# MUSKEG RESEARCH INSTITUTE

ROLLIGON TUNDRA DISTURBANCE TESTS

TUKTOYAKTUK AUGUST 1970



UNIVERSITY OF NEW BRUNSWICK

# ROLLIGON TUNDRA DISTURBANCE TESTS

# TUKTOYAKTUK AUGUST 1970

REPORT

TO

BECHTEL INCORPORATED

BY

THE MUSKEG RESEARCH INSTITUTE

UNIVERSITY OF NEW BRUNSWICK

DECEMBER 1970

TABLE OF CONTENTS

# FOREWORD

This report is an account of tests performed with an Albee Rolligon vehicle at Tuktoyaktuk, N.W.T. in August 1970. The results of these tests as expressed here are comparable with results of tests with other vehicles in the same area sponsored by the Government of Canada, Department of Indian Affairs and Northern Development. The cooperation of this department and the support of Bechtel Incorporated in completing this project are gratefully acknowledged.

# LIST OF ILLUSTRATIONS

# INTRODUCTION

Contemporary public concern about man's persistent environmental encroachment and his need to continually locate and develop the earth's natural resources have combined to generate a conflict of interests. One aspect of this problem has appeared in the disturbance of terrain (tundra) in some arctic areas caused by traffic of off-road vehicles.

While it is certainly true that such traffic has resulted in local destruction of vegetation and isolated cases of permafrost melt and surface erosion, there is, at time of writing, no accurate estimate of actual "environmental damage". A scientific investigation of this question has been initiated only during the past year.

Because there has been some objectionable disruption of the tundra surface industry, government and academic authorities are all anxious that future damage be reduced to an acceptable minimum. In order to do so it will be necessary to identify off-road vehicle configurations and to define operational techniques which are appropriate.

As part of an effort to acquire some knowledge in this area, a series of tests was conducted with a Rolligon vehicle at Tuktoyaktuk, N.W.T. (Fig. 1). Not only were effects of the vehicle on the ground assessed, but also some operational characteristics of the vehicle itself were observed.

An account of the tests performed and the results that were observed is presented in the following section.

## EXPERIMENTAL PROGRAM AND RESULTS

### TEST SITES

Three test sites were used and were located within a few hundred yards of each other on a tundra peninsula adjacent to the Tuktoyaktuk harbour. Site 1 was in a low lying level area almost at sea level. The topography was characterised by depressed centre polygons typical of the region, and vegetation consisted of sedges, mosses and small shrubs in that order of predominence (FIE in the Radforth classification system - see Appendix I). Scattered patches of lichen were found, especially on the raised polygon borders. The site was moist near the surface, and the depth to permafrost averaged 11 in.

Site 2 was on a well drained slope having a gradient of approximately 10 per cent. The ground surface was very firm and rough. Vegetal cover included heavier woody shrubs than those found in Site 1, mosses, and a few sedges (EIF - Radforth). Permafrost was present about 21 in. below the surface.

Site 3 was located on a plateau at the top of the slope on which Site 2 was selected. It was characterized by a dry, hard mounded surface of thin peat on a sub-layer of mixed sand and silt which appeared at the surface in sporadic patches. Vegetation consisted of sedges, light woody shrubs, and mosses (FEI Radforth) and permafrost depth was approximately 16 in.

### TEST VEHICLE

The vehicle used was an Albee Rolligon of the type shown in Fig. 2. The unique low pressure inflated bags are driven by top rollers which are in turn driven by a diesel engine torque

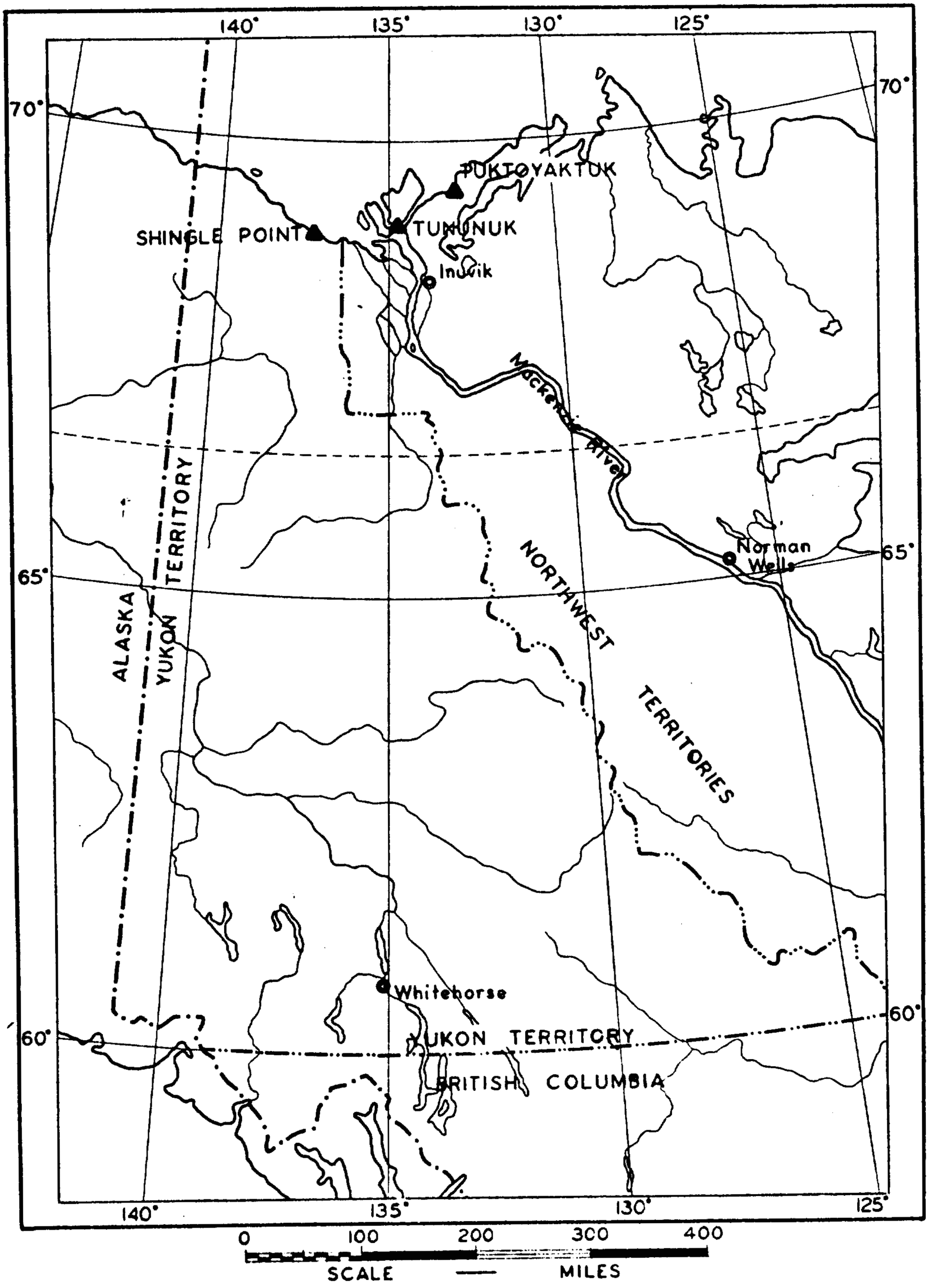
140°
135°
130°
125°
70°
65°
60°
TUKTOYAKTUK
TUNUNUK
SHINGLE POINT
Inuvik
Mackenzie River
Norman Wells
NORTHWEST TERRITORIES
YUKON TERRITORY
ALASKA
Whitehorse
BRITISH COLUMBIA
0
100
200
300
400
SCALE — MILES

Fig. 1

Fig. 2 Albee Rolligon

converter and power shift transmission. The six smooth inflated bags act as the suspension system and propel the vehicle over the ground. Inflation pressure can be controlled by the driver in the cab. Tare weight is in the neighbourhood of 11,000 lb.

