ARCTIC
VOL. 38, NO. 4 (DECEMBER 1985) P. 292-302

Surface Disposal of Waste Drilling Fluids, Ellef Ringnes Island, N.W.T.: Short-Term Observations

H.M. FRENCH[1]

ABSTRACT. An experimental procedure by which waste drilling fluids were placed upon the tundra was undertaken at the Panarctic Dome *et al.* Hoodoo N-52 wellsite on Ellef Ringnes Island during the early winter of 1981-82. Preliminary site investigations indicated ice-rich permafrost conditions and the potential for extensive terrain disturbance if a sump were constructed. During the summer of 1982 seepage of waste effluent away from the disposal area occurred, and a quantity of muds and supernatant waters entered an adjacent creek. Water-quality analyses indicated that leaching of heavy metals was slow in the short term and soluble components were quickly diluted to background levels. The major toxicity threat posed by drilling wastes is primarily one of high salinity. The low level of terrain disturbance associated with a sumpless operation is a major advantage of such a procedure.

Key words: drilling fluids, permafrost, tundra, land use regulations, terrain disturbance

RÉSUMÉ. Une procédure expérimentale fut mise en pratique au site de forage Hoodoo N-52 Panarctic Dome *et al* sure l'île Ellef Ringnes au début de l'hiver de 1981-82, selon laquelle les fluides de forage usés furent déposés sur la toundra. Des études préliminaires du site indiquèrent des conditions de pergélisol riche en glace et signalèrent la possibilité de dérangement important du terrain si une pompe était installée. Au cours de l'été de 1982, il se produisit une déperdition des déchets à partir du site de disposition et un quantité de boues et d'eaux "supernatantes" se déversèrent dans un ruisseau adjacent. Des analyses qualitatives de l'eau ont indiqué que le lessivage des métaux lourds s'effectuait lentement à court terme et que les composants solubles étaient rapidement dilués jusqu'au niveau du soubassement. La salinité élevée présente le principal danger de toxicité posé par les déchets de forage. Le peu de dérangement de terrain qu'occasionne une telle opération sans pompe devient donc un avantage important de ce processus.

Mots clés: fluides de forage, pergélisol, toundra, règlements concernant l'utilisation du terrain, dérangement du terrain

Traduit pour le journal par Maurice Guibord.

INTRODUCTION

An earlier paper (French, 1980) outlined some of the terrain and environmental problems associated with the disposal of waste drilling fluids in arctic Canada. Central to that discussion was the application of the Territorial Land Use Act and Regulations, specifically the requirement that waste drilling fluids be contained in below-ground sumps. Since that time, a comprehensive summary of many aspects of drilling fluids and cuttings (Symposium, 1980) and additional reports sponsored by the Arctic Land Use Research (ALUR) Program (e.g., French, 1981; Smith and James, 1979) have been published. Implicit in many of these studies is a reduced significance attached to the apparent toxicity of drilling effluent. According to Smith and James (1979), for example, the main inorganic contaminants associated with modern drilling muds in the High Arctic Islands are sodium, potassium, and chloride rather than, as previously thought, heavy metals. Furthermore, an industry-government working group, set up to investigate the disposal of drilling muds and cuttings in the offshore in northern Canada, states: "With present arctic drilling practices and systems, the disposal of waste drilling fluids by natural dispersion has not been shown to have detrimental environmental implications" (Kustan and Redshaw, 1982:7). Similarly, a recent consultants' report dealing with the decanting of reserve pit effluent at Prudhoe Bay, Alaska, concludes that "the direct tundra disposal of drilling reserve pit fluids can be an environmentally acceptable alternative under certain conditions" (Myers and Barker, 1984:v). Such comments necessitate a re-evaluation of the traditional procedure of containment in below-ground sumps for land-based drilling operations in northern Canada.

Within this context, an agreement was reached in the summer of 1981 between Panarctic Oils Limited, Calgary, and Land Resources, Department of Indian and Northern Affairs, Yellowknife, to obtain further information on the effects of alternate waste drilling-fluid disposal procedures for land-based wells. The specific agreement was to document a sumpless operation in which the waste effluent was placed upon the tundra surface. Sumpless operations were known to have occurred during the drilling of some of the early wells in NPR-4, Alaska, between 1949 and 1952 (French, 1978:29-34; Reed, 1958). However, they are not currently sanctioned in northern Canada, although in certain cases in Alberta sump fluids can be disposed to the lease (Younkin *et al.*, 1980). The proposed Panarctic Dome *et al.* Hoodoo N-52 well, to be located on southern Ellef Ringnes Island in the High Arctic, was chosen for this experiment. The well was drilled between September and late November 1981 and waste drilling fluids were deliberately disposed to the tundra adjacent to the rig.

This paper summarizes the progress of this experiment during the first two years and presents data that may indicate that this procedure is operationally acceptable under certain circumstances. The longer term biological implications will be summarized following further field observations in 1985.

LOCATION

The Panarctic Dome *et al.* Hoodoo N-52 wellsite is located on Meteorologist Peninsula, southern Ellef Ringnes Island, one of the most northerly of the Western Queen Elizabeth group (Fig. 1). The specific location is on the west side of the main Hoodoo River valley, approximately 20 km inland from the coast (78°11′59″N, 99°58′22″W).

[1]Departments of Geography and Geology, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5

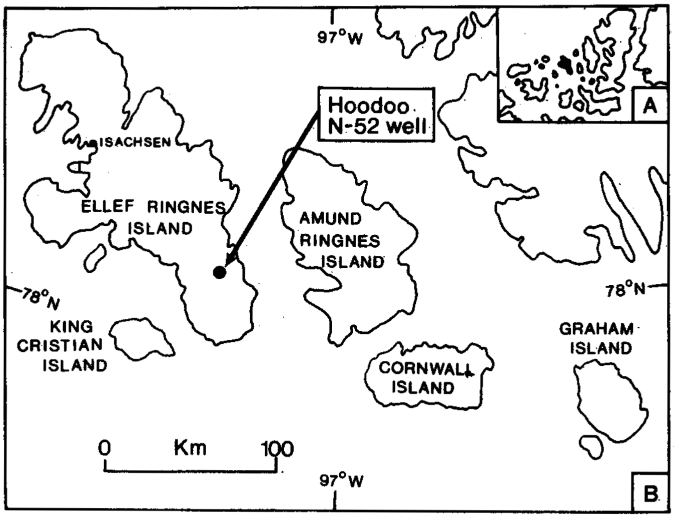

FIG. 1. Location map. A) Ellef Ringnes Island, Queen Elizabeth Islands. B) Hoodoo N-52 wellsite.

The wellsite was selected for this experimental procedure for several reasons. First, the well was to be drilled in one of the most arid polar desert environments of the High Arctic, where toxic effects, if present, would be minimized on account of the low levels of wildlife and vegetation. Second, the mud program was to consist of a Kelzan-bentonite system for the Surface Hole and a Kelzan-KCI-bentonite system for the Intermediate and Main holes. Thus, the possibility existed for testing the effects of different mud systems on the environment. Third, visits to the proposed site in July and September 1981, prior to drilling, indicated that a) the site was underlain by shales of the Christopher Formation, widely known to be ice rich and highly susceptible to thaw erosion and slope instability, and b) the sump was to be located adjacent to a small ephemeral water course draining to the main Hoodoo River. It was anticipated that below-ground containment would prove difficult and that substantial terrain disturbance would result from sump construction and infilling.

The remainder of this paper summarizes the preliminary site investigations in the summer of 1981, the progress of the drilling operation in the early winter of 1981/82, and observations made in the following summer.

