 TC at E. side also on edge of hot spot circle. Wide thaw bulb, many tension cracks - mostly vertical at edge to ditch thaw bulb, horizontal across toe. Snow depth at 91-6 is 2cm. (KLM/DD)
Hobo tension crack installation. Hobo #4430 was installed in a tension crack adjacent to a hot spot on west side of ROW at 12:15. Installed at a depth of 20cm, and the crack was 10cm wide. Hobo was attached to orange flagging tape and secured to a branch. (Photos were taken). Hobo #4433 was installed in a tension crack adjacent to a hot spot on east side of pipe at 12:20. Installed at a depth of 30cm, and the crack was 14cm wide. Hobo was attached to orange flagging tape and secured to a branch. Located half-way down ditch blocks (i.e. cross berms) (air photos taken). (DD)

Downloaded data from loggers 3627 and 4757 at site 109 with leased notebook 386SX (file ID's 3627RB5.DAT, 4757RB2.DAT and 3486TM4.DAT with corresponding *.HEX). Logger 4755 was brought back because of technical problems. Message via software as follows: SERIAL PORT TIMED-OUT - CHECK LOGGER !. Batteries could be dead.(DD)

IPL 112
River Between Two Mountains - North
KmP 352.3

31.08.83	Proposed slopes monitoring instrumentation. Design: cut to 16 degrees with 1100m of wood chips. Comments: significant ice rich clay, cut and insulate. Proposed Instrumentation: 2 shallow thermister strings, 2 shallow piezometers, 1 thermister string for side cuts. (Outline of Procedures and Schedules for Post-Construction monitoring of the Norman Wells to Zama Pipeline)
07.06.84	1st readings from cables T10 and T15.
07.84	RB2M. Design: C16 +1100. Comments: significant ice rich clay, cut and insulate. Instrumentation: 1T, 1P, CT, 1SP. (IPL- Post Construction Monitoring Programs for the Norman Wells Pipeline)
08.03.85	One lane winter road along east side of ROW, partially drifted in when visited. Snow depths at T10 are 55cm, 59cm,58cm,61cm, T15 are 42cm,40cm,40cm and 42cm. PT depths are 64cm,59cm,55cm, and 64cm. Snow depth: on ROW 40cm-64cm. (KM/AM)
08.06.85	In wood chips at T10. Mineral soil above chips at T15.
16.07.85	Major ice rich clay C16 + 1100NC (KM/SD)
29.09.86	New snow on wood chips, about 1cm. (KM/HB)
11.03.87	Snow density measurements taken. Snow depths on ROW at T10 are 14, 15.5in., T15 are 9, 11 and 11.5in. (KM/AM/LS)
25.05.87	Slope looks OK. Bear and two cubs on bottom of slope. (MB/AW)
11.07.87	Low water in river. (KM/AM)
15.09.87	River very low. (KM/DH)
08.02.88	Tripod over pipe. (AB/DT)
09.03.88	Tracked vehicle has been along ROW. (KM/DT)
19.04.88	Wood chip slope (south exposure) almost clear of snow. Tripod over pipe. (AB/FM)
11.08.88	Water low, clear. (AM/KLM)
11.88	Depression in wood chips. Proposed action for winter of '89: Investigation ongoing. Repair as necessary. (IPL- 1988 Report on monitoring of Construction and Operation)
11.88	Excavated to observe wide thaw bulb beneath wood chips. (1989 IPL maintenance and monitoring report)
88	Significant thaw across the whole width of the ROW. (1988 IPL maintenance and monitoring report)
24.01.89	North side. Haggland used - looks like tried to repair two berms on North slope. (AB/JG)
08.09.89	River level very low. (KLM/PK/CT)
11.89	Extra thaw around the pipe (a thaw bulb), being constrained laterally, is not expected to result in a significant reduction in overall slope stability that might impact on the pipeline. An excavation on 11.88 confirmed this theory. (IPL- 1989 Report on Monitoring of Construction and Operation)
27.12.89	Snow depths 48-57cm, or 1.5-2 feet. (KLM)
22.03.90	Did not read PT's north of slope. Snow depths at T10 are 52,52,53, T15 38,38,44.
05.90	Uneven surface. Subsided ditchline. (May 7-10 Field Trip)
15.09.90	River relatively low. (KM/CT/WS)
10.03.91	New cable (91-1) is downslope from T10. Slope showed an unfrozen zone (>0 degrees C) beneath the wood chips. (MB/VA)
05.91	Wood chip surface is uneven. Subsided ditchline. (May 8-12 Field trip)
20.06.91	River full across channel, clear. (KM/CT)
30.07.91	Water level high - good strong flow at RB2M. Sediment in water. Woodchips moist and dark color. (AR/AM)
07.03.92	Cable 91-1 thawed zone, cable T10 zone with temps near 0. (KM)
24.05.92	River open, muddy. Wood chip surface smooth. (KM/WS)
31.07.92	Uneven, no pronounced ditchline subsidence. Slumping / cracks along East edge of ROW near cables. (MB/JM)
04.10.92	Hot spot - below second berm below piez (RBTM) - classic circle hot spot - lower slope near helipad. Snow depth at T15 18,15,14cm, T10 14,14,15cm, 91-1 11,12,12cm. (KM/TL) Five or more hot spots. Small and medium size, 1-3m to 3-6m. Max. temp. recorded in degrees C at about 20cm depth in wood chips is 6. Samples #2 and #3 taken.
06.10.92	Sample 2, white mycel, odour plus 5 degrees C at 20cm depth, air at -2 degrees C at surface. Sample 3,

