VEGETATION INDICATORS OF TERRAIN CONDITIONS

IN SOUTHERN SASKATCHEWAN

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

Master of Science

in the Department of Civil Engineering

University of Saskatchewan

by

Edward Alexander Wilson

Saskatoon, Saskatchewan
June, 1971

SYNOPSIS

Geotechnical engineers have been using vegetation indicators of terrain conditions for engineering purposes in southern Saskatchewan. This terrain evaluation technique was based on empirical observations and there was a need for a formal investigation of the characteristics of vegetation indicators. This project undertook this formal investigation.

Documented information pertaining to vegetation-terrain relationships was consolidated from publications in botany, plant ecology, plant physiology, geobotany and geology. This information is presented to provide a basic understanding of the characteristics of vegetation indicators.

Subsequently, a field study area was selected on the North Saskatchewan River near Langham, Saskatchewan, in order to study the characteristics of vegetation-terrain relationships and to assess the applicability of vegetation indicators of terrain conditions for engineering purposes in southern Saskatchewan.

Field investigations sought to describe the total physical environment of the study area. These investigations involved aerial photography using several formats, terrain evaluation, geodetic surveying, subsurface investigations, ground-water studies, climatic studies and vegetation studies. The result of the investigations was a description of the study area in terms of geomorphology, stratigraphy, ground-water regime, climate and vegetation.

The correlation between vegetation and environment was then analyzed. As a result of this analysis, vegetation indicators of terrain conditions are recommended as a complimentary technique to traditional forms of evaluating the physical environment for engineering purposes in southern Saskatchewan.

ACKNOWLEDGEMENTS

This project was financially supported by a Joint Highway Research Scholarship, and research funds from the Saskatchewan Department of Highways and the National Research Council. This financial support is gratefully acknowledged.

A particular expression of gratitude is due to Dr. E.K. Sauer of the Department of Civil Engineering for his counsel throughout this project and to Dr. J.S. Rowe of the Department of Plant Ecology for his advice on the botanical aspects of this project.

Gratitude is also due to Mr. N.A. Skoglund of the Department of Plant Ecology for his enthusiastic assistance during field and laboratory botanical studies.

Drs. E.A. Christiansen and W.A. Meneley of the Saskatchewan Research Council gave freely of their time for discussions of aspects of geology and ground-water hydrology during this project.

Mr. W.B. McCoy of the Department of Civil Engineering made the arrangements for the 70mm aerial photography.

Mr. John H. Hudson identified the sedges collected from the study area.

The assistance of Mrs. Verna Skogland the typist, and Mr. Alex Kozlow, the draftsman, is appreciated.

TABLE OF CONTENTS

I. INTRODUCTION 1

1.1. Subject 1
1.2. Need 1
1.3. Objective 2
1.4. History of Vegetation Indicators of Terrain Conditions 2
1.5. Procedure 3

II. LITERATURE REVIEW 5

2.1. State of the Art 5

2.1.1. Geobotany in the U.S.S.R. 5
2.1.2. Vegetation Mapping 6
2.1.3. Ground-Water Studies by Geological Agencies 6
2.1.4. Estimating Water Levels 7

2.2. Botany, Ecology and Plant Physiology as Applied to Terrain Evaluation 8

2.2.1. Interrelations of Elements of the Total Environment 8
2.2.2. Environmental Factors Affecting Vegetation 9
Climatic Factors 10
Physiographic Factors 11
Edaphic 11
Topographic 13
Stratigraphic 14
Biotic Factors 14
Compensation by Environmental Factors 17
2.2.3. The Influence of Vegetation on the Environment 18
2.2.4. Vegetation Indicators 18
General Indicators 19
Specific Indicator Species in the Langham Study Area 20
2.2.5. Herbs and Shrubs as Indicators 22
2.2.6. Plant Communities as Indicators 23
2.2.7. Vegetational Delineation of Soil Boundaries 24
2.2.8. Vegetation Indicators of Moist Areas in Arid Regions 25
2.2.9. Vegetation Indicators of Ground-Water Chemistry 26
2.2.10. Vegetation Indicators of Miscellaneous Terrain Conditions 27

2.3. Summary 30

III. FIELD INVESTIGATIONS IN THE LANGHAM STUDY AREA 32

3.1. Location 32
3.2. Selection of a Study Area 35

3.2.1. Study Area Requirements 35
3.2.2. Selection of the Langham Study Area 37

III. Continued

3.3. Field Investigation Techniques 38

3.3.1. Aerial Photography 38
Vertical Panchromatic Photography 38
Scale of 1:40,000 38
Scale of 1:7,200 39
35mm Oblique Colour Photography 39
70mm Vertical Photography 40
3.3.2. Terrain Evaluation 40
3.3.3. Surveys for Horizontal and Vertical Control 43
3.3.4. Subsurface Investigations 44
Structural Testholes 45
Shallow auger borings 45
3.3.5. Ground-Water Investigations 47
Water Table Determinations 48
Ground-Water Discharge Quantities 50
Ground-Water Chemistry 50
3.3.6. Studies and Records of Climatic Conditions 51
3.3.7. Vegetation Studies 52
Selections of Vegetation Study Sites 54
Vegetation Description and Sampling 59
3.3.8. Laboratory Testing 61
Plant Samples 61
Soil Samples 62
Water Samples 62

3.4. Summary 62

IV. FIELD OBSERVATIONS IN THE LANGHAM STUDY AREA 64

4.1. Geomorphology 64
4.2. Stratigraphy 65

4.2.1. Description of Structural Testholes in the Langham Study Area 65
4.2.2. Description of Regional Stratigraphy 71

4.3. Ground-Water Regime 74
4.3.1. Position of the Water Table 74
4.3.2. Ground-Water Discharge Quantities 76
4.3.3. Ground-Water Chemistry 76
Identification of Ground-Water Source 76
Travertine Mounds 76

4.4. Climate 84
4.4.1. Regional Climate 84
4.4.2. Comparison of the 1970 Weather Conditions With the Long Term Average Conditions 84

4.5. Vegetation 93
4.5.1. Aerial Infrared Photography for Vegetation Studies 93
4.5.2. Vegetation Description of a Generalized Site 94
4.5.3. Vegetation Description by Sites 95
Site I 95
Site II 96
Sites III and IV 96
Sites V and VI 96
Sites VII through X 98

V. ANALYSIS OF VEGETATION INDICATORS OF TERRAIN CONDITIONS IN THE LANGHAM STUDY AREA 100

5.1. Site I 101
5.2. Site II 104
5.3. Site III 112
5.4. Site IV 115
5.5. Site V 117
5.6. Site VI 119
5.7. Site VII 121
5.8. Site VIII 125
5.9. Site IX 127
5.10. Site X 131
5.11. Summary of Significant Indicator 132

VI. OTHER ASPECTS OF VEGETATION-TERRAIN RELATIONSHIPS OF ENGINEERING SIGNIFICANCE 137

6.1. Edaphic Factors 139

6.1.1. Nutrient Selection 130
6.1.2. Soil Temperature 140
6.1.3. Organic Decomposition and Soil Acidity 141

6.2. Root Systems 143
6.2.1. Vegetative Reproductions 144
6.2.2. Root Configurations 145

6.3. Wilting by Drying 146
6.4. Wilting by Cooling 147

6.4.1. Field Observations 147
6.4.2. Theory 149

6.5. Halophytes 152
6.6. Water Consumption by Vegetation 152
6.6.1. Previous Studies 153
6.6.2. Engineering Applications 154

6.7. Summary 161

VII. CONCLUSIONS 164

7.1. Introduction 164
7.2. Characteristics of Vegetation Indicators 164
7.3. Applications of Vegetation Indicators 165
7.4. Interdiscipline Communications 166
7.5. The Langham Study Area 166
7.6. Further Studies 167
7.7. Vegetation as a Design Factor in Civil Engineering 167
7.8. Man's Influence on Vegetation 176

REFERENCES CITED 177

APPENDIX A 185

APPENDIX B 198

APPENDIX C 209

APPENDIX D 217

APPENDIX E 224

LIST OF FIGURES

FIGURE		PAGE
2-1	Vegetation Change at a Stratigraphic Boundary	16
2-2	Vegetation of a Seral Community	16
2-3	Forestry Inventory Map and Landform Overlay of Waskesiu Lake	21
2-4	Ecological Amplitudes with respect to Salinity	28
2-5	Relationship Between Depth to Ground-Water and Ground-Water Mineralization	29
3-1	Map Showing the Location of the Langham Study Area	33
3-2	Map of Surficial Soils in the Langham Region	34
3-3	Native Vegetation Zones of Saskatchewan	36
3-4	70mm Hasselblad Camera Mounted in Aircraft	42
3-5	Air Photo Interpretation of Mounted 70mm Positives	42
3-6	Locations of Subsurface Investigations in the Langham Study Area	46
3-7	Piezometer Installation in the Langham Study Area	49
3-8	Locations of Vegetation Study Sites in the Langham Study Area.	53
3-9	Oblique Aerial Photograph of Site I	57
3-10	Oblique Aerial Photograph of Site II	57
3-11	Oblique Aerial Photograph of Sites III and IV	58
3-12	Oblique Aerial Photograph of Site VII	58
3-13	Oblique Aerial Photograph of Sites VIII and IX	60
3-14	Mounting and Labelling Plant Samples	60
4-1	Air Photo Interpretation of the Langham Study Area	66
4-2	Stratigraphic Cross Section in the Langham Study Area	68
4-3	Location of Regional Stratigraphic Cross Section	72

List of Figures - Continued

FIGURE		PAGE
4-4	Regional Stratigraphic Cross Section	73
4-5	Sampling Locations for Water Chemistry Analysis	77
4-6	Water Chemistry Analysis at Spring VII	78
4-7	Water Chemistry Analysis at Spring VIII	79
4-8	Water Chemistry Analysis at Spring IX	80
4-9	Water Chemistry Analysis at Well at SW16-39-7-3	81
4-10	Water Chemistry Analysis at Well at SW7-39-7-3	82
4-11	Travertine Mound at Site IX-4B	83
4-12	Sample of Travertine Mound Material	83
4-13	Distribution of Temperatures Throughout the Year	85
4-14	Frost Date Distribution	86
4-15	Isotherms of Mean Soil Temperatures Throughout the Year	87
4-16	Monthly Precipitation Totals Throughout the Year	88
4-17	Wind Speed and Direction Data for Spring and Summer	89
4-18	Colour Aerial Photograph of Sites III and IV	97
4-19	Colour Infrared Aerial Photograph of Site IV	97
4-20	Colour Aerial Photograph of Sites IX and X	99
4-21	Colour Infrared Aerial Photograph of Sites IX and X	99
5-1	Geobotanical Profile of Site I	102
5-2	Geobotanical Profile of Site II	105
5-3	Geobotanical Profile of Site III	113
5-4	Geobotanical Profile of Site IV	116
5-5	Geobotanical Profile of Site V	118

List of Figures - Continued

FIGURE		PAGE
5-6	Geobotanical Profile of Site VI	120
5-7	Geobotanical Profile of Site VII	122
5-8	Geobotanical Profile of Site VIII	126
5-9	Geobotanical Profile of Site IX	128
6-1	Surface Heating by Ground-Water	142
6-2	Locations of Observed Wilting by Cooling	148
6-3	Vegetation Differences caused by Wilting by Cooling at Kelfield Coulee	150
6-4	Vegetation in Highway Cut at Kelfield Coulee	150
6-5	Moisture Retention Curve for Till with Plant Osmotic Potentials	157
6-6	Moisture Retention Curve for Gault Clay with Plant Osmotic Potentials	158
6-7	Moisture Retention Curve for Sandy Loam with Plant Osmotic Potentials	159
D-1	Electric Log of Testhole VII	218
D-2	Electric Log of Testhole V	219
D-3	X-Ray Diffraction Trace for Travertine Mound Material	220
D-4	X-Ray Diffraction Trace for Travertine Mound Material	221

LIST OF TABLES

TABLE		PAGE
II-1	Summary of Tree Species Symbols used in Figure 2-3	20
III-1	Summary of 70mm Aerial Photography	41
III-2	Criteria for the Selection of Each Vegetation Study Site	55
IV-1	Summary of Monthly Meteorological Records	91
V-1	Water Regime Classification for Prairie Potholes (Millar)	134
V-2	Water Salinity Classification for Prairie Potholes (Walker)	134
V-3	Water Regime Classification for Prairie Potholes (Stewart and Kantrud)	135
V-4	Water Salinity Classification for Prairie Potholes (Stewart and Kantrud)	135
V-5	Equivalent Engineering Descriptions of Botanical Descriptions of Soil Moisture Conditions	136
VI-1	Osmotic Potentials of Plants Grouped by Size	154
VII-1	Significant Indicator Species in the Langham Study Area	168
D-1	Summary of Laboratory Soil Testing Results	222
D-2	Record of Piezometer Readings at Site VII.	223

CHAPTER I

INTRODUCTION

1.1. SUBJECT

There are complex and intimate relationships between vegetation and environment. Many of these relationships have been known for a long time, but with the recent emphasis on considering the total physical environment as part of terrain evaluation* projects, these vegetation-terrain relationships should be examined for their potential as terrain evaluation techniques for engineering purposes.

1.2. NEED

Geotechnical engineers have used vegetation-terrain relationships developed empirically from their own observations. Primarily their interest has been in vegetation indicators of soil type and soil moisture because these are two of the factors which determine the mechanical properties of a soil. They are also aware, however, of their need for deeper understanding of the characteristics of these vegetation-terrain relationships. It was the purpose of this project to attempt to fulfill this need by formal study of the characteristics of vegetation-terrain relationships of primary interest to geotechnical engineers.

Frequently, a geotechnical engineer is required to evaluate the terrain in an area as quickly as possible. Consequently, obvious, quickly assessed indicators are very useful to determine specific locations where further investigations are most likely to reveal significant terrain information. Vegetation, as an expression of subsurface conditions for those who understand vegetation-terrain relationships, is an obvious, quickly assessed indicator. Moreover,

---

* Terrain evaluation is defined in Section 2.2.

the vegetation expresses the recent history of terrain activities in the area. An estimate of the time relationships of these activities allows a more complete terrain evaluation during the initial reconnaissance.

1.3. OBJECTIVE

The principal objective of the project was to study the characteristics of the vegetation-terrain relationships at a specific location in order that the potential use of vegetation indicators of terrain conditions could be evaluated by geotechnical engineers. In addition, there was a need to assess the applicability of vegetation indicators as a complimentary technique to traditional forms of evaluating the physical environment for engineering purposes in southern Saskatchewan.

1.4. HISTORY OF VEGETATION INDICATORS OF TERRAIN CONDITIONS

Because vegetation indicators of terrain conditions are a result of empirical observations, their use is not a particularly recent discovery. There are references to plant indicators of subsurface waters and soil conditions in the writings of Vitrivious, Pausanius, Palladus and Virgil. More recently, botanists began making vegetation maps in Europe during the nineteenth century. Originally, their intention was not to develop vegetation indicators of terrain conditions but they noticed correlations between vegetation and terrain conditions and subsequently they used these correlations as map units.

At the same time geologists (Hilgard, 1860) on this continent became involved with interpreting the virgin, native vegetation as an indicator of the agricultural potential of land in the then developing American mid-west. Homesteaders also used the vegetation to assess the agricultural potential of land when deciding where to settle. As the mid-west became populated, there was no need to use vegetation indicators of soil productivity because there was direct experience in nearby cultivated fields. Except within the past decade terrestrial applications of vegetation indicators have not received much attention in North America since 1920.

Shortly thereafter botanists, geographers and geologists were starting to develop the science of geobotany in the U.S.S.R.. After World War II, the Russian government used geobotanical methods to assess terrain conditions in vast areas of undeveloped land in preparation for planned development of these lands. With the advent of aerial photography, the Russian geobotanists developed vegetation indicators of terrain conditions to a highly sophisticated science.

Within the past decade in North America, very specialized applications of vegetation indicators have been developed. Work in this project modified many of these recent, specialized applications for use by geotechnical engineers for terrain evaluation purposes.

1.5. PROCEDURE

There is very little engineering literature available pertaining to vegetation indicators of terrain conditions in southern Saskatchewan. Consequently, documented information pertaining to this project was gathered from publications whose main interests were far removed from geotechnical engineering. Principally, references to vegetation-terrain relationships and to the characteristics of these relationships are found in publications in botany, plant ecology, plant physiology, soil physics, geobotany and geology.

In order to gather an understanding of vegetation-terrain relationships and to assess the applicability of vegetation indicators of terrain conditions for engineering purposes in southern Saskatchewan,* a field study was conducted near Langham, Saskatchewan. The Langham Study Area was examined using aerial photography, air photo terrain evaluation (Sauer, 1964), geodetic surveying, subsurface investigations, ground-water investigations, climatic studies and vegetation studies. Subsequently, the terrain information was analyzed to describe the study area in terms of geomorphology, stratigraphy, ground-water regime, climate and vegetation.

The correlation between vegetation and environment was then analyzed. This analysis includes a description of the characteristics of vegetation-terrain relationships as well as an assessment of the applicability of vegetation indicators of terrain conditions in southern Saskatchewan.

---

* For the purpose of this report, southern Saskatchewan is defined as the area delineated in Figure 301. This is the portion of Saskatchewan that is bounded on the north by a line from Lloydminster to Melfort to Yorkton. Furthermore, the Cypress Hills region in the south-west corner of the Province is not included in this report.

CHAPTER II

LITERATURE REVIEW

Vegetation indicator applications are a synthesis of botanical and geological sciences. It is therefore necessary to establish methods by which two pure sciences may be synthesized as a useful technique for an applied scientist. Much of the discussion is based on botanical science; consequently, the literature review is primarily a presentation of relevant botanical information to a readership with a geotechnical background.

2.1. STATE OF THE ART

Vegetation-terrain relationships have been used extensively in air photo interpretation but geotechnical engineers have not applied these relationships to terrestrial terrain evaluation to the same extent. As a result vegetation indicator applications to air photo interpretation are well documented in North America, whereas on-the-ground applications of vegetation indicators for engineering purposes are not. Vegetation indicators have been developed by plant ecologists for some time. However, only recently have North American geotechnical engineers become aware of vegetation-terrain relationships.

2.1.1. Geobotany in the U.S.S.R.

Geobotany is a multiple discipline of botany, geography and geology. After World War II, the Soviet Union divided the undeveloped portion of their holdings into regions to study their potential for development. Large tracts of land, of the order of thousands of square miles, were assessed by geobotanical teams for cultivation, grazing and industrial development. Such factors as surficial deposits, depth to water table and quality of ground-water were interpreted from the vegetation. As might be expected, the Russian geobotanical literature is the largest source of information on terrestrial applications of vegetation indicators to terrain evaluation.

2.1.2. Vegetation Mapping

European geographers, particularly in France and Germany, have been mapping vegetation for 150 years. Their map unit is a plant community which has relatively stable species composition within the studied area. Different kinds of vegetation maps are prepared for different purposes with most vegetation maps being used in agricultural development, forestry or range management. Maps for military and engineering purposes are less common. Unfortunately very little of the extensive literature in vegetation mapping is published in English; however, Küchler (1967) described much of the untranslated work while discussing the state of the art of vegetation mapping.

2.1.3. Ground-Water Studies by Geological Agencies

The prairie pot hole or slough is an important element of the ground-water flow system of moraine landforms. Sloan (1967) of the United States Geological Survey used vegetation indicators for dating water levels and estimating water chemistry of moraine sloughs. Once a system of indicators has been established as reliable, a large number of sloughs can be examined with little effort to determine which sloughs are influent or effluent and thereby develop the ground-water model for the area.

Meyboom (1966a) of the Geological Survey of Canada studied vegetation as part of the geohydrology of a willow-ringed slough in a hummocky moraine south of Saskatoon. He discovered that the water demands of the slough vegetation changed the slough from a recharge zone to a discharge zone in the ground-water flow system.

2.1.4. Estimating Water Levels

Highway engineers must be able to estimate the high water elevation in undrained depressions in order to design a foundation for the roadway that will be adequate structurally and remain above water. It is difficult to establish this elevation without adequate records or some clear physical indicator. Neither records nor indicators are available in the majority of situations where a design decision is needed regarding grade elevation above water. A design decision of this type can involve many thousands of dollars; thus it is clear that some reliable indicator of high water levels is urgently needed for highway designers.

Not only engineers but also wildlife ecologists are concerned about water levels in sloughs because water fowl population is a function of the dates of water levels in sloughs. Therefore, Millar (1969) of the Canadian Wildlife Service sought a reliable method of dating water levels. Through studies, the Canadian Wildlife Service has been able to establish reliable relationships between vegetation and dates of water levels in sloughs. These relationships are now used to estimate the number of suitable breeding areas for prediction of water fowl populations. Their technique may have useful applications in highway engineering.

