Muskeg impedence factors controlling vehicle mobility: the spot light is on Swan Hills

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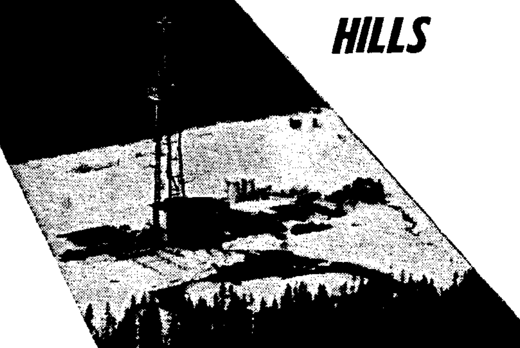
Publisher's version / Version de l'éditeur:

Technical Memorandum (National Research Council of Canada. Division of Building Research); no. DBR-TM-57, 1958-04-16

The Spot-light is on *SWAN HILLS*



Vehicle Mobility

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IN Canada, where muskeg covers 500,000 square miles of the land, access in these areas is becoming more and more important whether the new horizons are sought in the interests of agriculture, forestry, mining, or engineering development in areas like Swan Hills.

Access in muskeg country during the winter months probably presents no major problems in this mechanical age. In fact, winter is relied upon to lessen access problems, for then the frozen land no longer traps men and machines in its immobilizing grip. Winter, at one time the least desirable season for operations in the north has now become the time when the most work is done and when travel is easiest. It is the time when plans are made for summer operations and supplies are stock-piled for the advent of less favourable access conditions. It is the time when the summer's work, often conducted in a man-against-time fashion, because of the nature of the terrain, can be perused with deliberation, and information gleaned from it.

However, while winter conditions are favourable for access, it is not always possible to conduct or complete operations in this time. It is those who must continue their operations on a year round basis that this article seeks to help by outlining some of the problems of vehicular access over muskeg in the three seasons other than winter, and by presenting some suggestions for vehicle design.

Muskeg, or Organic Terrain as it is now, with good reason, frequently called, when considered in the light of research has revealed itself as a problematical but not disorderly medium. This research has led to the classification of muskeg by surface, sub-surface and topographic features, which when considered together present a quite complete picture of the existing conditions for a given area. These systems have been presented and enlarged upon in previous publications (1, 2, 3, 5). Briefly, surface vegetation has been grouped into nine classes, designated by letters A to I inclusive. Of these, A, B, D and E are woody and range in height from 15 feet and over to 0 feet (low, spreading, shrubby). Classes C, F, G, H and I are non-woody and include tall and short grass-like forms (C, F), herbaceous plants (G), and low, creeping forms (H, I). Class H is leathery to crisp and class I is moss-like. Combinations of these classes give Cover-

TABLE I
COMMON SURFACE — SUB-SURFACE MUSKEG STRUCTURAL RELATIONS

Common Formulae	Associated Topographic Features	Sub-Surface Peat Structure
AE	irregular peat plateaus	coarse-fibrous, woody
AEH	irregular peat plateaus, rock enclosures	woody coarse-fibrous with scattered woody erratics
DFI	stream banks	woody particles in non-woody fine-fibrous
DEI	ridges, stream banks	woody particles in non-woody fine-fibrous
EH	even peat plateaus, polygons	woody and non-woody particles in fine-fibrous
EI	ridges, mounds	woody particles in non-woody fine-fibrous
FI	hummocks, closed and open ponds, polygons, flats	amorphous granular, non-woody fine-fibrous

Surface cover represented by seven common cover formulae are shown along with the pertinent topographic and peat structure characteristics.

age Formulae by which the vegetation in any muskeg area may be classified. The formulae, when related to topographic features and sub-surface conditions give a fairly accurate description of the terrain (Table I). When these features are known, other conditions and conclusions may then be inferred. For example, for any coverage formula, such data as a range of peat depth, bearing capacity and the vegetation hindrance to vehicles may be interpreted.

Much preliminary work in assessing field conditions may be done with the aid of aerial photograps, systems now being available for photographs taken at altitudes of 150 to 30,000 feet 4, 6, 7). Thus, if use is made of low altitude photography as the next step after assessing the terrain from the ground, it becomes possible to interpret ground features from the air, and to apply this procedure at successively higher altitudes. By this means, route selection, construction sites and new operative features can be suggested prior to operations — a procedure which often minimizes access or construction difficulties.