TEST PROCEDURE - TERRAIN DISTURBANCE

To evaluate the effect of vehicle traffic on the ground surface in each site the Rolligon was driven back and forth over a test lane 200 feet in length. Photographs of the ground in the vehicle's path were taken after one, five, ten, twenty, forty, sixty, eighty and one hundred passes. The first test was conducted on Site 3 with a payload of 9000 lb. (gross weight 20000 lb.) and a bag inflation pressure of 5.5 p.s.i. During the test a ridge developed between the two tracks and appeared to increase the ground rolling resistance presented to the vehicle. This was evidenced by apparently increasing slip between the top drive rollers and the inflatable bags.

The test was terminated at 75 passes by immobilization caused by the centre ridge and subsequent blowout of a rear inflatable bag. It was felt that the age of the bag combined with heat of friction from the slipping roller were major factors contributing to the blowout. After this was repaired all further tests were carried out with the payload reduced to 6000 lb. and inflation pressure reduced from 5.5 to 3.5 p.s.i.

A second test was run on the same site with the modified loading, and the results of the two tests are compared in figures 3 to 16. In all subsequent tests the vehicle path was shifted

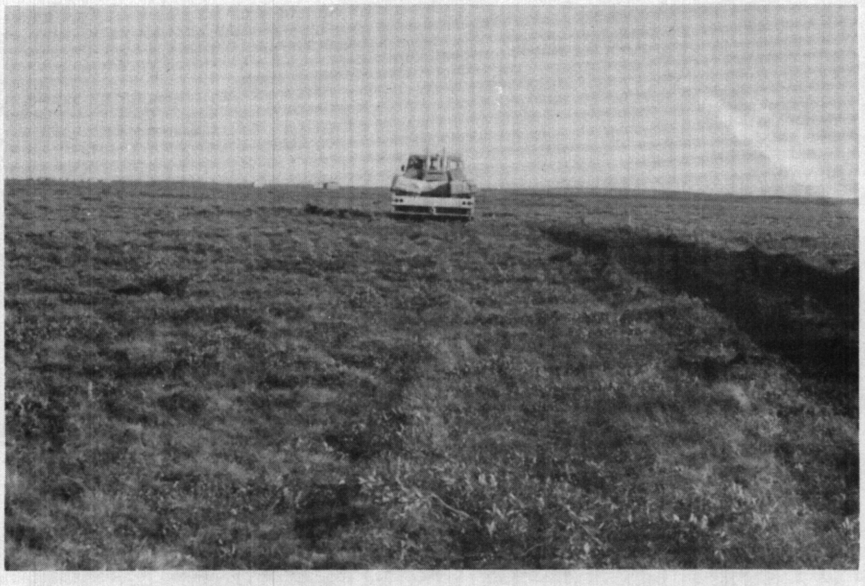

Fig. 3 Test Site 3, 1 Pass Heavy Load

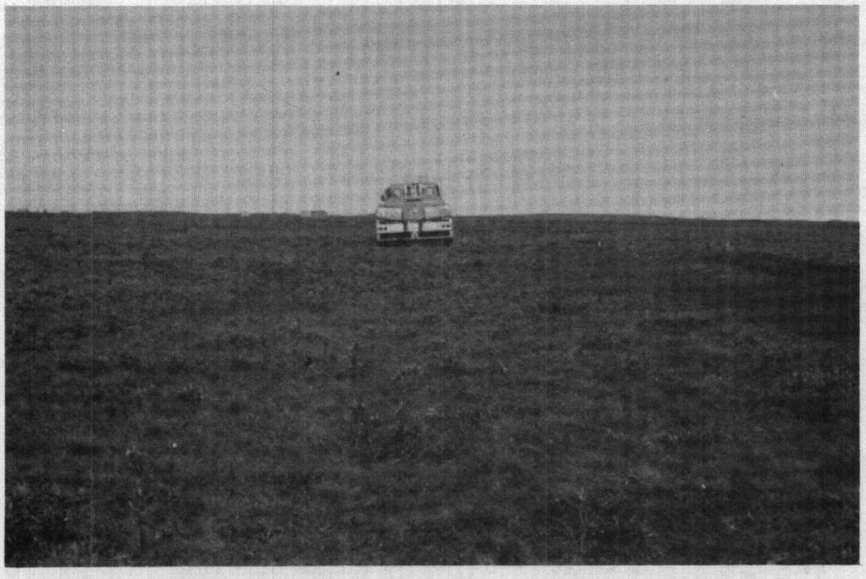

Fig. 4 Test Site 3, 1 Pass Light Load

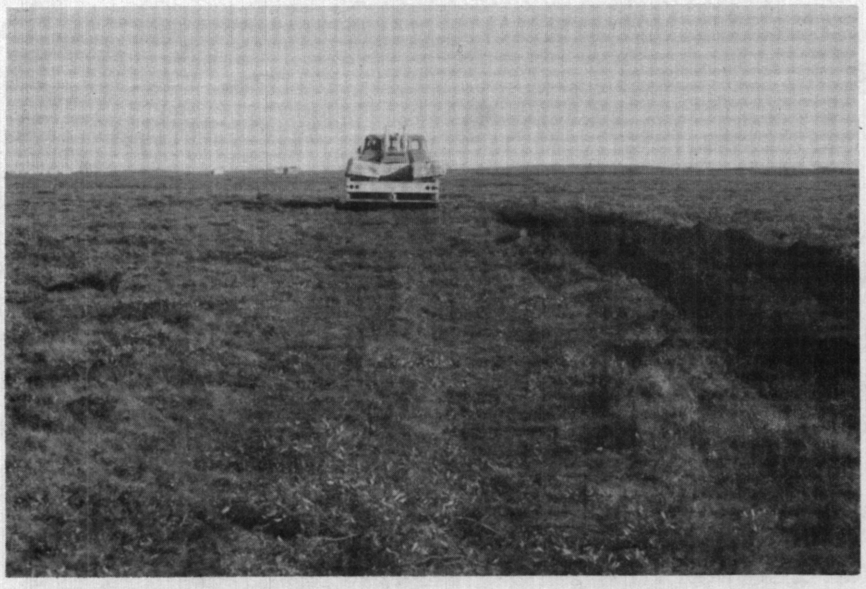

Fig. 5 Test Site 3, 5 Pass Heavy Load

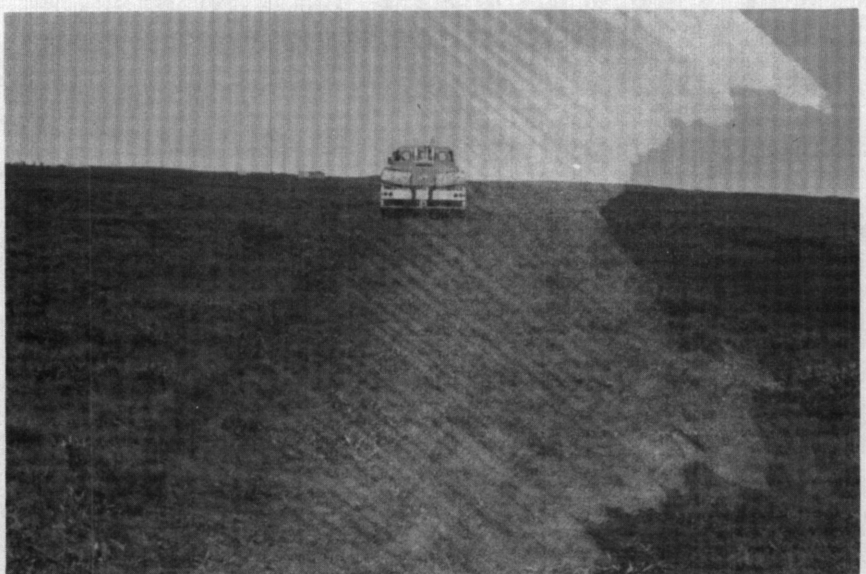

Fig. 6 Test Site 3, 5 Pass Light Load

Fig. 7 Test Site 3, 10 Pass Heavy Load

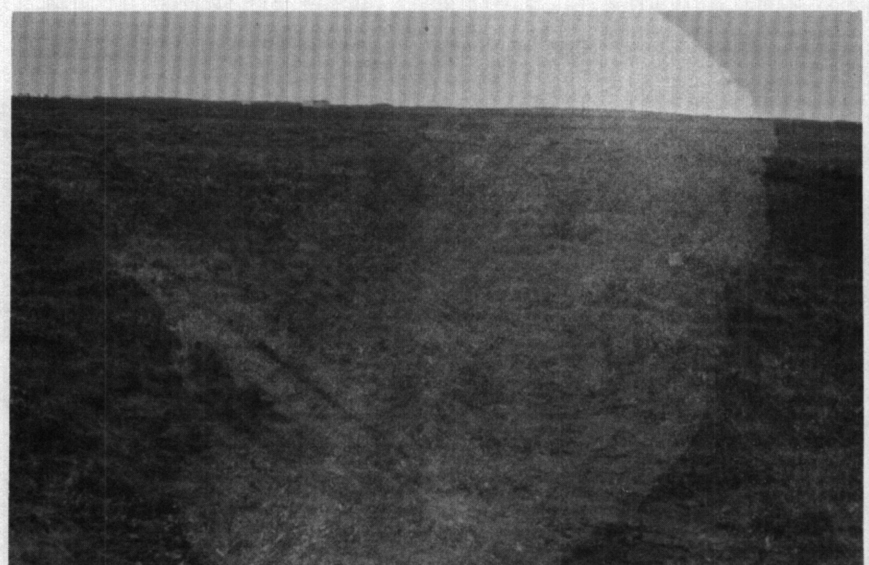

Fig. 8 Test Site 3, 10 Pass Light Load