2.2. BOTANY, ECOLOGY AND PLANT PHYSIOLOGY AS APPLIED TO TERRAIN EVALUATION

Geotechnical engineers, as applied scientists, have drawn upon knowledge of pure science to solve their problems of evaluating the terrain in terms of materials and their environment. Traditionally the geotechnical engineer has turned to the geological sciences for solutions. At the same time he recognized that vegetation indicators are useful but had no training in botany. As a result the use of vegetation indicators for terrain evaluation has been only partially exploited.

Terrain evaluation is, in part, the definition of the physical environment which involves the delineation of the boundaries of materials and ground-water systems. Moreover, the development of vegetation is related to the physical environment, and as a result vegetation patterns often correlate with terrain patterns. At the same time plant ecology is the study of the relationships between plants and their physical environment. Consequently, an understanding of the principles of plant ecology is fundamental in the use of vegetation indicators for terrain evaluation. Certainly explanations for these physical relationships will be found in a synthesis of the geological and the botanical sciences.

2.2.1. Interrelations of Elements of the Total Environment

Intimate but complex relationships exist between climate, vegetation, soils and physiography (Coupland and Rowe, 1969). Changes in vegetation patterns may be a response to one element of the environment or a combination of elements (Küchler, 1967). As the environment changes, the vegetation-terrain relationship changes.

For example, climatic variations cause a replacement in vegetation with no changes in edaphic factors*. As another example, well-drained soils in a wet area produce similar vegetation as heavy soils in a dry area (Vinogardov, 1965). There is rarely a one to one relationship between vegetation and terrain and therefore, it is necessary to study the total physical environment in order to relate vegetational response to terrain conditions.

2.2.2. Environmental Factors Affecting Vegetation

Elements of the environment, or habitat factors, can be separated into groups of climatic, physiographic or biotic factors (Leach, 1956). Climatic factors include precipitation, temperature, wind, atmospheric humidity and insolation. The physiographic factors, which have their origin in the form, behavior and structure of the earth's surface (Leach, 1956), are sub-divided into edaphic, topographic and stratigraphic. Edaphic factors pertain to soil: its physical and chemical composition, water content and temperature. Topographic factors are elevation, slope aspect and surficial drainage. Stratigraphic factors encompass the geological model and ground-water regime. Biotic factors are the influence of plant on plant or animal on plant but for the purposes of this thesis, biotic factors are restricted to the process of plant succession**. Within the framework

---

* Edaphic factors are conditions or characteristics of the soil, physical, chemical or biological, that influence organisms (Hanson, 1962).

** Succession is the replacement of one kind of community by another kind; the progressive changes in vegetation and in animal life which may culminate in ecological climax (Hanson, 1962).

just described each habitat factor will be treated individually, although each is inseparable from the total environment.

2.2.2.1. <u>Climatic Factors</u>

In a regional sense climate determines the general vegetation but within a small area, transitional variations in species are caused by microclimate. Vegetational changes caused by microclimate tend to obscure vegetational changes caused by edaphic conditions which are the main concern of the geotechnical engineer.

Precipitation may be considered uniform over several square miles in a season. For this reason it is unlikely to cause a differential response in the vegetation over a small area although precipitation will determine species presence in general.

Regional temperature will determine the kinds of species that may be present in an area but subtle temperature differences will control their distribution. Within a small area, air temperature varies with height above ground, shade and shelter from the wind. As a result vegetation varies locally in response to temperature. In most cases, however, species distribution is more strongly influenced by temperature associated factors, such as shading or atmospheric humidity, than by temperature alone.

Direct damage caused by wind is a factor limiting the distribution of vegetation. Any plant growing taller than, or away from the surrounding vegetation is subjected to greater wind forces and consequently to greater risk of breakage. However, the drying wind that removes the high atmospheric humidity from around vegetation does more to maintain the uniform height of vegetation than the breaking wind. Thus wind is primarily a factor limiting extension of the plant community upwards or outwards.

Tsatsenkin (1966), in a study of hay meadows in the U.S.S.R. found the vapor pressure deficit is a significant factor in zonal differentiation of vegetation. Pierre (1966) found that the rate of water loss by plant transpiration is inversely proportional to the relative humidity. Like temperature, atmospheric humidity varies with height above ground, as well as shade and shelter from the wind. As might be expected, several authors find atmospheric humidity important in species distribution.

Radiation from the sun, the energy source for botanical activity, does not reach every plant with equal intensity. Taller plants shade shorter plants; sloping ground receives more, or less, insolation per unit area than flat ground, and north facing slopes receive less insolation than south facing slopes. Consequently, there is a variation in species distribution in response to the variation in incident solar radiation, but these variations between plant communities are transitional.

2.2.2.2. Physiographic Factors

2.2.2.2.1. Edaphic

Changes in species presence is largely determined by changes in edaphic characteristics. As a result the visible above ground parts of a plant as well as the unseen root system are indicators of changes in subsurface conditions. In arid portions of the United States, the different types of native vegetation are often very sharply delineated, the transition being so abrupt that they cannot be attributed to climatic factors (Clements, 1928). Consequently, changes in edaphic factors cause sharp vegetation boundaries in contrast with the transitional boundaries caused by climatic factors.

The physical composition of soil controls moisture movements and nutrient content, and therefore has a strong influence on the character of the vegetation. Sandy soils drain internally and water is easily extracted by plant roots because the sandy soil is not capable of developing soil suctions greater than the osmotic potentials developed by the plants. Clay soils are relatively impermeable, and with their capacity to develop high soil suctions, are able to retain moisture for longer periods than sandy soils. Nutrient content is proportional to the cation exchange capacity which in turn is related to physical composition of the soil. As a result nutrient content and moisture retention by soil are fundamental mechanisms for the explanation of vegetation indicators.

Chemical substances, both organic and inorganic, are part of the soil complex. Vegetation reponds to the presence or absence of these substances; some chemicals restrict germination whereas others are outright poisonous to some species (Viktorov et al., 1964). On the other hand, some chemical substances are nutrients. For example, high concentrations of dissolved salts occur in soils in ground-water discharge areas where evaporation rates are high, moreover to extract water from an electrolytic solution, the plant must exert greater osmotic potentials. Not all plants can do this. Again, a habitat factor, chemical composition of the soil, restricts what species may be present because each species has a range of tolerance for certain chemicals.

Both soil moisture and soil temperature play major roles in determining variations in vegetational composition on prairie slopes in Saskatchewan (Ayyad and Dix, 1964). Vegetation also responds to the depth to water table and the amount of aeration within the unsaturated zone.

Soil temperature influences vegetation distribution directly and indirectly. The date of seed germination is directly determined by soil temperature, whereas indirectly the increase in soil suction with decreasing soil temperature limits the amount of soil water available to plants. Therefore, they wilt in dry soils earlier than in wet soils. Soil temperature has its greatest impact on vegetation indicators when acting in concert with other edaphic factors of soil texture and soil moisture.

2.2.2.2.2. Topographic

Changes in topography cause changes in microclimate which in turn cause changes in vegetation. In mountainous areas vegetation acquires significance mainly as a climatic indicator (Chikishev, 1965) because both climate and vegetation respond to changes in elevation.

The development of vegetation may be retarded by topography. It is very difficult for vegetation to establish on slopes of two horizontal to one vertical, and steeper. Similarly, erosion by water limits what species, if any, will take root in active drainage courses. However, mesophylous* plants develop along subtle drainage courses, and their presence is often useful where the natural drainage pattern is difficult to discern (Viktorov et al., 1964). Thus even a passive

---

* Mesophylous plants are plants requiring a moist habitat.

habitat factor like topography is an influence on the distribution of vegetation.

2.2.2.2.3. Stratigraphic

Stratigraphy and geologic structure are often primary controls to habitat factors which control vegetation patterns. The influence of geological parent material on edaphic characteristics is illustrated by Figure 2-1, which shows the abrupt change in vegetation at the stratigraphic boundary between glacial till and clay shale. Similarly a line of vegetation may follow a fault or other structural feature in response to the different character of the soil (Popova, 1965). Stratigraphy also partially defines geometry of the ground-water regime which is subsequently reflected in the vegetation. As a result the cause of vegetation changes may lie at depths much greater than normal root penetration.

2.2.2.3 Biotic Factors

Biotic factors are environmental influences caused by plants or animals such as shading by trees or trampling by animals (Hanson, 1962). Although climatic and physiographic factors may not vary, the replacement of one plant by another as part of plant succession will slowly change the character of vegetation until the plant community is at climax*. As a result of a climax community's permanence, in equilibrium with the environment, these communities are reliable vegetation indicators.

---

* Climax is the kind of community capable of perpetuation or at least changing only slowly under the prevailing climatic and edaphic conditions (Hanson, 1962).

When the balance in ecology is upset, vegetation will respond. Upon disturbance or destruction of the natural vegetation by man's activities such as lumbering, ploughing or grazing cattle, or by nature's activities, such as flood, drought or fire, the process of succession begins.

Initially a pioneer plant community develops on the disturbed area but it bears little resemblance to the previous climax community (Figure 2-2). Moreover, the presence of a pioneer community changes the microenvironment of the disturbed area; there is shade from the sun and shelter from the wind under the canopy of new vegetation; the atmospheric humidity is higher. After a few seasons there is an accumulation of organic matter on what was previously bare ground. Within the new microenvironment created by the pioneer community, other species begin to grow. Finally, after a series of changes in microenvironment and species have occurred, the climax community becomes fully re-established.

Each community in this series is called a seral community. During the seral stages of succession the importance of plant competition becomes evident. Although many species are capable of surviving under any particular set of environmental factors, it is the closeness of fit of each species to the factors concerned, and the relative importance of these factors, that will determine which species will grow (Walker, 1966). Therefore, the climax community does not develop in a haphazard manner, but is the product of a rigorous, natural trial and error process during its seral stages.

Figure 2-1: Photograph of the abrupt vegetation change at the stratigraphic boundary between glacial till and clay shales at the top of a bute.

Figure 2-2: Photograph of Site VII-A. This vegetation is a seral community in a pig pen abandoned more than twenty years ago. The Canada thistle in the lower right was the central part of the pen. Between the Snowberry (middle) and the Common nettles, the old fence lies partially buried.

As previously discussed, the climax community is a reliable indicator of the environment, however only skilled botanists can assess the stage of succession in a plant community. To the unskilled, a seral community is detected from clues of disturbance such as stumps, cattle dung, charred logs or flood debris.

2.2.2.4. Compensation by Environmental Factors

Vegetation indicators must be used carefully with reference to the total environment. Several environmental factors may be compensating such as to allow a plant to grow in an area where normally it would never grow (Gates et al., 1956). Consequently, compensation limits the extent to which vegetation indicators may be extrapolated. Vinogardov (1965) suggested that extrapolation be on the basis of zone (local area), geographical region or geomorphological unit in order to minimize the chance of indicator errors caused by compensating factors.

Vinogardov (1965) described three types of factor compensation; climatic, edapho-climatic and edaphic. As an example of climatic compensation he stated that phreatophytes* in the warm, arid zones, can use ground-waters of higher mineralization than in the moderately cool, arid zones. Edapho-climatic compensation occurs when a sandy soil in a wet area produces similar vegetation as clay soil in a dry area. Lastly, an example of edaphic compensation is the inability of a plant to draw mineralized water from as great a depth as it can

---

* Phreatophytes are plants which have their roots in a permanent water supply.

draw fresh water.

2.2.3. The Influence of Vegetation on the Environment

Vegetation is a dynamic agent in the total environment. For example, the climate in a well-treed farm yard differs from that of a nearby fallow field. In the first place the trees provide shade causing lower temperatures at the ground surface and higher atmospheric humidity below their crowns. Secondly, the trees block the wind and wind-born dust and snow. At the same time the trees are removing moisture and nutrients from the soil, whereas on the fallow field little moisture or nutrients are removed yet there is neither shade nor shelter.

Vegetation plays a major role in the modification of agricultural soil. Besides contributing to soil degradation and binding aeolian soils, it prevents erosion and modifies the microclimate. Vegetation enriches or exhausts soil nutrients, regulates snow-melt and runoff, and increases or decreases the water content of the soil. Finally vegetation further acts on the soil by trapping wind and water-born detritus and by stabilizing sand and gravel slopes. Just as vegetation responds to soil, soil responds to vegetation.

2.2.4. Vegetation Indicators

Practically every species has an optimum habitat and as such is an indicator of those habitat conditions. Good indicator species have narrow ecological amplitudes*;in addition they are

---

* Ecological amplitude is the range of one or more environmental conditions in which an organism or process can function (Hanson, 1962).

distinctive and dependable. Indicator vegetation is often most useful in undeveloped areas (Clements, 1928) where man's activities have not confused the vegetation-terrain relationships. For example, in Figure 2-3, the undisturbed vegetation boundaries on the base map coincide for the most part with the terrain boundaries shown on the transparent overlay.

Viktorov et al. (1965) classified indicators as direct or indirect. Direct indicators are present with the indicated object; whereas indirect indicators are related to some condition associated with the indicated object.

The most successful work with vegetation indicators has been done in regions characterized either by a relatively cool, humid climate with a short growing season like Finland, or by relatively low precipitation like the semi-arid portions of the United States. In such regions, the so-called "ecological margin of safety" is rather narrow (Stanley, 1938). As a semi-arid region, southern Saskatchewan has a narrow ecological margin of safety, and therefore, success in developing vegetation indicators for this region is anticipated.

2.2.4.1. General Indicators

Without reference to particular species, some aspects of the vegetation indicate general environmental conditions. For example, the well being of plants indicates the suitability of the habitat. Lynch (1955) found that the relative ages of trees in stands indicates the suitability of the site for that tree in the aspen groveland of Montana. General indicators are commonplace observations, nevertheless they provide useful terrain information.

TABLE II-1

SUMMARY OF TREE SPECIES SYMBOLS USED IN FIGURE 2-3

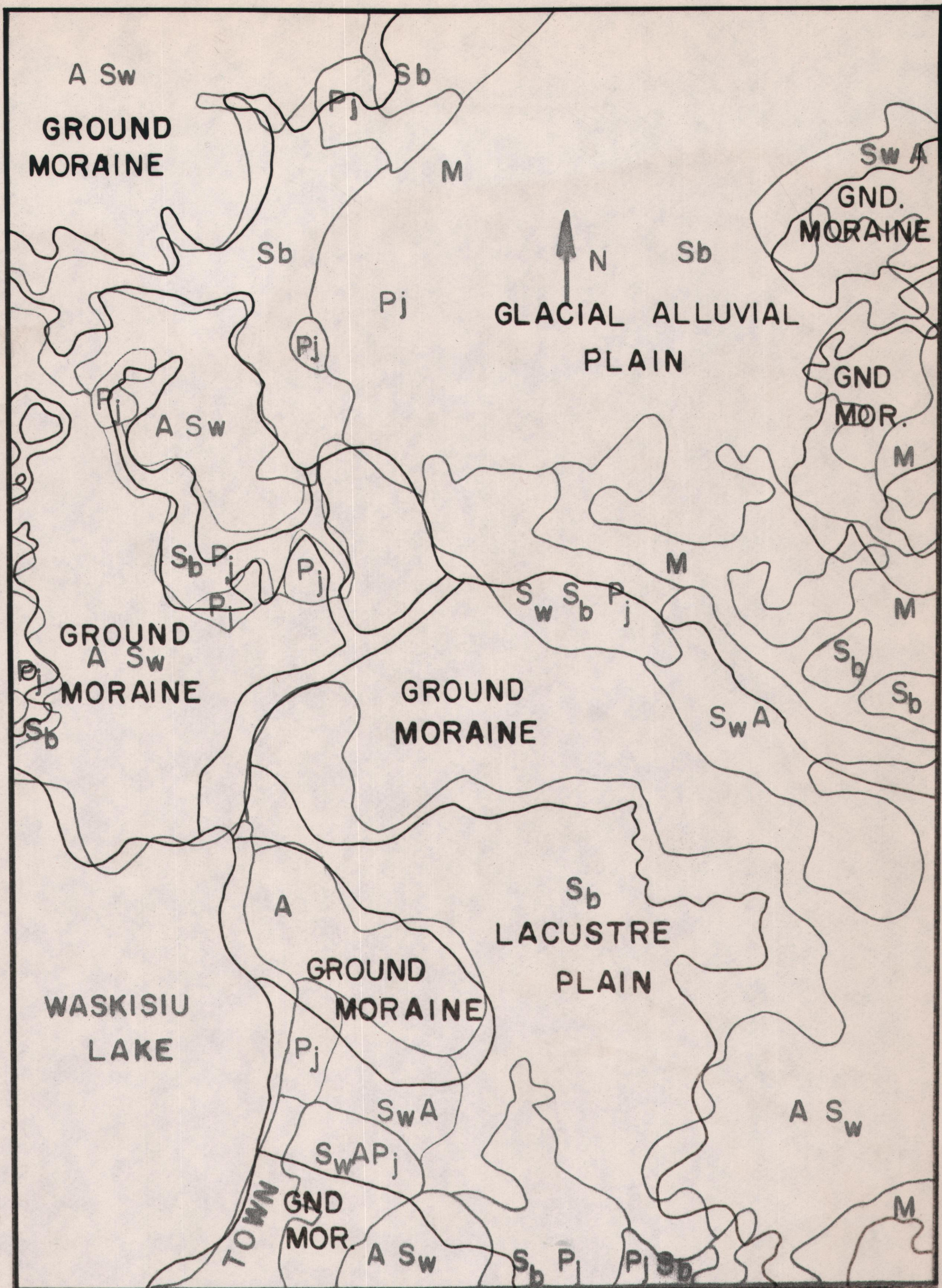
SYMBOL	TREE SPECIES
A	Trembling Aspen
S_b	Black Spruce
S_w	White Spruce
P_j	Jack Pine
M	Muskeg

2.2.4.2. Specific Indicator Species in the Langham Study Area

By way of introduction, several known indicators present in the Langham Study Area are listed as examples of species-terrain relationships. For instance, Wolf-willow *(Eleagnus commutata)* has a preference for xeric (dry) upper slopes. Moreover, Wolf-willow with Buffaloberry *(Shepherdia canadensis)* form an ecotone (boundary) between the prairie and the aspen groveland vegetation (Moss, 1932). Willows *(Salix spp.)* and Sedges *(Carex spp.)* indicate poorly drained depressions (Ellis, 1969).

Horsetail *(Equistetum spp.)* is a positive indicator of good quality water at a depth not greater than 1.5 meters (Voronkova, 1965)*. It is sometimes called an indicator of landslides when found on slopes. In fact, the Horsetail is found in habitats which are often associated

* The Russian experience is referred to here because the same relationships were found to be true for the Langham study area.



AFTER ANDERSON, 1971

FIGURE 2.3 FORESTRY INVENTORY MAP OF WASKISIU LAKE, NORTH-EAST QUADRANT. VEGETATION BOUNDARIES ARE ON THE BASE MAP. LANDFORM BOUNDARIES ARE ON THE OVERLAY.

with landslides, thus Horsetail became an indirect indicator of landslides.

On the other hand vegetation-terrain relationships found valid in one region should not be used as vegetation indicators of terrain conditions in another region. There is recent evidence (Rowe, 1971; personal communications) that there may be very subtle differences in species with respect to habitat preference from region to region although these differences are not detected by taxonomic groupings. For this reason references to vegetation-terrain relationships outside southern Saskatchewan must be considered as tentative vegetation indicators until these relationships can be verified in the field.

2.2.5. Herbs and Shrubs as Indicators

Empirical observations have led botanists to believe herbs and shrubs are superior indicators of terrain conditions. For example, Rowe (1956) described species-moisture regime relationships for the understory plants of the Boreal forst. Most trees are not as sensitive to the environment as the lesser vegetation (Buck, 1964). On the other hand, annual plants are less reliable in their indications because their development is to a greater extent influenced by the accidental circumstances of the seasons (Hilgard, 1860). Coupland and Johnson (1965) described the superior indicator value of herbaceous vegetation as follows:

> "The study of forbs* and shrubs is of particular significance because of the suspected sensitivity of several to variations in edaphic and aerial environment which are not always reflected by the grass cover. Their indicator value is enhanced by their relative ease of identification (as compared to graminoides**) by non-botanists."

Herbs and shrubs strike a balance between the environmental insensitivity of trees and the oversensitivity of annual plants, consequently they are superior indicators of terrain conditions.

2.2.6. Plant Communities as Indicators

The value of plant communities as indicators was stated by Clements (1928):

> There can be no doubt that the community is a more reliable indicator than any single species of it."