PRELIMINARY SITE INVESTIGATIONS

Prior to the commencement of drilling in late September 1981, preliminary site investigations focussed upon the terrain, permafrost, and vegetation conditions.

Relief and Drainage

A detailed topographic survey of the site was undertaken in mid-July 1981. The rigpad was to be located on a gently sloping surface at an elevation of 40.5 m a.s.l., approximately 300 m from the west bank of the main Hoodoo River channel (Fig. 2A) and approximately 250 m from a small tributary stream flowing north and then east in a shallow valley, 1-4 m deep, toward the main Hoodoo River (Fig. 2B).

A shallow semicircular depression, located approximately 75 m from the rigpad and draining to the north, was identified as a possible surface disposal area for waste drilling fluids. In all probability, the depression was the scar of an old earthflow, now stabilized.

Vegetation

Southern Ellef Ringnes Island and adjacent areas are in the zone of polar semi-desert vegetation (Bliss, 1975; Edlund, 1978). In such areas, flowering plants typically provide only 5-25% cover, lichens and mosses may account for 10-30% cover, and in many areas bare ground may be 50-90% cover.

Four native plant communities were identified within the lease area. The first was dominated by arctic rush (*Luzula* sp.) and mosses with no bare ground. The second, developed on fine silty sands, and with better drainage, consisted of more species and considerable moss and lichen cover (Fig. 3A). The third community, consisting of the arctic foxtail grass (*Alopecurus alpinus*), essentially no lichens and mosses, and a great deal of bare soil, occurred on silty clay-loam soils developed from Christoper shales (Fig. 3B). The fourth community was located on the low terrace of the main Hoodoo

FIG. 2. The Hoodoo N-52 wellsite. A) General view of wellsite. The proposed disposal area is adjacent to helicopter and the well location is indicated by arrow. Photo taken 15 July 1981. B) Hoodoo Creek, which drains areas immediately north and west of proposed wellsite. Photo taken 16 July 1981.

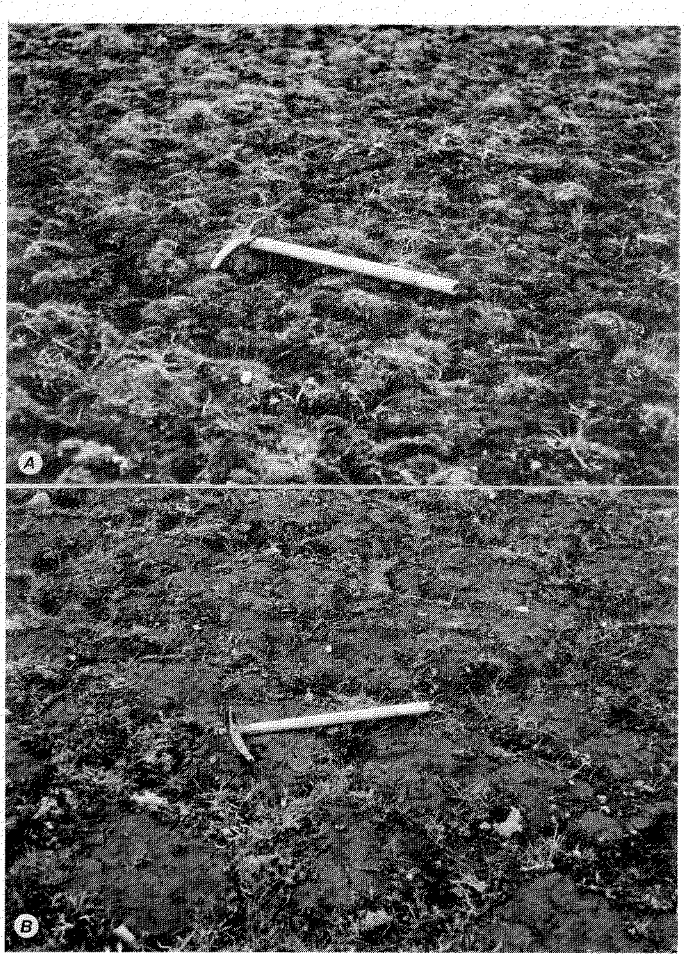

FIG. 3. Vegetation conditions near the wellsite location. A) Relatively well-drained upland tundra occurs on silty sandy alluvium, with *Luzula* sp. and *Alopecurus alpinus* dominant. Mosses and lichens constitute approximately 60% of the surface. Photo taken 17 July 1981. B) Mudboils (hummocks) occur in bare ground on silty sediments derived from Christopher shale in main disposal area. *Alopecurus alpinus* and mosses cover approximately 5–10% of the surface. Photo taken 17 July 1984.

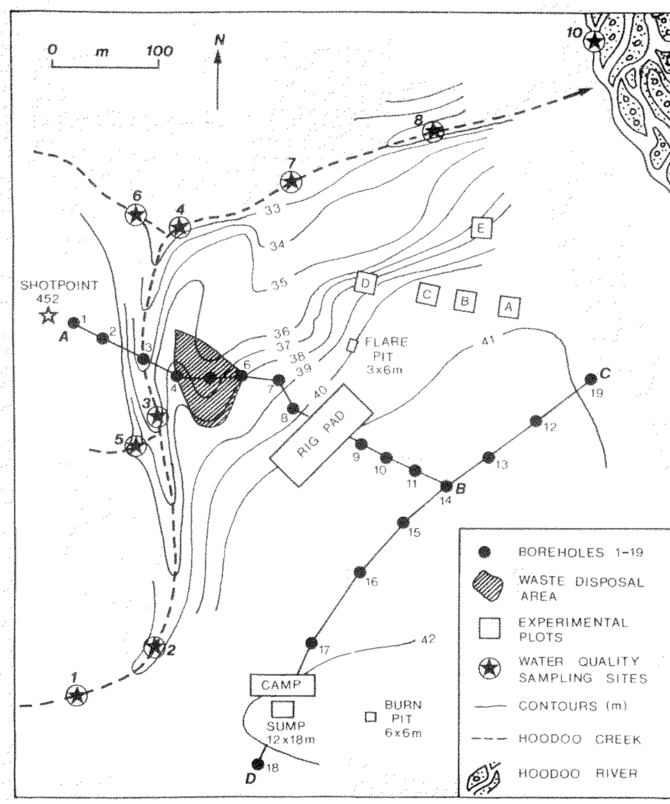

FIG. 4. Topography and site details of Hoodoo N-52 wellsite, showing location of rigpad, surficial geology boreholes, designated disposal area, experimental plots and water quality sampling positions.

River where mosses and lichens were abundant, along with arctic snow rushes (*Luzula nivalis*) and the arctic grass *Dupontia fisheri*. While this community was potentially important for muskox, it was a minor component on the lease.

The camp and wellsite had a plant cover similar to communities 1 and 2. The lower slope, where the drilling muds were to be deposited, was similar to community 3 but with some *Luzula*.

Surficial Materials

Nineteen boreholes were drilled to a depth of 10 m in two transects across the proposed site in mid-September 1981 to determine the nature of surficial materials (Fig. 4).

Two stratigraphic sequences were recognized (Fig. 5). First, sites 1-6 were underlain by non-calcareous, reworked and/or weathered silty clay thought to be derived from the Christopher Formation shale. At site 1 several resistant shale layers were encountered, suggesting the presence of unweathered bedrock near the surface. Elsewhere, and at lower elevations, the cores consisted almost entirely of ice-rich weathered and reworked clay. A second stratigraphic sequence characterized the terrace upon which the rigpad and the living quarters were to be located (i.e., holes 7–11 and 12–19). This area was underlain by a variable (1-5 m) thickness of medium and silty cross-bedded sand, lying above non-calcareous, weathered, and reworked silty sand, presumably derived in part from Christopher shale. The surficial geology seems best interpreted within the context of early Holocene marine emergence (Hodgson, 1982; St-Onge, 1965) followed by the deposition of deltaic and alluvial sediments by the ancestral Hoodoo River.

