

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

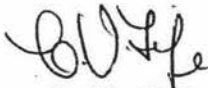
AN APPROACH TO A FIELD DRAINAGE
PROBLEM BY LABORATORY EXAMINATION OF
SELECTED PROPERTIES OF UNDISTURBED SOIL CORES.

Thesis
presented at Massey University of Manawatu
in part fulfilment of the requirements for
the Degree of Master of Agricultural Science.

by
C.J. BAKER

- 1964 -

The results on hydraulic studies reported herein represent the partial repetition of a more exhaustive study, all records of which were completely destroyed by a fire arising from an electrical defect in the laboratory. This loss has limited the drawing of conclusions and must be taken into account in evaluating the work.



C. V. Fife,

HEAD OF SOILS DEPARTMENT

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
A	INTRODUCTION	1
B	REVIEW OF THE LITERATURE	3
	I Techniques for obtaining "undisturbed" soil samples	4
	II The transportation, storage, and preparation of soil samples prior to laboratory investigations of hydraulic characteristics	11
	III Supplementary laboratory equipment associated with hydraulic studies of "undisturbed" soil samples	14
	IV The laboratory study of water flow through "saturated" soil	16
	V Soil and fluid properties responsible for variations in intrinsic permeability	21
	VI Methods of indirect assessment of intrinsic permeability .	26
C	SOIL AND SITE CHARACTERISTICS AND THEIR ASSOCIATED PROBLEMS	28
	I The problem	28
	II The profile	30
	III Sampling sites	30
D	FIELD AND LABORATORY TECHNIQUES	32
	I Techniques and equipment used in obtaining "undisturbed" soil cores	32
	II Transportation, storage and preparation of the cores prior to the laboratory investigation of their hydraulic characteristics	71
	III Supplementary laboratory equipment and techniques associated with hydraulic studies of the "undisturbed" soil cores	79
	IV Laboratory hydraulic studies of an artificially packed sand column	91
E	RESULTS AND DISCUSSIONS	94
	I Distilled water and tap water as the infiltrating fluids .	95
	II Examination of the flow rate from a capillary tube, as it was affected by diurnal air temperature fluctuations	96
	III Hydraulic tests on the stratified sand column	99

(cont.)

TABLE OF CONTENTS (cont.)

<u>Section</u>		<u>Page</u>
	IV Hydraulic tests on "undisturbed" soil cores from the Ongley Park profile	106
	V Hydraulic tests on "undisturbed" soil cores from the Ongley Park profile, with the flow direction reversed	126
	VI Measurement of the rate of rise of 'H' in individual piezometer tubes	139
	VII Indirect assessments of intrinsic permeability, based on laboratory examination of certain physical characteristics of "undisturbed" soil cores	141
	VIII A qualitative account of results obtained from previous hydraulic tests performed on soil cores from the Ongley Park profile	147
F	GENERAL DISCUSSION AND CONCLUSIONS	150
	I General considerations of sampler designs	150
	II General considerations of the laboratory treatment of cores prior to percolation or permeability experiments	150
	III General considerations of hydraulic conductivity investigations utilizing "undisturbed" soil cores	151
	IV The Ongley Park profile	154
G	SUMMARY	156
	REFERENCES	157
	ACKNOWLEDGEMENTS	162
	APPENDICES	163

LIST OF TABLES

<u>Table</u>		<u>Page</u>
I	The salient features of various rotary soil samplers developed between 1926 and 1960	8
II	Permeability classes of Smith and Browning (1946) for saturated subsoils	19
III	Permeability classes of O'Neal (1952) for saturated subsoils and the corresponding range of hydraulic conductivity and of intrinsic permeability	20
IV	The specific recovery ratio of cores extracted by the sampler	64
V(a)	Mean hydraulic gradients of the arbitrary layers of the sand column (normal flow direction)	103
V(b)	Relative impedances of the arbitrary layers of the sand column (normal flow direction)	104
VI(a)	Mean hydraulic gradients of the arbitrary layers of core G ₂ (normal flow direction)	118
VII(a)	Mean hydraulic gradients of the arbitrary layers of core H ₂ (normal flow direction)	118
VIII(a)	Mean hydraulic gradients of the arbitrary layers of core I ₂ (normal flow direction)	119
IX(a)	Mean hydraulic gradients of the arbitrary layers of core K ₂ (normal flow direction)	119
X(a)	Mean hydraulic gradients of the arbitrary layers of core L ₂ (normal flow direction)	120
VI(b)	Relative impedances of the arbitrary layers of core G ₂ (normal flow direction)	122
VII(b)	Relative impedances of the arbitrary layers of core H ₂ (normal flow direction)	122
VIII(b)	Relative impedances of the arbitrary layers of core I ₂ (normal flow direction)	123
IX(b)	Relative impedances of the arbitrary layers of core K ₂ (normal flow direction)	123
X(b)	Relative impedances of the arbitrary layers of core L ₂ (normal flow direction)	124