The definition of muskeg (1, page 10) indicates that collectively, physiographical attributes of the terrain help to characterize and are just as important for purposes of definition as is peat, the main material of which muskeg is constituted. This suggests that if mobility problems are to be adequately and effectively faced, they must be assessed in relation to features of organic terrain other than peat structure. One of these features is ice form.

An attempt has already been made to designate the sub-surface ice conditions that characterize given kinds of organic terrain (3), but the study is not yet complete. Ice form is not static. Therefore, when it is assessed in relation to mobility, its dynamic qualities are inevitably isgnificant. For this reason, seasonal changes become important. This is the implication that has not yet been fully explored.

On the other hand, for applied work it is often convenient to characterize ice form in specified times of the year, when, because of ice form, mobility is critical. Indeed, the pressing circumstances where ice form seriously affects vehiclce mobility must be met, for the time being, through this approach.

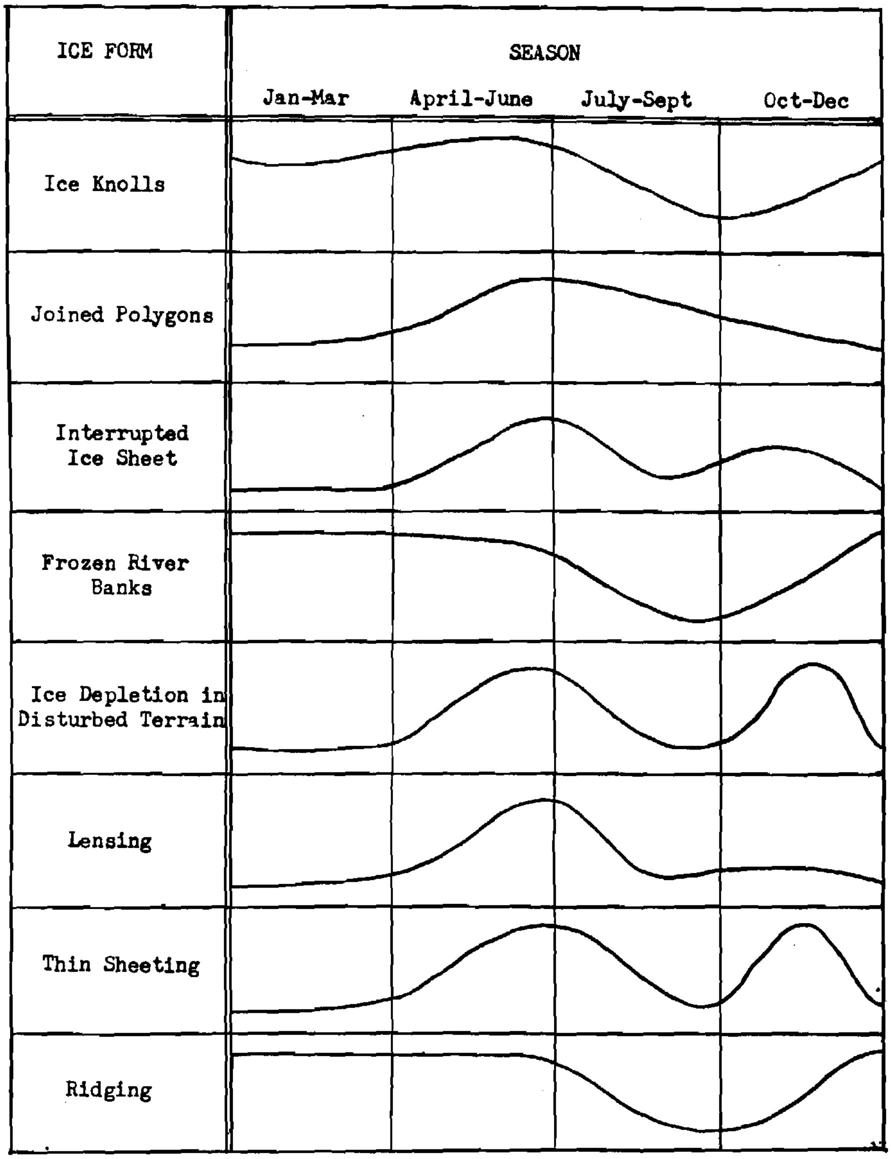
An examination of Table II, reveals that there are eight ice form conditions that seriously impinge on successful mobility. To portray the effectiveness of each condition at different seasons, graphic aids have been used. Where amplitude in each graph is greatest, the influence of the ice form feature in hindering effective mobility is at its height. The graphs are intended to represent relative values of a qualitative nature and are derived from an analysis of descriptive data. They are in no way a rendition of statistical measurement. Their use provides primarily for an understanding of the principles involved in ice form-mobility relations.