Permafrost Conditions

The entire island is underlain by continuous permafrost that exceeds 300 m in thickness (Taylor *et al.*, 1979). Temperatures logged at the adjacent abandoned Hoodoo Dome H-37 well indicate permafrost to be approximately $-15\,^{\circ}C$ at a depth of 15 m. An active layer develops between snowmelt in late June and freeze-up in late August. According to Hodgson (1982), the maximum depth of the frost table ranges from 30-50 cm in silt and clay to 50–70 cm in sand and gravel.

Little is known about ground ice conditions on the island. Hodgson (1982) presents data from 95 shallow cores, some of which were taken on Meteorologist Peninsula, and concludes that ground ice amounts vary between 5 and 50% by volume, depending upon lithology and site-specific characteristics. A few observations indicate the existence of isolated ground-ice

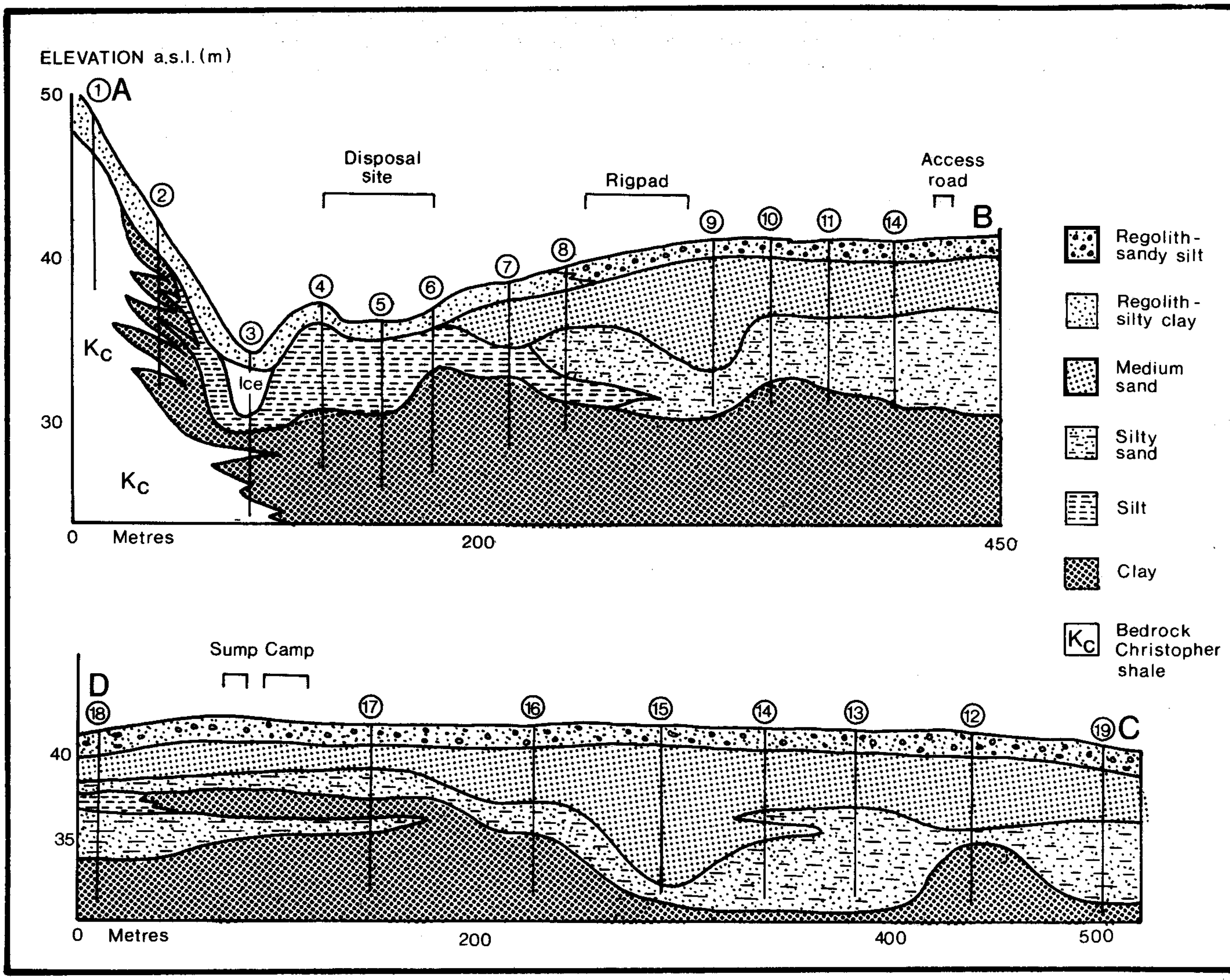

FIG. 5. Surficial geology and stratigraphy at the Hoodoo N-52 wellsite. Compiled from borehole investigations undertaken 11-14 September 1981.

bodies, especially in lowland terrain lying below the inferred maximum marine limit. For example, during the excavation for a radio beacon foundation at Isachsen in 1959, massive ice was encountered at depths of 50-70 cm (St-Onge, pers. comm. 1981), and ground-ice slumps occur in the silty sediments of the lowlands near Isachsen (Lamothe and St-Onge, 1961).

During surficial drilling small ice lenses and ice-rich sediments containing excess ice were frequently penetrated within the upper 2–3 m of permafrost. Much of the upper 5 m was ice rich. In general, ground ice amounts vary between 30 and 50% in the upper 1–3 m of permafrost and decrease to approximately 30% at depths of 5–10 m (Fig. 6). Comparison with other ground-ice distribution curves (e.g., Pollard and French, 1980) indicated that the ice content of the sediments underlying the Hoodoo wellsite was high.

DRILLING SCHEDULE AND MUD PROGRAM

Few problems were encountered during drilling in the early winter of 1981–82, although extensive reaming and directional survey at the 1250 m depth (days 27–34) took place prior to penetration of the target depth of 1450 m. Figure 7 shows the actual and projected drilling schedule for the well.

A freshwater drilling mud system was used for the Surface Hole. This consisted of Kelzan X-C polymer, a biodegradable carbohydrate biopolymer, together with GEL (Aquagel-sodium type montmorillonite, Hydrogel-Wyoming bentonite), caustic soda (NaOH), and H_2O. The Intermediate and Main holes were drilled with a potassium chloride (KCl)-based mud system. Kelzan X-C polymer and GEL (Aquagel, Hydrogel) were the other principal components. A list of mud products and chemical additives stockpiled at the site prior to spud on 29 September 1981 is given in Table 1. During drilling salinities were maintained with a preferred average of between 45 000 and 48 000 $mg \cdot L^{-1}$, the pH was maintained at between 9.5 and 10.0, and mud densities ranged between 1050 and 1150 $kg \cdot m^{-3}$.

