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PRELIMINARY INVESTIGATIONS OF PETROLEUM SPILLAGE, HAINES-FAIRBANKS MILITARY PIPELINE, ALASKA

Warren E. Rickard
and
Frederick Deneke

April 1972

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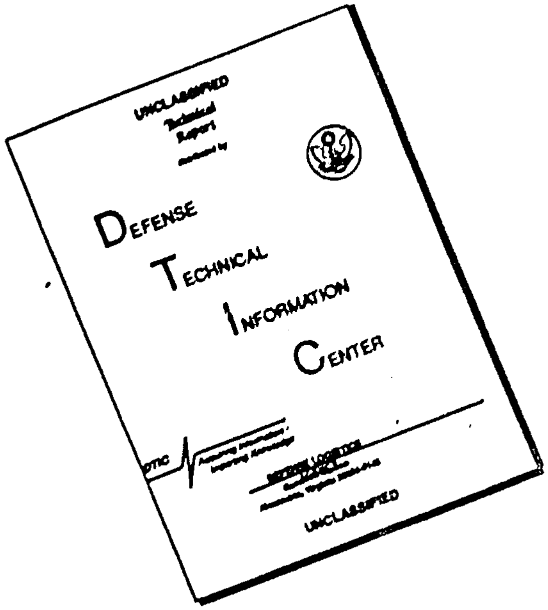

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13. ABSTRACT

The effect of various petroleum products on arctic and subarctic environments is of considerable importance. As part of the USA CRREL research effort into this problem past fuel spills along the Haines to Fairbanks military pipeline were investigated. Since the incorporation of the pipeline in 1956 there have been 40 reported ruptures in the 8-in.-diameter pipe that traverses 626 surface miles. In the spring of 1956 it was necessary to remove ice from the pipe at 26 locations. The ice resulted from water left in the line during hydrostatic testing. Portions of the line had JP-4 jet fuel in them at this time, and when the line was cut large amounts of fuel flowed out over the soil surface. Little new vegetation has grown in these areas. Currently vegetative growth is located in small drainage areas where sufficient leaching of the fuel has occurred. Considerable new growth has occurred in one area where fire had removed the overlying organic material prior to fuel spillage. Similar results are evidenced in more recent arctic diesel fuel spills resulting from bullet holes and corrosion. New vegetative growth is mostly restricted to drainage patterns subjected to sufficient leaching.

14. Key Words

Alaska-petroleum	Military transportation
Alaska-vegetation	Oil spills
	Petroleum pipelines

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PREPARED FOR
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COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

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PREFACE

This report was prepared by Mr. Warren E. Rickard, Botanist, and Lt. Frederick Deneke, Forester, Earth Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory (USA CRREL).

The study was conducted as part of Project 2N061102B71D, *Effect on the Ecology and Biochemistry in Cold-dominated Environments of Oil Seepages and Spills*, sponsored by the Army Research Office, Life Sciences Division.

The investigation required a great deal of cooperation from personnel concerned with pipeline operations. For their excellent assistance the authors are indebted to the following: Lt. Col. Billy Spinks and Mr. Leo Krupa, Petroleum Distribution Office, Fort Richardson, Alaska; Mr. Harry Young and Mr. Ben Northcott, Haines Pumping Station; Mr. Roy Ebby, Blanchard River Pumping Station; Mr. Hans Anderson and Mr. Fred McLaughlin, Destruction Bay Pumping Station; Mr. Darrel Duensing, Donjek Pumping Station; and Mr. Jack Stalberg, Beaver Creek Pumping Station. Thanks are also extended to Captain Brent McCown, USA CRREL Alaska Field Station, Fairbanks, Alaska, for his assistance in coordinating the study with the personnel at the Petroleum Distribution Office at Fort Richardson.

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PRELIMINARY INVESTIGATIONS OF PETROLEUM SPILLAGE, HAINES-FAIRBANKS MILITARY PIPELINE, ALASKA

by

Warren E. Rickard and Frederick Deneke

Introduction

In conjunction with other research into the effects of oil spills on tundra terrestrial ecosystems, USA CRREL began observations of past cuts and breaks along the Haines-Fairbanks military pipeline. Since the pipeline was built in 1956, forty recorded spills have occurred along it. Spills of differing ages provide the opportunity to compare the effects of petroleum products on vegetation and microbial activity, and to determine the relative amounts of oil remaining in the soil. This is particularly important considering current environmental concern over the proposed Trans-Alaska Pipeline and potential spills.

Description of pipeline

As early as 1950 a recognizable, growing demand existed for military petroleum products north of the Alaska Range in interior Alaska. A pipeline was considered the best possible means for transporting these products, and the Fluor Corporation, Los Angeles, California, was given the task of pipeline design by the U.S. Army Corps of Engineers. Installation of the pipeline was completed in October of 1955 with the Army assuming responsibility for its operation and supervision at that time.