There are, thus, good and bad times for operations dependent on effective mobility. Selection of the period for implementation of a project might well be considered in relation to seasonal controls rather than to administrative preference.

In addition to showing the relative degree to which mobility will be affected by ice form on a seasonal basis, Table II suggests that ice is present in amounts significant enough to afford potential at times of the year when perhaps it has been thought heretofore that

TABLE II

SEASONAL IMPEDENCE OF ICE FORM IN MUSKEG



A series of curves showing qualitatively for each of eight ice form features, variation in influence on mobility throughout the year. Peaks in the curves indicate when impedence is greatest.

no ice was present. To take advantage of ice for operations it will be necessary to know the kinds of muskeg in which the phenomena listed in Table II actually occur (3, 4).

Perhaps it is not clear as to how ice form affects mobility. Ice knolls are of such amplitude and distribution as to seriously promote frequent pitching of the vehicle. Speed of travel is cut down to a minimum, acceleration rates are highly variable, loads are almost constantly at a precarious angle and the operator becomes very much overworked. Probability for mechanical damage to tracks is very high and vehicle depreciation is excessive.

Ice polygons have a similar effect to knolling except that here change in angle of pitch is less frequent. Also the phenomenon itself is far less common.

The condition designated "Interrupted Ice Sheet" can terminate an operation. It is highly important to know where — even in shallow muskegs — these "holes" occur. In the majority of cases, buoyancy of the vehicle becomes an important factor if mobility is to be sustained, and well directed winching will be required in most cases.

Frozen river banks may result in sudden change in weight distribution with dangerous forward pitching. Manoeuvrability is often practically eliminated depending somewhat on the size and kind of vehicle.

In disturbed organic terrain, the natural insulating value of the peat is largely eliminated, drainage is modified and because a black surface is freshly exposed, heat is absorbed thus discouraging reformation of ice. It is important to estimate in different kinds of muskeg, the degree to which this situation will limit operations. It could not be tolerated at all by some vehicles that might, under more favourable conditions, traverse one or two kinds of muskeg.

Lensing of ice causes difficulties similar to those encountered for interrupted ice sheets. The lenses vary in size, but often they may be from ten to twenty feet in their horizontal diameter, sometimes contiguous but more often not. Under these conditions, subsidence of some vehicles can be expected. Here again, it is important to know where this condition might arise in the muskeg. This is now predictable.

THE AUTHORS

Margaret Jean Evel was born on August 4, 1924, in Hamilton, Ontario. She was educated in Hamilton and obtained her B.A. degree from McMaster University in 1948 in the Botany and Zoology course.

From 1948-1952 she participated in floristic studies of counties bordering the north shore of Lake Erie for the Ontario Research Council. From 1952 until the present time, she has been engaged in Organic Terrain studies supported by the National Research Council and Defence Research Board, under the direction of Dr. A. W. Radforth.

N. W. Radforth

Jean Evel

Norman William Radforth was born on September 22, 1912, in Barrow-in-Furness, Lancashire, England. He emigrated to Canada in 1920.

Most of his primary and all of his secondary education was completed in Toronto. He graduated in 1936 in Honour Biology, from Victoria College, University of Toronto.

Post-graduate studies in experimental botany in 1936-7 at the Department of Botany, University of Toronto, were followed by research in palaeobotany in 1938-9 at the Department of Botany, Glasgow University, Scotland.

Dr. Radforth's teaching career began in the Department of Botany, University of Toronto in 1939. His appointment at McMaster University in 1946 included administrative duties as Head of the Department of Botany. While holding this post, he became the first Director of the Royal Botanical Gardens, Hamilton. He is now engaged, full time, as Professor of Botany at McMaster University.