The total volume of waste drilling effluent was projected to be approximately 800 m^3. This consisted of a) drill cuttings

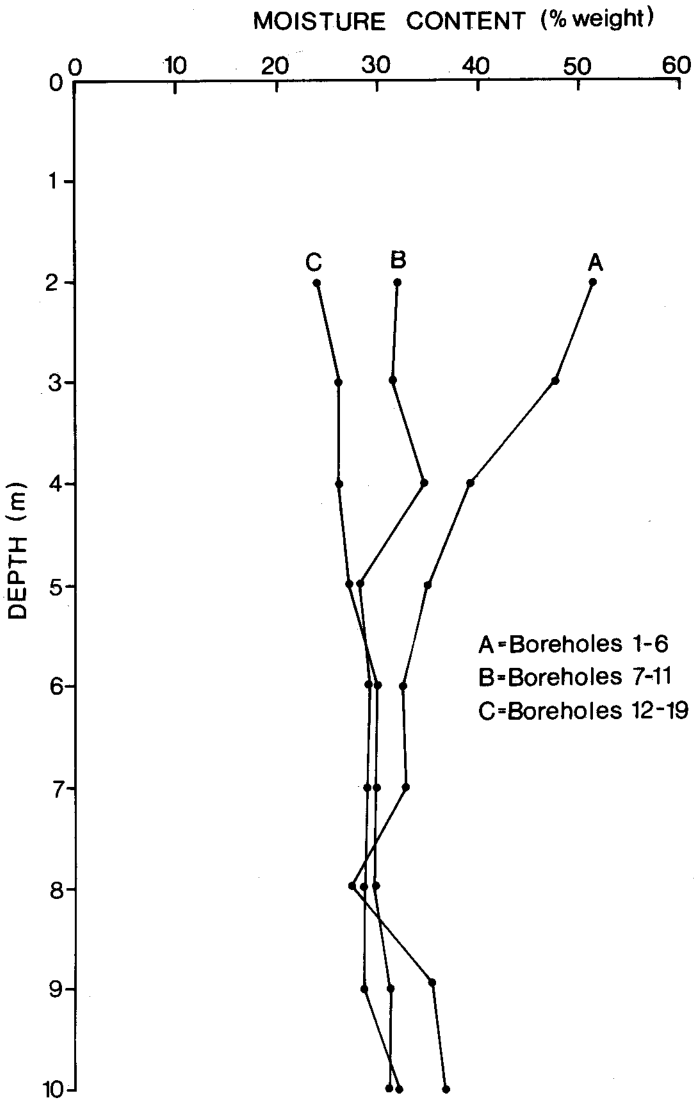

FIG. 6. Variations in ground ice volume with depth at the Hoodoo N-52 wellsite.

(i.e., solids), based upon the hole diameter and the depths drilled, and b) mud effluent. During the drilling operation, a total daily effluent volume was calculated, based upon chemicals added, the depth drilled, and the various desander and desilter losses. The estimated total volume of waste fluids, not including rigwash, was 950 m^3 for the entire operation (Panarctic Oils Limited, 1982a).

SURFACE DISPOSAL PROCEDURES

The rig was located such that the shallow depression, designated as a possible disposal area during the preliminary site investigations in July, was downslope of the rig at a distance of 75 m. The depression was capable of holding approximately 2000 m^3 of material, at least twice the estimated volume of drill cuttings and waste fluids.

It was originally envisaged that a heated pipe would carry fluids and cuttings to the disposal area, under normal gravity processes. However, there was concern that even a heated line would not prevent the freezing of effluent and cuttings in the pipe, given the often slow rate of movement at times of low effluent discharge and sub-zero temperatures. Therefore, a holding tank was constructed approximately 12 x 3 m with sides 0.75 m high, open at one end. This was placed beneath the shaker pipe outlet and parallel to the mud tanks. A front-end loader was then used to scoop the unfrozen fluids into the bucket, transport them to the disposal area and dump them (Figs. 8A, B).

Five experimental plots, each approximately 5 × 5 m, were identified and waste effluent was applied from the Surface Hole (Plot A), the Intermediate Hole (Plots B and C), and the Main Hole (Plots D and E). Between 10 and 15 m^3 of material were placed on the tundra surface and allowed to freeze.

Six freshwater fish bioassays were performed on samples of the waste effluent. An attempt was made to coordinate the sampling of waste for bioassay and chemical analysis with the laying out of the experimental plots. For example, sample 1 was collected from the Surface-Hole effluent at the time experimental Plot A was laid out. Likewise, sample 2 relates directly to Plot B. Samples 3 and 4, taken at intervals during the drilling of the Intermediate Hole, are thought to be representative of the effluent covering Plot C, although the latter was established several days after the bioassay sample was collected. Samples 5 and 6, taken at depths of 1330 and 1650 m respectively, were collected immediately before and immediately after the establishment of plots D and E. Details of the plots and the bioassay samples, and the results of the bioassay tests and chemical analyses, are presented in Tables 2 and 3.

In general there is a clear relationship between the bioassay results and the chemical composition of the drilling effluent. Least toxic was effluent from the Surface Hole (LC50 = 30%), reflecting the freshwater-based polymer system used. By contrast, the potassium chloride-based mud system, used for the Intermediate and Main holes, gave LC50 values of less than 20%. Since the bioassays were freshwater tests using rainbow trout (*Salmo gairdneri* [Richardson]), as stipulated by Land Resources, Yellowknife, and given the KCl mud system employed, these results are, perhaps, not surprising. Comparable saltwater bioassay results from offshore wells, using similar mud programs to that employed at the Hoodoo well, give LC50 values of 50% or greater (e.g., Whitefish G-63; A.R. Rossiter, Panarctic Oils Ltd., pers. comm. 1982).

SHORT-TERM RESULTS

Evaluation of Surface Disposal Procedures

During the drilling in late 1981, the absence of a sump had caused little, if any, lost drilling time. Difficulties associated with surface disposal of the drilling fluids centered upon their high mobility prior to freezing. The relatively high initial temperatures of the effluent at the outlet pipe and the depressed freezing point, resulting from the high salinity, meant