A plant community is more specific as to environmental conditions since a single species may have a wide ecological amplitude (Vereiskii and Vostakova, 1963). For example, assume a community of principally three species in a sheltered ravine that appears mesic by the general vegetation indicators. The first species is mesophylous and has a

---

* A forb is a herbaceous plant that is not a grass nor grasslike, such as pasture sage.

** Graminoides refer to herbs with long, narrow leaves (Hanson, 1962). For the purpose of this discussion graminoides means grass.

wide range of salinity tolerance. The second species, also mesophylous, is restricted to fresh to mildly brackish water habitats. Using the combined indicator value of the two species, it is possible to evaluate the habitat as mesic with fresh to brackish ground-water. With the consideration of the third species, which is hygrophylous with a shallow root system, the habitat is further evaluated as very mesic with fresh to mildly brackish ground-water at shallow depths.

Very similar plant communities are present in several locations in which environmental conditions are similar (Leach, 1956). These communities are called'plant associations' and take their name from the dominant species in the association. Coupland (1950) correlated plant associations of the Saskatchewan mixed prairie with terrain conditions with very considerable success.

2.2.7 Vegetational Delineation of Soil Boundaries

In an area of relatively constant climate, changes in vegetation indicate edaphic conditions (Allread and Clements, 1949). Furthermore, a study in California found that eighty-seven per cent of the total length of soil boundaries coincided with vegetation boundaries (Woeslander and Storie, 1953). The coincidence of soil and vegetation boundaries is not uncommon (Viktorov et al., 1964), consequently soil boundaries are often delineated by changes in vegetation. Therefore, no special training in species identification is needed to apply vegetation indicators of soil boundaries.

Vegetation indicators of soil boundaries have been used occasionally in terrain evaluation in southern Saskatchewan. Ellis (1969) gave a table relating common species to pedological soil types in prairie wetlands. While discussing intertill sands, Sauer (1964) stated:

> "These deposits are difficult to detect from surface features, unless they are revealed by vegetation patterns on valley slopes."

Many vegetation changes caused by edaphic changes are sharp. The edaphic factor (Manson, 1946) is most likely to occur in sharply defined patterns, often covering only small areas. Similarly Küchler (1967) reported:

> "There is no doubt that sharp vegetation boundaries are very common due to a more or less abrupt change in the topography, the soil, the geology, or the water economy of the substratum."

Vegetation is therefore a good indicator of soil boundaries as a result of the tendency to sharp changes in the vegetation in response to edaphic changes.

2.2.8. <u>Vegetation Indicators of Moist Areas in Arid Regions</u>

Like vegetation indicators of soil boundaries, indicators of moist areas in arid regions are detected as a change in vegetation, or more often as a change in colour of the vegetation; consequently, no special training in species identification is needed for the use of either of these indicators.

The water content of the soil is more important in causing differences between plant communities than any other ecological factor (Leach, 1956). In arid regions in the U.S.S.R. Viktorov et al. (1964) found vegetation reacts sharply to the smallest changes in hydro-geological conditions. Moreover, vegetation has indicated water bearing sand lenses in the southern deserts of the U.S.S.R. to a depth of fifteen meters with depths of six to ten meters not being uncommon (Shavyrina, 1965). Accordingly, only plants with a preferred moisture supply can thrive during the hot, dry part of the growing season in arid regions.

The use of vegetation indicators of moist areas came into its own with the development of air photo interpretations. Xerophytes appear pale grey on photographs from panchromatic film because they are pale green in colour as a result of their low chlorophyll content. On the other hand mesophytes, with their higher chlorophyll content, are greener and appear darker (Popova, 1965). Similarly the "tear drop" vegetation pattern on the valley slopes which indicates a spring to the air photo interpreter (Sauer, 1964) is distinctly visible from the ground on the opposite side of the valley. Thus these criteria are equally applicable to terrestrial interpretation of moist areas.

2.2.9. Vegetation Indicators of Ground-Water Chemistry

Vegetation is a collective response to both the presence and quality of ground-water. Ground-water chemistry is an important factor in assessing a water source for domestic, agricultural or industrial purposes. Civil engineers must also consider the possibility of sulphate attack on concrete and corrosion of metal structures under conditions of adverse ground-water composition. The problems associated with construction within a local ground-water flow system are completely different from those associated with a regional ground-water flow system. Meyboom (1966a, 1966b) found that there is a relationship between ground-water flow path and its chemical composition. Therefore, any indication of ground-water chemistry such as vegetation patterns, may be valuable in assessing the ground-water flow system. In fact, frequently the vegetation is the only indicator of the ground-water regime in the absence of subsurface explorations.

Each plant community has an ecological amplitude with respect to ground-water salinity. Many communities as illustrated by Figure 2-4, have narrow salt tolerance amplitudes at various degrees of salinity. Some common species have been classified by salt tolerance (Walker, 1966, 1968; Dodd and Coupland, 1966). Figure 2-5, taken from Beideman (1965) shows the difference in plant communities on a plot of depth of ground-water versus mineralization of ground-water. These correlations between plant species and ground-water salinity can be used to estimate both depth and quality of ground-water.

2.2.10. Vegetation Indicators of Miscellaneous Terrain Conditions

Vegetation indicators have been used for the detection of economically significant mineral deposits. Gigantism and other plant abnormalities are caused by oil near the surface; plant associations are also known for boron, cobalt, nickel, zinc and copper (Viktorov et al., 1964). Küchler (1967) reported that the United States Geological Survey developed a botanical method of prospecting for uranium.

Approximating the date of recent terrain events, although mundane in contrast with uranium and oil searches, has its importance to terrain evaluation. Dating water levels in sloughs by their concentric sequence of vegetation is done by Walker (1966, 1968), Millar (1969), and Sloan (1967). Perhaps most significant about dating slough water levels for vegetation is that vegetation changes rather slowly in

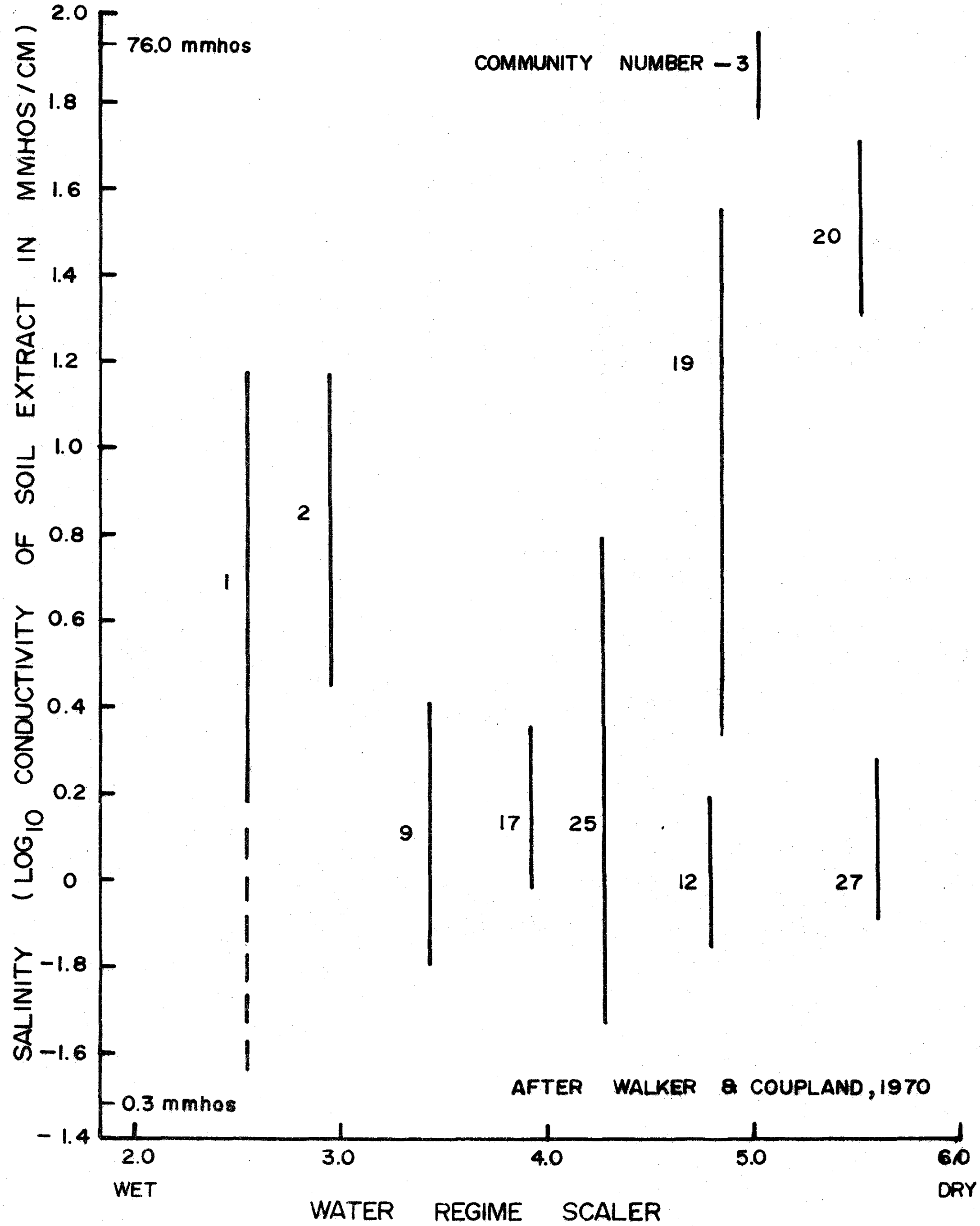


FIGURE 2.4 ECOLOGICAL AMPLITUDE OF SOME COMMON PLANT COMMUNITIES WITH RESPECT TO SALINITY.

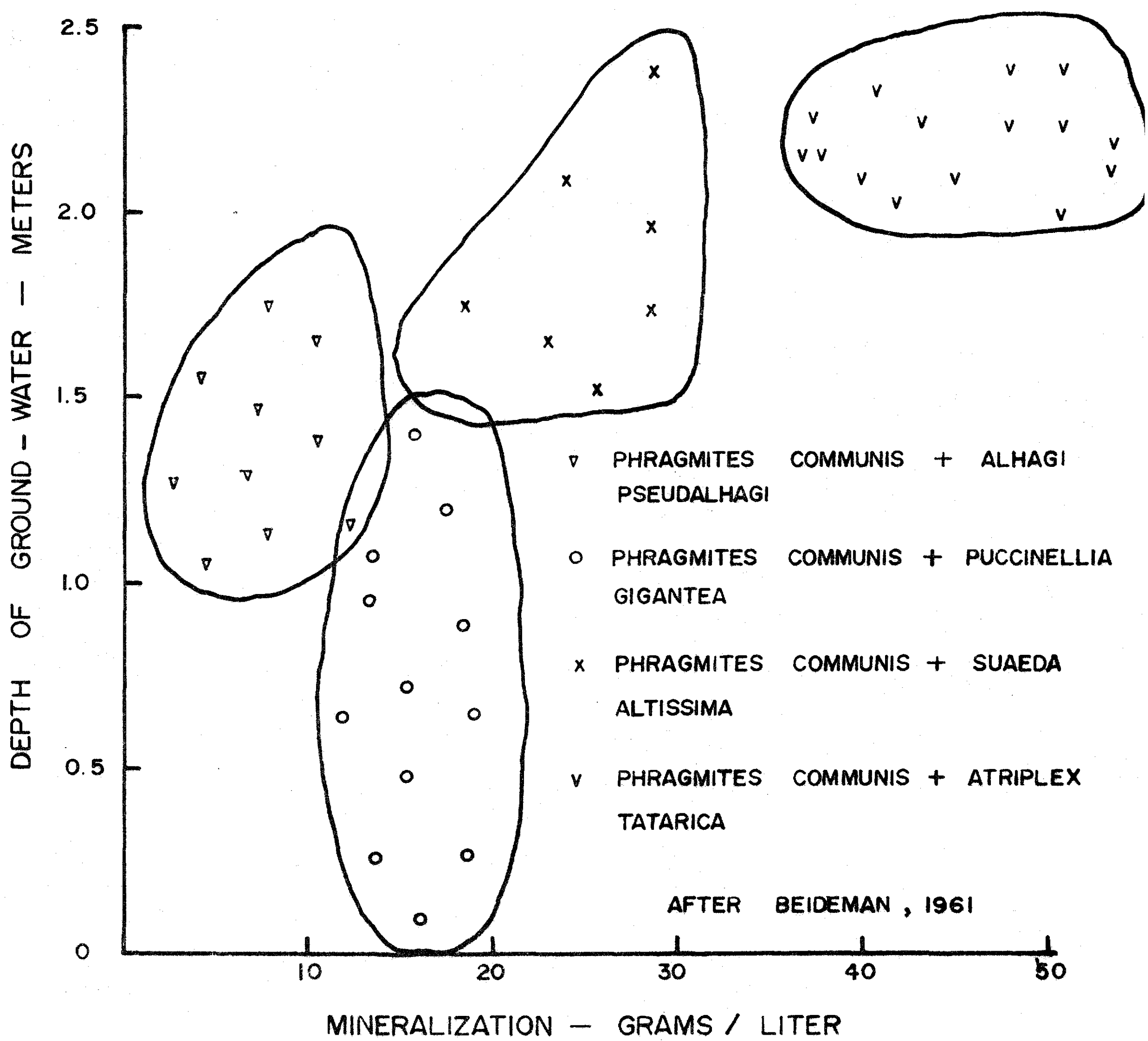


FIGURE 2.5 RELATIONSHIP BETWEEN DEPTH TO GROUND WATER AND GROUND-WATER MINERALIZATION SHOWING PLANT COMMUNTIES

response to fluctuations in salinity and water permanence, so that it tends to integrate the short term changes and adjust to a season or even longer term of hydrology of a slough (Sloan, 1967).

Sand dune stability can be assessed quickly by vegetation indicators (Hullet, 1962); however only a trained botanist could suggest dates of recent terrain events from vegetation. Landslide activity can be evaluated and dates of recent major movements can be estimated by the age and condition of trees in the slide area (Rowe, 1968; Sauer, 1964); likewise forest and prairie fires are dated by the nature of the regrowth or fire scars on old trees. Even the coming and going of the beaver, whose habits frustrate drainage engineers, show in the condition of the trembling aspen *(Populus tremuloides)* growing near streams.

2.3. SUMMARY

The use of vegetation indicators is well developed by Russian geobotany and European vegetation mapping although North Americans have used terrestrial vegetation indicators sparingly. Only in the past ten years has the geotechnical community in North America developed solutions to terrain evaluation problems with information from the biological sciences.

Environmental factors influencing vegetation are complex in their interaction. The moisture regime, aerial and edaphic, is perhaps the dominant factor influencing species distribution. Moreover, compensating effects of environmental factors and the influence of vegetation on the environment complicate vegetation-terrain relationships.

However, there are good vegetation indicators of several terrain conditions. Distinctiveness, dependability and narrow ecological amplitude are characteristics of good indicator species. Herbaceous species and plant communities, as indicators, seem to provide the sensitivity and reliability needed for terrain evaluation.

There is evidence of successful applications of vegetation indicators in environmental conditions similar to southern Saskatchewan. In fact, as a semi-arid region with a narrow ecological margin of safety, southern Saskatchewan may be very well suited to the development of meaningful vegetation-terrain relationships. The examples of vegetation indicators of soil boundaries,moist areas in arid regions, ground-water chemistry and miscellaneous terrain conditions further encourage the development of vegetation-terrain relationships for this region.

CHAPTER III

FIELD INVESTIGATIONS IN THE LANGHAM STUDY AREA

It has been established that the use of vegetation indicators for evaluating terrain conditions may be feasible in southern Saskatchewan. In order to assess the applicability of these indicators to local conditions, a field study was carried out near Langham, Saskatchewan.

3.1. LOCATION

The Langham Study Area is located on the south slope of the North Saskatchewan River valley, three miles north-west of the village of Langham, Saskatchewan, as shown by Figure 3-1. The study area is approximately twenty miles from Saskatoon by road. By legal land description this area is in Sections 19, 29 and 30 of Township 39, Range 7, west of the third meridian. The map coverage of the study area is 73B/6 and 73B/7 of the 1:50,000 map series of the National Topographical System.

In addition to its geographical location, the Langham Study Area has a location with respect to zones of physiography, surficial soil, and vegetation. The study area lies in a level plain of glacial and proglacial landforms at 1700 feet above sea level. This plain is called the Saskatchewan Rivers Plain Physiographic Region (Acton et al., 1960). The surficial soils in the study area are classified as Elstow Association (medium to heavy textured soils on silty glacial lake deposits) of the Dark Brown Soil Zone (Figure 3-2). Similarly the native vegetation is classified as the Aspen Parkland

