concentrations were 50 and 200 ppm TPH (total petroleum hydrocarbons), in a silt subjected to four freeze-thaw cycles. When TPH values approached 1000 ppm hydraulic conductivity decreased from 2.9 x 10^{-4} cm s^{-1} (uncontaminated silt) to between 5.3 x 10^{-5} cm s^{-1} and 8.48 x 10^{-5} cm s^{-1}.

These differences in hydraulic conductivity were explained by White and Coutard's (1999) observations on interparticle and inter-aggregate porosity. Inter-aggregate porosity (between aggregates) increased from 25 to 29% for TPH concentrations of 10 ppm, and to 33% with TPH concentrations of 100 ppm. On the other hand, sharp declines in inter-aggregate porosity (to 10%) were observed to take place when TPH concentrations exceeded 1000 ppm.

When an organic contaminant at low concentration of 50 to 200 ppm enters the pore space of a soil containing clay minerals such as smectite, the organic molecules (which have a low dielectric constant) begin to replace the water molecules in the double layers that surround clay minerals. There is a tendency for the particles to move closer together and form aggregates as reported by White and Williams (1999) and White (1999). In contrast when organic contaminant concentrations exceed 1000 ppm a significant effective stress is apparently created which may prevent the development of new macroporosity (between aggregates), causing the soil to consolidate *as a whole*. The double layer surrounding the clay minerals also undergoes shrinkage, and there is a significant reduction in the overall permeability of the soil.

Objectives of research project

The two spills of crude oil made in the Caribou-Poker Creeks Research Watershed provide a unique opportunity to examine insitu microstructural alteration of the active layer and to determine what implications these changes have for sub-surface migration of contaminants. The research project described in this interim report had two principal objectives:

1.To compare for the Caribou-Poker Creeks Research Watershed, the microstructure of seasonally frozen soils over permafrost in the uncontaminated and contaminated states.
2.To relate the identified microstructure to macroscopic properties such as hydraulic conductivity and from this to predict the rates of subsurface migration of the contaminant.
3.To ascertain the effects thus produced in the terrain, and to examine the remote sensing of these effects.

Field reconnaissance

Field observations were carried out in September 1998. Undisturbed contaminated soil samples from the summer and winter spill sites were obtained along with samples from a control site situated between the two spill sites (Figure 2).

The soils which are classified as histic pergelic cryaquest (US classification) are affected by permafrost (and thus are cryosols). Johnson et al (1980) reported that this lay 40–60 cm below the surface where the control site was located in the current project. The cryosol profile is characterized by a 5 cm layer of moss and lichen above a 15 cm thick horizon of undecomposed peat (O1). This lies above a 5 cm horizon of decomposed black organic peat (O2) which lies on top of a 5 cm thick layer of dark grey silt (A1). Below the silt is a grey-brown mineral soil (C1) which extends down 300 cm to a schist bedrock.

The cryosols examined in the excavated sampling pits situated in the summer and winter spill sites were clearly contaminated by crude oil. The presence of the hydrocarbons was readily discerned by sight (thin dark bands in the A1 horizon) and by smell for the O1 and C1 horizons.

The vertical distribution of the subsurface crude oil included oil visible along some roots penetrating down from the O1 and O2 horizons into the A1 horizon. Oiled zones (bands) were visually discernable in the O2, A1 and C1 horizons with band thickness varying from 1 to 3 mm in thickness up to 10 to 15 mm thick.

Undisturbed soil samples were obtained from three excavated sample pits situated in the summer and winter spill zones and at the control site situated between these two zones. Kubiena box samples for analysis of the micromorphology of the soils and adjacent core samples were taken every 15 to 20 cm beginning at the surface and extending downward until a water-saturated zone was encountered within the C1 horizon. This zone of saturation was encountered at 80 cm below surface for the summer spill site and control site and at 120 cm below surface for the winter spill site. The active layer is now deeper than Collins (1993) had found. The mineral soils at depth become saturated within the active layer during thaw periods because the underlying permafrost is essentially impermeable. Table 1, derived from analysis of core samples taken at the sites, shows bulk density, moisture content and porosity as a function of depth for all three sample sites.