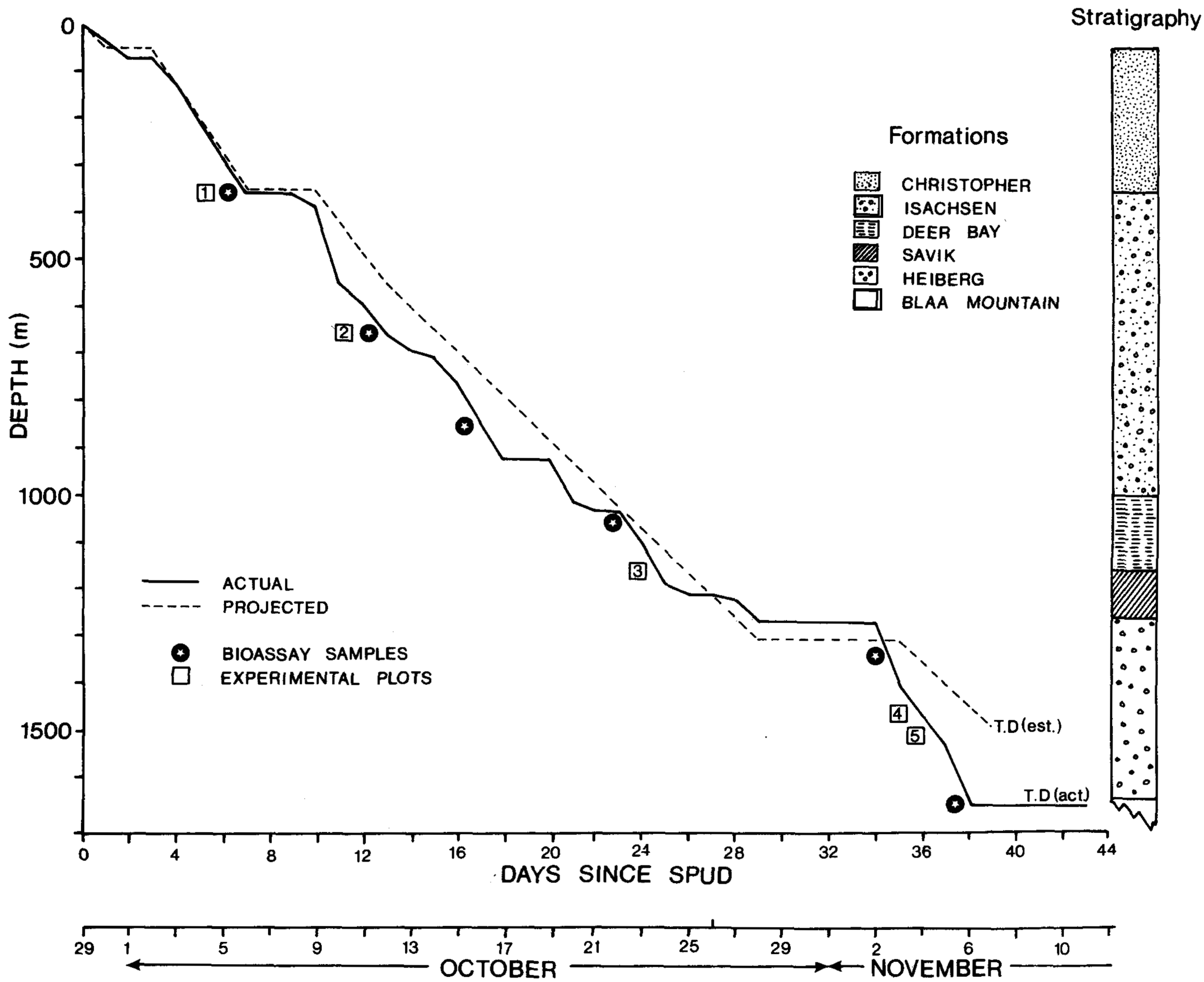

FIG. 7. Projected and actual drilling record and time of bioassay sampling and experimental plot layouts, Hoodoo N-52 well.

that the fluids took several hours to freeze (see Panarctic Oils Ltd., 1982a:55, Fig. 28).

Since drilling wastes quickly became covered with snow and were difficult to recognize in the winter darkness, a primary objective of observations the following summer was to determine the extent to which surface containment had been successful. In addition, although every effort had been made to eliminate snow from the waste fluid, the incorporation of a certain amount of snow had inevitably occurred, especially during two periods of blizzard conditions (see Panarctic Oils Ltd., 1982a:65). Thus, the volume of material involved had increased significantly from that originally projected, and the possibility of overflow from the disposal zone at the time of spring melt had to be considered.

Field observations in June and July 1982 and August 1983 indicate that the majority of the waste effluent had been contained within the designated disposal zone. In June 1982 the maximum thickness of the mud pile was 1.5–2.0 m, covering an area of approximately 0.15 km² (Fig. 9A).

TABLE 1. List of Mud and Chemical Additives Stockpiled at Site Prior to Spud, 29 September 1981

Item	Weight per Sack	No. of Sacks
Barite	40 kg	2460 sx
Bentonite	40 kg	894
Bicarbonate of Soda	100 lb	64
Caustic Soda	50 lb	180
Coat "888"		183
CMC	50 lb	25
Drispac/Staflo	50 lb	170
KCl	25 kg	2520
Kelsan	50 lb	176
Kwikseal	40 lb	84
Lime	50 lb	84
Mica	50 lb	14
Oilwell "B"	80 lb	1150
Permafrost Cement	80 lb	1750
Salt	50 lb	63
Sapp	100 lb	51
Sawdust	40 lb	180
Spersene	50 lb	163
Walnut Hulls	40 lb	37

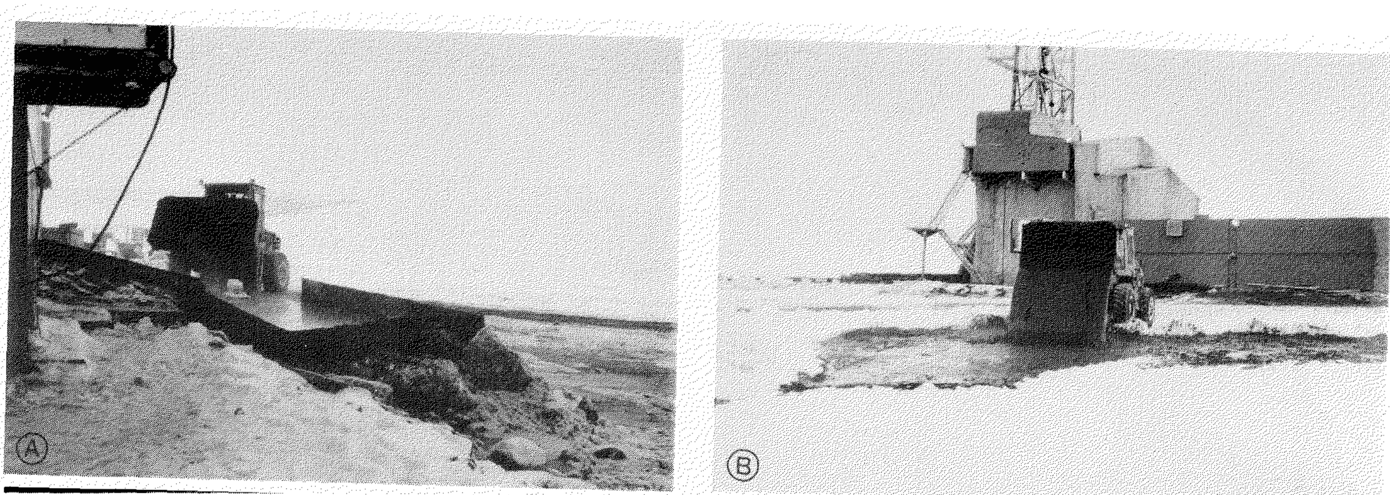

FIG. 8. Surface disposal procedures, early winter 1981–82. A) Front end loader entering holding tank to remove waste effluent. Photo taken 29 September 1981. B) Front end loader dumping waste effluent in surface disposal area. Photo taken 29 September 1981.

TABLE 2. Bioassay Results from Waste Drilling Fluid Samples, Hoodoo N-52 Well

Effluent Sample	Origin	Depth (m)	Relation to Experimental Plots	Plot Volumes	Bioassay Results* N.	T(°C)	LC50%
1	Surface Hole	350	Plot A	10m³	10	15	30.0
2	Intermediate Hole	650	Plot B	10m³	10	15	7.5
3	Intermediate Hole	850			10	15	5.0
4	Intermediate Hole	1050	Plot C	10m³	10	15	18.0
5	Main Hole	1330	Plots D,E	5m³	10	15	12.0
6	Main Hole	1650			10	15	6.0

*Test concentrations: Sample 1:10, 20, 30, 40, 50% by volume.
Samples 2, 3, 6:1, 2.5, 5.0, 7.5, 10% by volume.
Samples 4, 5:5, 10, 15, 20, 25% by volume.

