PERMAFROST AND SILTY SOILS

An Annotated Bibliography

Compiled for the
Region III Forest Practices Riparian Management Committee
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SUMMARY

Alaska forest management practices in Region III present a unique challenge not generally encountered in management areas south of the Alaska Range. The presence of perenially frozen ground, or permafrost, must be addressed as a critical factor in achieving responsible stewardship of fish-bearing streams in forest management areas in Interior Alaska. Permafrost may be of relatively small significance within many harvest areas, but it can be a major factor in virtually all access roads or trails. It is especially critical to bear in mind that the only way to confirm the presence or absence of permafrost at any given location is by geotechnical drilling or targeted geophysical surveys.

There is a commonly-held belief that large trees are indicators that an area is permafrost-free, and that there is therefore no need to consider permafrost an issue in tree harvest areas. Permafrost is a controlling factor in the distribution patterns of trees and shrub vegetation only when it occurs at a depth shallow enough to influence subsurface drainage, soil stability, and soil temperature within the zone of root growth. It is important to recognize that large ice bodies may be present at depth in areas that support large trees. There is evidence to suggest that there may be a correlation between the height of white spruce with the depth of the active zone using the relationship that the height of the spruce stand in feet indicates the minimum depth of the active zone in inches (Stoeckeler, 1952). Studies by Hopkins and others (1955) show that a pure stand of (harvestable?) white spruce in interior Alaska could have permafrost as shallow as 2 ft below the surface. Birch or black spruce in bottomlands usually indicates the soil is permanently frozen within four or five feet, although stunted birch can survive where the upper surface of the permafrost layer is within two feet of the surface.

The primary reason for concern regarding permafrost in fish-bearing stream habitat management is the danger of melting the frozen substrate, triggering subsidence, erosion, and increased sediment load in runoff waters. Essentially, any disturbance which eliminates or greatly reduces plant cover in an area shallowly underlain by permafrost will result in an increased thaw. If the vegetative cover is physically damaged and mineral soil is exposed the increased thaw may be accompanied by erosion, especially in sloping sites. Effects of vegetaion disturbance may include both short-term and/or point sources of sedimentation and erosion and longer-term, nonpoint source effects such as surface alterations and sheet flows. Many studies

show that removal of the vegetation leads to the most extensive modifications, but the subsequent response to disturbance varies with primarily four factors: 1) ground ice volume; 2) distribution and size of massive ground ice; 3) material properties during thaw; and 4) relief, including progressive changes during thaw subsidence. Terrain underlain by ice-poor sediments that are stable upon thawing are altered only by thaw subsidence and consolidation, while ice-rich sediments that are unstable at thaw are extensively modified by a complex interaction of slumping, sediment flow, and thermal and mechanical erosion. Drainage promotes meltwater erosion, whereas undrained areas will be modified significantly less and attain stability (that is, regain an equilibrium state with respect to permafrost conditions) more rapidly.

General controversy exists as to whether perenially frozen ground inhibits lateral erosion and bankline recession, or whether it increases bank recession rates. Studies show that the effects of permafrost will vary depending on local conditions. Perenially frozen streambanks erode because of modification of the bank's thermal regime by exposure to air and water, and because of various erosional processes. Factors that determine rates and locations of erosion may include: 1) exposure to currents and wind waves; 2) texture and stratigraphy of the bank sediments; 3) ice content, distribution and type; 4) slope aspect; 5) Coriolis force; 6) timing and depth of thaw; 7) water level and temperature; 8) vegetation; 9) ice and snow cover; and 10) groundwater. The response of channels ranges from total permafrost control of channel processes, including bed scour and lateral erosion, to only brief restriction of channel behavior in the early stages of flood rise. Permafrost has been cited both as the cause of extreme stability and the cause of unusual instability in arctic streams as compared to those elsewhere, although no detailed studies have identified whether these conclusions are valid in the subarctic as well. The net effect of the permafrost environment seems to be to create greater channel stability than is found in unregulated streams of similar size in nonpermafrost environments. Combinations of factors, particularly those that encourage high rates of thermo-erosional niching, can nevertheless cause extreme rates of erosion.