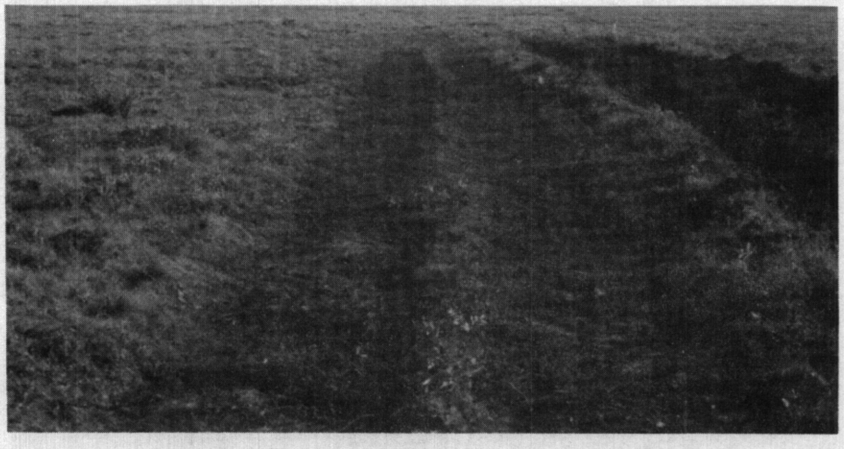

Fig. 9 Test Site 3, 20 Pass Heavy Load

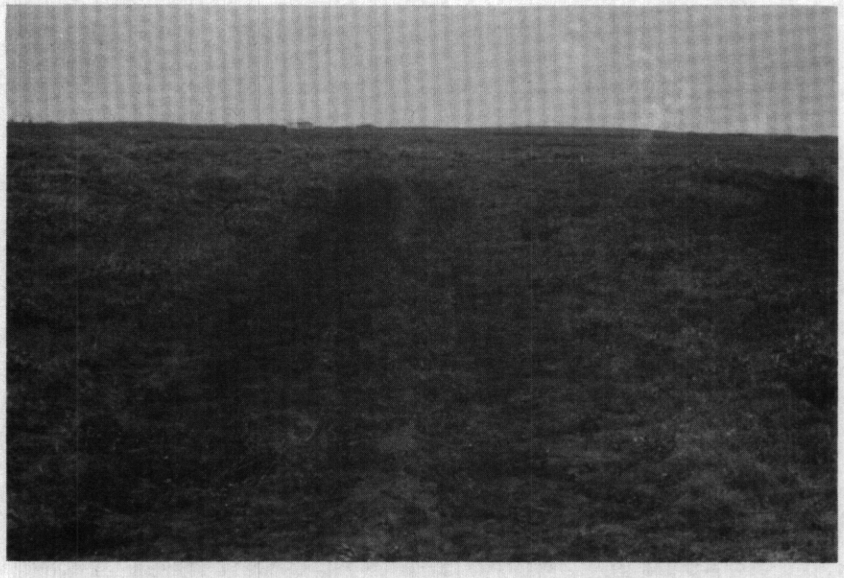

Fig. 10 Test Site 3, 20 Pass Light Load

Fig. 11 Test Site 3, 40 Pass Heavy Load

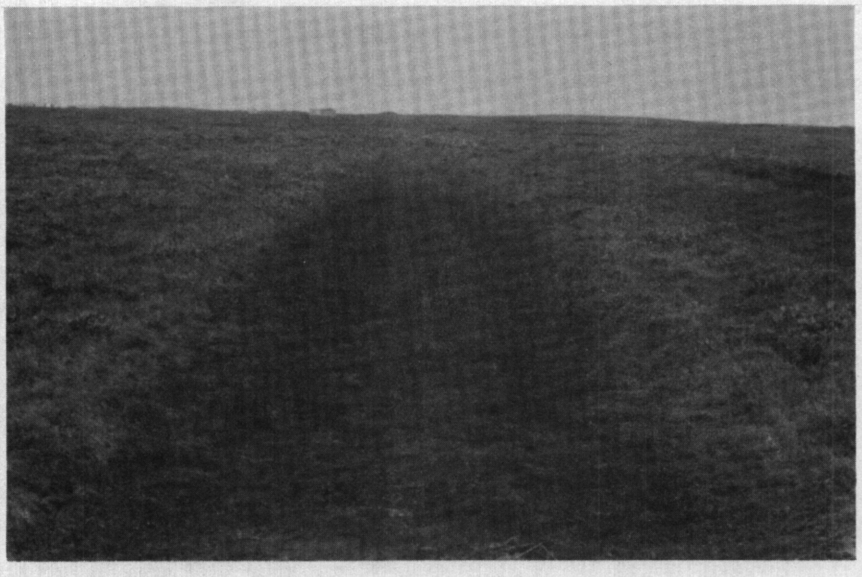

Fig. 12 Test Site 3, 40 Pass Light Load

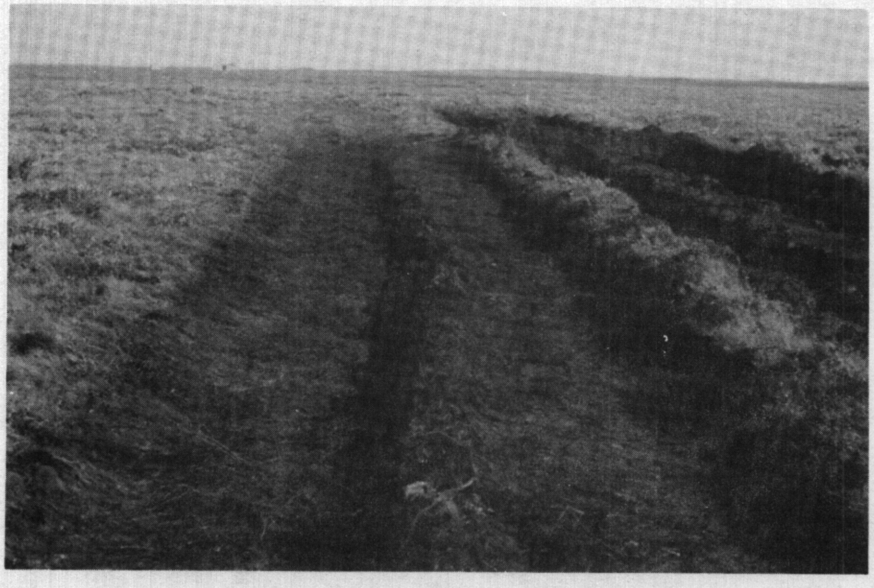

Fig. 13 Test Site 3, 60 Pass Heavy Load

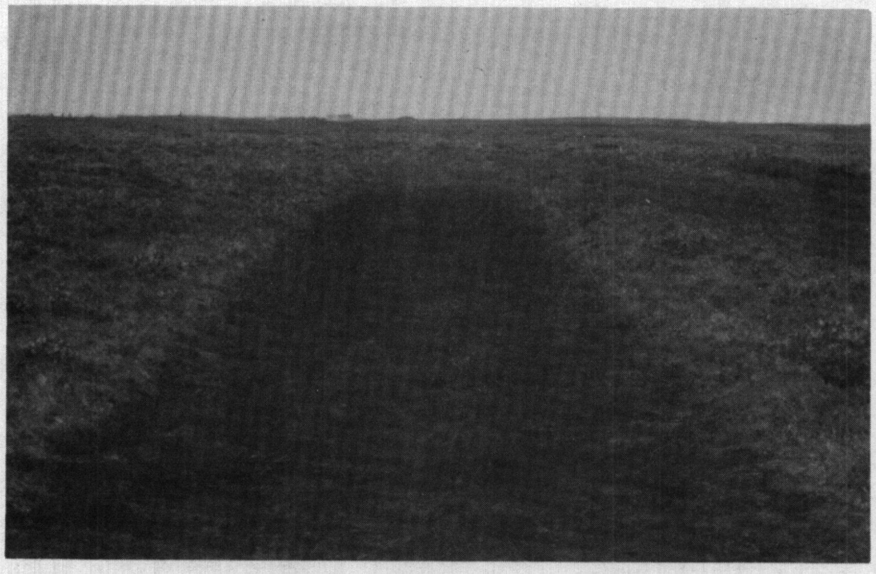

Fig. 14 Test Site 3, 60 Pass Light Load

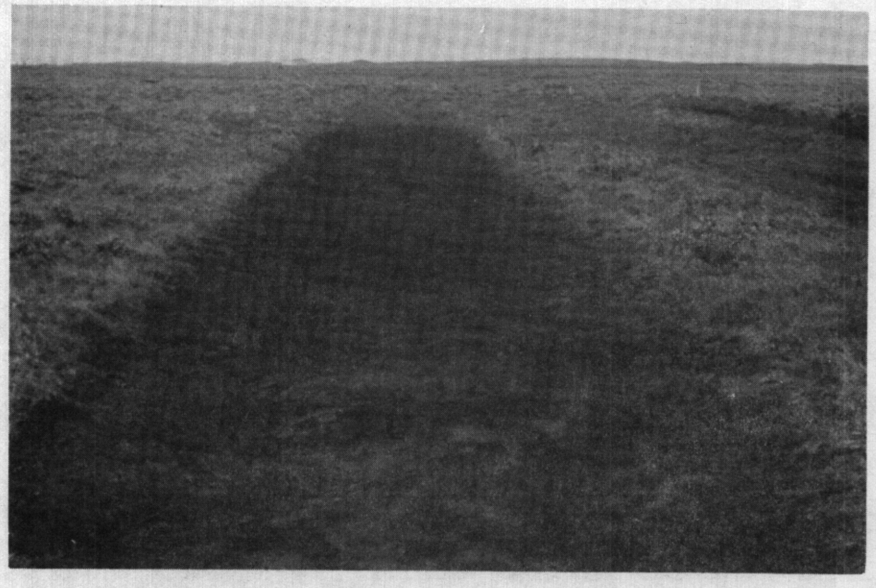

Fig. 15 Test Site 3, 80 Pass Light Load

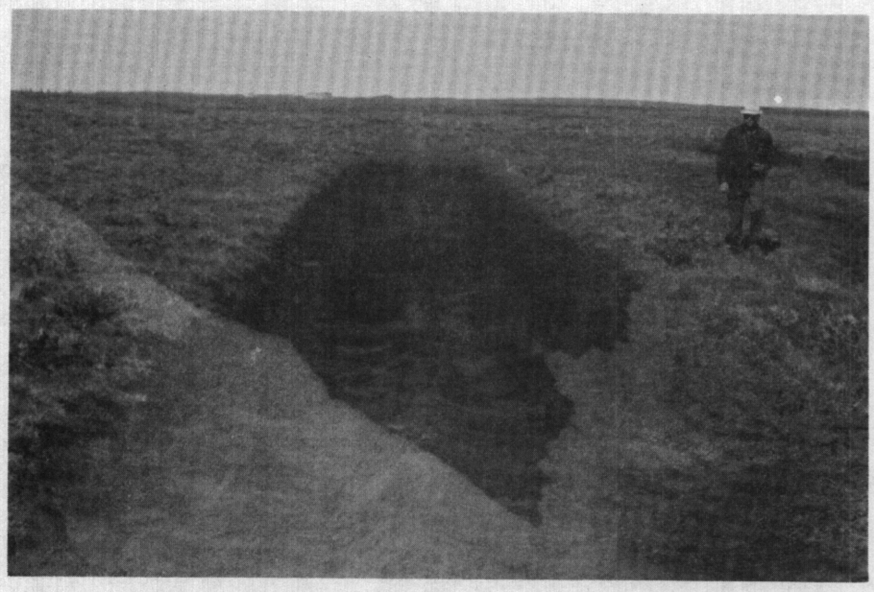

Fig. 16 Test Site 3, 100 Pass Light Load

laterally from time to time to press down the ridge which tended to develop between the ruts.

Similar tests were also run with the light loading conditions in Sites 1 and 2 with the results shown in figures 17 to 24 and 25 to 32 respectively.