(cont.)

LIST OF TABLES (cont.)

<u>Table</u>		<u>Page</u>
XI(a)	Mean hydraulic gradients of the arbitrary layers of core G ₂ (reversed flow direction)	133
XII(a)	Mean hydraulic gradients of the arbitrary layers of core H ₂ (reversed flow direction)	133
XIII(a)	Mean hydraulic gradients of the arbitrary layers of core I ₂ (reversed flow direction)	134
XI(b)	Relative impedances of the arbitrary layers of core G ₂ (reversed flow direction)	136
XII(b)	Relative impedances of the arbitrary layers of core H ₂ (reversed flow direction)	136
XIII(b)	Relative impedances of the arbitrary layers of core I ₂ (reversed flow direction)	137
XIV	Time rate of rise of 'H' in individual piezometer tubes	139
XV	Structural development evident in a sample from the Ongley Park profile	141
XVI	Visible porosity evident in a sample from the Ongley Park profile	143
XVII	Relative compaction data obtained from a sample of the Ongley Park profile	144
XVIII	Textural classes of a sample of the Ongley Park profile	145
XIX	Mechanical analysis of a sample of the Ongley Park profile	146

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
I	The generalized permeability - time curve of Allison (1947)	23
II	The drive head and thrust bearing assembly	39
III	The cutting head and soil cutting ring	42
IV	Transverse section through the inner stationary tube	45
V	The zero head water supply system	80
VI(a)	Flow rate from a capillary tube and maximum and minimum temperature curves	97
(b)	Flow rate from a capillary tube and maximum and minimum temperature curves	97
VII(a)	Sand column, permeability curve	101
(b)	Sand column, total pressure loss curves	101
VIII	Sand column, theoretical and actual profiles	105
IX(a)	Core G ₂ , permeability curve (normal flow direction)	108
(b)	Core G ₂ , total pressure loss curves (normal flow direction)	108
X(a)	Core H ₂ , permeability curve (normal flow direction)	109
(b)	Core H ₂ , total pressure loss curves(normal flow direction)	109
XI(a)	Core I ₂ , permeability curve (normal flow direction)	110
(b)	Core I ₂ , total pressure loss curves (normal flow direction)	110
XII(a)	Core K ₂ , permeability curve (normal flow direction)	111
(b)	Core K ₂ , total pressure loss curves (normal flow direction)	111
XIII(a)	Core L ₂ , permeability curve (normal flow direction)	112
(b)	Core L ₂ , total pressure loss curves (normal flow direction)	112
XIV	The theoretical profiles of cores G ₂ , H ₂ , I ₂ , K ₂ , and L ₂ (normal flow direction)	125

(cont.)

LIST OF FIGURES (cont.)

<u>Figure</u>		<u>Page</u>
XV(a)	Core G ₂ , permeability curve (reversed flow direction)	129
(b)	Core G ₂ , total pressure loss curves (reversed flow direction) ..	129
XVI(a)	Core H ₂ , permeability curve (reversed flow direction)	130
(b)	Core H ₂ , total pressure loss curves (reversed flow direction) ..	130
XVII(a)	Core I ₂ , permeability curve (reversed flow direction)	131
(b)	Core I ₂ , total pressure loss curves (reversed flow direction) ..	131
XVIII	The theoretical profiles of cores G ₂ , H ₂ and I ₂ (reversed flow direction)	138
XIX	Possible stream lines to the base of a piezometer tube, within a core	140