All his palaeobotanical studies, as well as being fundamental, have given attention to the special applied circumstances arising in Canada. Among the latter, the importance of microfossils in coal and oil bearing rocks has been examined, Pleistocene age determinations have been achieved under his direction, particularly as related to the Don and Scarborough beds. Also, the character of peaty terrain, particularly for the sub-Arctic, has been revealed to facilitate engineering practice. This study, involving designation of terrain features from high altitude (30,000 ft.) has been designated by Dr. Radforth, "Palaeovegetography." Its application is now playing its part as a new device to aid in route selection and the definition of operational design for year round engineering on muskeg.

Recently, Dr. Radforth was awarded a Royal Society of Arts (London) Silver Medal for his paper "Peat in Canada and Britain — Economic Implications."

Thin sheeting of ice occurs in some muskegs (FI, EI, DFI, DEI). If it supports the vehicle, it affords an excellent medium for travel. When the thickness becomes critical because of advancing season or when interruptions occur, this is the situation that limits mobility. For some vehicles, frequent pitching and partial subsidence can be expected and usually not more than two passes will be possible.

Ridging, recognized by the presence of elongate, often joined, thickenings of ice superimposed on a continuous foundation of ice that can be quite substantial in depth, is conducive to stalling, high frequency of pitch and in occasional "bogging" in the depressions between ridges, for the base ice between the ridges, is usually not flat but is somewhat depressed.

Topographic variations present circumstances which will inevitably set controls on travel over organic terrain. The significant topographic features are shown in Table I where their relationship to muskeg type is also indicated. An understanding of these topographic features suggests at once the way in which travel and operations generally will be impeded. Therefore, no further elaboration on this point seems necessary here

In Table III, a selection of four mechanical features appears which the writers regard as important design components for muskeg vehicles. Others could have been selected, for example, articulation, but the intent here is to demonstrate the principle that any special design features pertinent to organic terrain character are not only advantageous but may limit operations entirely if lacking. To illustrate this, the four features selected seem to be adequate. They are considered in relation to seven common coverage formulae.

It has been suggested that mobility in organic terrain in conjunction with transportation of equipment or in construction, is best achieved when the lower run of track conforms over all its area to the ground contour. This feature would seem to be essential to achieve optimum travel conditions because it affords better traction and weight distribution. In the very coarse and very fine muskegs, it is relatively less ignificant.

There is also fundamental advantage to be gained in having a frontal drive sprocket so arranged as to present to the muskeg mat an inclined face of track area. In organic terrain characterized with formulae AEH and DFI (Table III), this feature has greatest advantage. Formula AEH has deep soft pockets separating coarse woody members. Vehicles often nose into these pockets and were it not for a high front drive sprocket with its associated track incline, extraction of the vehicle would not be facilitated. In DFI terrain, the lower two-thirds of the track is frequently submerged at intervals. For this condition any mechanical feature which would assist the vehicle to rise on to the mat immediately, would be helpful. The frontal drive sprocket proves to be a prominent aid.

A third factor, derived by synchronization of winch and track speed, also proves effective in the majority of the muskeg types shown in Table III. For DFI and FI and to a lesser degree in EH and EI, absence of a speed differential between track and winch enables the vehicle to take advantage of any mat strength available in case of a high degree of subsidence. The vehicle can be relatively easily guided onto unbroken mat without risk of nosing down or creating unnecessary destruction to the structure of the peat it is attempting to traverse.

Low ground pressure is perhaps the most obvious mechanical aid. The slope to the crown in the appropriate diagram (Table III) may suggest why some vehicles with relatively high ground pressure can manoeuvre successfully on some muskegs (AEH, AE) — terrain types which in many areas are widely prevalent.