	white mycel, odour, plus 6 degrees C at 22cm, -1 degrees C at surface. (KLM)
18.11.92	Snow depth at T15/91-1 is 34cm, T10 33cm. (SDa/KH)
25.01.93	Hard crusty areas - hollow underneath - suspect hotspot underneath - approx. 3 meters across - spots are not marked so are probably new. Hotspot diagram on data sheet. Snow depth at T15 is 38cm, T10 47cm, 91-1 46cm. Snow depth: on ROW: 45 cm, off ROW: ? (KH/SDa)
15.03.93	Snow depth at T10/91-1 is 50cm, T15 45cm. (BM/VA)
24.07.93	Slump on N facing slope, chips eroding down stream. Water level normal. Tension cracks in chips along east side of ROW (JM/DEL)
06.10.93	Piezo. tube below 91-1 fallen over. Transect of Hobo-Temp. recorders in lower woodchip hot spot (center east side). Trace snow at T15/T10. (KLM) Hobo transect installation. Located delineation and extent of hot spot with needle-probe temperature sensors and wood chip temperatures were taken at 10:05. Installed four Hobo's along a transect on a Hot spot selected by Ted Lawrence (photo's were taken). Each hobo was secured with orange flagging tape and inserted in the wood chip layer at a depth of 30cm and a distance of 1m and 50cm, respectively. (gently pull on flagging tape to recover each hobo or carefully use shovel to get to sensor).(DD)

Slope 123, North
km 403.7

10.92 Areas of hot spots. Areas extending two-thirds across the ROW. (KLM/DEL)
One hot spot, extensive. Max. temp. recorded in degrees C at about 20cm depth in wood chips is 7.
Sample #1. Check photos.
Sample 1, white mycel, odour. (KLM)