LIST OF PLATES

<u>Plate</u>		<u>Page</u>
I	The soil coring machine, together with the modified "Halliday" post-hole borer, raised in the transport position	37
II	The cutting head	43
III	The inner stationary tube	46
IV	The soil cutting ring removed from the cutting head	47
V	The cutting end of the coring machine	50
VI	The cutting head and soil cutting ring commencing entry into the soil	51
VII	The soil cutting ring (with head removed) commencing entry into the soil	52
VIII	The first portion of a core, illustrating the cutting pattern of the head and soil cutting ring	53
IX	The soil coring machine in position for sampling	54
X	The soil coring machine at almost full penetration depth	55
XI	A soil core, part of which has adhered to the inner tube	56
XII	The core embedded in the opened inner tube	57
XIII	The transporting mould placed over the exposed core	58
XIV	The core, mould, and inner tube inverted	59
XV	The core embedded in the transporting mould	60
XVI	The upper portion of an "undisturbed" core, illustrating severed earthworm channels	65
XVII	Greatly magnified view of earthworm channels, severed by the leading edge of the soil cutting ring	66
XVIII	The excavated "paint hole", with entire portions of the walls and floor coated with plastic paint	68
XIX	Two cores extracted from a "paint hole" and picked down to the painted surface of the original undisturbed soil	69

(cont.)

LIST OF PLATES (cont.)

<u>Plate</u>		<u>Page</u>
XX	The upper portion of a reagent bottle (with supply line attached) sealed to the core	73
XXI	The hinged table (supporting six cores) in the near vertical position	76
XXII	The hinged table (supporting six cores) in the horizontal position during a permeability experiment	77
XXIII	The sand column and an overflow reservoir during a percolation experiment	92

LIST OF APPENDICES

<u>Appendix</u>		<u>Page</u>
I(a)	Mechanical analyses of two samples of the Ongley Park profile	163
(b)	Penetrometer scale readings at varying depths in a sample from the Ongley Park profile	164
II	Description of the physical characteristics of the Ongley Park profile	165
III	A scale engineering drawing of the disassembled soil sampling tubes	169
IV	Flow rates from a capillary tube as they were affected by temperature	170
V	Total pressure loss and flow data from a percolation experiment with the sand column	172
VI	Hydraulic gradients within the sand column at specific time intervals (normal flow direction).....	175
VII(a)	Total pressure loss and flow data from a permeability experiment with core G ₂ (normal flow direction).....	176
(b)	Total pressure loss and flow data from a permeability experiment with core H ₂ (normal flow direction).....	177
(c)	Total pressure loss and flow data from a permeability experiment with core I ₂ (normal flow direction)	178
(d)	Total pressure loss and flow data from a permeability experiment with core J ₂ (normal flow direction)	179
(e)	Total pressure loss and flow data from a permeability experiment with core K ₂ (normal flow direction)	180
(f)	Total pressure loss and flow data from a permeability experiment with core L ₂ (normal flow direction)	181
VIII	Hydraulic gradients within core G ₂ at specific time intervals (normal flow direction)	182
IX	Hydraulic gradients within core H ₂ at specific time intervals (normal flow direction)	183
X	Hydraulic gradients within core I ₂ at specific time intervals (normal flow direction)	184

(cont.)

LIST OF APPENDICES (cont.)

<u>Appendix</u>		<u>Page</u>
XI	Hydraulic gradients within core K ₂ at specific time intervals (normal flow direction)	185
XII	Hydraulic gradients within core L ₂ at specific time intervals (normal flow direction)	186
XIII(a)	Total pressure loss and flow data from a permeability experiment with core G ₂ (reversed flow direction)	187
(b)	Total pressure loss and flow data from a permeability experiment with core H ₂ (reversed flow direction)	188
(c)	Total pressure loss and flow data from a permeability experiment with core I ₂ (reversed flow direction)	189
(d)	Total pressure loss and flow data from a permeability experiment with core J ₂ (reversed flow direction)	190
(e)	Total pressure loss and flow data from a permeability experiment with core K ₂ (reversed flow direction)	191
(f)	Total pressure loss and flow data from a permeability experiment with core L ₂ (reversed flow direction)	192
XIV	Hydraulic gradients within core G ₂ at specific time intervals (reversed flow direction)	193
XV	Hydraulic gradients within core H ₂ at specific time intervals (reversed flow direction)	194
XVI	Hydraulic gradients within core I ₂ at specific time intervals (reversed flow direction)	195