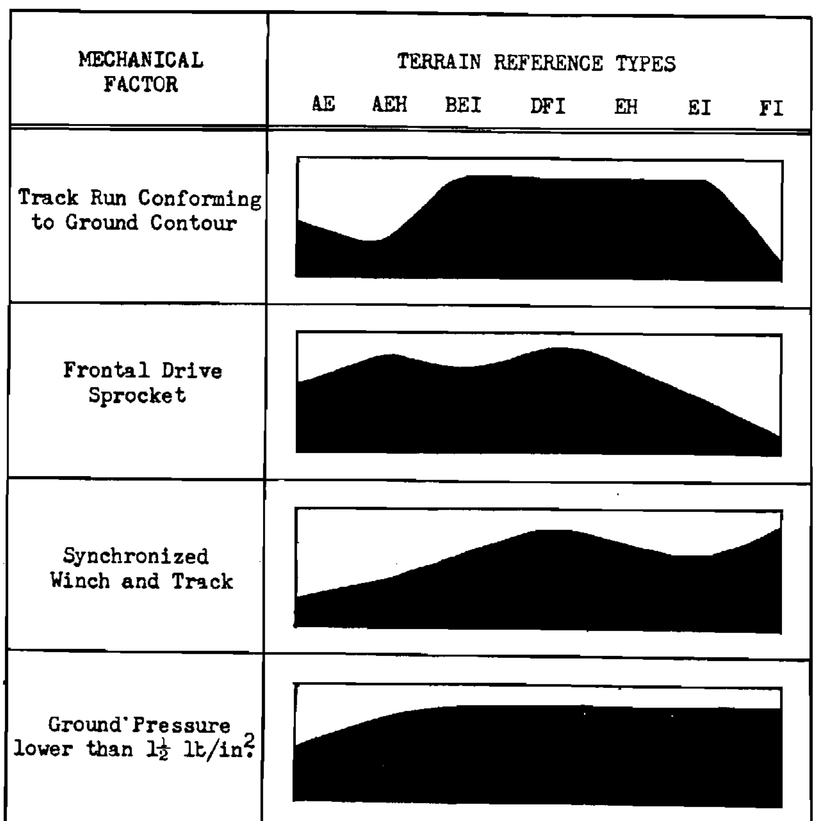
It is difficult to plan wisely for an operation on muskeg unless some assessment can be made of how the vehicles are going to respond in the different sets of conditions that the terrain imposes. In Table IV are listed six functional response factors that relate to the fundamentals of operations in muskeg. For purposes of comparison, they have been compared with the same terrain types as were selected for Table III. In different ways and degrees each reflects its independent relationship to given terrain types.

In planning for an operation, a comparison of these curves, made in the knowledge of the type of terrain to be traversed, would prove its usefulness. Thus, if the terrain type with the best bearing potential (AE, AEH) is selected for travel and loads of several tons are to be transported, the possibilities for a maximum speed of 6 mph. are least; effective manoeuvrability is unlikely because of the high density of surface obstruction, ice knolling (Table II) and terrain irregularity; pitch that is great in amplitude and frequent in incidence can be expected. If a non-powered trailer were being towed its displacement would be negligible but it would be an inconvenience unless something were done to improve manoeuvrability for the tractor towing it. Displacement for the lead vehicle also would be slight and therefore if the load is not excessive with respect to the carrying specifications of the lead vehicle it would be better to dispense with the trailer.

Selection of another common type of terrain (say EI, Table IV), requires a different kind of vehicle arrangement and operation for best effect. Though bearing capacity of this terrain is relatively low (but not nearly as low as for FI), it is possible to maintain a maximum speed of 6 mph, and to manoeuvre with ease with little embarrassment through pitching. On the other hand, if is highly desirable to tow the load because displacement is high. The lead vehicle can be used more effectively for personnel purposes and for local tasks *en route* in that it will be free from encumbrance of load. With manoeuvrability so favourable excessive winching can be avoided. It is quite likely that this terrain under the circumstances suggested would result in a faster and cheaper op-

TABLE III

IMPORTANCE OF VEHICLE DESIGN IN VARIABLE ORGANIC TERRAIN



Diagrams showing variability in functional effectiveness for four selected vehicle design factors as these apply for seven common organic terrain types.

NOTE: Black areas contain the ordinates indicating relative effectiveness of the design feature. Black areas in each rectangle suggest the degree of influence the feature imposes for organic terrain in general.

eration involving a minimum of road preparation and the entire operation can be performed in the summer.