An additional potential concern with permafrost is its effect on stream hydrology. The presence of permafrost exerts a major influence on the behavior of streams, but this influence is rather indirect. Its most important roles are in: 1) supporting a shallow or perched water table beneath the valley bottom area, so that overland flow derived from standing water in this area dominates the hydrograph rise and peak; 2) restricting deep groundwater flow from reaching the stream if no thaw buld exists around channels; and 3) providing an impermeable surface beneath the moss on the north-facing slopes, over which water infiltrating the moss flows to the stream to dominate the hydrographic recession. Permafrost-underlain terrain is much more responsive to precipitation inputs than is permafrost-free terrain, and proportion of permafrost, with concomitant cold, thick organic layers overlying mineral soil, is the primary determinant of differing streamflow characteristics in headwaters catchments. A permafrost-dominated first-order stream generally has higher peak streamflow, higher storm-flow suspended sediment concentration, lower base (non-storm) streamflow, and lower base-flow suspended sediment concentrations than do nearby, virtually permafrost-free first-order streams **(**Slaughter et al, 1983). Although comparisons of spot discharge measurements of predominantly permafrost and non-permafrost subwatersheds generally show that permafrost-dominated watersheds have a much "flashier" response to precipitation than non-permafrost watersheds (Haugen et al, 1982), several studies have indicated extremely long hydrograph recessions for streams draining permafrost areas, and some large basins have a high proportion of their runoff occurring as groundwater outflow (Dingman, 1975).

REFERENCES

Abele, G. 1990. Snow roads and runways: CRREL Monograph 90-3.

Discusses snow characteristics and presents detailed snow pavement construction techniques, evaluation, and design criteria. Includes lots of testing data.

Benninghoff, W.S. 1952. Interaction of vegetation and soil frost phenomena. Arctic 5(1):34-44.

Basic discussion of the interactions between vegetation and soil frost, and how each can affect the character of the other.

Benninghoff, W.S. 1966. Relationships between vegetation and frost in soils. Pages 9-13 in National Academy of Sciences, National Research Council, Proceedings of Permafrost: International Conference.

Examines the effects of vegetation on permafrost and discusses calculations of thermal energy in soils. The total effect of vegetation is to: 1) reduce the quantity of radiant energy that escapes either directly (by reflection) or indirectly to the atmosphere; 2) increase the long wave length infrared component in the energy that does escape to the atmosphere; 3) increase the energy diverted to work as in metabolism of organisms, physical and chemical weathering of rock materials, etc.; and 4) increase the store of energy on the earth in short-term forms as in vaporized water and in long-term forms as in humus and coal. The significance of vegetation in governing the occurrence of permafrost decreases the more the earth surface mean annual temperature is depressed below the freezing point. Where the surface mean annual temperature is not more than 2° or 3° C below 0°C, the kind and condition of the vegetation cover will be critical to the development and duration of permafrost, but where the surface mean annual temperature is more than several degrees below 0°C, the vegetation cover exercises little control. Vegetation does exert an influence, however, on the occurrence, extent, and effects of seasonal frost in the upper layers of the soil, wherever the climate will produce such freezing.

Brown, J., W. Rickard, and D. Vietor. 1969. The effect of disturbance on permafrost terrain. CRREL Special Report 138.

Reemphasizes the importance of the surface layer in preserving permafrost terrain. Essentially, any disturbance which eliminates or greatly reduces plant growth will result in an increased thaw. If the vegetative cover is physically damaged and mineral soil is exposed the increased thaw will be accompanied by erosion.

Brown, J., and N.A.Grave.1979. Physical and thermal disturbance and protection of permafrost. CRREL Special Report 79-5.

A review of the major findings of site and regional investigations dealing with human-induced and natural disturbances of permafrost terrain throughout the world. Excellent summary tables of terrain disturbances of permafrost in North America and the U.S.S.R.

Crory, F.E. 1991. Construction guidelines for oil and gas exploration in northern Alaska. CRREL Report 91-21.

This report presents construction guidelines for activities associated with petroleum exploration in northern Alaska. Examples of both new and old ways of constructing and operating on snow, ice and frozen ground are presented. The guidelines address how to construct winter trails, drill pads, roads and airfields, and includes information on how each is to be abandoned and the natural environment restored. Includes a general discussion of permafrost and thermal regimes.

Delaney, A.J., S.A. Arcone, and E.F. Chacho, Jr.,1990. Winter short-pulse radar studies on the Tanana River, Alaska. Arctic 43(3):244-250.

Subsurface profiles were obtained during airborne and surface short-pulse radar surveys along a winter roadway over the Tanana River near Fairbanks. The airborne profiles were intended for ice thickness profiling but also revealed sporadic reflections from a deeper horizon beneath the bars. The study shows that airborne radar surveys are capable of detecting open channels beneath an ice cover and measuring depth of frost beneath bars in a braided river. The airborne technique may be an effective way to determine the position of significant anomalies, such as local thaw zones. A surface profile confirmed the unfrozen horizon detected by the airborne survey.