The Haines-Fairbanks pipeline, as it came to be called, originates in the deepwater port of Haines and traverses 626 surface miles through Canada and Alaska to its termination at Fairbanks (Fig. 1). The pipe is 8 inches in diameter and 0.280 inch thick. It can potentially hold 210,000 barrels of fuel with an estimated value of $1,500,000. For further details see Table 1.

The primary fuels pumped through the line are:

Diesel fuel, grade DFA
Aircraft turbine and jet engine fuel, grade JP-4
Automotive combat gasoline, grade 95C
Aviation gasoline, grade 115/145.

The dispatching of products through the line is controlled from the Dispatch Division at Fort Richardson, Alaska. Through an elaborate telecommunications system all phases, including pumping pressure at individual pump stations, are monitored on a large display panel. In addition any combination of fuels can be transported through the pipe at one time by maintaining turbulent flow in the pipe. To maintain turbulent flow 450 bph (barrels per hour) must be pumped through the line. The maximum throughput of the line is 27,500 bpd (barrels per day) if all pumping stations are utilized. Table II lists the pumping stations.

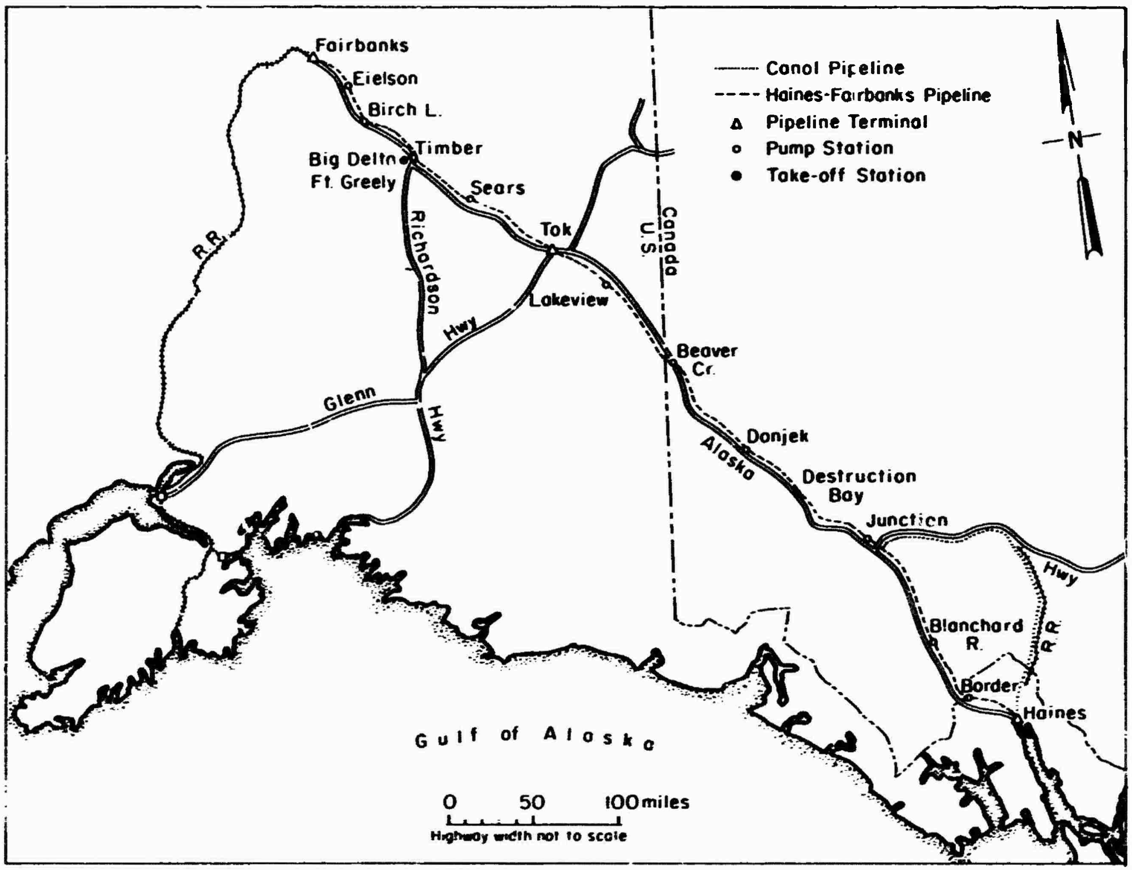

Figure 1. Pipeline route from Haines terminal to Fairbanks adjacent to the Haines and Alaska Highways.

Table I. Details of pipeline characteristics.

(From Pamphelt 360-1, *Haines-Fairbanks pipeline/ Whittier-Anchorage pipeline: General description of facilities.* Hq Petroleum Distribution Office, USARAL Support Command, December 1968.

Max discharge pressure	1440 psi	Trailers	60
Length	626 miles	Sets of quarters	52
Buried	148 miles	Permanent buildings	52
Aboveground	478 miles	Storage tanks (24 million gal)	52
Pump stations	12	Mainline valves 8 boxes	89
Major river crossings	25	Cost	$43,749,796
Major stream crossings	82	Cost per mile	$69,888
Highway crossings	49	Capacity (bpd)	27,000
Secondary road crossings	39	Capacity (gpd)	1,100,000
Major swamp and tundra areas	11	Profile range	30 to 3750 ft

Table II. Pumping stations.