Slope 142
MacKenzie South
KmP 529.74 - 529.78

31.08.83	Proposed slopes monitoring instrumentation. Design: cut to 16 degrees with 1200mm of wood chips. Comments: major ice rich till, cut and insulate, Proposed Instrumentation: 3 shallow thermister strings, 3 piezometers, 2 thermistor strings for side cuts. (Outline of procedures and schedules for post-construction monitoring of the Norman Wells to Zama Pipeline)
07.84	Design: C16 +1200. Comments: major IRT, cut and insulate. Instrumentation: 3T, 3P, 2CT. (IPL- Post Construction Monitoring Programs...)
02.03.85	1st readings from T22.
12.03.85	1st readings from TA13, TA14, and T10.
29.03.85	Upper side cut at CT4. Borehole S142-T2 at T10. TA14 in woodchips, upper slope. Lower side cut, thick woodchips (about 4m) at CT1. TA13, and T22 are lower slope. (KM/MM)
08.06.85	1st readings from CT1, and CT4.
19.07.85	Need specs. (KM/SD)
13.08.85	Trench above woodchips hand filled since July 19. CT4 switch is stripped. Not sure of numbers on box switch. (KLM/JH)
07.09.85	Note CT1 thermistor #9 plus heating in woodchips. Not able to read T4, switch is broken. (KM/DH)
04.03.86	Deep loose snow. Snow depths are 47cm, 47cm, 54cm, 59cm, 64cm, and 65cm. Snow is 10cm over top of tube at T10. Considerable warmth noted in lower slope. (KM/WP)
27.05.86	2-3 slump cracks between top and bottom boreholes. Movement on lower slope. (MB/WP)
22.06.86	No tension cracks currently visible on woodchips. Still appears water could collect in trench above wood chip slope. (KM/DH)
15.07.86	Tubes TA14/ T10 leaning toward river, top CT tube leaning toward pipeline. (KM)
29.09.86	CT-4, could get only 5 readings, needs knob and repair. (not sure of number of thermistors). (KM)
25.10.86	Surface becoming fairly uneven, undulating lower slope shows some settlement beside trench, esp. on east side. Cracks on lower slope seen in May, no longer visible (wood twigs marking position at earlier cracks). (MB/VA)
16.01.87	Frozen switchbox at CT-4. (DT/BH)
04.02.87	West end of ROW cleared bare beginning at top, 10m above chip slope. CT4A needs knob on switchbox. T2(top) 15"12"14"14"10"17" 85T10 85TA14. T1(bottom) 18"13"15"15"17"12" T22 85TA13. CT14 3"4"2"2". (JP)
11.03.87	Chips removed and replaced. On ROW snow , wc removed. (KM/AM/LS)
13.04.87	1st readings from HT144, and HT145.
25.05.87	Smooth fresh chip surface. Layer looks 30cm thinner than before. At CT cables ridge is very steep. Aerial shots show clearly the area where chips were removed. No cracks. AT CT4A one missing top or bottom switch plug lost knob. (MB/AW)
18.06.87	Berm at top of upper slope replaced after remedial work. Lower berms (on travel side) have sand bags "plowed" down slope. Some depressions in trench above wood chips. Conditions dry. (KM/HB)
09.07.87	At T4 knobs missing needs repair. Uncertain of sequence (using vice grips). (KM/AM)
19.08.87	As in previous summers this thermistor warms up. My guess is water movements near the trench. (KM/CT)
15.09.87	Site is wet. (KM/DH)
18.01.88	Snow depth: on ROW: 60-80cm, off ROW: 55cm. (AB/DT)
08.02.88	Snow depth: on ROW: 65cm-80cm, off ROW: 50cm. (AB/DT)
08.03.88	Snow depth / density measured. (KM/DT)
27.05.88	Dry around slope. Didn't read CT4. (KM/CT/DK)
10.08.88	CT4 no knob, not sure of sequence. (AM/JN)
15.09.88	Is lower slope settling? (tube longer) at HT144. (KM/DH)
24.01.89	Snow depth at CT4 is 23cm, CT1 25cm, T22 53cm, HT144 53cm, T10 52cm, HT145 52cm. (AB/JG)
29.06.89	No tension cracks observed. (KM/PE/TL)
30.10.89	Snow depth: on ROW: 35cm, off ROW: 35cm. (DT)
11.89	At the lower portion of the slope, a thaw zone was apparent at depth in autumn of '87. The thaw appeared to encroach laterally at depth. It is suspected that an unfrozen zone remained since wood chip removal/

replacement. All thermistors froze back by 01.88. 07.88 it started again, however by autumn, the thaw from the surface coalesced and total thaw extended 2m. '89 indicated similar conditions. Since this zone previously thawed prior to wood chip removal/replacement, this is not considered significant. (IPL- 1989 Report On Monitoring Of Construction And Operation)

07.12.89 Snow depth is 50 to 56cm (excluding position of CT) (KM)

08.02.90 CT4A has no switch knob on box. (JG/SDa)

22.03.90 All frozen. CT4 and CT1 are windswept. No knob on box at CT4. Snow to top of thermistor tube. Snow depth at CT4 is 0-6cm, T10 75cm,76cm,77cm, HT145 is same as T10, CT1 5cm, HT144 70cm,71cm,74cm. (KM/DR/JB)

09.05.90 River open- opened at or same time as Liard. Smooth w.c. surface. (HB/KM)

30.07.90 The eagle is here. Warm temperatures here suggest water movement under wood chips, also note warm temp. at 3rd thermistor of HT145. (AM/KM)

16.10.90 Snow cover even. Wood chip surface uneven.
Snow depth: on ROW: 2cm. (MB/AW)

10.03.91 1st readings from 91-7, new cable, between mid. and lower ones. Snow depths at T10 are 54cm,54cm,52, HT145 are 50cm,54cm,57cm. There seems to be a lower factor of safety at this slope, IPL plans more detailed study. Slope showed an unfrozen zone (>0 degrees C) beneath the wood chips. (MB/VA/KM)

11.05.91 Tension crack- top of cut slope. (KM/MS)

05.91 Wood chip surface is smooth. Comments: holes.

20.06.91 Logs coming down river, water level appears high. (KM/CT)

29.07.91 Water high and full of sediment. (KM/AR)

11.91 There is more thaw adjacent to the pipe due to the influence of the pipe, and in some cases, this deeper thaw is probably reducing the safety factor against failure to less than the designed target of 1.5. This slope may be considered more serious.