Dingman, S.L. 1973. Effects of permafrost on stream flow characteristics in the discontinuous permafrost zone of central Alaska. Pages 447-453 in National Academy of Sciences, National Research Council. Proceedings of Permafrost: North American contribution to the Second International Conference.

Looks at the effects of permafrost in the watershed of Glen Creek, 13 km NNE of Fairbanks. The presence of permafrost is shown to be a major influence on the behavior of the stream, but this influence is rather indirect. Its most important roles are in supporting a high water table beneath the valley bottom area, so that overland flow derived from standing water in this area dominates the hydrograph rise and peak; restricting groundwater flow to the stream; and providing an impermeable surface beneath the moss on the north-facing slopes, over which water infiltrating the moss flows to the stream to dominate the hydrographic recession.

Dingman, S.L. 1975. Hydrologic effects of frozen ground: Literature review and synthesis. CRREL Special Report 218.

Summarizes the hydrologic effects of frozen ground and describes the general characteristics of seasonally frozen ground and its geographical distribution. The hydrologic effects of permafrost are profound, but these effects can be considered static unless one is concerned with long-term climatic changes. Permafrost acts as an aquiclude, restricting the movement and recharge of groundwater. The effects of this on streamflow are not necessarily the expected straightforward ones of increased runoff and flashier streamflow. Several studies have indicated extremely long hydrograph recessions for streams draining permafrost areas, and some large basins have a high proportion of their runoff occurring as groundwater outflow. Although runoff percentages estimated for small central and northern Alaskan watersheds are moderately high (around 50%), most of this is snowmelt, and the thaw season runoff percentages are much lower (as low as 5% at Barrow). The susceptibility of frozen ground to erosion by running water has a profound effect on the geomorphology of permafrost areas.

Ferrians, Jr., O.J., R. Kachadoorian, and G.W. Greene. 1969. Permafrost and related engineering problems in Alaska. U.S. Geological Survey Professional Paper 678.

Discusses the problems of construction and maintenance of structures underlain by frozen ground and gives guidelines to minimize the adverse effects of permafrost and frost action upon structures. Also provides a very good summary of permafrost, its origin and thermal regime, its areal distribution and thickness, and related geomorphic features.

Gatto, L.W. 1984. Tanana River monitoring and research program, relationships among bank recession, vegetation, soils, sediments and permafrost on the Tanana River near Fairbanks, Alaska. CRREL Special Report 84.

The report evaluated whether data on vegetation, soils, sediments, and permafrost could be used to assess their relative contribution to bank erosion on two reaches of the Tanana River. The data were visually compared to the locations and estimated amounts of historical recession to evaluate if any relationships were obvious. Results indicate no useful relationships. Vegetation was similar in eroded and uneroded areas and its distribution did not show any obvious relationship to the locations of bank recession. Surface sediments and soils in the eroded areas had little, if any, effect on bank erodibility because the river erodes the bank over its entire depth, which is well below the surface zone. Permafrost occurrences are about equal in eroded and uneroded sites, although it appears that recession can be higher where permafrost is common than where its is absent.

Haugen, R.K., C. W. Slaughter, K.E. Howe, and S.L. Dingman, S.L. 1982. Hydrology and climatology of the Caribou-Poker Creeks Research Watershed, Alaska. CRREL Report 82-26.

Comparisons of spot discharge measurements of predominantly permafrost and non-permafrost subwatersheds showed that permafrost-dominated watersheds have a much “flashier” response to precipitation than non-permafrost watersheds.

Heginbottom, J.A. 1973. Some effects of surface disturbance on the permafrost active layer at Inuvik, N.W.T., Canada. Pages 649-657 in National Academy of Sciences, National Research Council. Proceedings of Permafrost: North American contribution to the Second International Conference, p. 649-657.

Assesses the effects of disturbance on permafrost terrain by grouping the disturbances into the following categories, ranked by the intensity of their initial impact: compaction of ground surface; mechanical damage to vegetation; destruction of vegetation; removal of vegetation; removal of vegetation-peat mat; and removal of surface vegetation and soil.

Higgins, C.G., D.R. Coates, T.L. Péwé, R.A.M. Schmidt, and C.E. Sloan. 1990. Permafrost and thermokarst: Geomorphic effects of subsurface water on landforms of cold regions. Pages 211-218 in C.G. Higgins and D.R. Coates, editors. Groundwater geomorphology: The role of subsurface water in Earth-surface processes and landforms. Geological Society of America Special Paper 252.