Station	Distance (miles) Between stations	Distance (miles) From Haines
Border Station	47	47
Blanchard River	40	87
Junction	71	158
Destruction Bay	51	209
Donjek	39	248
Beaver Creek	76	324
Lakeview	45	369
Tok	61	430
Sears Creek	54	484
Fort Greely	44	528
Timber	15	543
Birch Lake	26	569
Eielson	29	598
Fairbanks	28	626

1956 Pipeline fuel spills

Upon completion of pipeline construction in 1955 water was pumped into the line for hydrostatic testing. With all systems working satisfactorily the U.S. Army assumed command of the pipeline operations in October 1955. When petroleum was first introduced into the pipeline it would not pass through the pipe. It was discovered that the water used to test the line had not been completely removed and that it had frozen inside the pipe, blocking petroleum flow in several locations. In January 1956 the Army began efforts to determine the exact locations of the frozen sections. By maintaining a constant line pressure of 1000 psi near the origin of the pipe, pressure differentials could be noted at various locations, thus pinpointing blocked areas. When areas of low pressure were found the line was walked and tapped with a 10-lb hammer. A sharp ringing sound indicated a clear pipe, and a peculiar sound indicated the presence of ice in the line. When ice was located the pipe was cut and the loose end placed off to the side of the 50-foot-wide right of way. It was necessary to discharge the fuel off the right of way to eliminate fire hazard when the pipe was welded back together. In some instances attempts were made to construct catch basins but these proved impractical because of the frozen ground. The line was then purged and the fuel allowed to run out onto the frozen surface. The rate of flow from the open end varied, depending on the amount of ice in the pipe, but it was known to often exceed 500 bph. The exact amount of fuel loss cannot be assessed with any degree of accuracy. A rough estimate of the volume of ice removed is in excess of 500 yd^3, ranging from small fragments to full 8-inch-diameter pieces of varying lengths.

During the deicing operations 28 known cuts were made (Table III). The methods used in the deicing work were experimental. The main objectives were 1) clearing of the line as soon as possible, 2) conservation of the product, 3) protection of natural resources and 4) safety of personnel. Wherever possible, cuts were made away from civilization and with consideration given to watershed locations. In at least one instance the fuel was burned off, with smoke being visible for miles. This method was later discarded and the fuel was left to dissipate through the natural environment.

Table III. Location of pipeline cuts.

Cut no.	PLMP*	Date cut (1956)	Date purged (1956)	Highway mile access road
1	206.1	23 Jan	2 Feb	1074.9
2	203.6	24 Jan	31 Jan	1074.9
3	196.4	28 Jan	29 Jan	1066.0
4	195.8	29 Jan	29 Jan	1066.0
5	197.1	30 Jan	30 Jan	1066.6
6	205.0	1 Feb	2 Feb	1074.9
7	207.6	2 Feb	3 Feb	1082.5
8	208.2	3 Feb	4 Feb	1082.5
9	208.6	4 Feb	4 Feb	1082.5
10	217.1	9 Feb	9 Feb	1084.6
11	217.4	9 Feb	10 Feb	1084.6
12	253.0	16 Feb	17 Feb	1124.0
13	252.4	17 Feb	17 Feb	1124.0
14	233.2	18 Feb	18 Feb	1107.3
15	251.4	19 Feb	19 Feb	1124.0
16	253.4	21 Feb	21 Feb	1124.0
17	247.9	22 Feb	23 Feb	1124.0
18	236.0	22 Feb	22 Feb	1110.0
19	242.0	24 Feb	24 Feb	1117.0
20	268.0	25 Feb	25 Feb	1146.1
21	274.5	26 Feb	4 Mar	1152.0
22	264.8	28 Feb	26 Feb	1142.0
23	273.02	29 Feb	3 Mar	1148.0
24	268.9	1 Mar	1 Mar	1146.1
25	266.0	1 Mar	1 Mar	1143.6
26	256.8	2 Mar	2 Mar	1133.6
27	303.5	7 Mar	7 Mar	1182.0
28	382.5	16 Mar	16 Mar	1266.0

*PLMP = pipeline mile post

Other pipeline fuel spills

There have been twelve recorded ruptures in the pipeline since the events described above. Of the twelve, five are attributed to corrosion of the pipe. The remaining seven were caused by man (accidents and bullet holes). Table IV contains a record of dates and locations of breaks that have occurred.

1971 Reconnaissance trip

This section describes the spill areas investigated 14, 15 and 16 June 1971.