It is evident, that as the number of passes increases the vegetation in every case gradually becomes flattened, shrubs have their leaves knocked off and many of the most brittle branches become broken. Eventually some soil is displaced by repeated application of the vehicle weight and shallow ruts develop. Small mounds become flattened to some extent.

The degree to which these forms of disturbance progress depends on several factors including vehicle weight, ground pressure, vegetation composition, and ground moisture content. The decrease in vehicle weight and ground pressure has a profound effect on reducing surface disturbance as can be seen in figures 3 to 16.

The vegetation in Site 2 appeared to be damaged more rapidly than in Sites 1 and 3 probably because of the higher proportion of brittle, fragile woody plants in Site 2.

Good drainage in Site 2 provided a lower soil moisture content and a firmer ground surface.

Preservation of the microtopography at high numbers of passes resulted and ruts were slow to develop. This is especially important on slopes where ruts can act as drainage channels and promote erosion.

In observing these and other vehicle tests it has been

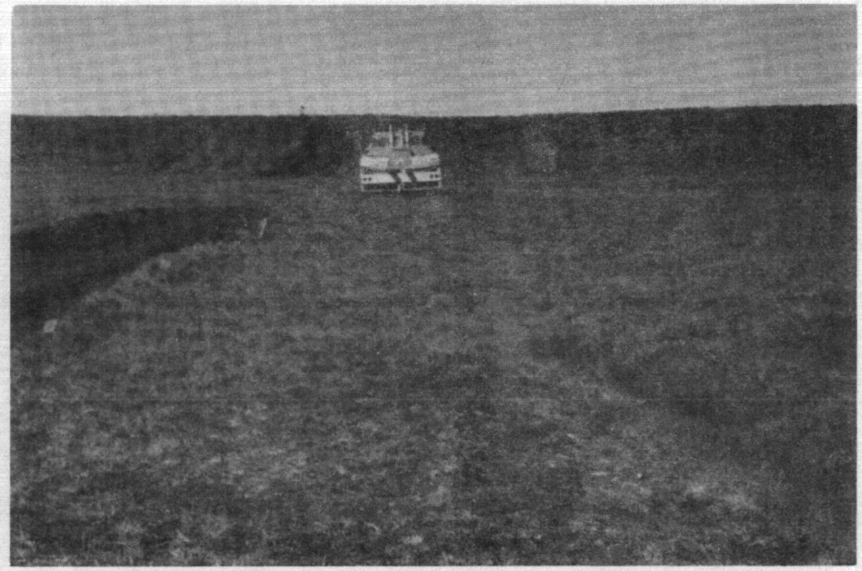

Fig. 17 Test Site 1, 1 Pass

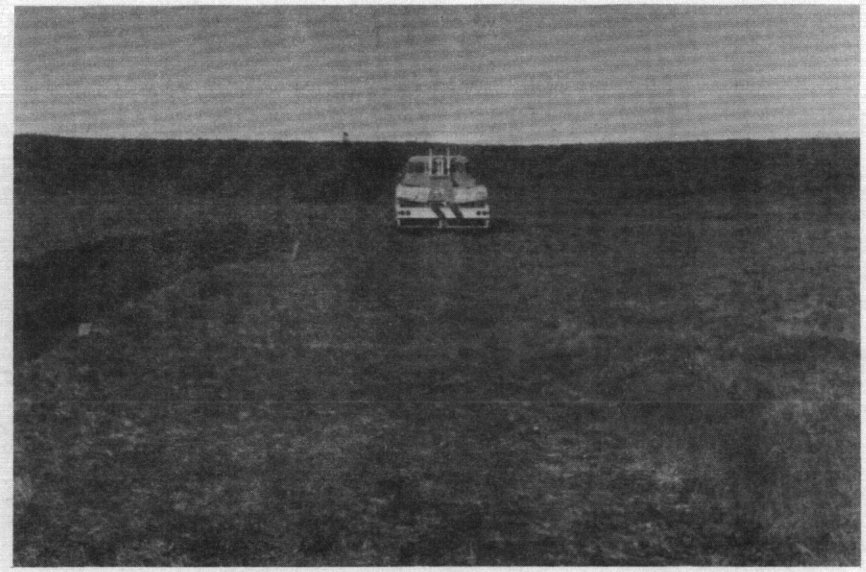

Fig. 18 Test Site 1, 5 Pass

Fig. 19 Test Site 1,10 Pass

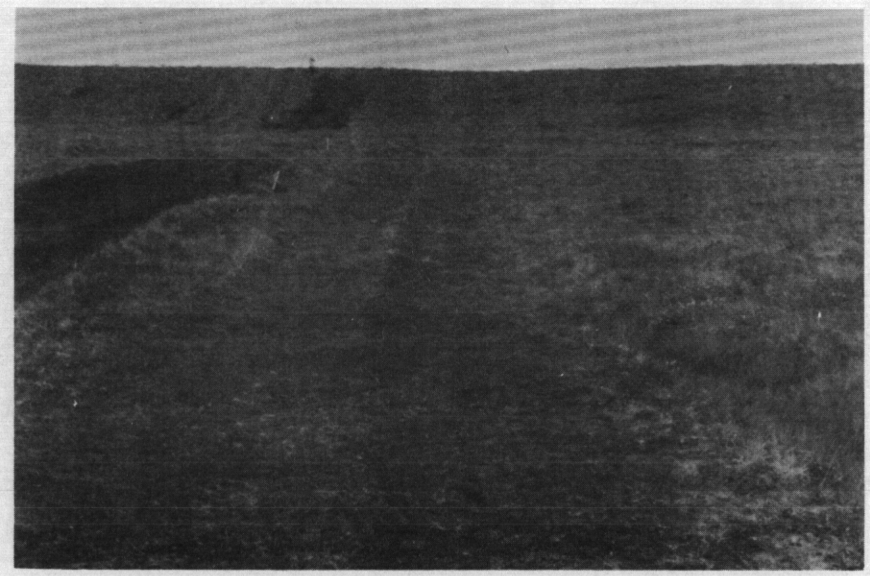

Fig. 20 Test Site 1, 20 Pass

Fig. 21 Test Site 1, 40 Pass

Fig. 22 Test Site 1, 60 Pass

Fig. 23 Test Site 1, 80 Pass

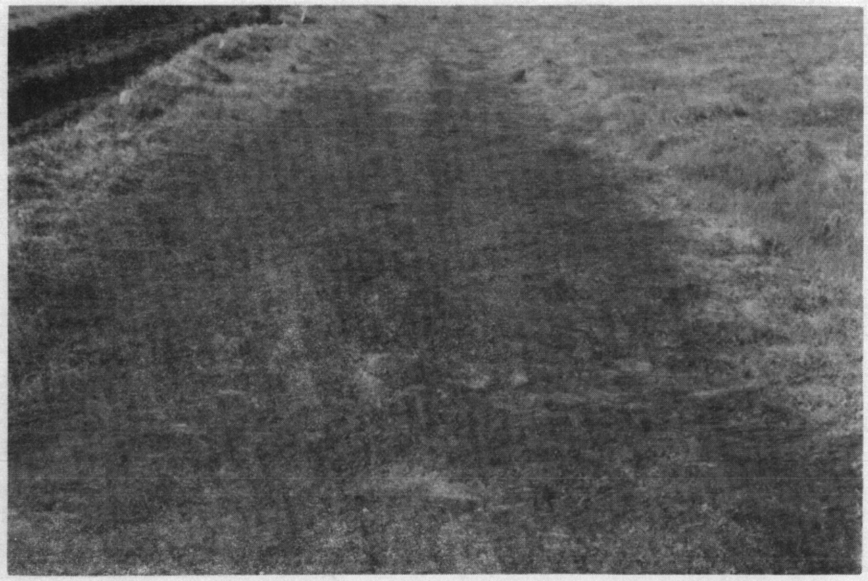

Fig. 24 Test Site 1, 100 Pass

possible to classify the progress of vegetation and microtopography disturbance into easily recognizable stages as outlined in Table I below.