A brief summary of permafrost and permafrost-related landforms.

Hopkins, D.M., and six coauthors. 1955. Permafrost and ground water in Alaska. Pages 113-146 in U.S. Geological Survey Professional Paper 264-F.

A study of the interrelations of permafrost and ground water, and a discussion of the role of aerial photography in the mapping of permafrost conditions. The distribution of ground water in Alaska affects and is affected by the distribution of permafrost. Knowledge of permafrost and ground-water conditions is summarized for the following representative areas of Alaska: the Arctic slope and northern Seward Peninsula in the continuous-permafrost zone; southern Seward Peninsula, the Yukon Flats, the middle Tanana River valley, and the upper Kuskokwim River valley in the discontinuous-permafrost zone; the Bristol Bay region in the sporadic-permafrost zone; and the Kenai lowland in the no-permafrost zone. The application and limitations of aerial-photograph interpretation in permafrost studies are discussed.

Of particular note is a discussion of the use of vegetation types as an indicator of permafrost depth. The authors state that permafrost is a controlling factor in the distribution patterns of trees and shrub vegetation only when it occurs at a depth shallow enough to influence subsurface drainage, soil stability, and soil temperature within the zone of root growth. The following table indicates the **minimum depth to permafrost**, if it is present, beneath some vegetation assemblages that are widespread in Alaska. It does not indicate maximum possible depth.

Tall willows on flood plains	8 ft
Pure stands of mature aspen or white birch	4 ft
Mixed willow, alder, and white birch	3-4 ft
Pure stands of balsam poplar	3-4 ft
Mixed white spruce and balsam poplar	3 ft
Pure stands of white spruce	2-3 ft
Mixed stands of white birch and white spruce	2-3 ft
Mixed white and black spruce	1-2 ft
Black spruce in wet tundra or muskeg	1 ft

In other words, a pure stand of (harvestable?) white spruce in interior Alaska could have permafrost as shallow as 2 ft below the surface.

Johnson, P.R., and C.M. Collins. 1980. Snow pads used for pipeline construction in Alaska, 1976: Construction, use and breakup. CRREL Report 80-17.

Describes construction methods for three snow pads used by Alyeska Pipeline Service Company during the winter of 1975-1976, which were deemed generally successful in providing a surface for construction while protecting the underlying vegetation and permafrost.

Jorgenson, M.T., C.H. Racine, J.C. Walters, and T.E. Osterkamp. In press. Permafrost degradation and ecological changes associate with a warming climate in central Alaska: Climatic Change 38.

Studies from 1994–1998 on the Tanana Flats in central Alaska reveal that permafrost degradation is widespread and rapid, causing large shifts in ecosystems from birch forests to fens and bogs. Fine-grained soils under the birch forest are ice-rich and thaw settlement typically is 1–2.5 m after the permafrost thaws. The collapsed areas are rapidly colonized by aquatic herbaceous plants, leading to the development of a thick, floating organic mat. Based on field sampling of soils, permafrost and vegetation, and the construction of a GIS database, the authors estimate that 17% of the study area (263,964 ha) is unfrozen with no previous permafrost, 48% has stable permafrost, 31% is partially degraded, and 4% has totally degraded. For that portion that currently has, or recently had, permafrost (83% of area), ~42% has been affected by thermokarst development. Based on airphoto analysis, birch forests have decreased 35% and fens have increased 29% from 1949 to 1995. Overall, the area with totally degraded permafrost (collapse-scar fens and bogs) has increased from 39 to 47% in 46 y. Based on rates of change from airphoto analysis and radiocarbon dating, the authors estimate 83% of the degradation occurred before 1949. Evidence indicates this permafrost degradation began in the mid-1700s and is associated with periods of relatively warm climate during the mid-late 1700s and 1900s. If current conditions persist, the remaining lowland birch forests will be eliminated by the end of the next century.

Jorgenson, M.T., Y. Shur, and H.J. Walker. 1998. Factors affecting evolution of a permafrost dominated landscape on the Colville River Delta, northern Alaska. Pages 523-530 in Lewkowicz, A.G. and M. Allard, eds., Proceedings of Permafrost: Seventh International Conference. Universite Laval, Sainte-Foy, Quebec, Collection Nordicana, No. 57.