MP 1.9, 20 June 1968. External corrosion of the pipe caused a weak spot and under pressure a hole developed in the pipe resulting in fuel spraying 100 feet into the air and saturating the surrounding vegetation and soil. The spray was blown downwind for 100-120 feet. An estimated 100 barrels of jet fuel (JP-4) were lost. All vegetation the fuel came in contact with was killed, including hemlock (*Tsuga heterophylla*), spruce (*Picea glauca*) and balsam poplar (*Populus balsamifera*). A soil pit dug in the gravelly substratum in the middle of the kill area had a strong fuel odor down to the 50-cm depth. A small stream passing through the area had some oil film on the surface. Some new growth of woody plants was noted, and a few annuals were beginning to reestablish on the banks of the small stream.

Table IV. Pipeline breaks.

Time	*Pipeline milepost locations*	*Cause*	*Loss*
a. Spring 1956	33.5	Bullet hole	Unknown
b. 3 Nov 1964	3.0	Corrosion	Unknown
c. 15 Dec 1967	420.0	Vehicle hit valve	Unknown
d. Summer 1967	585 0	Power pole auger	Unknown
e. 17 May 1968	119.1	Corrosion	4,000 Bbl
f. 20 June 1968	1.9	Corrosion	100 Bbl
g. 14 July 1968	114.5	Bullet hole	200 Bbl
h. 22 July 1968	6.5	Corrosion	50 Bbl
i. 3 Dec 1968	17.7	Corrosion	800 Bbl
j. 18 May 1969	511.0	Bullet hole	Unknown
k. 12 June 1969	290.8	Bullet hole	100 Bbl
l. 28 Sep 1970	19.5	Corrosion	1,776 Bbl

MP 3.0, 3 November 1964. A rather large corrosion hole released JP-4 into a garden. The leak was first detected through the presence of fuel in a small drainage stream that runs through the area. The fuel was discharged into the stream and followed it through a residential area and on into the bay. There was no apparent damage to vegetation other than the garden and no fish kill was reported. The soil is highly organic. Currently a strawberry patch is growing over the location and no visible aftereffects were evident.

MP 3, 1956. A weld on a small bleeder valve gave way, causing a high pressure leak with slow loss of fuel. The pipeline is buried about 4 feet deep in this location and no evidence of fuel loss was noted on the surface. First indications of fuel loss came from a resident who reported an oily taste in water from a well located ¼ mile down the slope from the valve. No vegetation kill was ever reported and currently there is nothing visible that would indicate damage.

MP 6.5, 22 July 1968. This was a very small corrosion leak that occurred in a small drainage basin. The leak was first reported by a passerby who detected the odor. The pipe was buried at this location and the fuel apparently traveled down the valley, into a small stream and eventually into a large river. Repair crews excavated the pipe, repaired the leak, and reburied the pipe when finished. A soil pit in the valley center had a strong petroleum odor down to 60 cm in the fine-grained mineral soil. The surface is currently covered with a luxuriant growth of brome. Seven to ten small birch on the perimeter of the area were among the dead vegetation present, but it was not possible to distinguish if death occurred from the spill or from mechanical damage in excavating the pipe.

MP 17.7, 3 December 1968. A small corrosion leak in a buried portion of the pipe resulted in an estimated loss of 800 barrels. The pipe had to be excavated for a great distance before the high pressure leak could be found. Fuel soon filled the excavated trench and was subsequently pumped into a tank and burned off numerous times throughout the winter. Some large cottonwoods and alders in a nearby depression were killed back, apparently from the effects of the fuel. Currently two of ten large cottonwoods have a few leaves in some upper branches. In addition, a number of new branches are growing out from the bases of the alders. However, the interior of the stand was devoid of lower canopy vegetation whereas adjacent areas showed luxuriant growth.

MP 19.5, 28 September 1970. This rupture blew a large hole in the pipeline. An Alaska Highway Department employee came upon the break soon after it began and closed a valve that was within 300 feet of the break. The spillage flowed directly into a small mountain stream and into other river tributaries. Fisheries biologists found some fish kill and damage to spawning beds and bottom life. Vegetation along the stream appears to be undamaged.

MP 33.5, 1956. This break was caused by a bullet hole in the pipe where an aerial crossing occurs on Little Boulder Creek. Immediate loss of pressure led to quick detection of the break. The fuel flowed into the rapidly moving stream and apparently was dissipated. No reports of damage to aquatic or terrestrial habitats were made.

MP 114.5, 14 July 1968. A bullet hole caused by target practice produced this break. This location is beside a garbage dump on a north-facing 20° slope. The pipe was buried following the incident and the area was greatly disturbed so that no reliable indicators of vegetative damage exist. No vegetation is growing in the area.

MP 119.1, 17 May 1968. The initial spill area is located some 600-700 feet above the west banks of Dezadeash Lake, Yukon, Canada. This spill is considered by the pipeline personnel to be the most significant in the 15-year history of the pipeline, as an estimated 4000 barrels of diesel fuel were lost. Soils in the area are highly acid and corrosive and caused the weak spot and eventual leak to form in the pipe. Large quantities of fuel permeated down the slope and out into the lake before the leak was located. Strong prevailing winds scattered much fuel along the north shore of the lake five to six miles away. Straw was scattered over the water to absorb the fuel and was then collected and burned. On the slope below the pipe, trenches were dug to collect the fuel as it flowed down the slope. The fuel from the pits was pumped into barrels and burned. A small cleanup party was left at the site for months to clean up any fuel that appeared.