| Disturbance Level | Structure | Vegetation |
|---|---|---|
| 1 | Undamaged | Undamaged |
| 2 | Slight chopping | Shrubs broken, leaves knocked off |
| 3 | Mound top scuffing/ flattening | Cutting and/or flattening of all vegetation |
| 4 | Mound top destruction | Tearing and scattering of vegetation - 10% destroyed |
| 5 | Ruts start to form, less than 50% structure destroyed | 25% destroyed |
| 6 | Ruts slightly deeper, more than 50% structure destroyed | 50% destroyed |
| 7 | Ruts half bare | 90% destroyed |
| 8 | Ruts entirely bare | 100% destroyed |
| 9 | Ruts to permafrost | |

TABLE I

Vegetation and structure disturbance classification system.

The test sites in which the Rolligon was run have been analyzed in accordance with this classification system, and the results are displayed in Table II. In the values shown, the first digit in each pair represents the structure disturbance level and the second digit corresponds to the vegetation disturbance level.

| No. of Passes | Site 1 Light Load | Site 2 Light Load | Site 3 Light Load | Site 3 Heavy Load |
|---|---|---|---|---|
| 1 | 1-1 | 1-1 | 1-1 | 1-1 |
| 5 | 3-3 | 1-2 | 1-2 | 2-2 |
| 10 | 4-3 | 2-2 | 1-3 | 4-3 |
| 20 | 4-3 | 2-3 | 4-3 | 4-3 |
| 40 | 4-4 | 3-3 | 4-3 | 5-4 |
| 60 | 5-4 | 4-4 | 5-4 | 6-3 |
| 80 | 5-5 | 5-5 | 6-4 | 6-3 |
| 100 | 6-6 | 6-6 | 6-5 | 6-4 |

TABLE II

Comparison of tundra disturbance in sites 1, 2, 3 according to the disturbance classification system.

Pending observation during the next few years of the vegetative regrowth and any erosion which may occur in the sites it has been tentatively suggested that level 4 is the maximum amount of structural and vegetation damage which can be tolerated if the disturbed tundra is expected to regain a semblance of its original state.

With this in mind it may therefore be concluded that a Rolligon type vehicle with a gross weight of 17000 lb. and an inflation pressure of 3.5 p.s.i. would be able to make about 40 passes over the same path without exceeding the desirable limit of tundra disturbance. For the reason stated above this should be regarded as a conservative and tentative conclusion.

It can also be concluded from Table II that if the vehicle weight is increased to 20000 lb and the inflation pressure to 5.5 p.s.i., 10 to 20 passes would be the amount of traffic tolerable. It should be noted that adjustment of the loading conditions within a fairly small range can result in substantial increase in the amount of traffic that is tolerable.

DRAWBAR PULL TESTS

Several drawbar pull tests were also conducted in Site 3. The Rolligon was made to pull a second vehicle on which the brakes were gradually applied to increase the load. The resulting horizontal pull from the Rolligon was measured by a load cell in the tow cable and recorded on a strip chart recorder.

As with all vehicles subjected to this test, varying amounts of slip between the inflatable bags and the ground surface, and between the bags and the top drive rollers resulted from increasing drawbar pull. Slip can in some cases cause scarring of the ground surface and when it does, it is undesirable if tundra disturbance is a critical consideration.

In the tests, the Rolligon carried a 6000 lb. payload for a gross weight of approximately 17000 lb., and the bag inflation pressure was maintained at 3.5 p.s.i. Maximum pull measured was approximately 4000 lb. and effective slip varied from low values up to 100%. The term "effective" is used here because true slip between the bags and the ground surface was not very noticeable. Considerable slip occurred between the bags and the top drive rollers.