To help provide information essential for engineering design and evaluation of potential environmental impacts in preparation for oil development on the Colville River Delta, studies on soil stratigraphy and permafrost development were conducted during 1992–1996 to investigate the nature and distribution of surficial deposits in the delta. The studies involved investigation of stratigraphy of near-surface materials along numerous toposequences in the delta, classification and mapping of terrain units, classification and description of cryostructures, dating and analysis of material accumulation rates, and determination of erosion rates. After detailed classification and analysis of the microscale and macroscale differences in soil properties across this complex landscape, the patterns and processes that were observed were synthesized into a simplified conceptual model of the evolution of the deltaic landscape.

Kreig, R.A., and R.D. Reger. 1982. Air-photo analysis and summary of landform soil properties along the route of the Trans-Alaska Pipeline System. Alaska Division of Geological & Geophysical Surveys, Geologic Report 66.

The results of a compilation of detailed subsurface information on soils, bedrock, ground water, permafrost, and other environmental factors along the Trans-Alaska Pipeline System (TAPS) are summarized. Includes a collection of aerial photographs that illustrate the broad diversity of landforms crossed by the TAPS route, and discussions of subsurface data from soil borings. Many good examples of permafrost-related features in interior Alaska and elsewhere.

Lawson, D.E. 1983. Erosion of perennially frozen streambanks. CRREL Report 83-29.

General controversy exists as to whether perenially frozen ground inhibits lateral erosion and bankline recession, or whether it increases bank recession rates. This report concludes that the effects of permafrost will vary depending on local conditions. Perenially frozen streambanks erode because of modification of the bank's thermal regime by exposure to air and water, and because of various erosional processes. Factors that determine rates and locations of erosion include: exposure to currents and wind waves; texture and stratigraphy of the bank sediments; ice content, distribution and type; slope aspect; Coriolis force; timing and depth of thaw; water level and temperature; vegetation; ice and snow cover; and groundwater. Thermal and physical modification of streambanks may also induce accelerated erosion within permafrost terrain removed from the immediate river environment. Bankline or bluffline recession rates are highly variable, ranging from less than 1 m/year to over 30 m/year and, exceptionally, to over 60 m/year.

Lawson, D.E. 1986. Response of permafrost terrain to disturbance: A synthesis of observations from northern Alaska, U.S.A. Arctic and Alpine Research.18(1):1-17.

Examines disturbances of perenially frozen terrain in the National Petroleum Reserve-Alaska that resulted from activities in the late 1940s and early 1950s. The disturbances were grouped into trampling of vegetation, killing of vegetative cover, removal of the vegetative mat, and removal of the vegetation and soil. Removal of the vegetation led to the most extensive modifications at all sites, but the subsequent response to disturbance varied with primarily four factors: ground ice volume; distribution and size of massive ground ice; material properties during thaw; and relief, including progressive changes during thaw subsidence. Terrain underlain by ice-poor sediments that are stable upon thawing was altered only by thaw subsidence and consolidation, while ice-rich sediments that are unstable at thaw were extensively modified by a complex interaction of slumping, sediment flow, and thermal and mechanical erosion. Drainage promoted meltwater erosion, whereas undrained areas were modified significantly less and attained stability more rapidly. Physical stability is required for growth of vegetation and thermal equilibrium, and has taken over 30 years to attain in ice-rich, thaw-unstable areas. Ice-poor, thaw-stable materials in undrained or low relief areas required an estimated five to ten years for

stability. Thaw depth measurements suggest that certain of these areas have also equilibrated thermally.

Linell, K.A. 1973. Long-term effects of vegetative cover on permafrost stability in an area of discontinuous permafrost. Pages 688-693 in National Academy of Sciences, National Research Council. Proceedings of Permafrost: North American contribution to the Second International Conference.

In 1946, the U.S. Army Corps of Engineers started a long-term experiment at its Farmers Loop Road Field Station near Fairbanks, Alaska, to investigate the effects of climatics and surface conditions on ground temperature. This paper presents information obtained as part of these studies, on the relationship between vegetative cover and permafrost degradation. The data extend through 1972, 26 years after the start of the experiment. A comparison of three 61-m square test sections – one kept in its natural tree-covered condition, a second cleared of trees but not stripped, and a third section stripped of all vegetative cover to a depth of about 0.4 m – has shown that only the original densely tree-covered section has remained free from permafrost degradation over the observation period of 26 years. In both the cleared and stripped sections permafrost degradation was still continuing, but at a much slower rate. It was concluded that in an environment like that of Fairbanks the maintenance or re-establishment of a random, mixed-type low vegetative cover can not be counted on to stop or prevent permafrost degradation in an area subjected to surface disturbance.

Lobacz, E.F. 1986. Arctic and subarctic construction: General provisions. CRREL Special Report 86-17.