A complaint was recieved in late June 1970 that the shoreline where fuel had been collected was turning reddish brown. Immediate investigations and subsequent analysis of water and soil samples showed the color to be the result of iron oxides in the water and not from the diesel fuel spill.* As the water was especially low at the time the reddish color was particularly evident.

The current investigation revealed that all vegetation in the immediate area of the spill was dead. Some elevated microrelief in the area was apparently above the greatest oil concentration and had some moss cover growing on it. Soil pits at the bottom, middle and top of the slope all had strong odors of petroleum. At least one area was observed where fuel was seeping to the surface. Fishing has apparently returned to near normal on the lake since the significant fish kill reported at the time of the spill.

MP 197.1, 30 January 1956. This area is on a north- to northeast-facing steep slope with the pipe nearly ¼ mile from the bottom of the slope. The fuel was allowed to run down the slope when the line was cut for purging. All species of vegetation were killed at the time of the spill. Some grass is growing in an old Cat trail that traverses the area but very little other new vegetation is evident. A few small white spruce 6 to 12 inches tall are growing at scattered locations within the area. There is at least one area where the surface organic mat has been washed away leaving a small depression 10 to 12 feet in diameter. Other visible evidence of slope movement is present as 2- to 4-inch cracks which can be seen where the organic mat has pulled apart. Strong petroleum odors were found in all three soil pits placed on the slope. Some hummocks have moss and labrador tea growing on them within the area. The lower portion of the slope has been cleared for construction of a telephone line and several small white spruce are growing there.

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*Tests conducted by FWQL, Portland, Oregon.

MP 207.6, 2 February 1956. This is a large area 200 feet wide near the pipe and forms an inverted V-shape 700-800 feet down a gentle slope. The area could be called a small watershed basin. Vegetation is completely lacking in the center of the main spill area. Three soil pits were placed in the kill area and on the fringe. Odors of petroleum were present in all three with the soil frozen at 20 cm.

MP 217.1, 9 February 1956. Spillage here was over an area 100 feet wide and 300 feet long on a very gentle slope. The soil appears to be very well drained. A fire had apparently covered the entire area prior to the spill as many fallen spruce were present. Areas outside the spill have good spruce and moss growth. Within the spill area a number of small spruce, labrador tea and other plants are growing. Of all the 1956 spill sites this one had the most abundant amount of vegetation.

MP 244.7, 1956. The exact date of this leak is unknown as a valve was left open by workmen when the line was being purged in 1956. An unknown quantity of JP-4 leaked out overnight into a small stream and over an area 100 feet wide by 400 feet long. Fish taken from the stream reportedly tasted of petroleum for 4 to 5 years after the spillage occurred. Currently vegetation appears to be doing quite well with willow, cottongrass, birch and moss growing over most of the area.

MP 256.8, 2 March 1956. Located on a slope, the kill area was within a small watershed. Appearance of the kill area leads to the conclusion that the fuel moved uphill on each side on the basin for 2 to 3 feet. Hummocks within the area have some spruce and willows growing on them.

MP 257.1, 1956. Same as above.

MP 268, 25 February 1956. The cut was made in a small flat area which is drained by a small stream. A soil pit at the edge of the drainage basin has a petroleum odor. A pit in the middle of the drainage area had 10-12 cm of organic matter on top with at least 2 feet of volcanic ash. No detectable odor was found here and a water sample was collected for analysis. Some spruce trees on the edge of the area were killed but a few small birch and spruce are returning.

MP 273.2, 29 February 1956. This is a rather large spill area at least 250 feet in diameter. The pipe was purged into a small drainage area on the 1-2° slope. All vegetation, of which black spruce predominates, was apparently killed at the time. The main drainage area now has vegetation growing in it. However, in those areas not directly in the drainage basin no vegetation has yet become established. A soil pit was placed in both living and dead areas.

MP 290.8, 12 June 1969. This leak was caused by a bullet that was intended for a bear in a garbage dump. The leakage progressed for 1 hour before pumping operations were stopped. The pipe in this area was buried following repair operations. As little vegetation was present prior to the spill no assessment of damage can be made. A strong odor is still present in the gravelly soil and no vegetation is growing in the area.

MP 382.5, 16 March 1956. Fuel spilled at this location was gasoline, called Mo Gas by the Petroleum Distribution Office. The site is on a very steep 40° south-facing slope. Soil is a well drained silt loam and contains a layer of fine volcanic ash. The spill killed aspen 4 to 6 inches in diameter and all the surface cover. Brumus, small aspen, fireweed and bearberry are growing at scattered locations within the area. Soil pits from mid-slope gave a strong odor of gasoline.