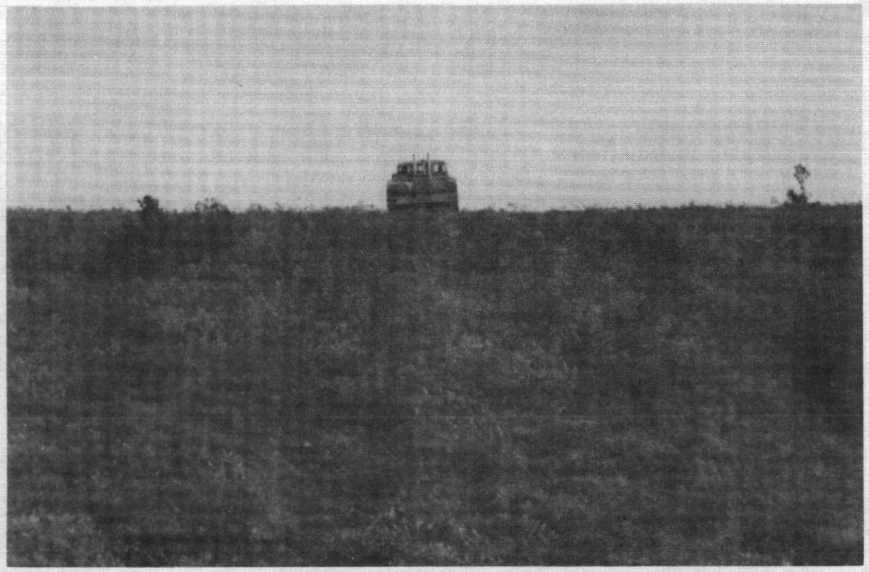

Fig. 25 Test Site 2, 1 Pass

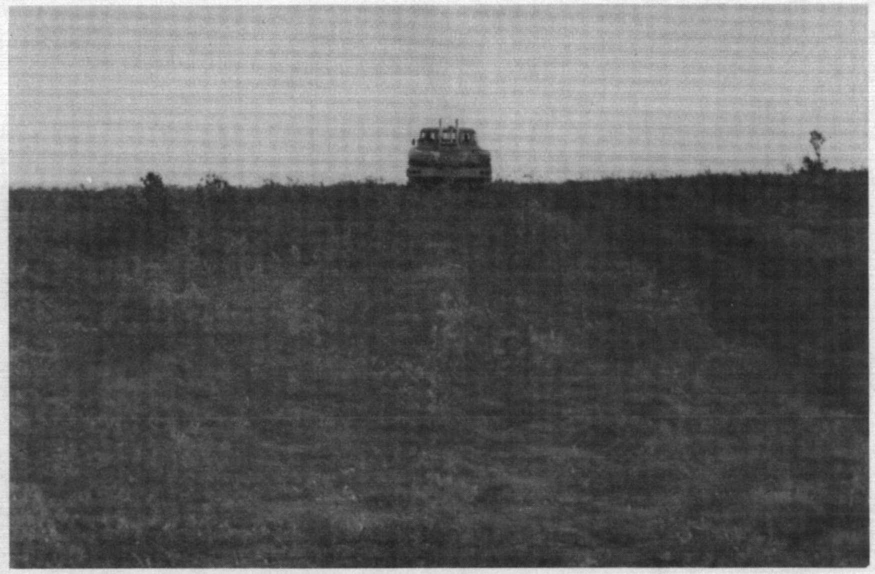

Fig. 26 Test Site 2, 5 Pass

Fig. 27 Test Site 2, 10 Pass

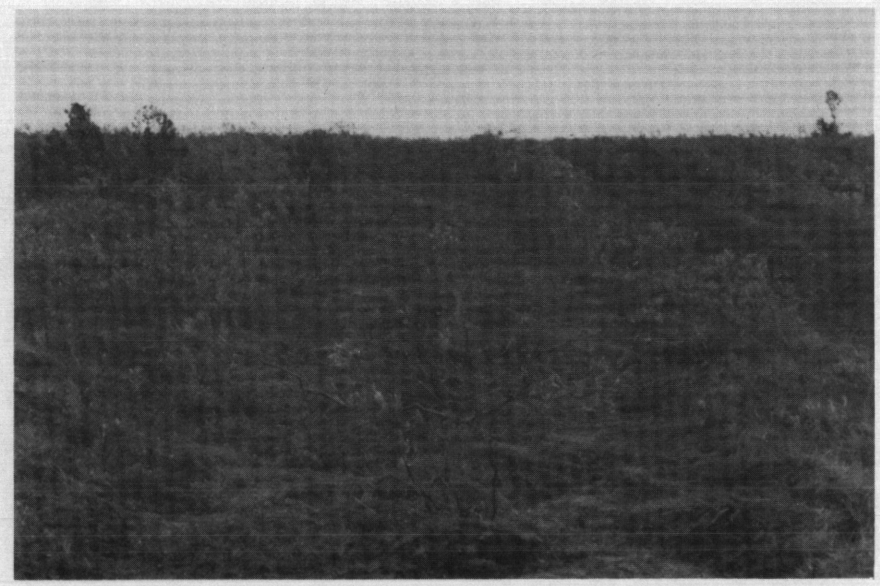

Fig. 28 Test Site 2, 20 Pass

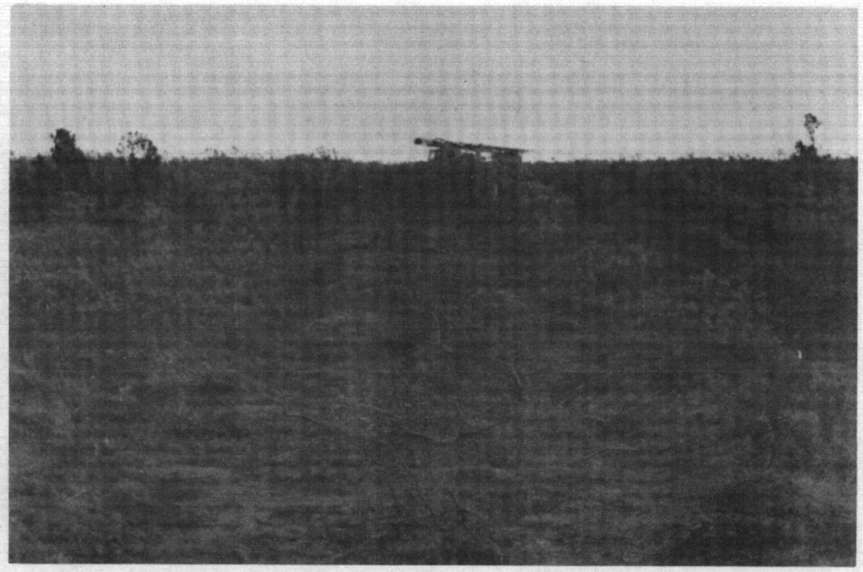

Fig. 29 Test Site 2, 40 Pass

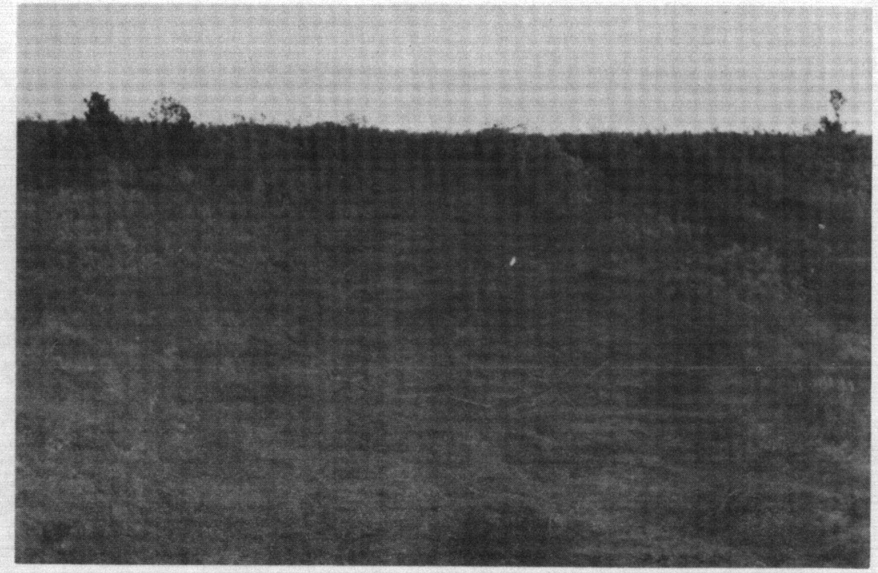

Fig. 30 Test Site 2, 60 Pass

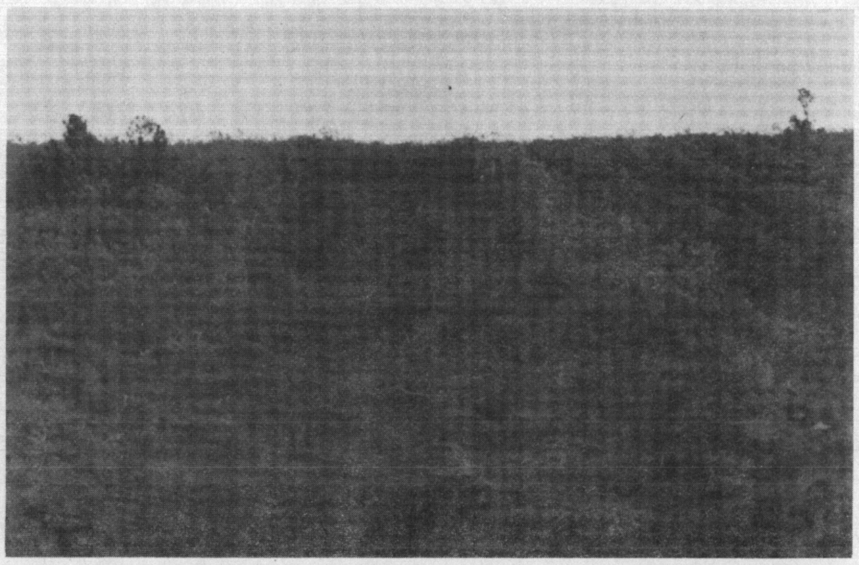

Fig. 31 Test Site 2, 80 Pass

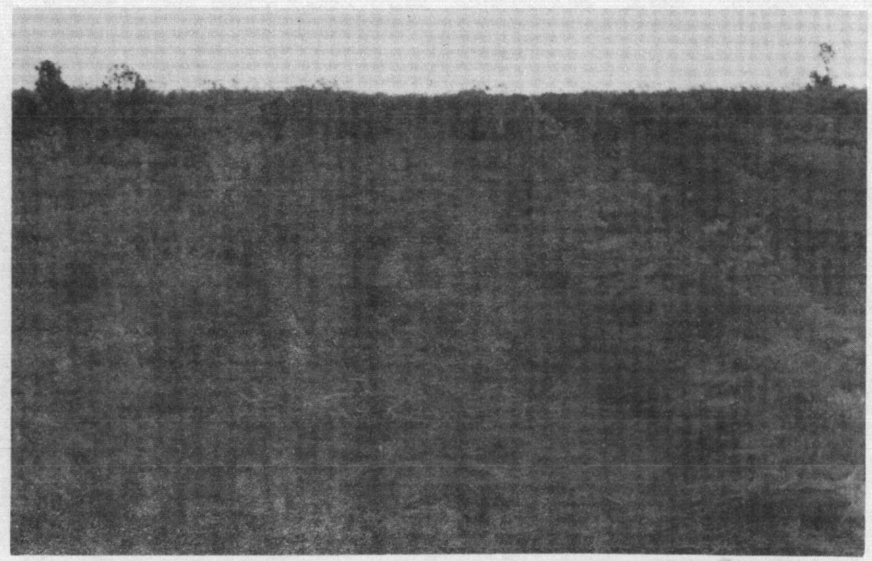

Fig. 32 TEst Site 2, 100 Pass

Several features of the drawbar pull performance are believed to significant with respect to the vehicle's mobility and to its effect on the terrain. First, it is understood that the Rolligon in the configuration tested is intended as a load carrier rather than as a tractor. However drawbar pull performance is often a good indicator of a vehicle's slope climbing ability. On a slope where a vehicle's tractive effort is required to balance the component of its weight parallel to the slope, the maximum drawbar pull attainable on level ground theoretically corresponds to a maximum gradient the vehicle can climb. This has been calculated to be roughly 23% assuming ground conditions similar to those encountered in the tests.

Secondly, the fact that very little slip occurs between the inflatable bags and the ground surface is important because relatively little damage to the terrain surface can result, even under maximum drawbar pull conditions. The smooth surface of the inflatable bag and the absence of cleats is also beneficial in this respect.

GENERAL PERFORMANCE OBSERVATIONS

A few additional aspects of the Rolligon's performance in moving over the tundra were unusual and are considered worth mentioning.

General compatability of the vehicle and terrain was evidenced by the fact that ground speed while travelling to and from the test areas was higher than is commonly found in off-road vehicles. This is made possible by the inflated bag drive system which provides a very soft and comfortable if somewhat underdamped, ride. The flexible inflated bags conform easily to the irregular, mounded tundra surface and absorb hundreds of small jolts, preventing their transmission to the main vehicle chassis. The advantages of extremely low unsprung weight are well illustrated by this concept.

In crossing ditches or large obstacles whose size and contour were roughly equal to the inflated bags, a radical reduction in speed was necessary for the "suspension" to accommodate.

Operating in wet peat and silt mixtures resulted in some slippery soil adhering to the inflated bags and caused slippage between the bags and top drive rollers. This could become a major problem in some operational conditions where slopes must be negotiated or tractive effort is required to overcome increased rolling resistance in soft wet ground.

## CONCLUSIONS

A summary of the conclusion arising from the foregoing observations is offered as follows:

1. With a payload to weight ratio of 0.55 and inflation pressure of 3.5 p.s.i. 40 pass traffic is possible without exceeding what is suggested as a maximum acceptable level of tundra distrubance.

2. With payload to weight ratio and inflation pressure increases to 0.82 and 5.5 p.s.i. respectively, the acceptable traffic load is reduced to about 15 passes.

3. 23% slopes are probably negotiable with a payload of 6000 lb. and inflation pressure of 3.5 p.s.i.

4. Low slip of the inflated bags during slope climbing or with drawbar loads present prevents serious terrain disturbance.

5. The ability of the inflated rubber bags to conform to the microtopography is a definite asset in minimizing terrain surface disturbance.