A manual that provides basic background data for and detailed criteria pertaining to arctic and subarctic facility design, including information for considering frost action and permafrost.

Lotspeich, F.B., and A.E. Helmers. 1974. Environmental guidelines for development roads in the subarctic. Environmental Protection Agency report EPA-660/3-74-009.

A set of guidelines based on Federal and State regulations that set standards to protect the total environment when constructing roads in the subarctic, with many examples from the Fairbanks area. Basically a collection and summary of road-related practices, with emphasis on resource development roads which meet environmental protection requirements. Includes brief sections on ice bridges and reclaiming temporary roads.

Mann, D.H., C.L. Fastie, E.L. Rowland, and N.H. Bigelow. 1995. Spruce succession, disturbance, and geomorphology on the Tanana River floodplain, Alaska. Ecoscience 2:184-199.

A long-standing paradigm in the ecology of the Alaskan taiga states that black spruce replace white spruce after several centuries of primary succession on floodplains. According to this Drury Hypothesis, autogenic thickening of organic horizons and shrinking of the active layer interact with the species' different physiological tolerances to cause black spruce dominance. The authors test the Drury Hypothesis on >200-year-old portions of the Tanana River floodplain

near Fairbanks, Alaska, and reject it. In the meander belt portion of the study area, white spruce mixed with black spruce persists on geomorphic surfaces approximately 3000 years old. Predictions of the Drury Hypothesis regarding active-layer and organic-horizon thicknesses are not substantiated. Neither of these variables correlates with the abundances of the different spruce species. Forest communities in the study area are distributed along geologically based environmental gradients and are shaped by secondary succession following fires and probably floods. Black spruce dominates in the poorly drained, permafrost-rich, and fire-prone backswamp and white spruce in the oppositely characterized meander belt. Although geological chronosequences can be identified along avulsion-prone rivers like the study reach of the Tanana River, superposition of a meander belt-backswamp plan and frequent fire and flood disturbances may negate any vegetation chronosequences older than several centuries.

Mason, O.K., and J.E. Begét. 1991. Late Holocene flood history of the Tanana River, Alaska, U.S.A. Arctic and Alpine Research 23:392-403.

A sequence of historic and prehistoric flood deposits of the Tanana River is preserved in a small bedrock-sheltered slough near Fairbanks. Examination of these deposits using a suite of radiometric dates, microstratigraphic observations, and granulometric statistics suggests that large changes in flood frequency occurred during the late Holocene. Three major litho-stratigraphic units are observed: (1) thick cross-bedded, pedogenically unaltered alluvial silty sands which were deposited between 3000 and 2000 yr BP, recording an interval of large floods: (2) a series of thin silty beds and paleosols formed after 2000 yr BP during an interval when large floods were uncommon: and (3) a sequence of sand units recording large floods during the last several hundred years. Flood frequencies appear to have changed in response to regional climate changes, with more frequent flooding occurring during times of widespread alpine glaciation and increased storminess.

McVee, C.V. 1973. Permafrost considerations in land use planning management. Pages 146-151 in National Academy of Sciences, National Research Council. Proceedings of Permafrost: North American contribution to the Second International Conference.

A very brief summary of permafrost effects as they relate to land use planning management, including new townsites and village expansion, rights-of-way, mineral and oil development, timber harvest, farming, recreation activities, control of wildfires, and military activities.

Ott, R.A. 1998. The impact of winter logging roads on vegetation, ground cover, permafrost, and water movement on the Tanana River floodplain in Interior Alaska: Alaska Department of Natural Resources Division of Forestry, Cooperative Agreement AK-DF-A97-RN0006, 10-97-052.

A study of active layer depths and vegetation and ground cover patterns on two winter roads and adjacent undisturbed areas in eight plant communities underlain by permafrost. Surface permafrost receded in the roadbeds of six sampled plant communities, with the greatest increase in active layer thickness occurring in two communities characterized by black spruce. The author notes that the entire organic mat on this roadbed had been removed, perhaps accounting for these sites being the most influenced. The four other plant communities where permafrost receded (paper birch forest, tamarack woodland, shrub birch-alder, and cottongrass tussock) were located in roadbeds which retained an insulating mat of organic material. Mean active layer depths indicate that permafrost aggraded in the roadbeds of the shrub birch-leatherleaf-Labrador tea and leatherleaf communities.

Péwé, T.L. 1954. Effect of permafrost on cultivated fields, Fairbanks area, Alaska. U.S. Geological Survey Bulletin 989-F, p. 315-351.