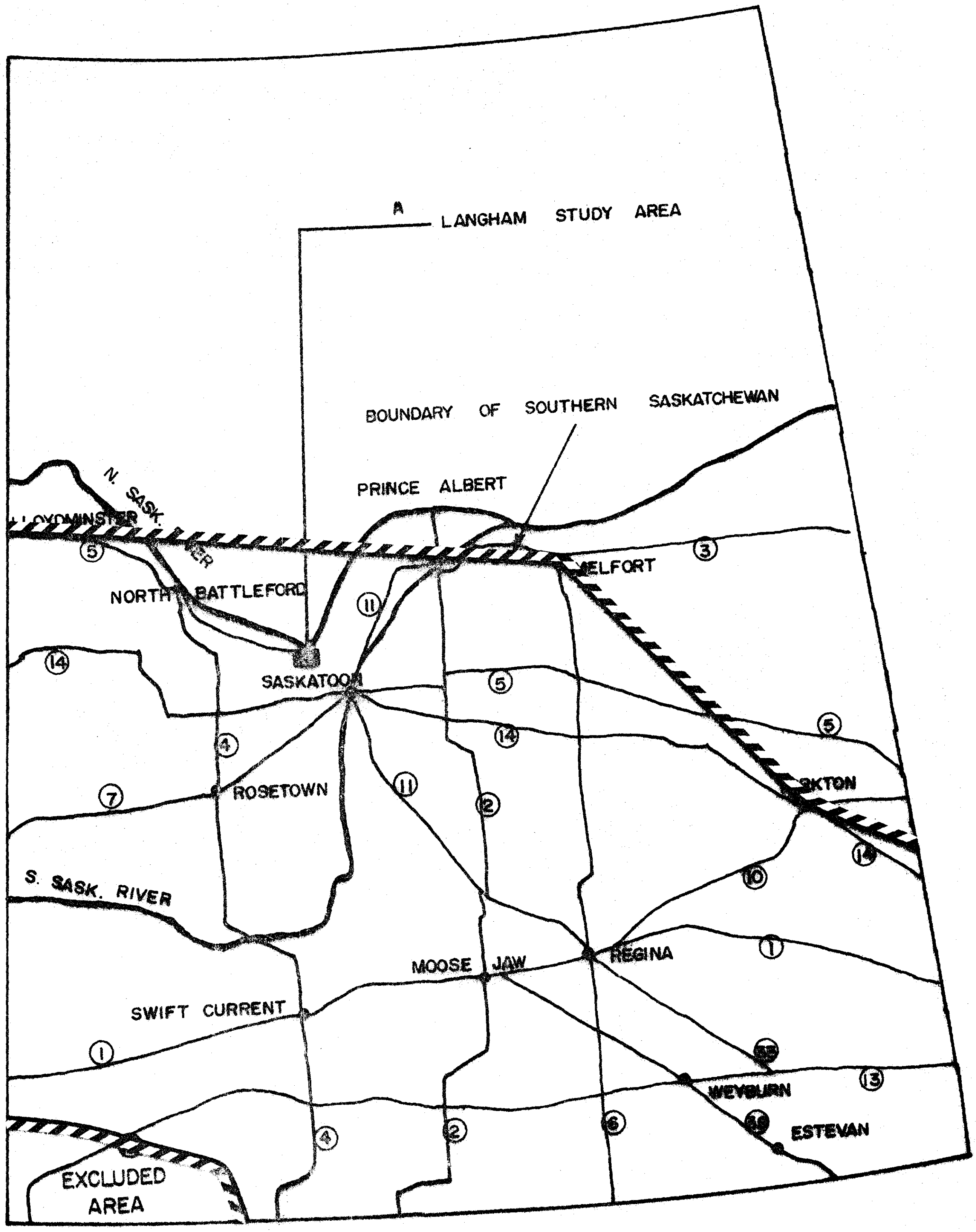


FIGURE 3.1 MAP OF SOUTHERN SASKATCHEWAN SHOWING THE LOCATION OF LANGHAM STUDY AREA

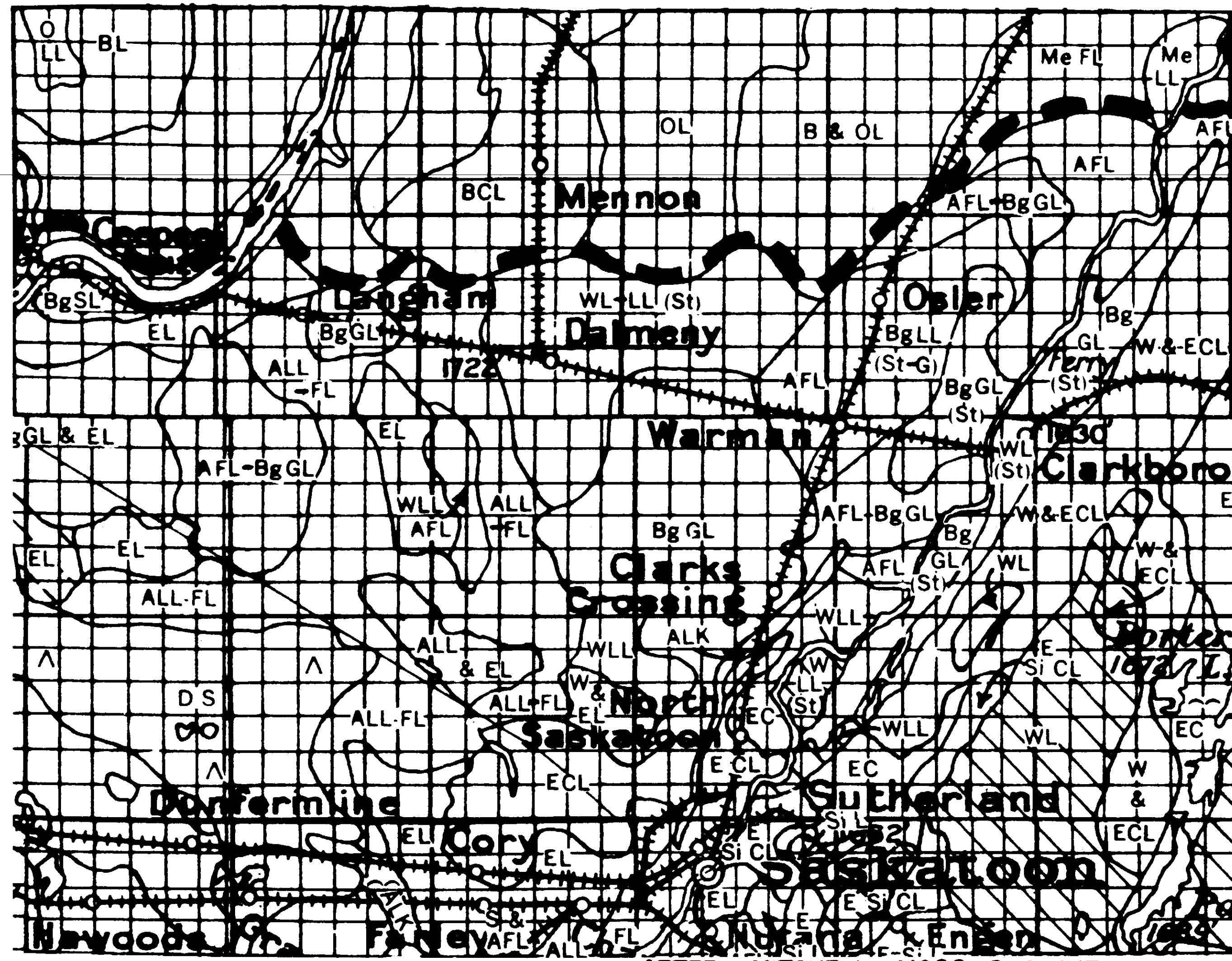


FIGURE 3.2 SURFICIAL SOIL ZONES IN THE REGION OF THE LANGHAM STUDY AREA

class of the Grassland major vegetation zone as shown by Figure 3-3.

3.2. SELECTION OF A STUDY AREA

3.2.1. Study Area Requirements

Before a specific area was selected for a field study of vegetation-terrain relationships, several requirements were established. First, the area had to be in the prairies of southern Saskatchewan. The primary reason for this was that the Saskatchewan Department of Highways, which funded this project, has the majority of its highway system in this region. The second major requirement of the selected area was that the area be well known with respect to geomorphology, stratigraphy, ground-water regime, climate and vegetation. Although the restriction of the study area to the prairie setting caused no difficulty, the second requirement for a well known area was idealistic. Nevertheless, it was felt that there were areas where the physical environment was known, in part, and further information could be gathered as part of this project.

The third requirement was concerned with the character of the vegetation in the selected area. Primarily the area had to have some suspected vegetation-terrain relationships. For an initial study of vegetation indicators of terrain conditions, vegetation-terrain relationships known from experience were to be used to select an area where positive results could be expected. Furthermore, it was important that the area support a wide variety of species in order to investigate their habitat preferences.

AFTER COUPLAND & ROWE, 1969

GRASSLAND AND GROVE REGION

B SPEAR GRASS — BLUE GRAMA
C SPEAR GRASS — BLUE GRAMA — WHEAT GRASS
D WHEAT GRASS — JUNE GRASS
E SPEAR GRASS — WHEAT GRASS
F FESCUE
G ASPEN GROVE

FOREST REGION

H ASPEN
J ASPEN — SPRUCE
L SPRUCE — ASPEN — POPLAR
M PINE
R SWAMP

AZONAL COMPLEXES

1 SANDHILL COMPLEXES
2 VALLEY COMPLEXES
3 SALINE COMPLEXES
4 SLOUGH - MOIST PRAIRIE COMPLEXES

FIGURE 3.3 NATIVE VEGETATION ZONES OF SASKATCHEWAN

The last requirement is not related to the physical environment but was rather a more practical consideration; the close proximity of the selected area to Saskatoon and the ease of access by automobile were therefore factors affecting the suitability of a study area.

3.2.2. Selection of the Langham Study Area

When presented with this list of requirements for a study area, Dr. W.A. Meneley of the Saskatchewan Research Council suggested the south side of the North Saskatchewan river valley near Langham because the geomorphology, stratigraphy, ground-water regime and climate of the Langham area has been established by the Saskatchewan Research Council.

As a result of preliminary air photo interpretation and field correlation, the Langham Study Area was found to fulfill most of the requirements for a study area. It is definitely in the prairie region. Its physical environment is well known with the exception of vegetation information. Consequently gathering vegetation information became a major part of the field investigations.

The vegetation requirements were also satisfied by conditions in the Langham Study Area. Along the main valley slope of the study area, there are great differences in vegetation over short distances. Primarily these changes are associated with the location of ground-water discharge areas. For example, the most striking vegetation change in the study area is from luxuriant vegetation around pools of spring water to dry prairie bluffs at comparable elevations within one thousand feet along the main valley slope. The reason for this will be discussed later because the cause of this striking change in vegetation lies much deeper than normal root penetration depths.

The last requirement of proximity and ease of access was also satisfied. The study area is twenty-three miles from the University campus in Saskatoon and only two of those miles are not paved highway.

3.3. FIELD INVESTIGATION TECHNIQUES

The techniques used to assess the physical environment of the Langham Study Area involved established site investigation practices used by geotechnical engineers with the exception of the detailed vegetation studies. Consequently, the discussion of field techniques used in the study area, with the exception of the botanical surveys, will be familiar to a readership with a geotechnical background as techniques for the description of geomorphology, stratigraphy, ground-water regime and climate.

3.3.1. Aerial Photography

3.3.1.1. Vertical Panchromatic Photography

3.3.1.1.1. Scale of 1:40,000

Panchromatic stereo-photographs at a scale of 1:40,000, obtained from the Air Photo Division of the Department of Energy, Mines and Resources, were used for the initial air photo interpretation of the Langham Study Area. This type of photograph is best suited for landform analysis and consequently the landslide and ground-water discharge areas within the study area were first identified using these photographs.

3.3.1.1.2. Scale of 1:7,200

At a scale of 1:7,200 or a photo contact scale of 1" = 600', it is possible to see vegetation detail. Individual trees are visible and can be identified by their crown characteristics. Aerial photographs at this scale are not well suited for landform analysis because many landform patterns are much larger than a single photograph. Since photography of this scale is used primarily for purposes where landscape detail is needed, it was useful to this study.

The 1:7,200 aerial photographs of the study area were taken on October 14 and November 4, 1970, by Northwest Survey Corporation. Fortunately this corporation was doing some aerial photography under contract to the Saskatchewan Department of Highways in the Langham area. As a result no ferrying charges were assessed against the cost of this project.

3.3.1.2. 35mm Oblique Colour Photography

By November, 1970 the leaves had fallen from the trees and there had been no permanent snow in the Langham Study Area. Furthermore a ground check at Site II in late October found signs of a rising water table. Consequently, a Cessna 180 aircraft was chartered for an aerial reconnaissance of the entire study area in search of any other signs of a rise in the water table since the end of the growing season. During this flight a number of oblique colour photographs of previously undetected terrain features were taken.

3.3.1.3. 70mm Vertical Photography

70mm aerial photographs were highly rated for their forestry applications because of the versatility of film/filter changes in flight and their low cost (Aldrich, 1966). Moreover, the Department of Civil Engineering, Saskatoon campus owns a 70mm Hass-elblad aerial camera. In view of the suitability of 70mm photography to the study of vegetation, this photo technique was used in the Langham Study Area. The summary of 70mm aerial photography for the study area is shown in Table III-1.

The 70mm aerial photography was taken on September 13 and 14, 1970 using a Piper Comanche aircraft (Figure 3-4). This was three days after the first killing frost of the 1970 growing season. The influence of frost on species in the study area was therefore photographed. At that time there was concern that the frost damage to vegetation would be recorded by the colour infrared photographs thereby masking the signs of moisture distress in the vegetation. Upon comparison of the colour and the colour infrared photographs, only one of the trees or shrubs appeared to have suffered frost damage. Consequently, there was no recorded masking effect of frost distress on moisture distress in the vegetation.

3.3.2. Terrain Evaluation

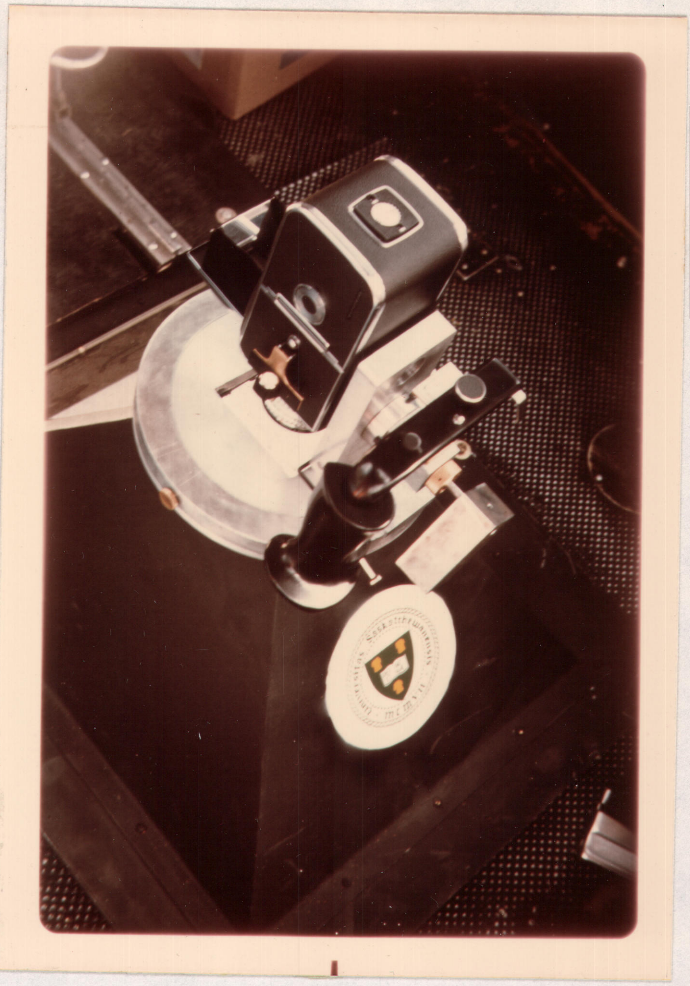
The terrain evaluation of the Langham Study Area was conducted in two parts: the interpretation of the 1:40,000 panchromatic stereo aerial photographs in the office, and the field checking of the air photo interpretation. Features identified from the aerial photos, such as landforms, surficial materials, stratigraphy,

TABLE III-1

SUMMARY OF 70mm AERIAL PHOTOGRAPHY

DATE	RUN	LENS	FILTER	ALTITUDE AMSL	SCALE	FILM TYPE
13/9/70	51	80mm	-blue	4700	1"=1000'	colour infrared
13/9/70	53	80mm	-blue	4700	1"=1000'	colour infrared
14/9/70	1	150mm	-blue	7500	1"=1000'	panchromatic
14/9/70	2	150mm	-blue	7500	1"=1000'	panchromatic
14/9/70	3	150mm	-blue	7500	1"=1000'	panchromatic
14/9/70	4	150 mm	polarizing	7500	1"=1000'	colour
14/9/70	5	150mm	polarizing	7500	1"=1000'	colour
14/9/70	6	150mm	polarizing	7500	1"=1000'	colour
14/9/70	7	150mm	polarizing	7500	1"=1000'	colour infrared
14/9/70	8	150mm	-blue	7500	1"=1000'	colour infrared
14/9/70	9	150mm	-blue	7500	1"=1000'	colour infrared
14/9/70	10	150mm	polarizing	7500	1"=1000'	colour infrared

Figure 3-4: Photograph of the 70mm Hasselblad camera mounted in a Piper Comanche aircraft.



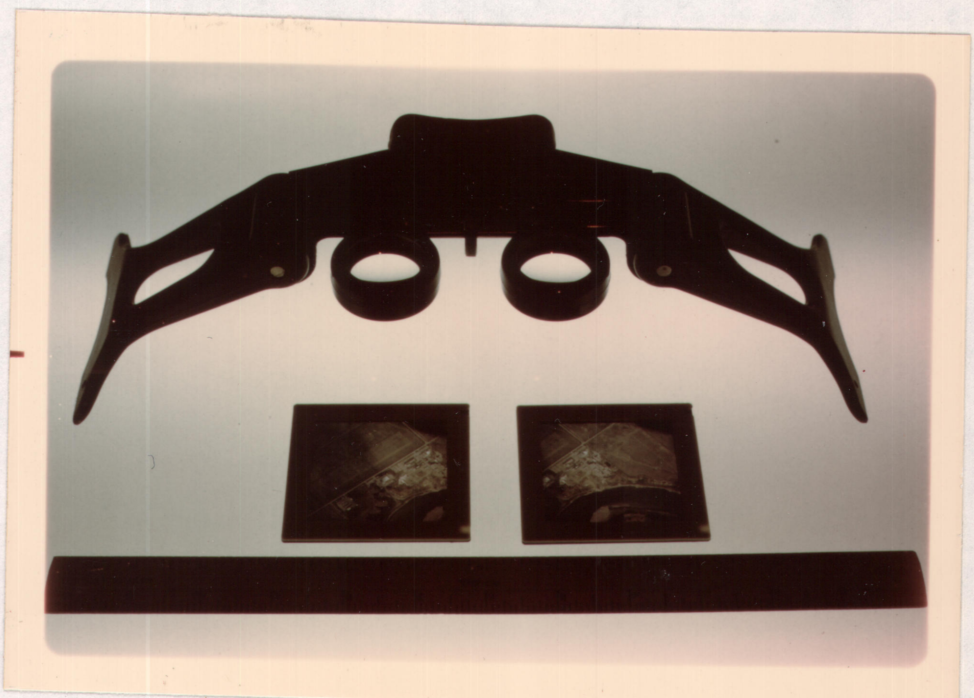


Figure 3-5: Photograph of air photo interpretation equipment. 70mm positives were examined using a four power stereoscope on a light table. There is a one foot ruler at the bottom of the photograph

vegetation, ground-water seepage and landslides were then investigated in the field. Many features appearing on the aerial photographs could not be confirmed without checking in the field. For example, suspected ground-water seepage areas can be delineated by air photo interpretation but field correlation is required to confirm the amount of seepage. Furthermore, the amount of seepage and its chemical composition can be better evaluated in the field by use of vegetation indicators.

3.3.3. Surveys for Horizontal and Vertical Control

Aerial and terrestrial surveys provided a system by which terrain information gathered by different techniques in the study area could be coordinated. This control is needed to correlate vegetation and terrain conditions in the development of vegetation indicators of those terrain conditions.

Elevations for the vertical control are given in feet above mean sea level. The reference bench mark for the Langham Study Area is the invert of an eighteen inch diameter corrugated metal through-grade culvert at Station 1034+00 of Control Section 5-11 on Highway No. 5. Bench marks were placed at the top of each site* in the study area using a Wild split bubble level. For future reference, the bench marks at Sites IV and VII are permanent. Working from these

---

* In order to study the vegetation in the Langham Study Area, ten different profiles of the valley slope were considered. Each profile was called a "vegetation study site" which is often shortened to "Site" in the discussion.

bench marks, hand level elevations were taken for site profiles, ground surface at structural testholes and auger borings, and water tables.

Horizontal control for the vegetation study site profiles was established as the slope was surveyed. All other horizontal distances are scaled from the 1:7,200 aerial photographs.

3.3.4. Subsurface Investigations

As a result of earlier discussions on the use of vegetation indicators of soil type and ground-water conditions, there was an established need for subsurface information for the development of vegetation-stratigraphic relationships.

In order to obtain complete subsurface information in the Langham Study Area, three techniques were employed. Two structural testholes served to define the deep stratigraphy as well as to establish a foundation from which regional stratigraphic correlations were made. In addition, two power auger borings allowed investigation of near-surface soil and soil moisture conditions. Finally, numerous hand auger borings were performed to examine the surficial soil where the plant roots were located.

Although plant roots reach a shallow depth in comparison to the depth of the structural testholes, the ground-water system and thus the character of the vegetation may be influenced by deep-seated geological conditions; therefore, any detailed study of vegetation as it relates to the physical environment is limited without deep stratigraphic information.

3.3.4.1. Structural Testholes

Hayter Drilling Company, under contract with the Saskatchewan Research Council, drilled testholes at two sites shown by Figure 3-6, with rotary drilling equipment. Testhole SDH 73B/6 1970 LANGHAM was terminated at elevation 1392 at a depth of 268 feet. This hole was at the top of Site VII and was called "Testhole VII". Testhole VII was located to determine the stratigraphy in the vicinity of the springs at Sites VII through X. At the top of Site V, near the dry section of the main valley slope, one testhole was abandoned at a depth of one hundred feet due to loss of drilling fluid circulation. Another hole in the same area was taken to a depth of 164 feet. This hole, SDH 73B/7 1970 LANGHAM, was called "Testhole V".

At both testholes the washed cuttings were dried and described in the field. At the same time the spontaneous potential and resistivity of each hole was logged. Then on the basis of the stratigraphic analysis from cutting descriptions and the electric log analysis, locations for sampling were decided. These samples were taken with a side-hole core sampler (Morrison, 1969), and were subsequently examined under laboratory conditions prior to the final analysis of stratigraphy in each test hole. Copies of the testhole logs are in Appendix D.

3.3.4.2. Shallow Auger Borings

The structural testholes revealed that the surficial silt was approximately thirteen feet thick overlying Battleford Till (Christiansen, 1968). In stratigraphic conditions such as this, it is common to find a water table in the silt because the relatively lower permeability of the underlying till will not allow rapid internal drainage. To investigate this possibility, two 4 inch diameter borings were performed with a power auger to a depth of fifteen feet near Sites VIII and X as shown by Figure 3-6. Samples taken at one foot intervals indicated a very high water content at the silt-till contact. Consequently, there is a small quantity of seepage near the top of the scarp above Sites VII through X.

In order to define the edaphic conditions at each zone in the study area, twenty-six hand auger borings were performed to varying depths from two to seven feet (Figure 3-6). Each hole was logged and sampled at one foot intervals. These samples were placed in plastic bags and sealed to prevent moisture loss before the natural water contents could be established.

3.3.5. Ground-Water Investigations

A clearly established stratigraphic model is prerequisite to a study of geohydrology because it defines the shape of the ground-water system. When the stratigraphy in the study area was correlated to the regional stratigraphy, it was then possible to examine the ground-water discharge in the Langham Study Area within the context of the regional ground-water system.