Installation of monitoring equipment on wood chip slope undertaken Jan. to Mar. 1991. (IPL- 1991 Report on Monitoring of Construction and Operations)

Tension cracks. (Oct 4-6 Field trip)

91 This slope is in a sensitive location. It is one of the highest and longest slopes along the entire ROW. Many large, deep-seated landslides are known in the area, some of which continue to be active and new ones continue to develop. Considerable evidence of settlement was noted on the ROW, but it was judged to be performing well.

29.01.92 Strange readings on 91-7 (need double female connector). Snow depth at T22 is 66cm, 91-7 50cm, HT144 66cm, T10 73cm, HT145 73cm, CT1A 24cm, CT4A 29cm. (MS/SD)

06.03.92 Snow depths at T22 and HT144 are 74,75,78, at T10 and HT145, 75,73,76, CT4 are 25,25,28, CT1 are 24,26,27, 91.7 are 53,43,46. Cable 91-7 all sensors >0. Cable T22 thawed zone. (MB/VA/KM)

23.05.92 Ice floating down Mackenzie. Slope undulating. Note HT 145 thermistor position at top. Side of tube / #2-2cm in w.c., #3 air at surface. T22- (peizo in grey tube and newer peizo 30m lower. Wood chip surface smooth. (KM/WS)

30.07.92 Uneven chips, lower section of slope. No subsided ditchline. Chips broken down/decomposed, very fine compared to other slopes visited. Cable in lower section appears to be no longer operational. (MB/JM)

05.10.92 Piez. - white tube at bottom, probe line x3. Cable 91-7 -probe line marker here and down slope. Snow depth at CT1, T22, HT144, T10, 91-07 is 0cm. (KM/TL/KH)

11.92 A preliminary parametric study indicated that for thaw bulbs with certain depth to width ratios, there could be a significannt reduction in factor of safety. Portions of six slopes indicated potential safety factors of less than 1.3, including slope 142. Additional piezometers and thermistors were installed in Feb. 1991.

The data from temperature and piezometer instrumentation does indicate potential instability. (1992 Report on Monitoring of Construction and Operation)

19.11.92 Snow depth at CT4 is 18cm, T22/HT144/T10 27cm, HT145 28cm.
Snow depth: on ROW: 28 cm. (KH/Davidson)

27.01.93 Cold. Snow depth at CT4 is 26cm, CT1 20cm, T22 32cm, HT144 36cm, T10/HT145 28cm, 91-7 27cm.
Snow depth: on ROW: 32 cm. (KH/Davidson)

15.03.93 Snow depth at T22/HT144 is 44cm, T10/HT145 56cm, CT1 25cm, CT4 7cm, 91-7 29cm. (BM/VA)

13.06.93 Tension cracks on wood chips lower side (where wood chips cover cut) of slope small tension cracks also above wood chips in berm go across slope. (KM,AM)

23.07.93 Wider and more tension cracks. New tension cracks noted on west edge of wood chips parallel with pipe.

	(KLM)
11.09.93	More small vertical and curving (vert-horizontal) tension cracks on W. side - mid to upper w.c. tension cracks formerly (June/July) on lower east side S. of CT1 not now visible - woodchips trampled etc. West side cracks haven't appeared to open further (small sticks in some cracks). CT1 sensor #8 water flow? Line conditions stable. (KM/CT)
05.10.93	Small tension cracks - horizontal - cut side, horizontal tension crack - lower W. side - just up from T22, W. of 91-7. Stable line conditions. Snow depth at CT4/CT1/ T22/91-7/HT145 is 0. (KM/DD)
02.12.93	Snow depth at CT4 is 5cm, CT1 6cm, T22/HT144 10cm, T10/HT145 9cm, 91-7 3cm. Need vise grips. Snow depth: on ROW: 8 cm, off ROW: 10 cm (KE/KH)
28.01.94	Snow depth at CT4/CT1 is 6cm, T22/HT144 36cm, T10/HT145 33cm, 91-7 20cm. Snow depth: off ROW: 40 cm (KE/KH)