SECTION AINTRODUCTION

For many years, soil drainage investigators, from a practical view point, have had to content themselves with expert appraisal of certain direct and indirect soil and environmental characteristics in order to ascertain the cause of a particular drainage problem. In a great many instances, observations of vegetative composition, topography and general soil type, aided by aerial photography and local experience, give completely adequate information. Normally, derivation of conclusions from such observations is based on well established principles, and the recognition of general broad classes of the cause of mal-drainage conditions. Such classes may be grouped as; (I) where infiltration capacity of a soil is inadequate to deal with the amount of water supplied to the surface, because of topography, abnormal rainfall, or through inherent inability of the soil to transmit water internally, (II) where the ground-water table rises to a height detrimental to vegetative survival and/or soil structure, or where its presence hinders the function of a free draining subsoil, and (III) where a similar situation exists, due to a perched or elevated ground-water table.

The allocation of a particular drainage problem to one or more of these broad classes is not usually difficult, but identification of causal processes within classes presents quite another problem. Often, drainage investigators have been content to evolve general treatments for each class, and, as a basic rule, such procedures have, more often than not, proved reasonably effective. However, with the increasing intensification of pastoral and agricultural farming, the fundamental causes of individual mal-drainage conditions must be positively identified and rectified within the broadly classified groups.

In many parts of the world, significant steps have been taken in this direction, especially within group (I) above. Here again, investigators pursue two different approaches; (a) indirect analysis of physical properties of soils, related, more or less, to the ability of the soil to transmit water, and (b) direct analysis of the hydraulic transmitting power of soils. The first approach includes critical examination of such factors as the following:

Type of structure

Grade (stability) of structural aggregates

Relative length of horizontal and vertical axes of structural aggregates

Texture

Comparative ease and direction of natural breakage

Size and number of visible pores, cracks and channels, visible under a hand lens

Character of clay minerals

Compaction

Size and shape of sand grains

Mottling

Organic Material

Soluble salts

While evaluation, on a basis of the above characteristics may be, in many instances, convenient, and relatively non time-consuming, O'Neal (1949), the joint proposer of the above list (1951), stressed that few factors individually could be considered good guides to intrinsic permeability. Rather, all factors should be considered singularly and in relation to one another, and even then the correlation with intrinsic permeability is not always entirely satisfactory.

The second approach involves measuring, directly, certain fundamental physical properties of the soil as a means of establishing causes of low intrinsic permeability. Among the workers involved in direct measurements, two general approaches are again apparent. There are those who measure permeability rates in the field. Their methods include various single "auger hole" determinations, pumping between two auger holes, piezometer tube installation, infiltrometers, watershed balance sheets, and rainfall simulators. The other approach to direct measurements is to study the permeability of the profile in the laboratory, thus obviating the only real practical disadvantage of field determinations - that of the inconvenience of providing equipment in situ, in the field. These two approaches are, however, more closely related in their objectives than most, as the prime object of the laboratory techniques is to determine intrinsic permeability values that will be directly related and applicable to the field determinations. The latter, per se, must be applicable to the practical application of drainage techniques.

Under certain conditions, the traditional methods of drainage investigations may suffice, whereas under other conditions the more fundamental studies may be required. However, as increasing instances of the more difficult problems are encountered, such as in gley podsol, some Northern podsolised Yellow Brown Earths and many recent alluvial soils, the emphasis on investigation must swing more from the subjective and empirical assessments towards the attainment of direct experimental evidence based on scientific approach. It is therefore imperative that experimental techniques be evolved which enable investigators to objectively study the hydraulic characteristics of soils in order to ascertain precisely the causes of individual drainage problems.

SECTION BREVIEW OF THE LITERATURE

The relevant literature is reviewed under the following headings:-

- I Techniques for obtaining "undisturbed" soil samples.
 - II The transportation, storage, and preparation of soil samples prior to laboratory investigations of hydraulic characteristics.
 - III Supplementary laboratory equipment associated with hydraulic studies of "undisturbed" soil samples.
 - IV The laboratory study of water flow through "saturated" soil.
 - V Soil and fluid properties responsible for variations in intrinsic permeability.
 - VI Methods of indirect assessment of intrinsic permeability.
-