Locating and understanding the ground-water system is one aspect of terrain evaluation. Therefore, vegetation indicators of ground-water conditions are extremely valuable for terrain evaluation purposes.

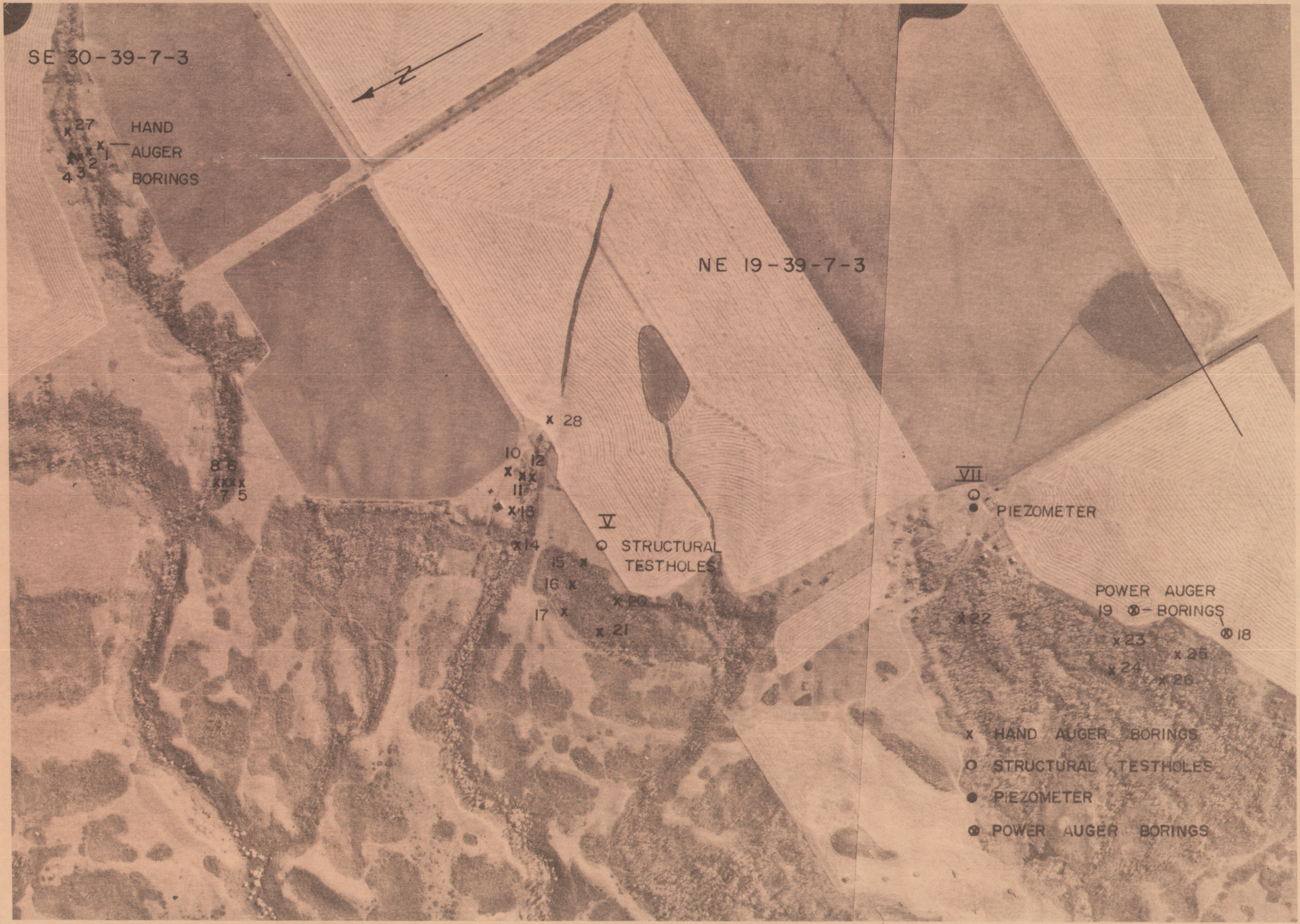


FIGURE 3.6 LOCATION OF SUBSURFACE INVESTIGATIONS

3.3.5.1. Water Table Determinations

Both structural testholes in the study area penetrated a thick stratum of water bearing stratified drift. This stratum was well known in that region (Christiansen, 1970) and is called the Dalmeny aquifer. This aquifer discharges through the landslide debris on the south slope of the North Saskatchewan River valley near Langham. In order to monitor the position of the water table in the Dalmeny aquifer a piezometer was installed beside Testhole VII in the aquifer at a depth of 110 feet, approximately 15 feet above its base. Details of this piezometer installation are shown in Figure 3-7. Records of the water table position in this piezometer are in Appendix D.

In areas where the water table was suspected to be near the surface, the hand auger borings were left open. Open boreholes were sealed at the top by a piece of sod to prevent surface runoff from entering the open boreholes. These open boreholes were periodically checked for water presence.

Measuring surface elevations of pools around springs in the study area was another method of water table determinations. These water surfaces cannot be considered as a true measure of the hydrostatic head in the Dalmeny aquifer because there is head loss due to seepage between the aquifer and the point of discharge. Consequently the surface elevations of spring pools will be less than the hydrostatic head within the Dalmeny aquifer.

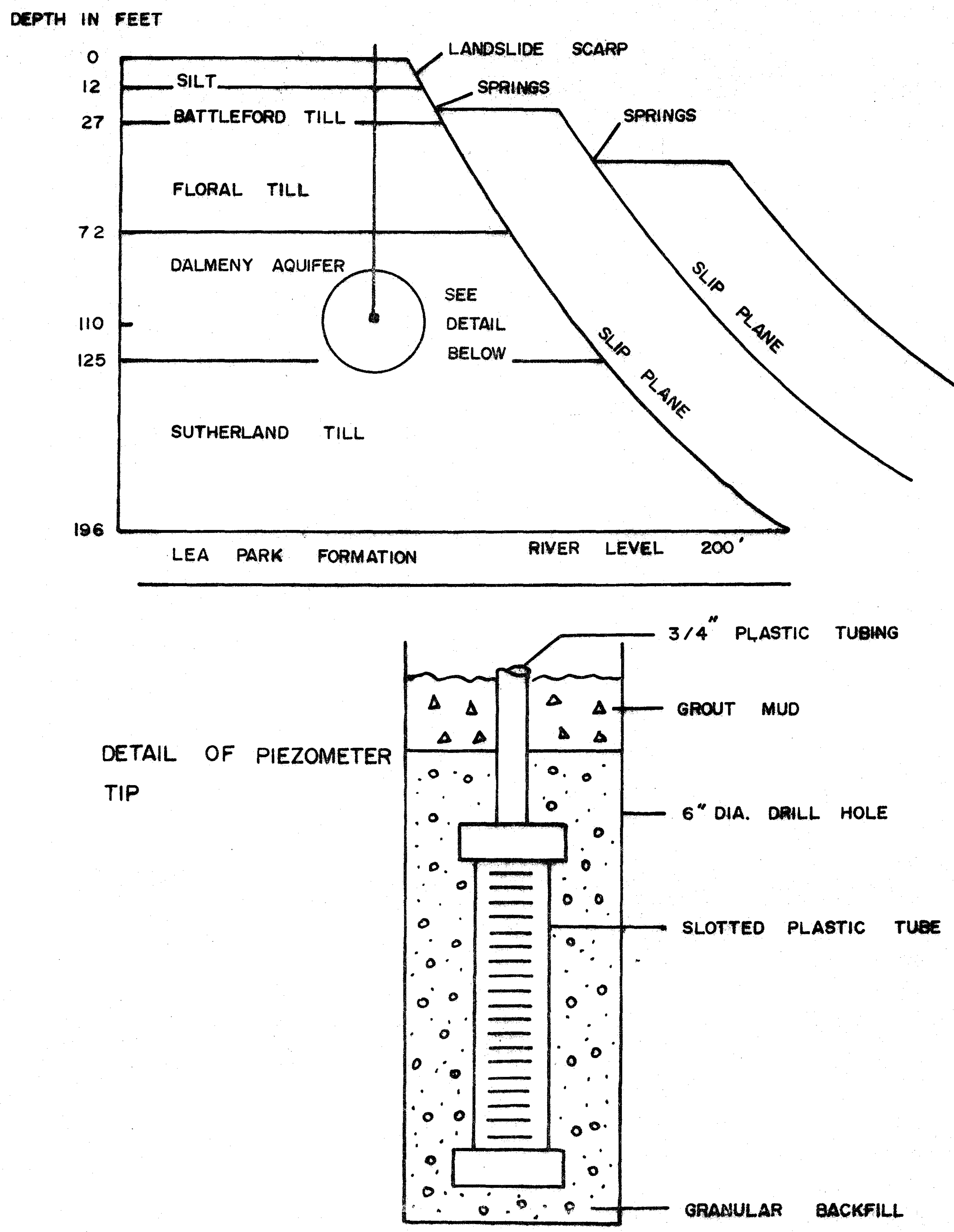


FIGURE 3.7 SKETCH OF THE PIEZOMETER INSTALLATION IN THE LANGHAM STUDY AREA

3.3.5.2. Ground-Water Discharge Quantities

Three of the vegetation study sites include flowing springs. These sites are VII-4*, VIII-4 and IX-4B. Flow at Sites VII-4 and VIII-4 was gauged by timing the filling of a five gallon pail at a small waterfall near the point of discharge. Conditions at these two sites were favourable to the measurement of flow quantities. Consequently the estimates of these flow quantities are reasonably accurate.

On the other hand the conditions at Site IX-4B did not allow a reliable measurement of flow quantities. Site IX-4B is a boggy area with a travertine**mound. Flow was gauged on the only channel leading from this mound by taking the average channel cross section and estimating its flow velocity by timing the movement of small pieces of floating matter over a measured distance. The flow quantity in this channel is some fraction of the total ground-water discharge at Site IX-4B. Moreover, there are numerous boggy areas between Sites VII and X where the volume of ground-water discharge cannot be estimated.

3.3.5.3. Ground-Water Chemistry

It was established that vegetation responds to ground-water chemistry. This was one reason for taking samples of water from the flowing springs at Sites VII-4 and IX-4B. Another

---

* Each vegetation study site was divided into zones according to vegetation types. A combination of site and zone number (Roman numeral-Arabic numeral) also designates a geographical position in the study area.

** Travertine is a calcareous deposit from springs, hardening on exposure (Concise Oxford Dictionary, 1964).

reason for sampling was the need to clarify the significance of the thick iron deposits on the channels leading from these springs and to discern the significance of the travertine mound at Site IX-4B.

It is possible to identify the source of ground-water discharge by comparison of the ground-water chemistry of samples from known sources. Water chemistry analysis for wells in the Dalmeny aquifer in the Langham vicinity had been determined by the Saskatchewan Research Council. As a result, this kind of comparison was possible for the ground-water discharge in the Langham Study Area.

3.3.6. Studies and Records of Climatic Conditions

The climate of the Langham Study Area was evaluated although no climatic observations were made as part of this field study because these observations were made by other agencies. Moreover, any vegetation-terrain relationships discovered in the study area can only be extrapolated to other areas having a similar physical environment; therefore climatic conditions are described to make possible extrapolation of these relationships. There is also a need for climatic data in order to correlate the climatic influence on the condition of vegetation in the study area during the field study of 1970 to its condition during growing seasons under long term average climatic conditions.

As mentioned earlier climatic observations were made by others, the Department of Transport Meteorological Station at the Saskatoon airport, eighteen miles south-east of the Langham Study Area, and the Saskatchewan Research Council Meteorological Station on the University campus, twenty-one miles south-east of the study area.

The Department of Transport publishes Monthly Meteorological Summaries which are distributed upon request. The Saskatchewan Research Council has presented their records (Christiansen, 1970) as a statistical analysis of the climatic conditions in the Saskatoon area. As a result of the availability of climatic data from these two sources, this aspect of the physical environment was well known at the time of the field study.

3.3.7. Vegetation Studies

The vegetation in the Langham Study Area was not known in detail before the field investigations. Within the scope of this project it was not possible to examine all the vegetation in the study area. In fact, very rarely has all the vegetation been studied in areas of similar dimensions. Therefore, small vegetation study sites were selected where there appeared to be some relationship between vegetation and terrain conditions.

Each vegetation study site represents a profile of a slope on the main valley or ravine connecting to the main valley. Ten of these profiles, as shown by Figure 3-8, were selected such that there were at least two vegetation study sites in each location of suspected vegetation-terrain relationships. These sites vary in length from 100 feet to 220 feet. Vegetation study sites were designated by Roman numerals I to X, and are referred to as "Sites" throughout this discussion.

Each site was subsequently divided into zones on the basis of species composition. These zones are very distinct because they are areas along the profile where there is relatively constant species

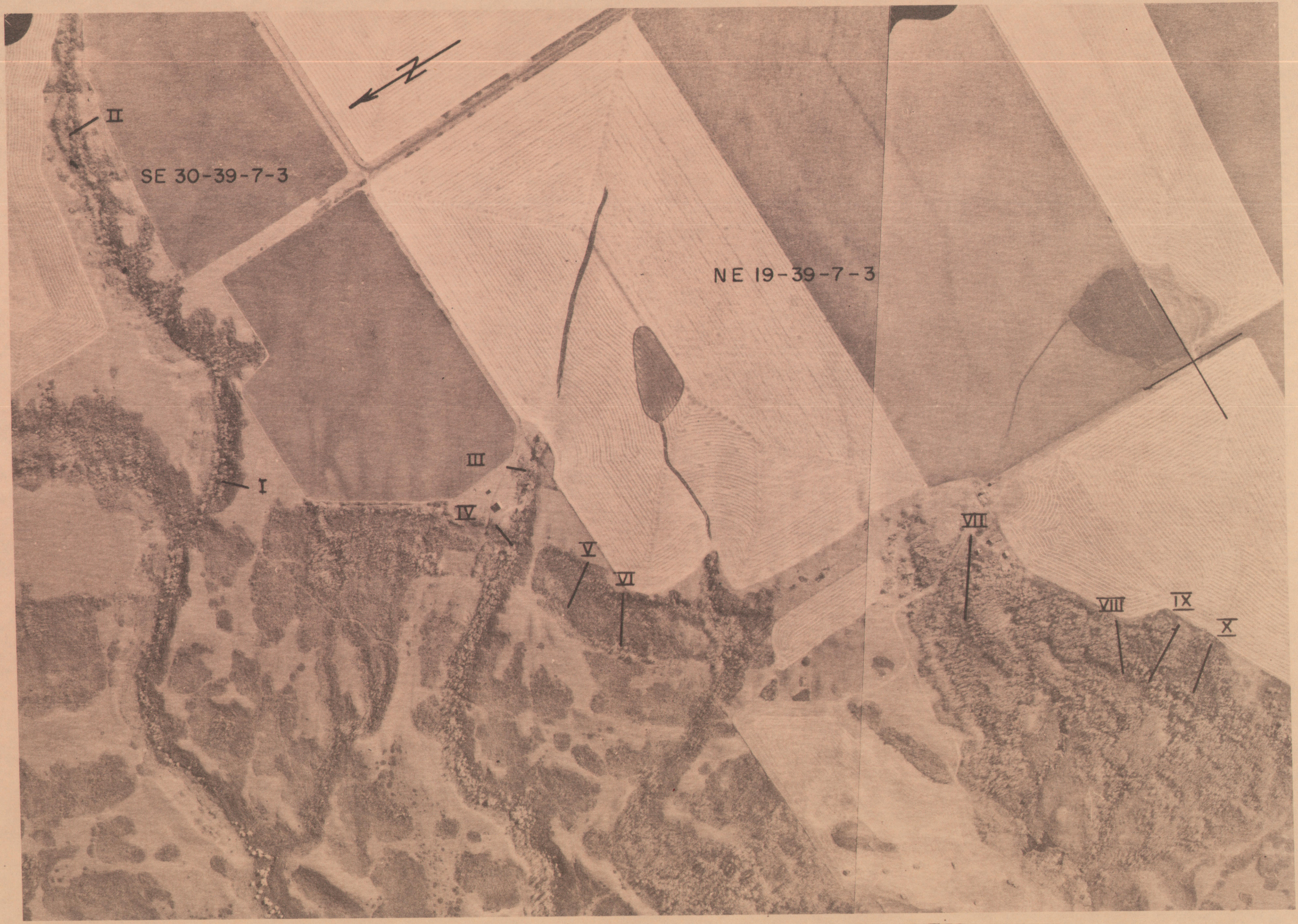


FIGURE 3.8 LOCATIONS OF VEGETATION STUDY SITES
PHOTO SCALE 1" = 600'

composition. The zones were then designated by Arabic numerals and were numbered from the top of the slope downwards. Thus the combination of site and zone numbers allowed reference to a specific location within the study areas. For example, Site VII-4 refers to the fourth distinct vegetation community down from the top of vegetation study Site VII.

Using this system of designating vegetation communities it was possible to plot the surveyed profile for each site and then mark on each vegetation community by zone as well as testhole logs, borehole logs and water table elevations. These profiles called "geobotanical profiles" provide descriptive information of all aspects of the physical environment related to the development of vegetation-terrain relationships except climate.

3.3.7.1. Selection of Vegetation Study Sites

Vegetation study sites in the Langhan Study Area were selected as potential examples of vegetation indicators of groundwater conditions. Accordingly each site was classified as xeric, mesic or hygric*. Sites III, IV, V and VI are xeric; I and II are mesic; and VII, VIII, IX and X are hygric.

Most sites were undisturbed by man's activities. None of them has been cultivated but cattle have grazed at all sites. At Site III there is vegetation obliteration by trampling. Similarly, there is vegetative evidence of overgrazing at the top of Sites V and VI.

* With respect to the general moisture conditions of a vegetation habitat above and below ground surface, xeric means dry; mesic means moist; and hygric means wet.

TABLE III-2

CRITERIA FOR THE SELECTION OF EACH VEGETATION STUDY SITE

Site Number	Moisture Condition	Species Present	Suspected Terrain Condition
I	Mesic	White birch growing on a slope contour	Seepage along a stratigraphic boundary
		Exceptionally large Saskatoon and Choke-cherry bushes	Moist, nutrient rich soil conditions
II	Mesic	Balsam poplar in shallow ravine	Moist to wet soil; potential ground-water discharge area.
		Willow	Area of high water table or ground-water discharge
III	Xeric	Manitoba maple Columbian hawthorne Large Saskatoon bushes	Slightly moist soil
IV	Xeric	Pin cherry High bush cranberry	Moist, nutrient-rich soil
V	Xeric	Xeric vegetation	The vegetation is typical of dry valley slopes in the study area
VI	Xeric	White birch	Seepage along a stratigraphic boundary
		Xeric vegetation	Dry valley slopes similar to those in Site V.
VII	Hygric	Balsam poplar Willow	High water table and known ground-water discharge
		Large number of hygric species	Upper portions of landslide scarp For positive correlation of species present with a known ground-water discharge area
VIIA	Mesic	Canada thistle Stinging nettles	Area of ponding water or an area disturbed by man's activities
VIII	Hygric	A zone of xeric species amongst mesic to hygric species on the slope	An irregularity in the seepage pattern on the valley slopes

Table III-2: Continued

Site Number	Moisture Condition	Species Present	Suspected Terrain Condition
VIII (Cont.)		Hygric species	For positive correlation of species present with known ground-water discharge areas
IX	Hygric	Balsam poplar and American vetch	Clarification of the course of the presence of mesic species in an apparently dry habit at the top of this site
		Hygric species	For positive correlation of species present with known ground-water discharge areas
X	Hygric	Balsam poplar and other Hygric species	Ground-water discharge Delineation of a landslide scarp

Figure 3-9: Oblique aerial photograph of Site I. Notice the abrupt change in the vegetation on the right hand side of the ravine. This vegetation change corresponds to a break in slope in the ravine.

Figure 3-10: Oblique aerial photograph of Site II.

Figure 3-11: Oblique aerial photograph of Sites III and IV. Site III is at the top of the photograph. Site IV is towards the middle of the photograph from the larger granery.

Figure 3-12: Oblique aerial photograph of Site VII. The bare vegetation in the middle right appears darker. This darker vegetation is Willow trees along an area of ground-water discharge.

Although disturbance by man's activities was found to be the most important factor governing species distribution by Walker (1968), the amount of disturbance in the study area is minimal. Consequently, species distribution in the study area was assumed to be related to natural factors of the physical environment.