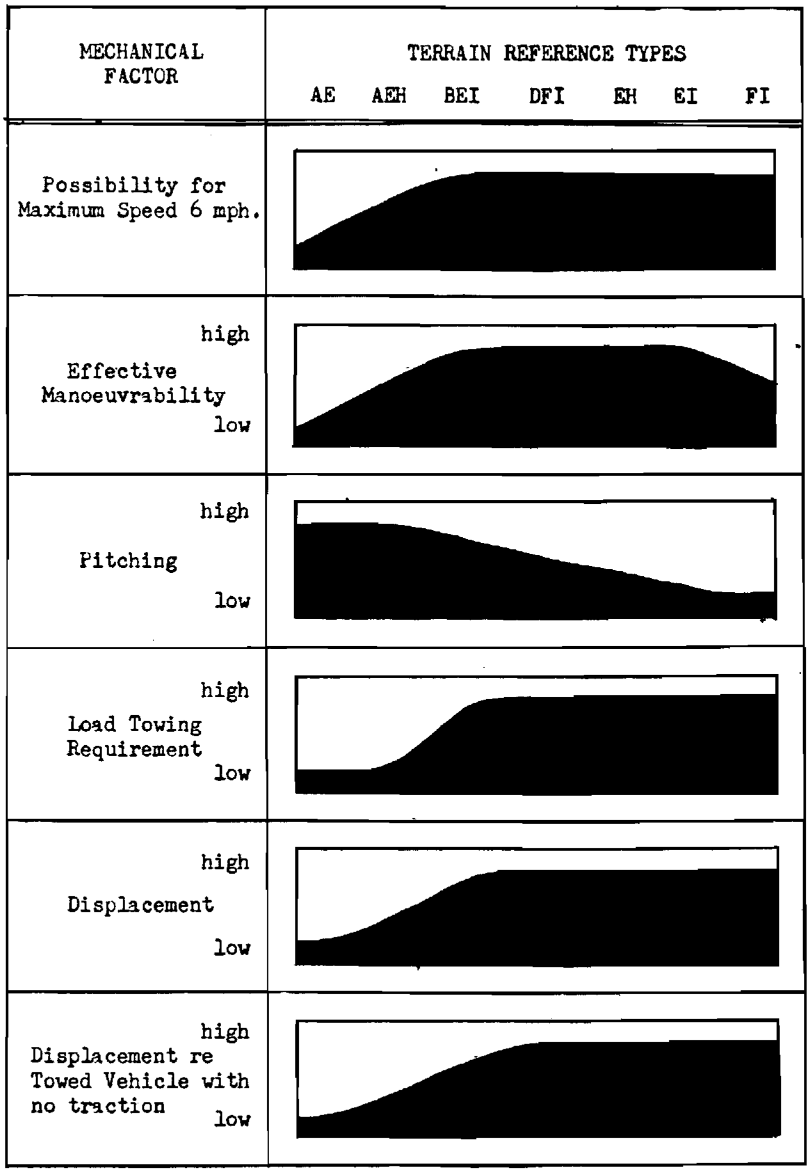
It is possible to select routes which present the fewest transportation problems for men and machines, but even at the best of times, there are many hazards which, perhaps because they arise from combined circumstances, are unpredictable and may impede progress. Also, before attempting to penetrate a muskeg area, even on selected routes, consideration should be given to the equipment available for organic terrain travel.

Vehicles are now being designed with muskeg access in mind. It will be appreciated, however, that vehicle design is not solely, a function of terrain, but that it relates to the purpose or range of purpose for which the vehicle is to be applied. Best performance will be achieved, therefore, not by one all-purpose vehicle, but by a range of vehicle types. For these reasons, it is advisable to select equipment with known specifications for muskeg access and to procure an operator who is ware of the potentials and performance of the vehicle of which he is in charge.

Operations in muskeg on a year round basis may thus be successfully accomplished if preliminary consideration is given to the problems of vehicle adaptability and terrain characteristics.

The observations and developed principles expressed in this account have been made possible through a grant-in-aid from the Associate Committee on Soil and Snow Mechanics, National Research Council, Canada. That prediction of vehicle-terrain relations can be made from aerial inspection of the organic terrain is a direct result of support from the Defence Research Board of Canada (Geophysics). To both these organizations the authors express their gratitude.

TABLE IV
VEHICLE RESPONSE IN VARIABLE ORGANIC TERRAIN



Diagrams showing variability in vehicle performance for six selected mobility functions as these are controlled by seven organic terrain types.

NOTE: Black areas contain the ordinates indicating relative low-high values for specified organic terrain types and as a whole suggest a composite value for the terrain.

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