MP 511, 18 May 1969. This location is directly behind a scenic viewpoint at MP 1041 of the Alaska Highway. A bullet hole released an unknown amount of fuel. The pipeline has since been buried and no vegetation is growing over the disturbed area. The biggest scar left at this site is the ridge of surface material that was pushed back into the edge of the wooded area by a bulldozer.

Discussion

As has been indicated in the preceding section, methods used to evaluate the effects of petroleum spillage were both quantitative and qualitative. Originally a series of transects were planned for analysis of vegetation types growing both within and outside of spillage areas. However, after viewing the extent of dead vegetation and the time involved, this idea was abandoned. Instead qualitative observations were made as to types and locations of plants. Most areas had little or no evident vegetation regrowth even after the 15 years that had elapsed since the 1956 line cuts. New vegetation was growing within and adjacent to drainage pathways. Apparently growing conditions here had been improved by leaching of petroleum from the soil by runoff water.

Effects on woody vegetation can be seen by examining cross sections through the larger trees. Growth rings show a definite suppression in size (width) during the year spills occurred. A black spruce growing at the edge of the MP 207.6 1956 line cut has 15 years of very little growth. All growth rings since 1956 are very narrow, appearing as a band effect. Another sample of a hemlock from the rupture at MP 2 on 20 June 1968 has a very narrow growth ring with no "latewood" growth occurring during 1968. A third sample from near Dezadeash Lake shows suppressed growth following the spill. This sample also has an increase in the number of resin cells in this ring with considerable resin being exuded from the sample. This increase in resin cells is found quite often in trees subjected to fire. As the number of samples was quite small, definite conclusions cannot be made at this time. Further sampling should allow for the formulation of a definite hypothesis on the effect oil spills have on forest growth.

A series of soil samples were taken for laboratory analysis of petroleum content and microbial respiration. At the time of this writing analysis for petroleum content has been delayed as standard arctic diesel and aviation fuel samples have not arrived in the laboratory. Determination of respiration rates has begun and will take some time to complete due to the number of samples. The samples are being run on a Gilson respirometer using standard techniques. Depending on the weight per unit area of the sample 1 or 2 grams are placed into the respirometer flasks with a KOH solution placed into the center well. The flasks are placed on the respirometer and allowed to equilibrate, and then hourly readings are made of microliters of oxygen absorbed. Results are expressed as microliters per gram dry soil per hour. Preliminary results from the 1956 spill at mile 207.6 indicate a very slow rate of respiration in samples from the spill areas in contrast to control groups. Again definite conclusions can not be made until analyses of remaining samples are completed.

The fact that vegetative growth has been depressed or absent over the 15-year period is somewhat surprising. First thoughts on the matter lead to the conclusion that all of the active petroleum products should be decomposed or leached from the soil by this time. Quite apparently this has not occurred. To find reasons for this phenomenon a review was made of the military specifications of the fuel spilled from the pipeline. Thoughts were that possibly some additives had been placed into the fuel to prevent microbial growth. From form VV-F-800a, dated 22 May 1968, the only additive in diesel fuel is cetaine which is for the improvement of engine performance. No apparent antimicrobial agents are present in this fuel.

For examination of aircraft turbine and jet engine fuels used in 1956, Mil-F-5624B dated 7 December 1953 was consulted.* The JP-4 fuels are low vapor pressure, wide-cut gasoline type fuels. Among inhibitors in 1953 were the following:

(a) 2, 6-ditertiary butyl-4-methyl phenol
(b) N, N' disecondary butyl-para-phenylenediamine
(c) 2, 4-dimethyl-6-tertiary-butyl phenol.

*Copies of military specification material were supplied by Mr. Richard Horton, Quality Surveillance, Army Materiel Command, Washington, D.C.

These were added in a total concentration not to exceed 1.0 pound of inhibitor per 5000 U.S. gallons of fuel for the prevention of gum formation. It is possible that these concentrations of inhibitors could be responsible for the lack of vegetation growing on the spill areas. As of 30 October 1970 the list of antioxidants in JP-4 has grown to nine (Mil-T-5624H). The current concentrations are 9.1 g/100 gal (U.S.), 24 mg/liter or 109 mg/gal (U.K.) for gum prevention. More detailed analysis may be required to determine which, if any, compounds are still present in the soil.

Another factor that may have some influence on the presence of the petroleum in the soil is the degree of solubility in water of the petroleum. Among requirements for the JP-4 is one that states "JP-4 fuel shall separate sharply from the water layer, and there shall be no evidence of an emulsion or precipitate within or upon either layer." As the pipeline does lie in the subarctic, precipitation and temperatures are quite low. Because the fuel is not soluble in water and because of the lack of precipitation, leaching of chemicals from this soil is very slow. This also could substantiate the fact that some vegetation has been able to grow in drainage basins within the fuel spills where larger volumes of runoff occur.

APPENDIX A: PHOTOGRAPHS OF THE PIPELINE ROUTE

Figure A1. Spill area at MP 2. The road and electric line have been installed since the initial spill.