3.3.7.2. Vegetation Description and Sampling

The division of vegetation study sites into zones of distinct plant communities was the first step towards methodically describing vegetation. As the next step the vegetation in each zone was described by vertical layers. In the Langham Study Area these layers were taken from the tallest to the shortest vegetation, as tall trees, trees and shrubs approximately the height of a man, shrubs to a man's waist height, grasses and shrubs not taller than a man's knee, and finally low growing species*. As a result of the system of sites, zones and layers, used in the study area, the species distribution of vegetation was recorded for plotting on the geobotanical profiles.

For the development of vegetation-terrain relationships the frequency of species presence is as important as its spatial distribution. Two methods of estimating species frequency within each vegetation layer were attempted. The first method of estimating a frequency in percentage of total vegetation in a vegetation layer was abandoned because of the difficulty in deciding frequency by the number of plants of each species or by the basal area covered by

---

* For the purposes of this report little consideration was given to the Bryophyta because of the difficulty in identifying species of this phylum. The Phylum Bryophyta comprises mosses, liverworts and hornworts.

Figure 3-13: Oblique aerial photograph of Sites VIII and IX. Site VIII is middle left; Site IX is middle right. Notice the absence of Balsam poplar trees at the base of the landslide scarp along the area of ground-water discharge.

Figure 3-14: Photograph of mounting and labelling plant samples in a plant press in the field.

CHAPTER IV

FIELD OBSERVATIONS IN THE LANGHAM STUDY AREA

In order to define the physical environment in the Langham Study Area, seven established techniques of gathering terrain data were used. This terrain data has been evaluated to describe the physical environment in terms of geomorphology, stratigraphy, ground-water regime, climate and vegetation. All of this data, except climatic data, has been plotted on geobotanical profiles shown herein.

4.1. GEOMORPHOLOGY

The shape and character of the earth's surface in a small area can be ascertained by methods which are primarily visual. In the Langham Study Area the geomorphology was first assessed from topographical maps and air photo interpretation. Then in the field, the air photo interpretation was confirmed. Finally the establishment of horizontal and vertical controls completed the compilation of data descriptive of the shape and character of the earth's surface.

In the study area, the North Saskatchewan River valley is eroded to a depth of 200 feet into a flat plain. This plain is intensely cultivated because of its flatness and its fertile lacustrine surficial soils. Along the valley slope in this area, there are three ravines joining the main valley slope. All are less than a mile long and carry only the local surface drainage.

More important than surface drainage in terms of quantity of flow is the subsurface drainage and its discharge from the north-west facing valley slopes. The location of this discharge is shown each species.

The second method proved more suitable to the type of vegetation study conducted in this project even though it was more subjective than the first. Frequency of species presence in each vegetation layer was rated as exclusive, abundant, frequent, or rare. As a result of the success in the application of this method of assessing the frequency of species presence, it is recommended for use by non-botanists in their description of vegetation.

As part of the field study and description of vegetation, a large number of plant samples were collected as shown by Figure 3-14, for later identification by botanists. To further improve the quality of the vegetation description of the study area, an experienced field botanist examined each site.

3.3.8. Laboratory Testing

3.3.8.1. Plant Samples

To prevent deterioration and deformation, samples were oven dried at one hundred degrees Centigrade while they were still in the field plant press*. Dried samples were then flat mounted on botanical mounting paper in preparation for identification at the W.P. Fraser Herbarium of the University of Saskatchewan, Saskatoon.

---

* A plant press is a number of layers of corrugated cardboard and plain newsprint paper. Plant specimens are placed in each layer, sandwich style. The top and bottom layers are usually open but rigid wooden frames to which compression is applied by tightening canvas straps around the entire plant press.

3.3.8.2. Soil Samples

Soil samples from the auger borings were taken to the Soil Mechanics Laboratory of the Department of Civil Engineering where the natural water components were measured on the day of sampling. Then all samples were air dried, replaced in their original sample bags and stored.

Soil samples considered significant for the identification of stratigraphic boundaries were sent to the Materials Research Laboratory of the Department of Highways in Regina to determine gradation and Atterburg limits.

Core samples taken from the structural testholes were inspected at the Saskatchewan Research Council Laboratory by Dr. E.A. Christiansen. As a standard test for the identification of the till stratigraphy, these samples were then tested for carbonate and dolomite content.

3.3.8.3. Water Samples

The chemical analysis of the three water samples gathered at Sites VII-4, VIII-4 and IX-4B respectively was done at the Saskatchewan Research Council laboratories. This agency also conducted an X-ray diffraction analysis of some inorganic matter taken from the travertine mound at Site IX-4B.

3.4. SUMMARY

After the decision to select a field area to study the application of vegetation indicators of terrain conditions in southern Saskatchewan, a series of study area requirements were developed. Subsequently, the Langham Study Area was selected as satisfying these requirements because it was well known with respect to geomorphology, stratigraphy, ground-water regime and climate. Field investigations, therefore, undertook to further describe the physical environment and gather the vegetation data which had not yet been documented.

The description of the physical environment was achieved by applying seven established field investigation procedures. As might be expected, the amount of time spent on each procedure seemed inversely proportional to the amount of each kind of information available before this study. Accordingly, vegetation studies required the most work, followed by subsurface investigations and ground-water studies. Aerial photography work was relatively straight forward as was the ground surveying and the terrain evaluation. Climatic data was available in a very usable form and therefore minimal effort was expended collecting copies of Monthly Meteorological Summaries.

on the photo mosaic, Figure 4-1. Undoubtedly this ground-water discharge is a major cause of landslides in the study area. At this time the slopes appear to be stable at a net slope of ten horizontal to one vertical. As will be discussed in more detail in Section 4.2.1. the elevation of Lea Park Shale is approximately river level in this area. Slopes of ten to one are typical of landslide slopes where the sliding is caused by weakness in the bedrock clay shales (Peterson et al., 1960). Moreover, the valley slopes in the study area are on the outside bend in the river where the water currents eroded away the toe of the valley slope. As a result of a combination of ground-water discharge from the slope, bedrock shale foundation and the erosion of the toe of the slope, landslide scarps and slump blocks dominate the landscape.

4.2. STRATIGRAPHY

4.2.1. Description of Structural Testholes in the Langham Study Area.

As a result of the proximity of the Langham Study Area to the Saskatoon region studied by the Saskatchewan Research Council (Christiansen, 1970), only two structural testholes within the study area were needed to relate the local stratigraphy to the regional stratigraphy. This regional correlation is needed to produce a complete stratigraphic model for the analysis of the ground-water regime.

In order to relate the structural testhole designation to other locations in the study area, these testholes were referred to by a site number corresponding to the vegetation study site nearest to

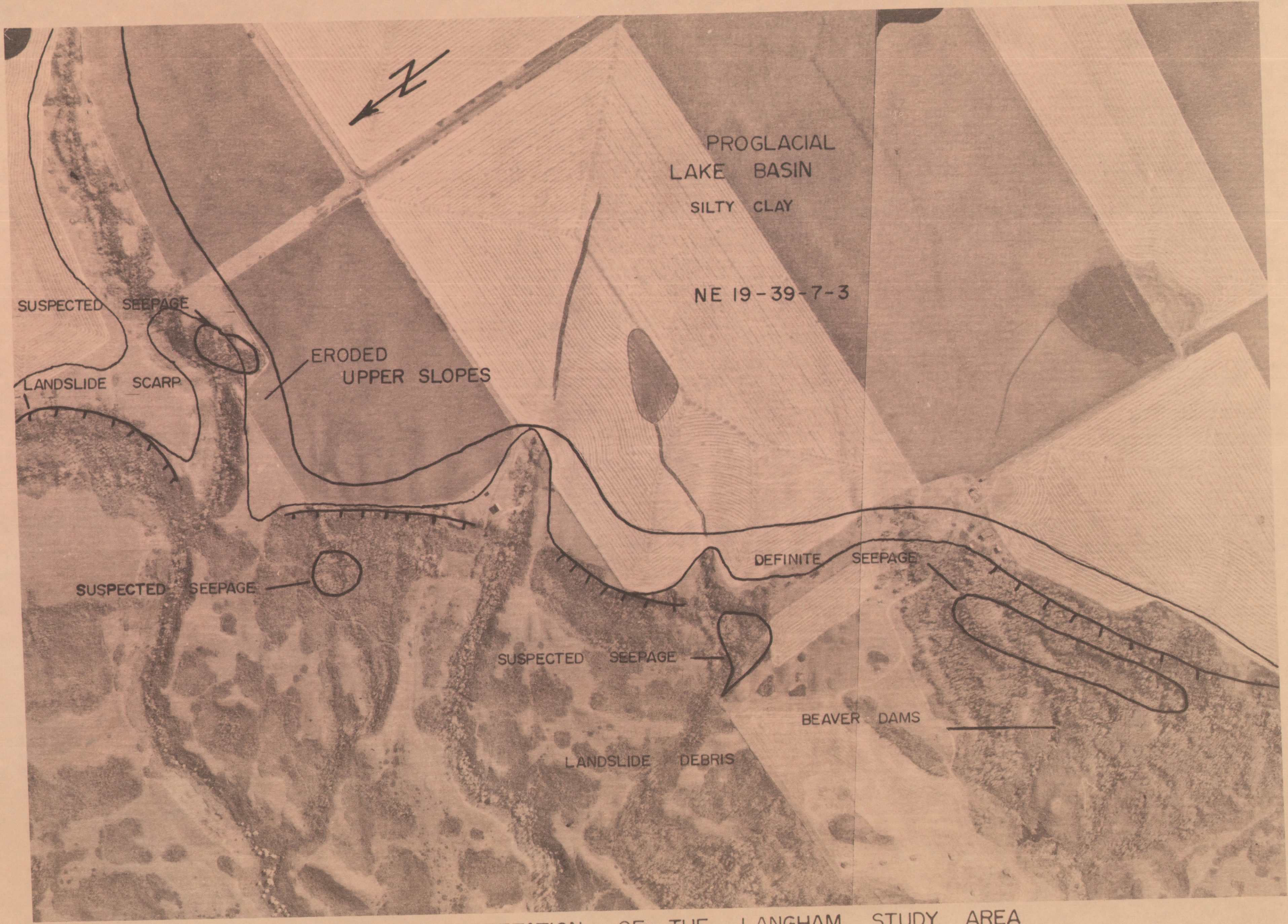


FIGURE 4.1 AIR PHOTO INTERPRETATION OF THE LANGHAM STUDY AREA
PHOTO SCALE 1" = 600'

the testhole. Accordingly, Testhole SDH 73B/7 1970 LANGHAM became Testhole V, and Testhole SDH 73B/6 1970 LANGHAM became Testhole VII. These testhole logs are shown in Figure 4-2. The electric logs are in Appendix D.

Normally the stratigraphy is described from the lowermost formation upwards. However, only Testhole VII was taken to the base of the stratigraphic drilling. Drilling difficulties led to the abandoning of Testhole V above this base. As a result, there is no common base formation for these two holes. Therefore, the description of the stratigraphy interpreted from these two testholes is given starting from ground surface.

The surficial deposit, identified as silty clay from air photo interpretation was in fact silt to a depth of twelve feet. Near the bottom of this unit were several layers of wet sand. The presence of this wet sand was confirmed by the sharp peaks on the electric log of Testhole VII as well as power auger borings at Sites VIII and X. The dense vegetation at the top of the valley scarp is undoubtedly related to seepage in the wet sand within the surficial silt.

Below the silt was approximately fifteen feet of soft, olive gray Battleford Till. Both the surficial silt and the Battleford Till dipped gently to the south-west.

Continuing downward in the stratigraphic column, there was forty to fifty five feet of Floral Till. The side-hole core descriptions of the Floral Till samples were slightly different for the two testholes. In Testhole VII, the Floral Till was very hard, olive gray with distinct yellow-brown staining along the joint planes;

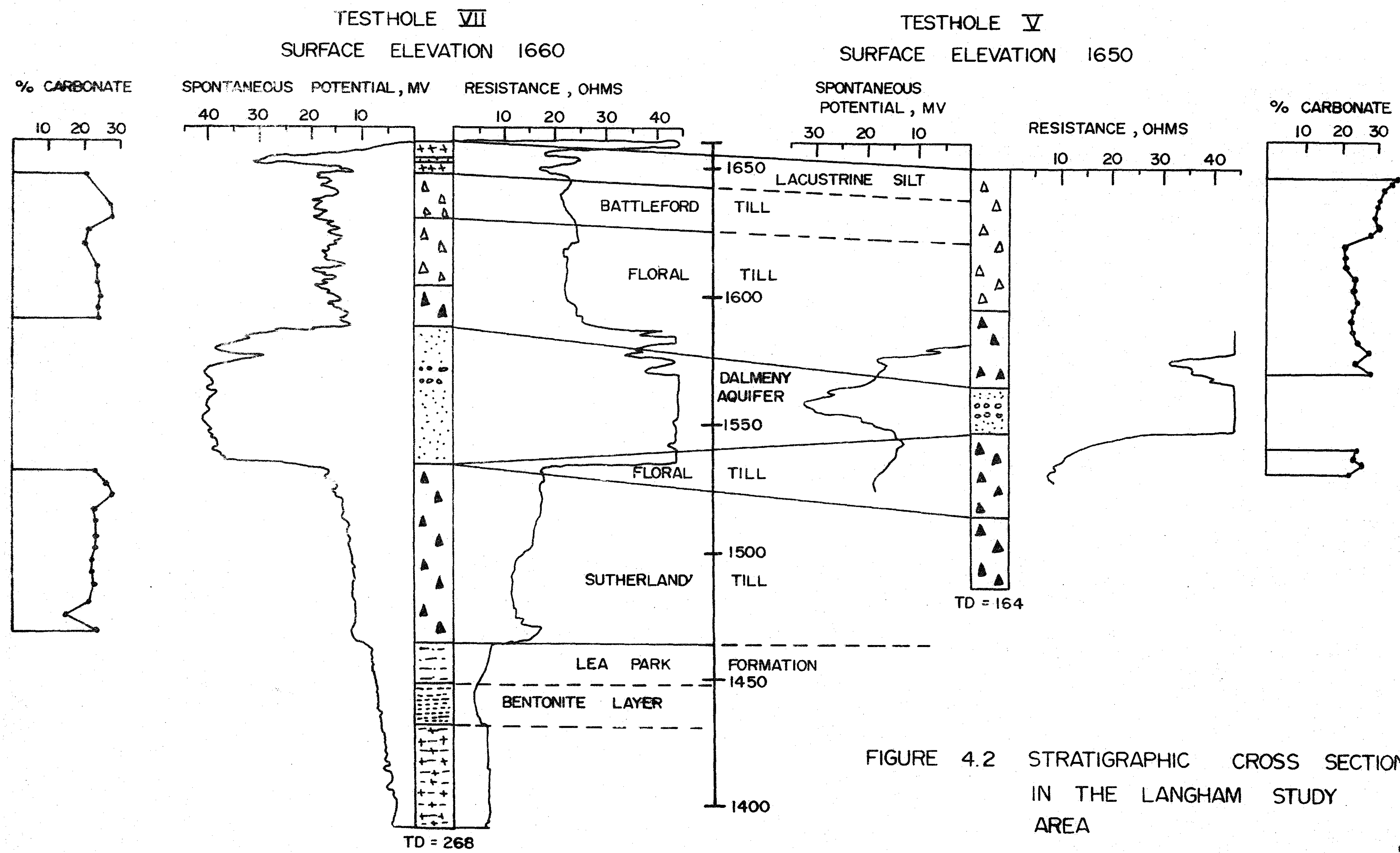


FIGURE 4.2 STRATIGRAPHIC CROSS SECTION IN THE LANGHAM STUDY AREA

whereas, in Testhole V, the same Till was unstained to weakly stained and weakly jointed. The magnitude of the carbonate content of Floral Till was the same in both testholes. These testholes were further correlated by their gypsiferous character at elevations 1590 to 1600. Within the Floral Till Formation was a thick unit of stratified drift consisting of coarse sands and gravel with well rounded pebbles. This unit was known as the Dalmeny aquifer and has been intensively studied by the Saskatchewan Research Council (Christiansen, 1970).

At the base of the stratified drift, the correlation in stratigraphic sequence between the two testholes was broken. In Testhole V the base of the stratified drift was at elevation 1546 on Floral Till. The stratigraphic sequence at this testhole, therefore, correlated with the regional stratigraphic sequence. However, in Testhole VII, there was no Floral Till present below the stratified drift and the base of this unit was at elevation 1535 on Sutherland Till. This difference of 11 feet in the elevation of the base of the stratified drift between two testholes 1,800 feet apart probably doesn't strongly influence the ground-water flow system.

At Testhole V, the Floral Till is underlain by Sutherland Till. Normally, the contact between Floral Till and Sutherland Till can be marked by a sharp change in their carbonate contents across the stratigraphic boundary (Christiansen, 1968). Unfortunately, the carbonate content of samples from this testhole showed no distinction between the two tills.

At Testhole VII, the Floral Till above the stratified drift unit could not be distinguished from the Sutherland Till below this unit on the basis of differences in the carbonate contents of samples of each till. Nevertheless, one differentiating factor was that the till below the stratified drift was gray as opposed to the olive gray of the till above the stratified drift. Another factor which seemed to differentiate the tills above and below the stratified drift at Testhole VII was the different character of the spontaneous potential trace on the electric log. This trace for the till above was jagged and averaged seventeen millivolts, whereas the trace for the till below was relatively even, averaging approximately twelve millivolts. These differences in character of the spontaneous potential trace indicated different material properties in the tills above and below the stratified drift. In particular, the lower spontaneous potential of the till below indicated its higher clay content relative to the till above. Sutherland and Floral Tills can often be differentiated by the higher clay content of the Sutherland Till (MacDonald, 1969); therefore the interpretation of the spontaneous potential trace of the electric log of Testhole VII indicated Floral Till above the stratified drift and Sutherland Till below.

In Testhole V, the till below the stratified drift was called Floral Till on the basis of correlation with the well established regional stratigraphy. In order to confidently report the presence of Floral Till below the stratified drift at Testhole V, additional testholes and sampling are needed. It is possible, however, to say with reasonable certainty that there is no Floral Till below the stratified drift in Testhole VII.

Loss of circulation of drilling fluid at Testhole V led to the abandonment of this testhole at a depth of 164 feet in the Sutherland Till. For this reason the hole was not referenced to bedrock.

Testhole VII was carried seventy feet into the bedrock to confirm the base of this stratigraphic drilling. The bedrock in the study area is the Lea Park Formation of the Upper Colorado Group. Its surface was at elevation 1464. This agrees with other bedrock surface elevations in the area. The composition of the Lea Park Formation was found to be gray, non-calcareous, clayey-silt. Within this formation was a layer of bentonite, fifteen feet thick at elevation 1440 or approximately river elevation. This bentonite layer is a plane of weakness in the valley slope. Any exposure by erosion of this layer would lead to a complete loss of its already low strength. The slope instability in the Langham Study Area may be related to the exposure of this bentonite layer.

4.2.2. Description of Regional Stratigraphy

The Geology Division of the Saskatchewan Research Council has established several structural testholes in the Langham area as part of their field investigations of the Dalmeny aquifer. The regional stratigraphic cross section (Figures 4-3 and 4-4) was interpreted from four of these structural testhole's logs plus logs from the two structural testholes in the Langham Study Area.