TABLE 3. Chemical Analyses and Total Solids Breakdown of Waste Drilling Fluid Samples, Hoodoo N-52 Well

		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Sample Number		3847	6705	6709	6710	6734	6742
Depth (m)		350	650	850	1050	1330	1650
Total mercury	μg/L	2.0	6.85	94.6	51.0	87.0	63.0
Total copper	mg/L	0.71	2.53	3.17	1.64	9.32	7.08
Total lead	mg/L	1.32	6.22	15.98	1.74	46.5	15.35
Total chromium	mg/L	0.24	6.83	1.73	0.17	7.64	2.68
Total cadmium	mg/L	0.27	0.37	0.29	0.10	1.25	0.55
Total nickel	mg/L	9.17	16.28	29.46	9.42	26.5	28.15
Total zinc	mg/L	18.2	6.09	9.80	22.6	50.9	26.06
Dissolved mercury	μg/L	1.1	0.82	1.52	0.87	< 0.1	1.2
Dissolved copper	mg/L	<0.005	0.09	0.07	0.07	0.04	0.08
Dissolved lead	mg/L	<0.02	0.11	0.15	0.12	0.22	<0.02
Dissolved chromium	mg/L	<0.01	0.08	0.05	0.90	0.03	<0.01
Dissolved cadmium	mg/L	0.25	<0.01	0.01	0.01	<0.01	<0.01
Dissolved nickel	mg/L	0.13	0.08	0.04	0.04	0.10	0.26
Dissolved zinc	mg/L	0.21	0.12	0.08	0.05	0.16	0.78
Dissolved potassium	mg/L	111	56 880	49 720	26 220	14 400	26 600
pH		6.22	8.66	9.89	7.84	11.16	10.73
Conductivity	mS/cm	4.18	92.61	123.5	68.36	58.76	86.04
Density		1.7504	1.1321	1.1586	1.3006	1.270	1.121
Chloride	mg/L	493	21 750	30 250	20 750	36 000	46 000
Total solids	mg/L	487 380	196 620	235 760	233 660	450 160	228 575
Suspended solids	mg/L	309 100	112 312	129 676	201 540	399 100	162 400
Chemical oxygen demand	mg/L	5200	1680	3880	4080	6720	15 760
Oil and grease	mg/L	43	23	34	42	115	119

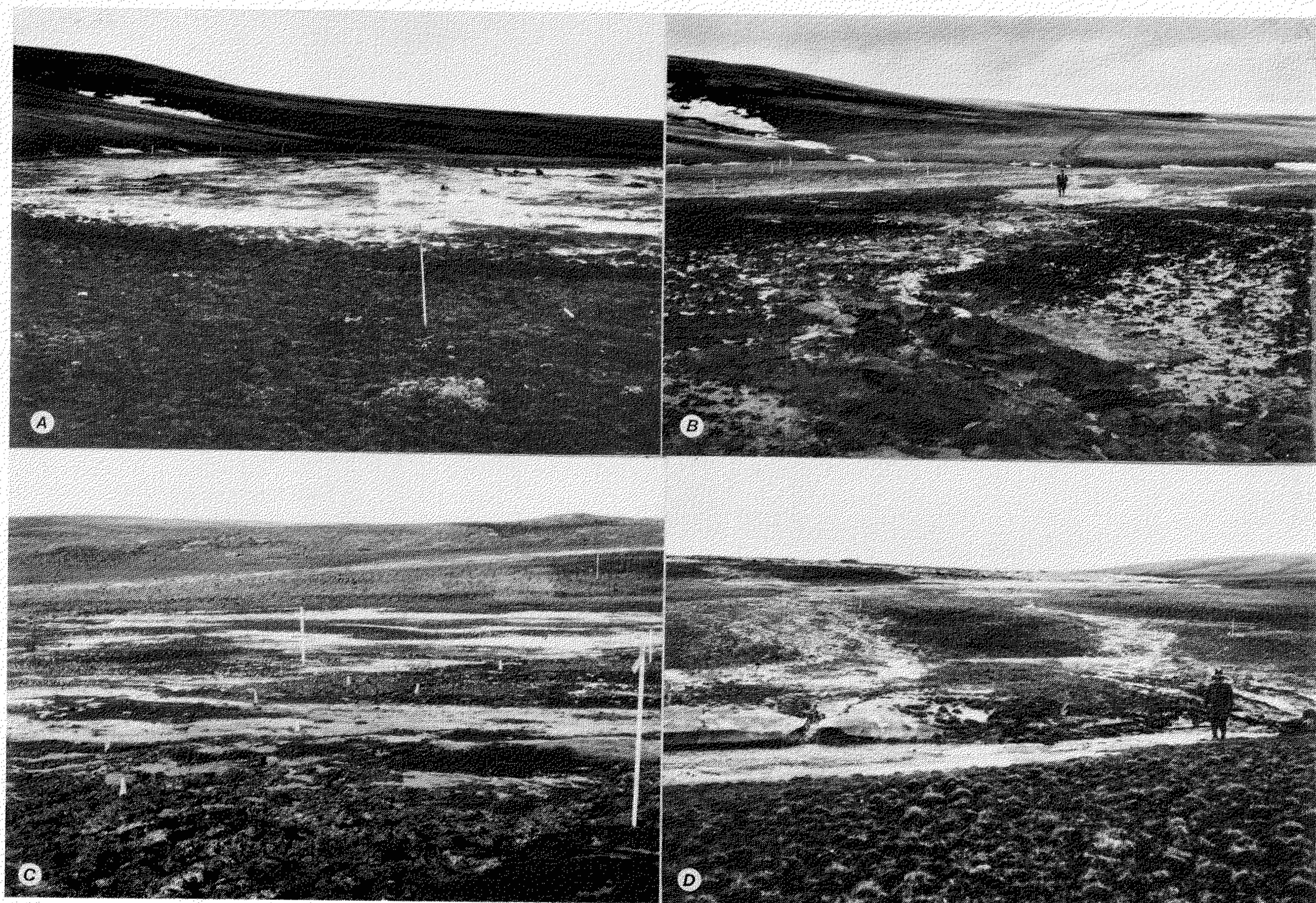

FIG. 9. Waste effluent movement, Hoodoo N-52 wellsite, early summer 1982. A) Frozen pile of drilling fluids and cuttings. Snowmelt had commenced approximately 10 days earlier and the waste drilling muds are frozen at a depth of 10 cm. Photo taken 25 June 1982. B) Looking north from main disposal zone toward Hoodoo Creek. The light-coloured muds (adjacent to person standing) are waste effluent associated with the Surface Hole. Photo taken 23 June 1982. C) Seepage zone of KCl muds and supernatant waters immediately downslope of the main disposal area. Photo taken 26 July 1982. D)Mud and supernatant water entering Hoodoo Creek (foreground). Photo taken 23 June 1982.

Thawing and Movement of Waste Effluent

By 22 June 1982 the thaw of the mud pile had already led to substantial seepage downslope toward Hoodoo Creek. Observations indicated that some mud, and certainly a significant volume of supernatant water, was entering Hoodoo Creek (Fig. 9B) and thereby being transmitted into the main Hoodoo drainage system. A thin (1-5 cm) film of mud covered approximately 8000 m² downslope of the main disposal zone. The volume of waste effluent that had moved was estimated to be 160 m³ (Panarctic Oils Ltd., 1982b:17).

Surface Water Quality

A water-quality program was undertaken during the summer of 1982 to document the magnitude and nature of the pollution that occurred. A number of sampling stations were identified on Hoodoo Creek both upstream and downstream of the point of entry of the muds and on Hoodoo River both upstream and downstream of the Hoodoo Creek junction (see Fig. 4).

At each sampling point, temperature, pH, and conductivity were measured in both June and July 1982, except at positions 5 and 6 where discharge had ceased by July. In general, temperatures in Hoodoo Creek in June were between +0.5 and +1.0°C and clearly reflected the dominance of snowmelt at that time. As might be expected, the Hoodoo River was warmer, with temperatures as high as 3.5°C. In both systems, pH values varied between 5.5 and 6.5 and were not regarded as possessing special significance, since weakly acidic values might be expected at a time when discharge is dominated by snowmelt.

Conductivity values increased immediately downstream of the mud-effluent entry point. While this probably reflected the impact of saline muds on the creek system, an equally high value was recorded upstream at point 6 on a small tributary stream (see Panarctic Oils Ltd., 1982b:27, Table 3). This may be explained by exceptionally heavy sediment concentrations derived from earthflows occurring in that gully.

