

Microstructural alteration in permafrost-affected soils due to hydrocarbon contamination: implications for subsurface transport

T.L. White¹, P.J. Williams¹, Y. Marchand², and W.G. Rees³

¹Geotechnical Science Laboratories, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada

²Marie Curie Fellow (European Union), Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge, England CB2 1ER

³Head, Remote Sensing Group, Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge, England CB2 1ER

ABSTRACT. Contamination modifies the microstructure of soils. Such changes will inevitably cause changes in soil thermal, mechanical and hydrological properties. As a further consequence, depth of annual freeze thaw (depth to permafrost), frequency of soil movements on slopes, disturbances to drainage and other effects may be expected to produce changes in vegetation and terrain which will often increase with time. To investigate this relationship of microstructure modification (by contaminants) to changes in ground surface conditions in a region with permafrost, a study has been made of the sites of two 24 year-old experimental oil spills: An artificial spill of 7600 litres of crude oil, created in February 1976, and another of similar size in July 1976. Located at the Caribou-Poker Creeks Research Watershed in Alaska, these spills are probably the most closely investigated of any in the Arctic.

The density, moisture content, porosity, hydraulic conductivity and contaminant content of samples from each site and from a control site were measured. The microstructure was examined optically and by scanning electron microscope. The effects of contamination are evident including (unexpectedly) in the 'control' site, indicating wider spread of oil than expected. Changes in vegetation are clearly visible but the spill sites are not large enough for these to be analysed at the presently available precision of remote sensing.

Contents

Introduction	7	Sparrow et al (1978). The experimental spills each
Objectives of Research Project	9	consisted of 7600 litres of Prudhoe Bay crude oil and
Field Reconnaissance	9	took place in the winter (February 1976) and
Microstructural Observations	14	summer (July 1976) to test what happened when
Hydraulic Conductivity Observations	18	crude oil was spilled in permafrost-underlain black
Resulting Terrain Modifications and Remote		spruce forest of interior Alaska. In 1990 these spill
Sensing	19	sites were revisited by CRREL research personnel
Conclusions	20	to assess the long term effects on permafrost and
References	20	vegetation, as well as changes in oil chemistry.

Introduction

Earlier field studies

Following oil, gasoline or other hydrocarbon contamination it is important to know what will happen to various hydraulic, thermal and geotechnical properties of soils. Freezing soils behave differently to unfrozen soils. The majority of surface hydrocarbon spill studies have addressed what impacts petroleum spills have on vegetation and the depth of the active layer (Collins et al 1993). While many studies report the rate of contaminant spreading on the surface, these reports are generally descriptive and are limited to the short term migration (1-5 years) through the active layer.

In 1976 two large-scale experimental crude oil spills were made in the Caribou-Poker Creeks Research Watershed (Figure 1) located 48 km north of Fairbanks, Alaska by CRREL researchers.

For the original study (Johnson et al, 1980) a distribution map of the oil in each of the two spills was prepared showing the extent of the spills and

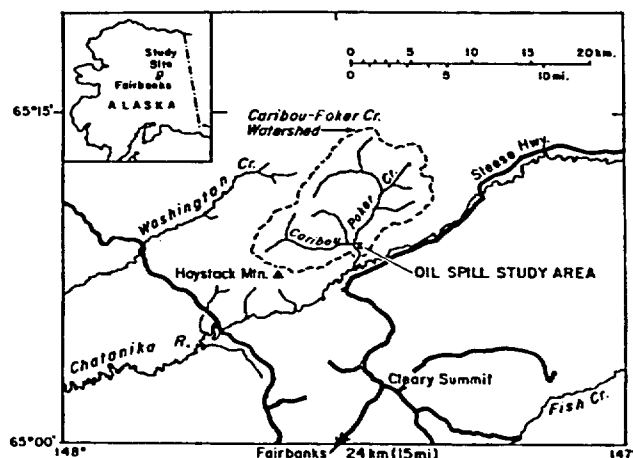


Figure 1: Caribou-Poker Creeks Research Watershed and experimental crude oil spill site