Normally in this area, the Floral Formation consists of a central unit of stratified drift bounded above and below by till. At Testhole VII, the bottom till was missing from the Floral formation. Furthermore, there was a thickening of the stratified drift to the top of the Sutherland group. As a result of this thickening of the stratified drift, its base was at the lowest elevation in the regional cross section at Testhole VII. Topographical lows, such as

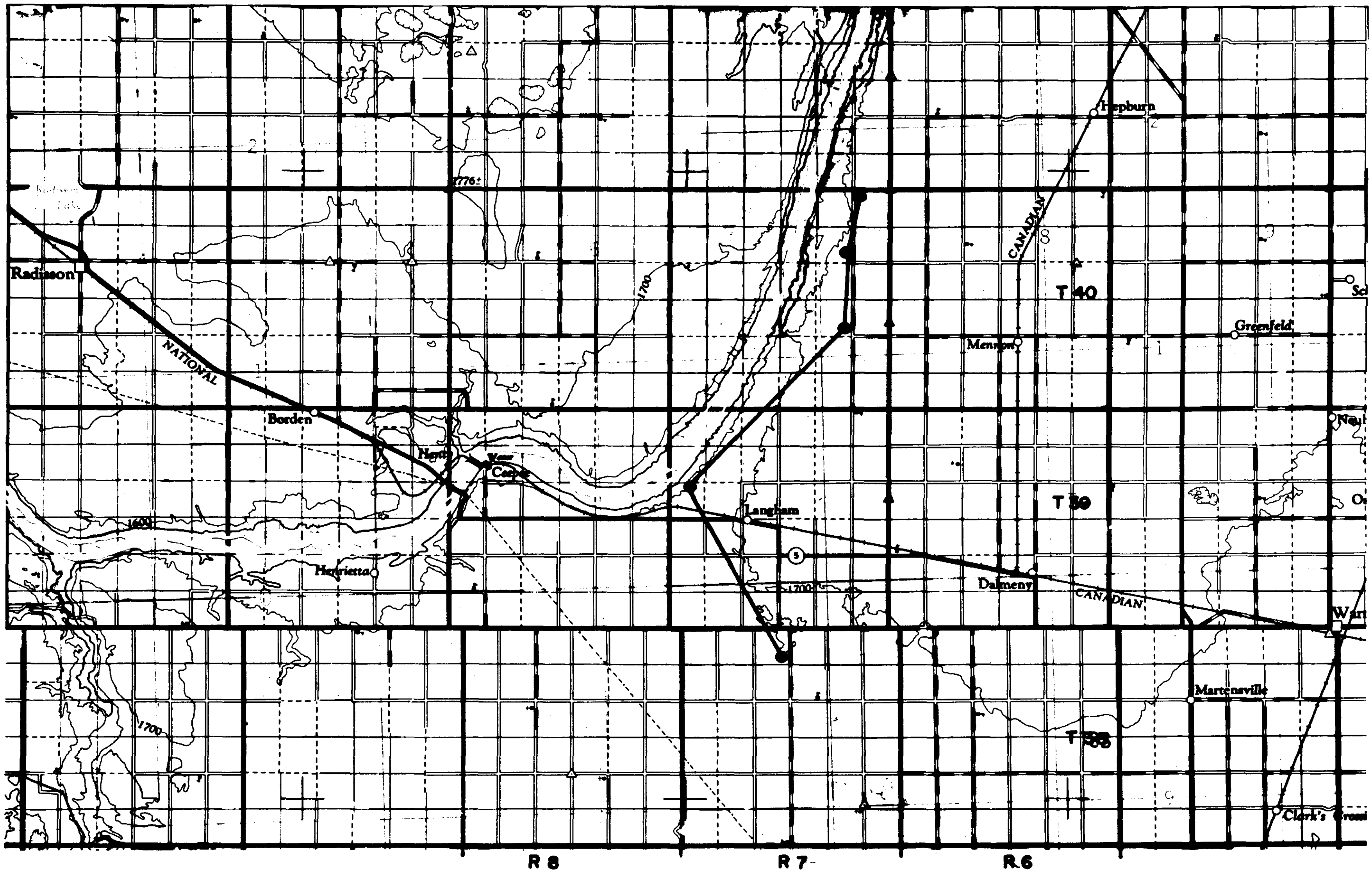


FIGURE 4.3 LOCATION OF THE REGIONAL STRATIGRAPHIC CROSS SECTION SHOWN IN FIGURE 4.4 SCALE 1" = 4 MILES

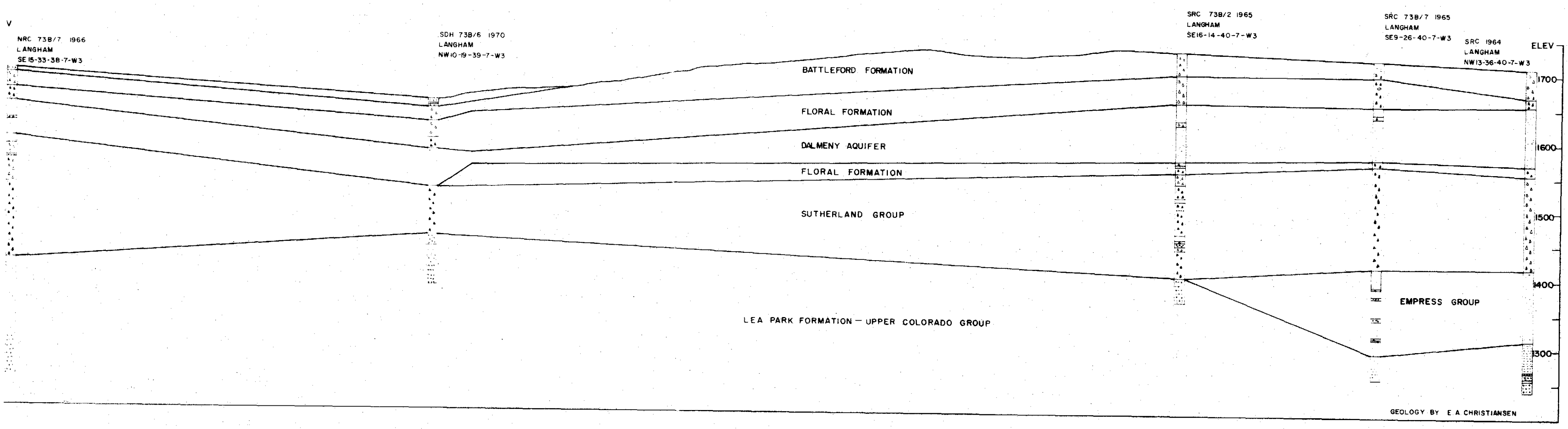


FIGURE 4.4 REGIONAL STRATIGRAPHIC CROSS SECTION

this, in an aquifer system can act as subsurface drainage courses for ground-water flow.

In addition to this abrupt change in the stratigraphic sequence in the Floral formation, the study area overlies a topographical high in the bedrock surface. With the amount of subsurface information available at the study area, it is not possible to comment on the relationship between the bedrock high and abrupt changes within the Floral formation.

4.3. GROUND-WATER REGIME

As the water content of engineering soils change, their strength properties change. Moreover, seepage forces must be considered for the analysis of slope stability and the calculation of hydraulic uplift pressures on foundation excavations. For these reasons the geotechnical engineer requires a definition of the ground-water regime as an important part of the stratigraphic model.

4.3.1. Position of the Water Table

The ground-water regime at Sites VII through X has been complicated by the stratigraphic disorder created by landslides. As a result of these landslides, the free discharge of ground-water from the Dalmeny aquifer has been blocked. This blocking of the free discharge has caused the water table to rise within the confined aquifer until sufficient hydrostatic pressure had developed to create seepage channels in the landslide debris. As a result of this seepage, there are springs along the tops of the landslide shear zones in these sites.

In order to measure the level of the water table in the stratified drift unit in the Floral formation, a piezometer was set at elevation 1545, or ten feet above the base of the aquifer. The hydrostatic head in the stratified drift was at elevation 1641, sixty-three feet above the top of the aquifer. This head elevation did not vary appreciably during the winter of 1970-71 although a drop in water table was recorded in the Saskatchewan Research Council Dalmeny observation well in the later part of the winter season in 1971. This discrepancy in changes in water levels suggested that the ground-water regime of the Dalmeny aquifer is very complex in the Langham Study Area.

The elevations of free water surfaces at spring pools in Sites VII-4, VIII-4 and IX-4B confirmed the water table elevation of 1641 as recorded by the Piezometer at Site VII. The elevation of springs is controlled by the geometry of the shear zones of the more recent landslides. At Sites VII and IX the springs are at the top of the highest shear zone on the slope at elevations 1623 and 1630 respectively. At Site VII the spring is at the top of the second highest shear zone at elevation 1610. When head losses due to seepage are added to the elevations of free surfaces in these springs, the total head on the confined aquifer was estimated to be approximately elevation 1640. Therefore, the water supply that causes the dense vegetation in Sites VII through X is coming from an aquifer at least seventy feet below ground surface.

4.3.2. Ground-Water Discharge Quantities

The flow from these springs was found to be large. Measured flows were 3.5 gallons per minute at Spring VII; 60 gallons per minute at Spring VIII and 30 gallons per minute at Spring IX. There was no significant change in flow volumes during the winter of 1970-71. Only a large aquifer system such as the Dalmeny aquifer could produce continuous ground-water flows of these magnitudes.

4.3.3. Ground-Water Chemistry

4.3.3.1. Identification of Ground-Water Source

In order to confirm the source of spring water in the Langham Study Area, water samples were chemically analyzed. The water analysis was then compared to water analysis of samples from two nearby wells in the Dalmeny aquifer as shown by Figures 4-5 and 4-6. There was very little difference amongst the water analysis for all samples. Therefore, the Dalmeny aquifer is probably the source of ground-water discharge in the study area.

4.3.3.2. Travertine Mounds

At Sites IX-4B and X-4 there are mineral encrustations at the point of ground-water discharge. These encrustations are travertine mounds. At Site IX-4B the mound is thirty feet in diameter and two feet high in the middle (Figures 4-11, 4-12). By an X-ray diffraction analysis, the non-organic material from these encrustations was found to be pure calcium carbonate (See Appendix D for the X-ray diffraction trace). The growth of moss on the mounds and then the deposition of calcium carbonate on the moss has produced a coral-like mound.