Describes the destructive effect of permafrost on cultivated fields and delineates the parts of the Fairbanks area which are least suitable for agriculture because of the character of the underlying permafrost.

Scott, K.M. 1978. Effects of permafrost on stream channel behavior in arctic Alaska. U.S. Geological Survey Professional Paper 1068.

A study of five streams in northern Alaska to assess the effects of frozen bed and bank material on channel behavior and the importance of the annual breakup flood in forming the channels of arctic streams. The response of channels ranged from total permafrost control of channel processes, including bed scour and lateral erosion, to only brief restriction of channel behavior early in the rise of early flooding. Permafrost has been cited both as the cause of extreme stability and the cause of unusual instability in arctic streams as compared to those elsewhere. While comparison of absolute rates of lateral erosion were not deemed feasible, the author concludes that the net effect of the permafrost environment is to create greater channel stability than is found in unregulated streams of similar size in nonpermafrost environments. He goes on to note, however, that combinations of factors, particularly those that encourage high rates of thermo-erosional niching, can nevertheless cause extreme rates of erosion.

Sigafoos, R.S., and D.M. Hopkins. 1952. Soil instability on slopes in regions of perenially-frozen ground. Pages 176-192 in National Academy of Sciences, National Research Council. Frost action in soils: A symposium. Highway Research Board Special Report No. 2.

A good summary paper describing soil-instability features in permafrost areas. Roads are often preferably built on hill slopes in regions of perenially frozen ground because the hill slopes are subject to less heaving and less severe subsidence than the marshy lowlands. However, because of poor drainage, wet soils, disturbances caused by repeated cycles of freezing and thawing, and the presence of a glide plane at the surface of the perenially-frozen ground, slopes subject to rapid creep are much more common in northern latitudes than in more temperate regions. Recognition of micro-relief features can assist in selecting the best of several routes when building access roads.

Slaughter, C.W., J.W. Hilgert, and E.H. Culp. 1983. Summer streamflow and sediment yield from discontinuous-permafrost headwaters catchments. Pages 1172-1177 in National Academy of Sciences, National Research Council. Proceedings of Permafrost: Fourth International Conference.

Examines how the presence of permafrost in a catchment system affects the hydrology and water quality of streamflow in the discontinuous-permafrost taiga of central Alaska. Permafrost-underlain terrain is much more responsive to precipitation inputs than is permafrost-free terrain, and proportion of permafrost, with concomitant cold, thick organic layers overlying mineral soil, is the primary determinant of differing streamflow characteristics in headwaters catchments. A permafrost-dominated first-order stream has higher peak streamflow, higher storm-flow suspended sediment concentration, lower base (non-storm) streamflow, and lower base-flow suspended sediment concentrations than does a nearby, virtually permafrost-free first-order stream.

Stoeckeler, E.G. 1952. Trees of interior Alaska: Their significance as soil and permafrost indicators. U.S. Army Corps of Engineers investigation of military construction in Artic [sic] and Subartic [sic] regions. 25 p.

A discussion of the habitats and growth characteristics of eight species of trees in interior Alaska and implications for predicting permafrost depth. The author correlates the height of white spruce with the depth of the active zone using the relationship that the height of the spruce stand in feet indicates the minimum depth of the active zone in inches. Other observations of note: black spruce occurs principally in soils permanently frozen within three feet of the surface; tamarack nearly always grows in cold ground which is permanently frozen two to three feet below the surface; balsam poplar requires substrate in which permafrost lies at least six feet below the surface; quaking aspen grows best on unfrozen, deep soils on warm slopes; Alaska birch in bottomlands usually indicates the soil is permanently frozen within four or five feet, although stunted birch can survive where the upper surface of the permafrost layer is within two feet of the surface.

Viereck, L.A. 1965. Relationship of white spruce to lenses of perenially frozen ground, Mount McKinley National Park, Alaska. Arctic 18(4):262-267.

This study reports an investigation of ice lenses beneath white spruce trees and suggests ways in which permafrost may form under vegetation where it has previously been absent. The frozen lenses are thought to result from the insulating effect in summer of a thickened moss mat and from soil cooling in winter as a result of a thin snow layer under the trees.

Viereck, L.A. 1970. Forest succession and soil development adjacent to the Chena River in interior Alaska. Arctic and Alpine Research 2(1):1-26.