Salinity and heavy metal concentrations are widely regarded as the most critical characteristics of waste drilling fluids with respect to possible toxic effects (e.g., Falk and Lawrence, 1973; Hrudey *et al.*, 1974). Accordingly, seven water samples were collected during the snowmelt period in June and an ad-

TABLE 4. Heavy Metals Analysis of Water Samples Obtained from Hoodoo Creek 26 June 1982, together with Overland Seepage Sample from Area Adjacent to the Mud Disposal Zone

	A. Upstream of Mud Disposal Zone		B. Downstream of Mud Disposal Zone		C. Overland Seepage
Sample Position:[1]	1	4	7	8	—
TOTAL[2]					
zinc	0.410	2.60	0.690	0.95	6.10
nickel	0.05	0.20	0.05	0.10	1.40
lead	*0.02	*0.02	*0.02	*0.02	7.95
cadmium	*0.002	0.005	0.003	*0.002	0.072
copper	0.015	0.170	0.045	0.045	0.20
mercury	0.0028	0.0013	0.0006	0.0005	0.0038
chromium	0.01	0.10	0.02	0.05	
DISSOLVED[2,3]					
zinc	0.270	0.290	0.060	0.040	0.380
nickel	0.025	0.125	0.05	0.075	1.125
lead	*0.02	*0.02	*0.02	*0.02	7.90
cadmium	*0.002	0.005	0.003	*0.002	0.072
copper	0.015	0.155	0.045	0.045	0.20
mercury	0.0001	0.0001	0.0001	0.0003	0.0002
chromium	0.01	0.01	0.01	0.01	0.01
potassium	1.93	4.4	80	52	5790

[1]See Figure 4. [2]All results are in mg/L, or ppm.
[3]Dissolved heavy metals were analyzed using 0.45 micron filter paper. Nitric acid was added before filtration and therefore the results of the dissolved heavy metals are higher than normal.
*Means less than.

TABLE 5. Chemical and Heavy Metal Analyses of Water Samples Obtained from Hoodoo Creek (Samples 2, 7, 8) and Hoodoo River (Sample 10), 25 July 1982

	A. Upstream of Mud Disposal Zone	B. Downstream of Mud Disposal Zone		
Sample Position[1]	2	7	8	10
pH	7.01	1.50	6.20	6.70
Conductivity (micromhos/cm)	85	19 500	295	280
Density	0.9991	1.0095	0.9991	0.9991
Chlorides	8.0	100.0	73.0	66.0
Total Solids	3520	5450	3840	1370
Total Suspended Solids	3200	4200	3620	1040
C.O.D.	202	313	287	101
TOTAL				
zinc	0.274	0.293	0.325	0.105
nickel	0.143	0.143	0.123	0.078
lead	0.07	0.05	*0.02	*0.02
cadmium	0.008	0.005	0.003	0.003
copper	0.125	0.145	0.135	0.043
chromium	0.10	0.10	0.10	*0.010
potassium	13.0	34.5	45.0	38.5
mercury	0.0004	0.0004	*0.0001	*0.0001
DISSOLVED				
zinc	0.057	0.156	0.045	0.063
nickel	0.03	0.123	*0.01	*0.01
lead	0.02	0.02	*0.02	*0.02
cadmium	*0.002	0.003	*0.002	*0.002
copper	0.005	0.108	0.005	0.005
chromium	*0.01	0.05	*0.01	*0.01
potassium	1.40	31.5	37.5	38.0
mercury	*0.0001	*0.0001	*0.0001	*0.0001

[1]See Figure 4.
*Means less than.
N.B.: All results are in mg/L, or ppm, except pH (units), conductivity (micromhos/cm) and density (gm/ml).

ditional four samples were collected in July. All were analyzed for total and dissolved solids and heavy metals. In Hoodoo Creek (Table 4), total and dissolved concentrations of zinc, nickel, lead, and cadmium were low and not markedly different between locations upstream and downstream of the mud entry point. Only copper showed a marked increase, and mercury levels actually decreased. As might be expected, an overland seepage sample, collected at a position approximately 70 m downslope of the main disposal zone in an area of maximum drilling fluid movement, showed higher concentrations of heavy metals, especially lead, zinc, and nickel.

Further analyses in July (Table 5) suggest that heavy metal concentrations did not increase significantly downstream from the point of entry. On the other hand, potassium and chloride concentrations were significantly higher downstream, suggesting that the major toxicity threat posed by drilling wastes is primarily one of high salinity.

This conclusion is supported by additional water analyses undertaken by DIAND (Sonniassy, 1982). These analyses indicate that only the soluble constituents of the waste drilling fluid, namely sodium, potassium, and chloride, were being leached out and that little or no leaching of heavy metals was occurring. However, Sonniassy (1982) cautions that there may be a lag period for the leaching of heavy metals, and the presence of high levels of soluble constituents (sodium/sulphate) and certain heavy metals (nickel/zinc) in adjacent creeks complicates interpretation.

Terrain Disturbance

One of the most striking features of the Hoodoo N-52 wellsite was the relative absence of significant physical terrain damage (Figs. 10A, B). With the exception of the camp sump and the flare pit areas, the surface of the tundra, although compacted in places, remains essentially intact. Without doubt, this situation can be attributed to a) the well being drilled in early winter when the ground was frozen, b) no main (i.e., rig) sump being constructed, and c) an on-site monitor discouraging the use of vehicles around the lease during the drilling operation. Given the highly ice-rich and unconsolidated nature of much of the underlying sediment, the prevention of extensive terrain disturbance must be regarded as a major positive result of the sumpless operation, against which the negative effects of the surface disposal program must be weighed.

CONCLUSIONS

The immediate short-term conclusions of this experiment are as follows: 1) The absence of a sump caused little, if any, drilling time to be lost. 2) Movement of muds and supernatant water away from the site during the spring snowmelt and early summer periods of 1982 was of limited extent. 3) Terrain disturbances associated with the sumpless operation were considerably less than those that might have occurred if a sump had been constructed.

The broader implications of the study have yet to be developed. If typical, the short-term observations from this study suggest that the surface disposal of drilling wastes from discrete land-based exploratory wells is operationally acceptable in the polar semi-desert regions of the High Arctic. Uncontrolled spillage and extensive physical or toxic damage need not occur in a sumpless operation. At the Hoodoo N-52 wellsite, leaching of heavy metals appears to be slow or negligible in the short term, and soluble components are quickly diluted to background levels.

From a regulatory viewpoint, a preliminary assessment of this experiment is that direct surface disposal may be an operationally acceptable procedure in those polar semi-desert environments where plant and animal productivity is low, suitable site-specific conditions are present for partial surface containment, and the potential for terrain disturbance is high.