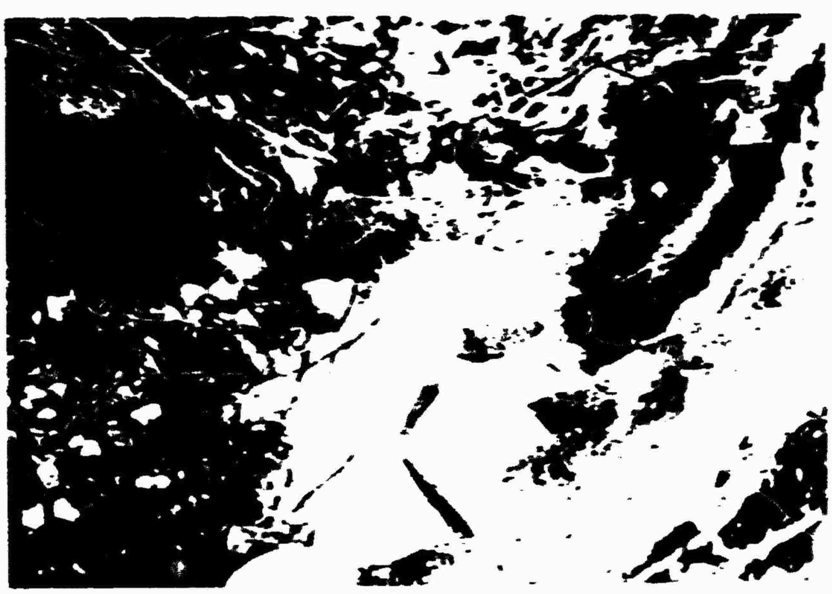

Figure A2. View of small stream at MP 2 with a thin film of fuel on the surface of the stream.

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Figure A3. A small leak at MP 17.7 saturated the soil in swale where large cottonwoods are growing.

Figure A4. Closeup of interior of the cottonwood stand at MP 17.7 showing some willow and alder growing out from base of original trunk.

Figure A5. Control area adjacent to MP 1[illegible] with luxuriant growth.

Figure A6. A partial view of kill area at MP 119.1.

Figure A7. A close-up of the overturned moss mat at MP 119.1 with the lower portion saturated with diesel fuel.

Figure A8. An example of a collection trench near Lake Dezadeash used to collect the fuel that flowed down the slope.

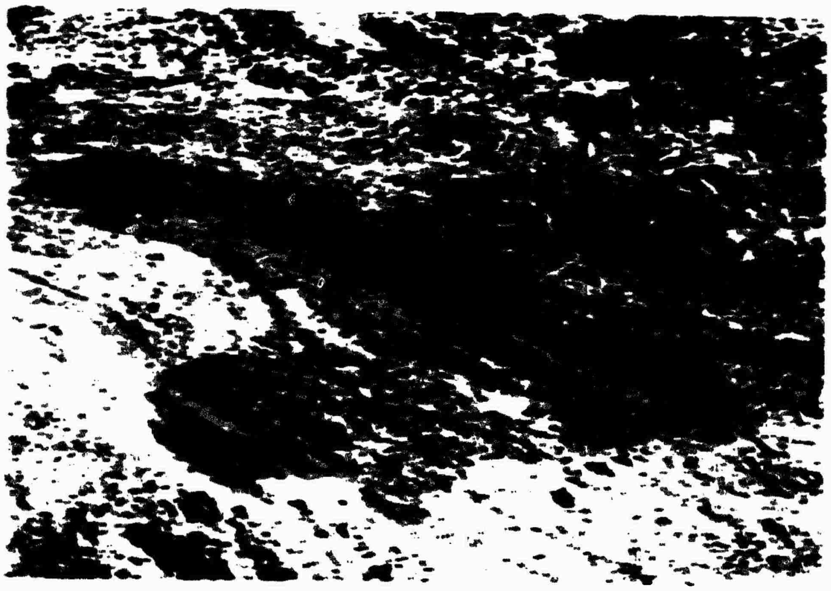

Figure A9. Fuel seepage on the surface of an access trail through the spill area at MP 119.1.

Figure A10. Overall view at MP 197.1 looking downslope during a 1956 spill.

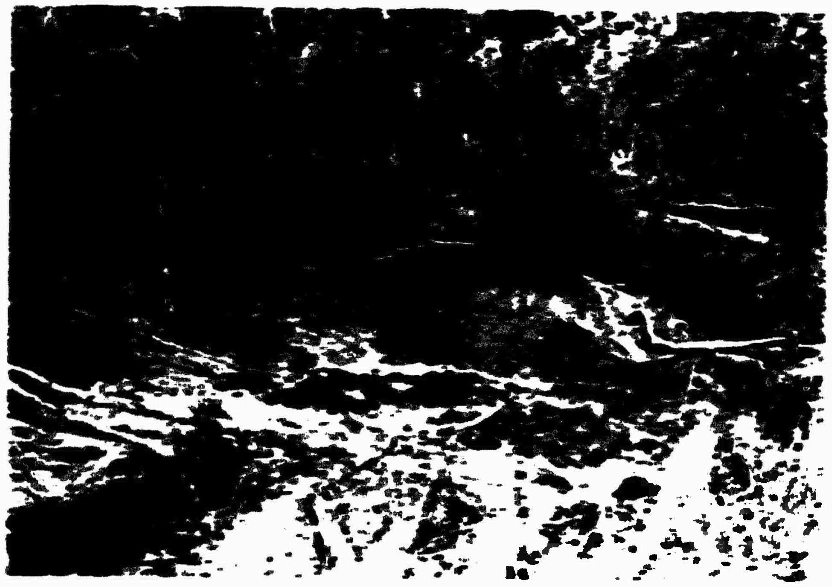

Figure A11. Erosion of organic mat at MP 197.1.