6. The Rolligon in its present form appears to represent a highly successful concept with respect to ride quality, speed, and lack of disturbance of the terrain surface.

7. Obstacle crossing speed and payload to weight ratio are acceptable for a prototype. A production version of the vehicle would benefit greatly from any improvements which could be effected in these aspects. It is possible that scaling up of the vehicle could substantially contribute to this.

## RECOMMENDATIONS

If a pre-production prototype vehicle based on the Rolligon concept and designed for specific industrial operations is planned, it would probably be advantageous to evaluate not only its performance from a mechanical standpoint, but also with respect to tundra disturbance.

Lack of terrain surface disturbance is one of the most promising features of the Rolligon concept. In view of the prominence of this aspect of off-road vehicle activity in tundra regions, an assessment of terrain disturbance would be significant in any further evaluation of the concept.

# APPENDIX I

## RADFORTH MUSKEG VEGETATION CLASSIFICATION SYSTEM

## APPENDIX I

## RADFORTH MUSKEG COVER CLASSIFICATION SYSTEM

An important feature of muskeg is that it is characterized by a finite number of vegetation structural types. These types consist of nine basic cover classes, each designated by one of the first nine letters of the alphabet, listed in table I in combinations called cover formulae.

| cover class | Description |
|---|---|
| A | Trees over 15 ft. high |
| B | Trees up to 15 ft. high |
| C | Non-woody, grass-like 2-5 ft. high |
| D | Woody, tall shrubs or dwarf trees 2-5 ft. high |
| E | Woody shrubs up to 2 ft. high |
| F | Sedges and grasses up to 2 ft. high |
| G | Non-woody broad-leaf plants up to 2 ft. high |
| H | Leathery to crisp mats of lichen up to 4 in. high |
| I | Soft mats of moss up to 4 in. high |

TABLE I - MUSKEG COVER CLASSES

The cover classification does not depend on the naming of plant species, and since these classes can be used to describe any muskeg, the system has worldwide application.

On any given muskeg area, certain of these cover classes are found in combination, and the cover formula used to describe that muskeg area is derived by listing in descending order of prominence the cover classes which can be observed to be growing there. To be included in the cover formula, any cover class must represent at least 25% of the total cover, based on estimate from visual observation. This estimate may seem to be a rather subjective type of evaluation, but in practice there is rarely any doubt that a given cover class represents more or less than 25% of the total cover.

As an example of the application of this classification system, a muskeg area covered by tall spruce trees over 15 ft. high, woody shrubs from 2-5 ft. high, and woody shrubs up to 2 ft. high would be referred to as ADE. A muskeg area covered by grasses and sedges up to 2 ft. high and a carpet of moss would be called FI and so on.

It might appear that all the combinations of the nine cover classes in groups of two or three would lead to an unwieldy number of possible cover formulae. In reality many possible combinations, such as GAD, and BGC, do not occur. The most common include: ADE, ADF, ADI, AEH, AEI, AFI, BDE, BDF, BEF, BEH, BEI, BFI, C, CI, DEF, DFI, DI, EFI, DH, EI, FI, FEI, FIE, G, HE.

The fact that muskeg vegetal cover can be classified depends on the recurrence of cover formulae on a worldwide scale and this in turn reflects the orderliness and predictability of conditions such as peat depth, water content and climate which prevail in areas where muskeg occurs. The significance of this fact is that results obtained from tests on one muskeg area of a given cover type are applicable to all other muskeg areas with the same cover type.