Compares four forest stands on varying aged river deposits with a climax stand on a higher and older terrace to show changes in soil and vegetation with time on the floodplain of the Chena River. The succession proceeds from the near xeric conditions of the gravel bar to the mesic balsam poplar and white spruce stands. Autogenic changes brought about by the development of a thick organic layer and interaction with the cold climate result in the development of a permafrost layer. Succession then proceeds from the mesic conditions of the poplar and white spruce stands to the hydric conditions of a slow-growing black spruce stand with a thick, saturated sphagnum mat on a permafrost table only 20 to 30 cm below the moss surface.

Viereck, L.A. 1973. Ecological effects of river flooding and forest fires on permafrost in the taiga of Alaska. Pages 60-67 in National Academy of Sciences, National Research Council. Proceedings of Permafrost: North American contribution to the Second International Conference.

Examines the effects of flooding and fire on thermal regime of permafrost in the Fairbanks area. Observations of flooding effects include: 1) flooding and water-table rise by warm water can quickly thaw existing permafrost or cause higher soil temperatures over at least the upper 150 cm of the substrate; 2) siltation during flooding results in the compaction and death of the moss layers, thus reducing their insulating value in summer which results in higher soil temperatures and an increase in thickness of the active layer; 3) the result of thawing of frozen layers heavily laden with ice can be surface subsidence, tipping of trees, and eventually the formation of thaw ponds; 4) in some cases, flooding over permafrost results in the separation of the organic layer at the permafrost boundary and a compression and rolling of the organic layer into peat mounds. Fire in forests underlain by permafrost results in a temporary thickening of the active layer. For the first 15 years after fire, thaw is more than 1 m; return to preburn thaw levels takes about 50 years.

Walker, D.A., D. Cate, J. Brown, and C. Racine. 1987. Disturbance and recovery of arctic Alaska tundra terrain: A review of recent investigations. CRREL Report 87-11.

This is a summary of over a decade of CRREL-managed research regarding disturbance and recovery in northern Alaska. The impacts that are discussed include bladed trails, off-road vehicle trails, winter trails, ice roads, gravel pads and roads, borrow pits, roadside impoundments, road dust, hydrocarbon spills and seawater spills. The main themes to come out of the report are: most anthropogenic disturbances have natural analogs, which can provide information that can be related to modern disturbances and their rates of recovery; most single-event disturbances will heal and develop a functioning ecosystem within a human life span, but a return to the original ecosystem can rarely be expected for major impacts; and, in permafrost regions with massive ground ice, recovery of the vegetation is limited by alterations to the permafrost regime.

Walters, J.C., C.H. Racine, and M.T. Jorgenson. 1998. Characteristics of permafrost in the Tanana Flats, interior Alaska. Pages 1109-1116 in Lewkowicz, A.G. and M. Allard, eds., Proceedings of Permafrost: Seventh International Conference. Universite Laval, Sainte-Foy, Quebec, Collection Nordicana, vol. 57.

The Tanana Flats is a wetland region located on the distal slopes of an extensive alluvial fan complex built out of the Alaska Range. Vegetation in the Flats consists of a mosaic of fen, birch forest, black spruce forest, shrub, and bog. Permafrost is not present in the fen and bog areas, but it exists on the bordering forested and shrub areas 0.5 to 2 m above water level. The studies show that permafrost in the Flats is relatively warm at –0.2 to –0.7°C, and that the distribution and characteristics of permafrost are related to the geobotanical conditions at the specific site. In general, permafrost is more ice rich and shows higher secondary porosity where finer-grained sediments (silts) are abundant. These are environments characterized by birch forest vegetation. Permafrost in areas of birch forest appears more susceptible to thaw and is currently showing signs of extensive degradation.

Williams, J.R. 1970. Ground water in the permafrost regions of Alaska. U.S. Geological Survey Professional Paper 696.

The presence of permafrost imposes certain unique limitations on ground-water occurrence, including: 1) Permafrost acts as an impermeable barrier to the movement of ground water, because the pore spaces are generally filled with ice within the zone of saturation. Recharge and discharge of water to and from aquifers beneath permafrost are therefore limited to the unfrozen zones that perforate the permafrost. 2) Permafrost limits the number of sites from which water can be produced from shallow wells. It commonly is necessary to drill to greater depths in permafrost regions than in comparable geologic environments in temperate regions. The near-surface unconsolidated deposits that provide abundant water in some parts of the temperate regions are commonly frozen, and utilization of aquifers of lower yield or poorer quality beneath the permafrost may be necessary. 3) The ground-water temperature ranges from 0° to 4.5°C because of low ground temperature above and below permafrost. In this temperature range, ground water is more viscous and moves more slowly than in temperate regions.