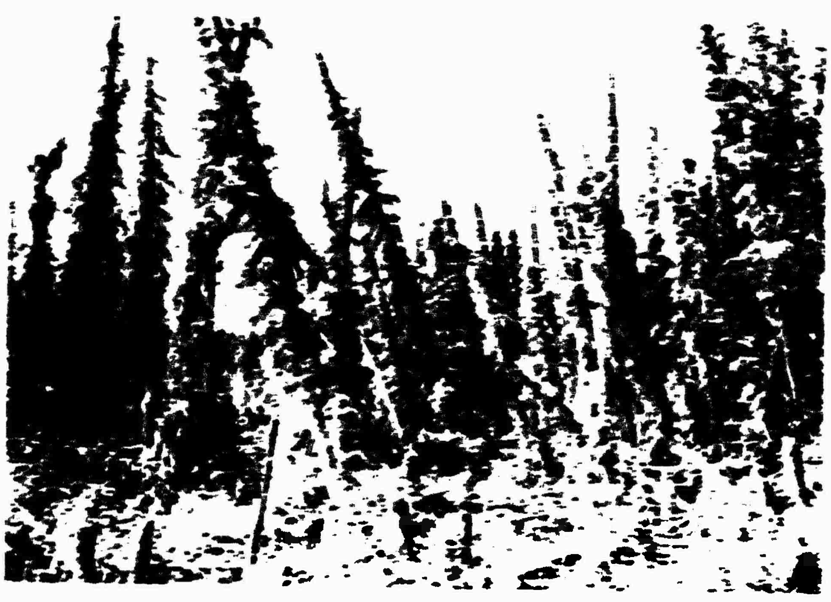

Figure A12. Looking upslope at MP 197.1 into kill area. Small spruce are growing in the cleared area at the base of the slope.

Figure A13. View of 1956 line cuts at MP 207.6.

Figure A14. View of 1956 line cuts at MP 207.6.

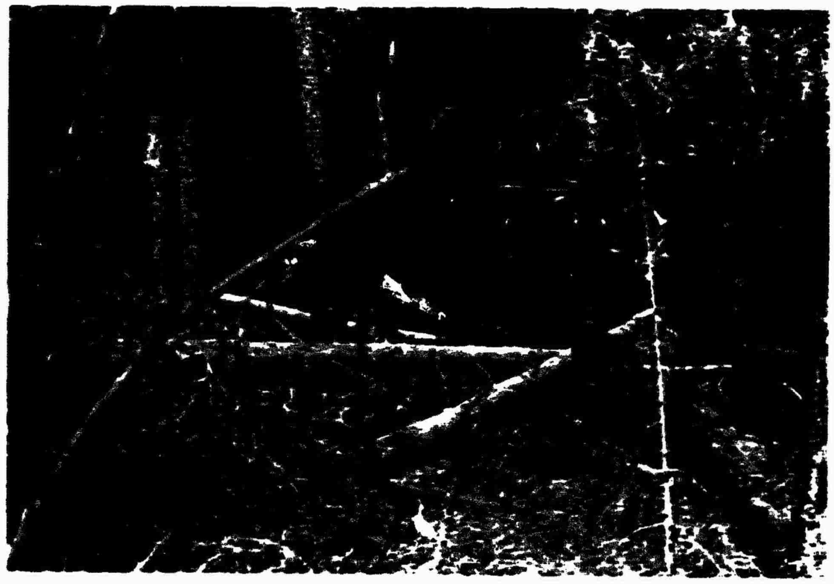

Figure A15. A sharp boundary exists between the spillage and non-spillage area as shown in this photograph from MP 207.5.

Figure A16. A line cut at MP 217.1 during 1956 retarded new growth in an area burned prior to the fuel spill.

Figure A17. The interior of the MP 217.1 spill is covered with considerable recent growth.

Figure A18. A spill at 273.2 has little new growth except in the drainage basin that traverses the area.

Figure A19. Downslope view of area at MP 382.5.

Figure A20. Side view at edge of MP 382.5 spill with dead aspen in foreground.

Figure A21. Close up of bearberry at MP 382.5 growing at edge of spill area to left of photo.

Figure A22. General view of pipeline right of way near the highest point along the pipeline route.

Figure A23. Vegetation sprayed with herbicide to allow aerial inspection for leaks.