ACKNOWLEDGEMENTS

The surface disposal experiment at the Hoodoo wellsite is being supported by the Arctic Petroleum Operators' Association (APOA), Calgary, and Land Resources, Department of Indian and Northern Affairs (DIAND), Yellowknife. A.R. Rossiter, Environmental Manager, Panarctic Oils Ltd., Calgary, undertook coordination and

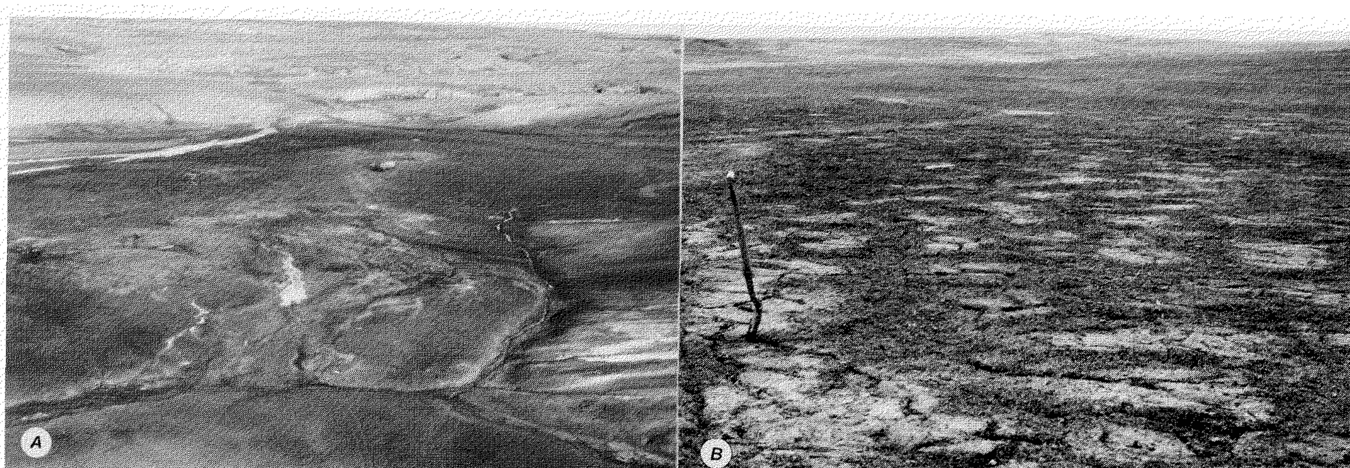

FIG. 10. Terrain disturbances associated with the Hoodoo N-52 wellsite. A) The Hoodoo wellsite following drilling. The absence of a main (rig) sump reduced terrain disturbance to a minimum. Photo taken 26 July 1982. B) Compaction and scraping of the tundra surface occurred around the wellsite but no thermokarst activity or gullying was initiated. Photo taken 25 July 1982.

logistical support, and J. Ganske, Head, Land Resources, Yellowknife, initially provided a "one-window" approach by government regulatory agencies. The interest, encouragement and constructive criticism by numerous other individuals is also acknowledged. These include: Dr. D.M. Barnett, DIAND, Ottawa; Dr. K. MacInnes, DIAND, Yellowknife; C. Cuddy, DIAND, Ottawa; B. Wilson, EPS, Yellowknife; P. Gray, GNWT, Yellowknife; and R.J. Lynn, DIAND, Yellowknife.

The determination of heavy metals and dissolved solids analyses were undertaken by both Protech Laboratories, Calgary, under the supervision of B. Wong, and the Water Resources Division Laboratory, Department of Indian and Northern Affairs, Yellowknife, under the supervision of R. Sonniassy.

On-site monitoring of the surface disposal experiment between September and December 1981 was undertaken jointly by D.G. Harry and W.H. Pollard. Field assistance during the summer of 1982 was provided by D. Burich and P. Smith.

REFERENCES

BLISS, L.C., ed. 1975. Plant and surface responses to environmental conditions in the western High Arctic. Arctic Land Use Research Program, Department of Indian Affairs and Northern Development, Ottawa. ALUR 74-75-73. 72 p.

EDLUND, S.A. 1978. Vegetation. In: Hodgson, D.A., and Edlund, S.A. 1978. Surficial materials and vegetation, Amund Ringnes and Cornwall islands, District of Franklin. Geological Survey of Canada, Open File 541.

FALK, M.R., and LAWRENCE, M.J. 1973. Acute toxicity of petrochemical drilling fluid components and wastes to fish. Technical Report Series No. CEN T-31-1. Fisheries and Marine Service, Operations Directorate, Department of the Environment, Winnipeg. 108 p.

FRENCH, H.M. 1978. Sump Studies: I. Terrain disturbances. Indian and Northern Affairs, Ottawa. Environmental Studies No. 6. 52 p.

______. 1980. Terrain, land use and waste drilling fluid disposal problems, Arctic Canada. Arctic 33:794-806.

______. 1981. Sump Studies: IV. Permafrost terrain disturbances adjacent to exploratory wellsites, Northern Yukon Territory. Indian and Northern Affairs, Ottawa. Environmental Studies No. 19. 41 p.

HODGSON, D.A. 1982. Surficial materials and geomorphological processes, western Sverdrup and adjacent islands, District of Franklin. Geological Survey of Canada, Paper 81-9. 44 p.

HRUDEY, S.E., MICHALCHUK, J., and McMULLEN, J.D. 1974. A preliminary assessment of water pollution from abandoned oil and gas drilling sumps in the Northwest Territories. Report to the industry-government working group "A" on the disposal of waste drilling fluids in the Canadian Arctic. Environmental Protection Service, Northwest Region, Environment Canada. 42 p.

KUSTAN, E.H., and REDSHAW, A.G. 1982. Report on offshore oil and gas drilling fluid disposal in the Canadian North. Industry/Government Steering Committee and Working Group. APOA, Calgary, and DIAND, Yellowknife. 9 p.

LAMOTHE, C., and ST-ONGE, D.A. 1961. A note on a periglacial erosional process in the Isachsen area, N.W.T. Geographical Bulletin 16:104-113.

MYERS, K.C., and BARKER, M.H. 1984. Examination of drilling reserve pit fluids and effects of tundra disposal at Prudhoe Bay, Alaska, 1982-84. Consultants' Report for ARCO Alaska, Inc., Prudhoe Bay, Alaska. 109 p.

PANARCTIC OILS LTD. 1982a. Surface disposal experiment of waste drilling fluids, Hoodoo N-52 well, Ellef Ringnes Island, N.W.T. Initial Report, Phase One. Consultants' Report, March 1982, by French Arctic Consults Ltd. 76 p.

______. 1982b. Surface disposal experiment of waste drilling fluids, Hoodoo N-52 well, Ellef Ringnes Island, N.W.T. Phase Two Report. Consultants' Report, December 1982, by French Arctic Consults Ltd. 57 p.

POLLARD, W.H., and FRENCH, H.M. 1980. A first approximation of the volume of ground ice, Richards Island, Pleistocene Mackenzie Delta. Canadian Geotechnical Journal 17:509-516.

REED, J.C. 1958. Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, Northern Alaska, 1944-1953. U.S. Geological Survey Professional Paper 301. 192 p.

ST-ONGE, D.A. 1965. La géomorphologie de l'ile Ellef Ringnes, Territoires du Nord-Ouest, Canada. Geographical Branch, Paper 38. 58 p.

SMITH, D.W., and JAMES, T.D.W. 1979. Sump Studies III: Biological changes in permafrost terrain adjacent to High Arctic oil and gas wellsites. Indian and Northern Affairs, Ottawa. Environmental Studies No. 16. 150 p.

SONNIASSY, R. 1982. Monitoring of surface disposal of waste drilling fluids at Hoodoo N-52 wellsite, Ellef Ringnes Island, July 1982. Internal Report, Water Resources Division, Northern Affairs Program, Department of Indian and Northern Development, Yellowknife, N.W.T. 5 p.

SYMPOSIUM. 1980. Research on environmental fate and effects of drilling fluids and cuttings. 21-24 January 1980. Lake Buena Vista, Florida. Co-sponsored. Two vols. 1122 p.

TAYLOR, A.E., JUDGE, A.S., and BURGESS, M. 1979. Canadian geothermal data collection — northern wells, 1977-78. Earth Physics Branch, Geothermal Series No. 11. 188 p.

YOUNKIN, W.E., STROSHER, M.T., and JOHNSON, D.L. 1980. Environmental assessment of the terrestrial disposal of waste drilling muds in Alberta; chemistry of sump fluids and effects on vegetation and soils. Calgary: Canadian Petroleum Association. 181 p.