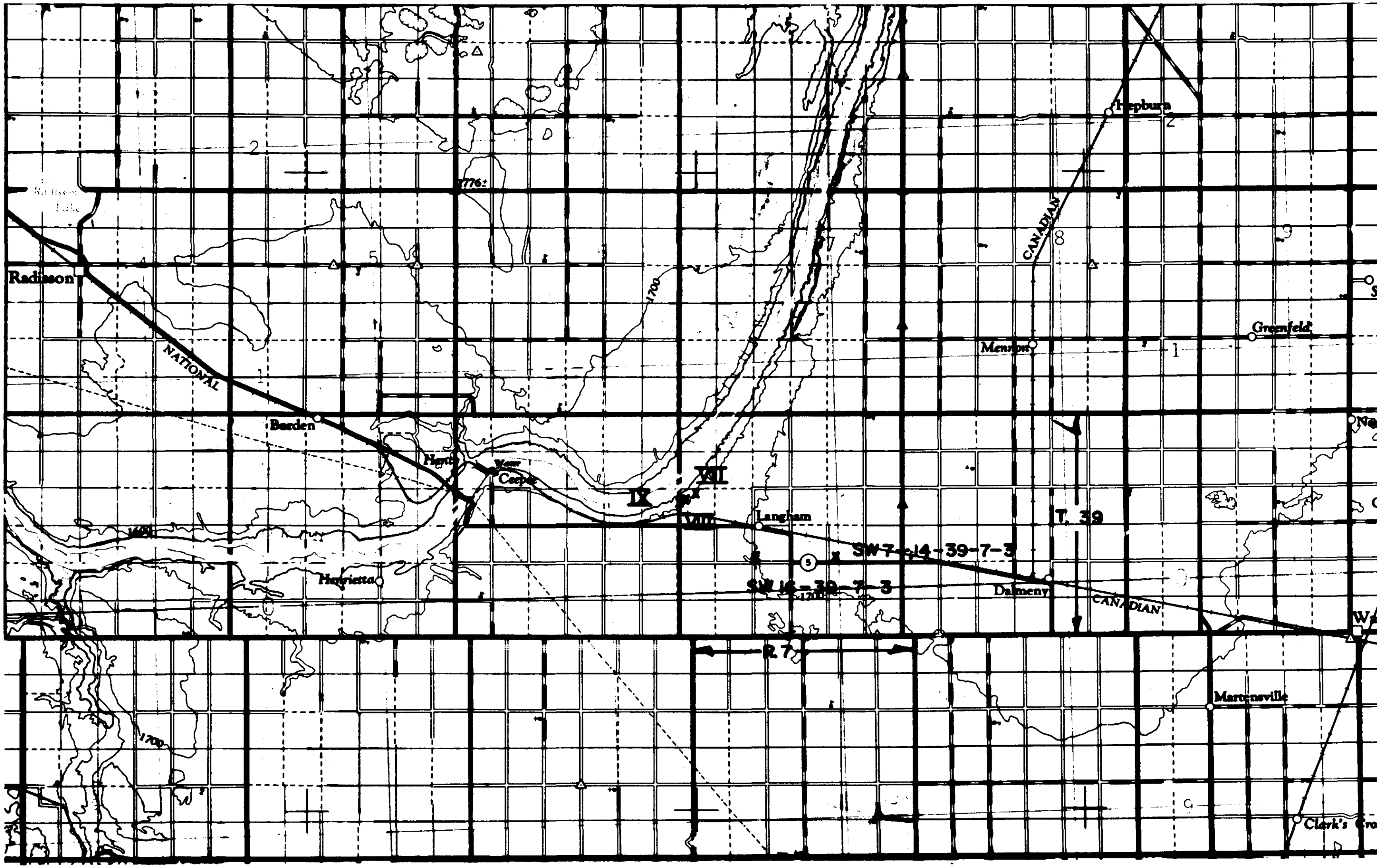


FIGURE 4.5 SAMPLING LOCATIONS FOR WATER CHEMISTRY ANALYSIS

SCALE : 1" = 4 MILES

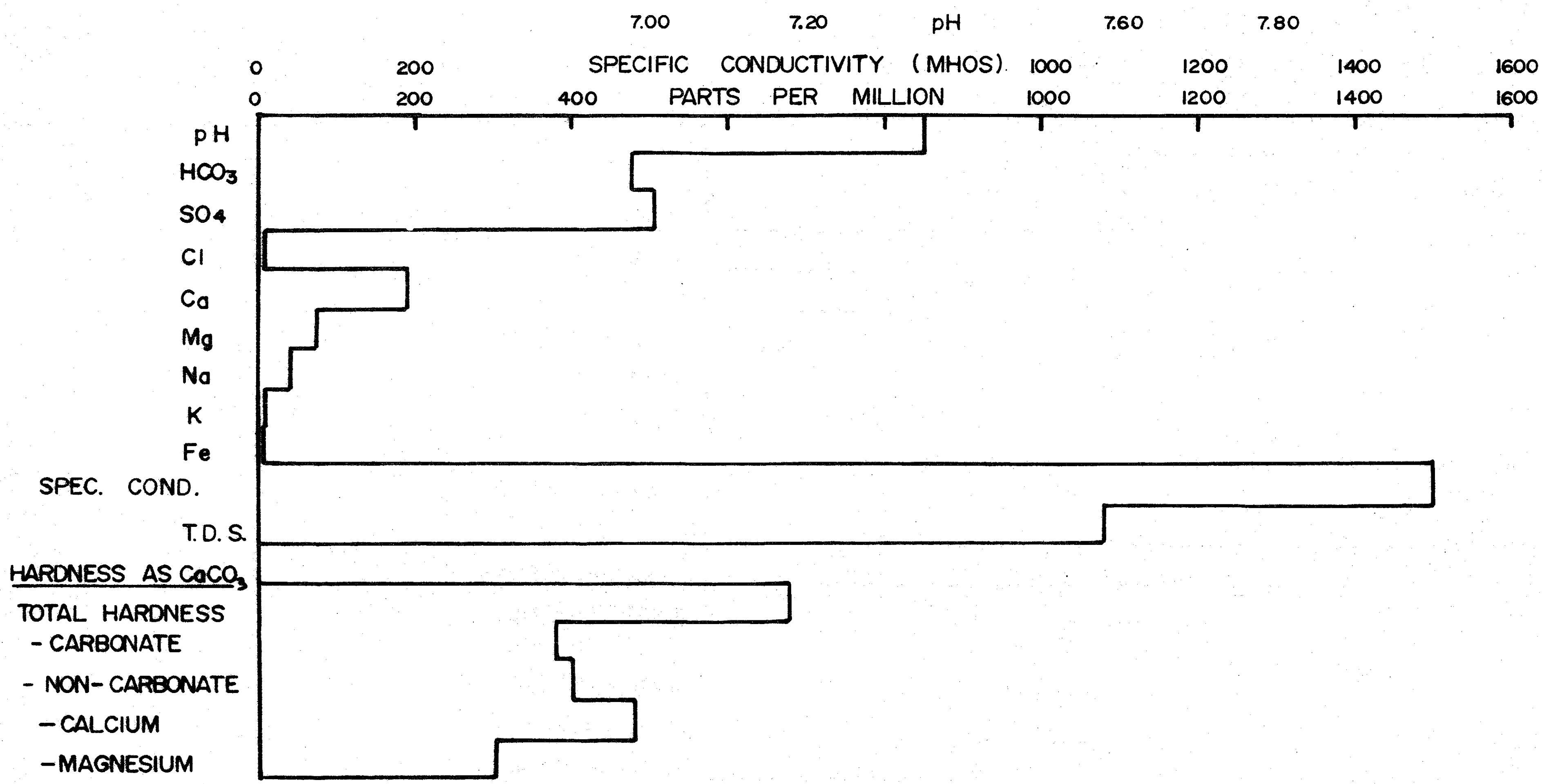


FIGURE 4.6 CHEMICAL COMPOSITION OF WATER FROM SPRING AT SITE VII

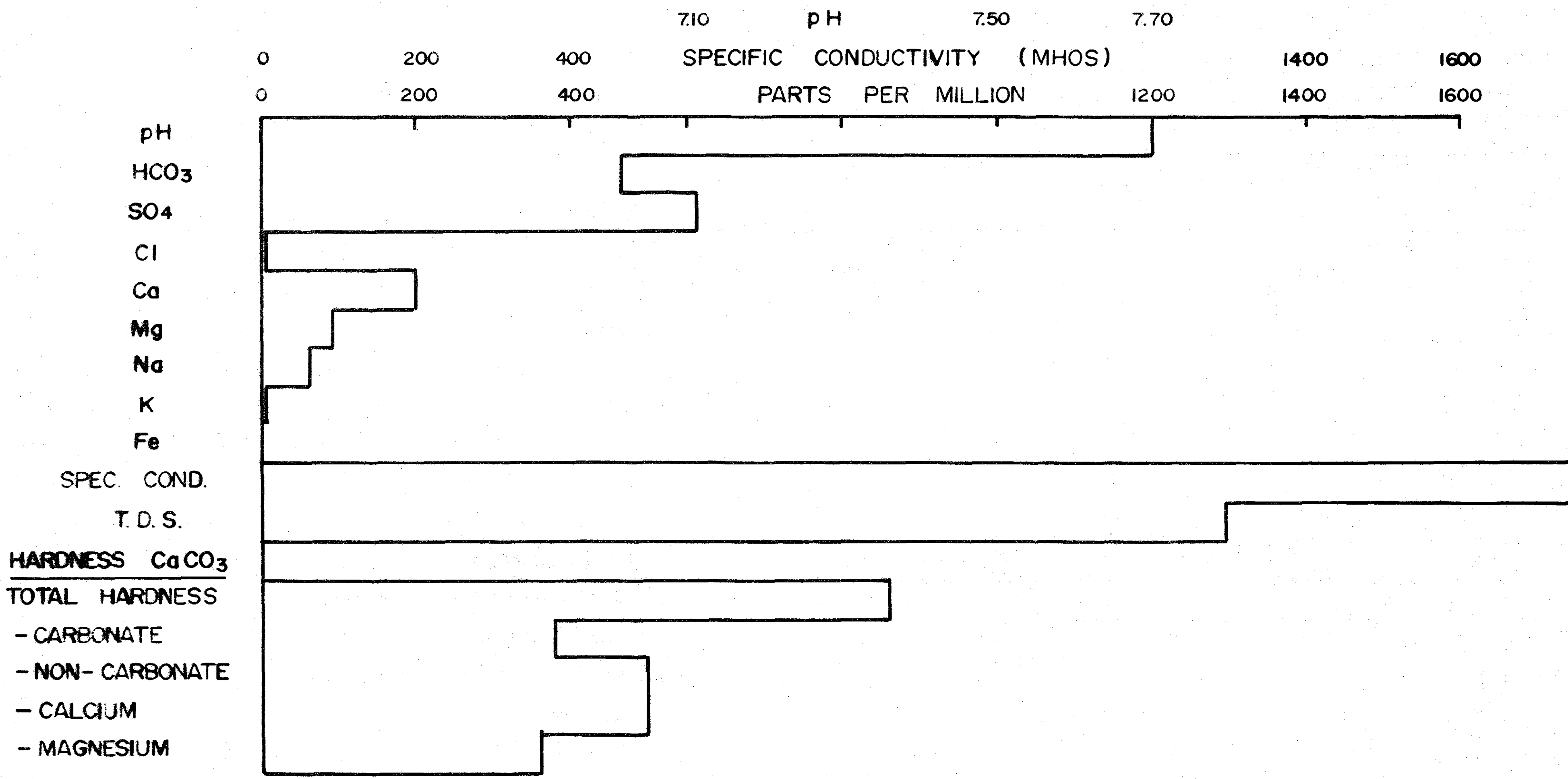


FIGURE 4.7 CHEMICAL COMPOSITION OF WATER FROM SPRING AT SITE VIII

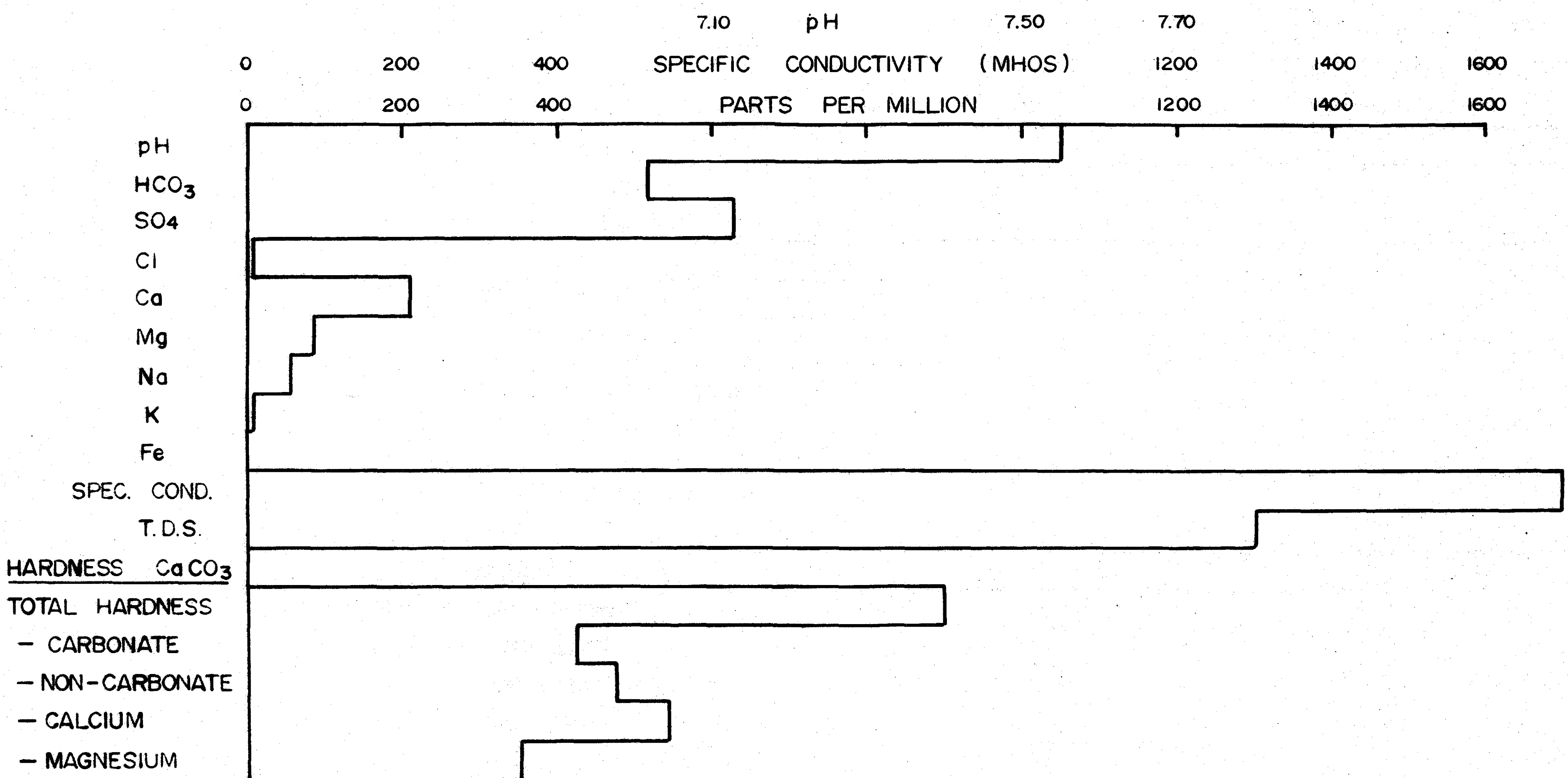


FIGURE 4.8 CHEMICAL COMPOSITION OF WATER FROM SPRING AT SITE IX

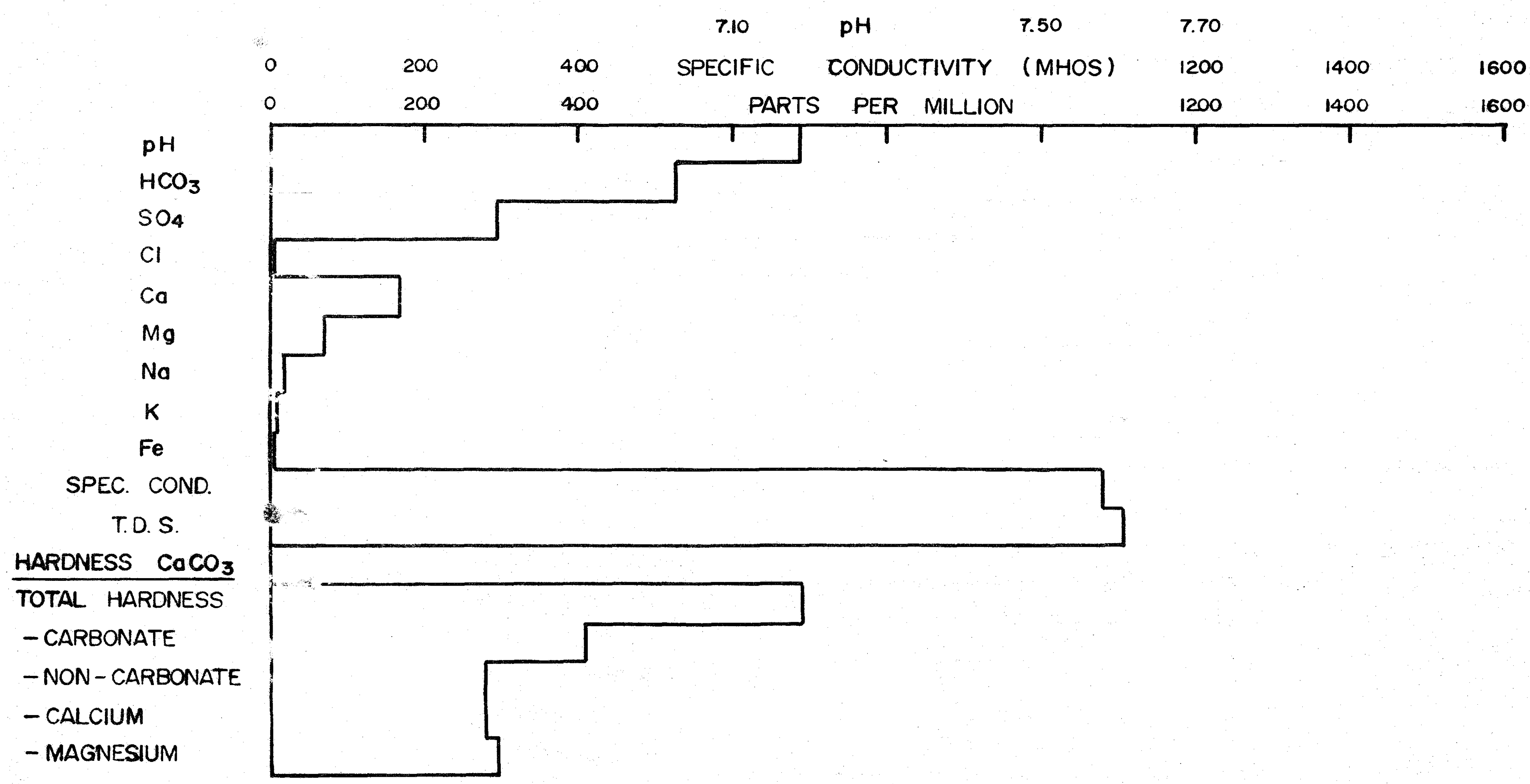


FIGURE 4.9 CHEMICAL COMPOSITION OF WATER FROM WELL AT SW16-39-7-3

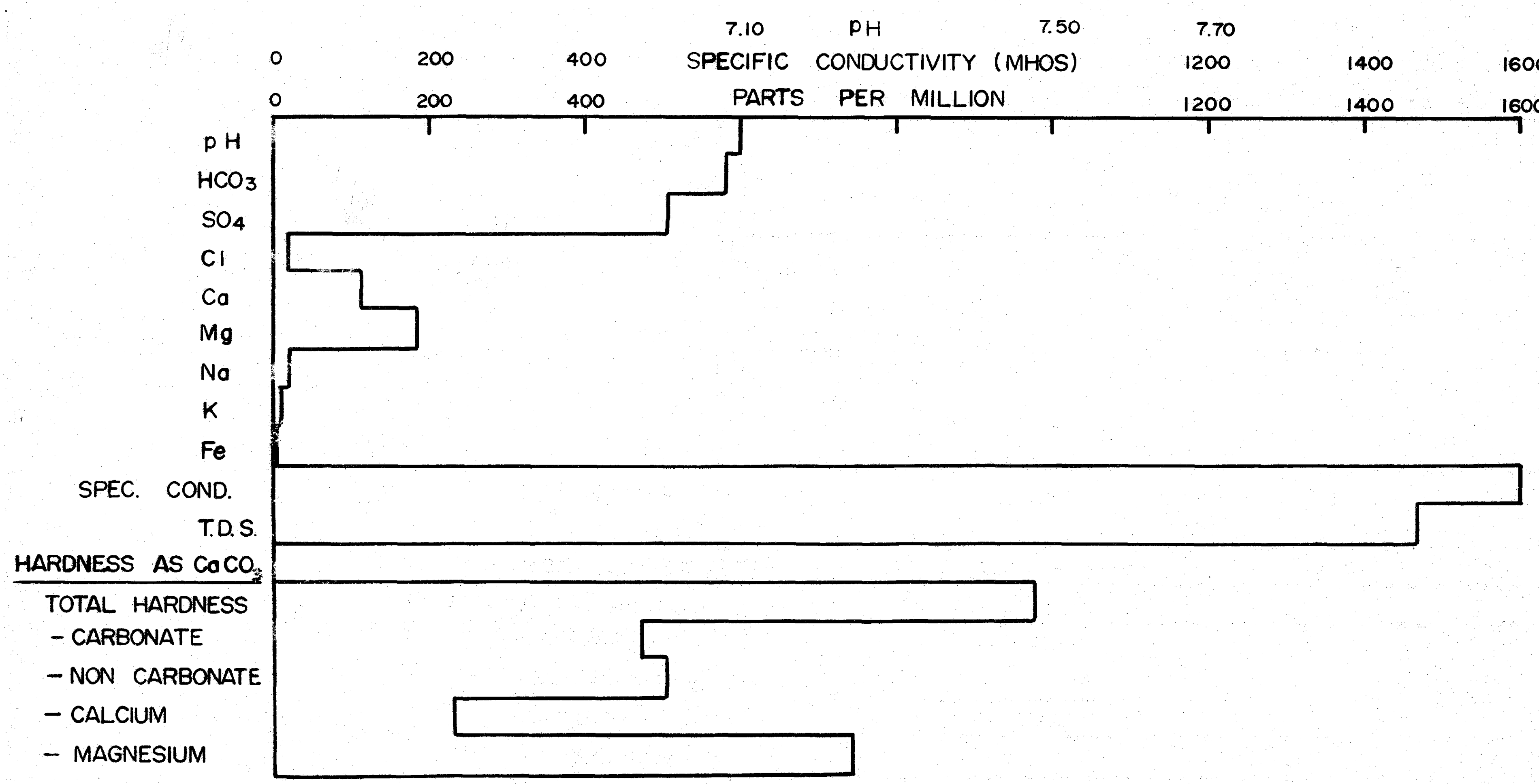


FIGURE 4.10 CHEMICAL COMPOSITION OF WATER FROM WELL AT SW7-14-39-7-3

Figure 4-11: Photograph of the travertine mound at Site IX-4B. The tall, grass-like plant in the lower left is sedge.

Figure 4-12: Photograph of a sample from the travertine mound at Site IX-4B. Notice its porous, coral-like appearance.

4.4. CLIMATE

It has been pointed out (Section 2.2.3.1.) that climate has a strong influence on vegetation. Variations in the microclimate are important to the application of vegetation-terrain relationships because they create variations in the species distribution. However, if any of these relationships developed in the Langham Study Area are to be used elsewhere, a similar regional climate is a prerequisite for any such extrapolation. It is for this reason that descriptive information of the regional climate is included in this report.

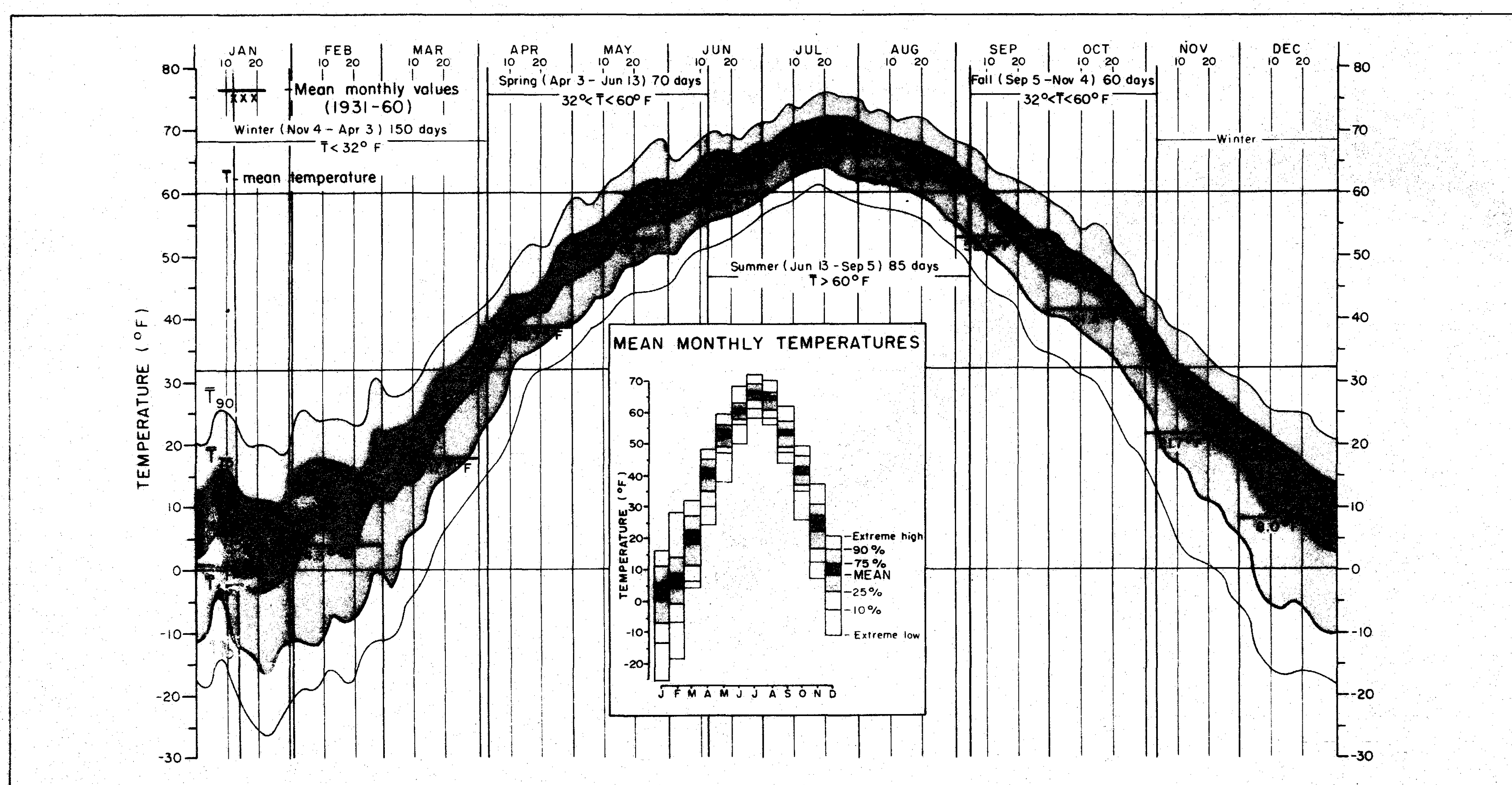
Similarly, it is not possible to extrapolate the conditions of the vegetation in the Langham Study Area during the year of examination, 1970, to the condition of the same vegetation in other years without knowledge of the year to year weather. Since a comparison of the annual weather conditions was not practical on this project, 1970 weather conditions were compared with the long term average conditions.

4.4.1. Regional Climate

The Saskatchewan Research Council has analyzed meteorological data on a statistical basis for the Saskatoon area (Christiansen, 1970). Their analysis provides a comprehensive description of the regional climate, and is shown in part in Figures 4-13 through 4-17 as descriptions of the regional climate of the Langham Study Area.

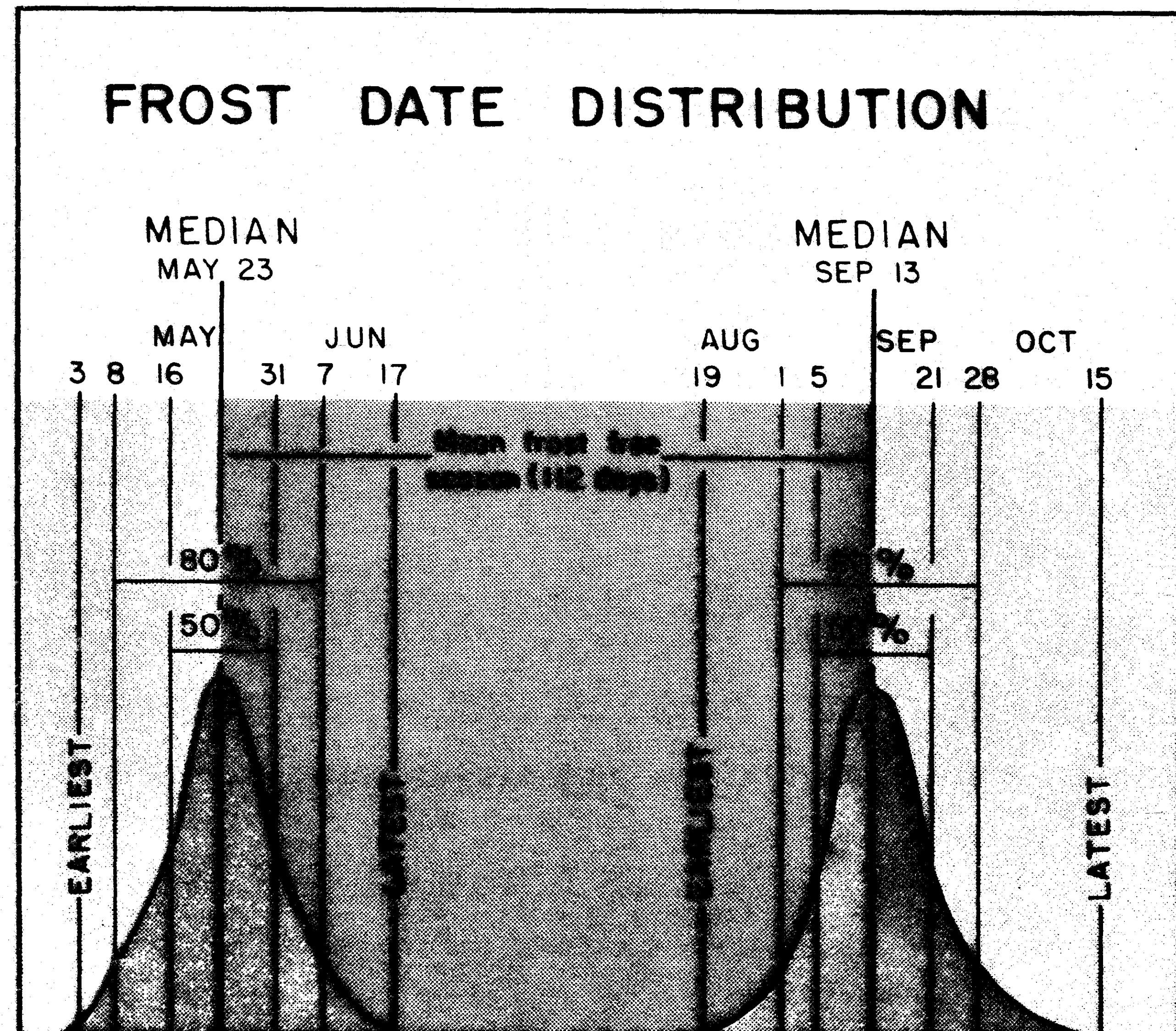
4.4.2. Comparison of the 1970 Weather Conditions with the Long Term Average Conditions

It is necessary to relate the climate of the 1970 growing



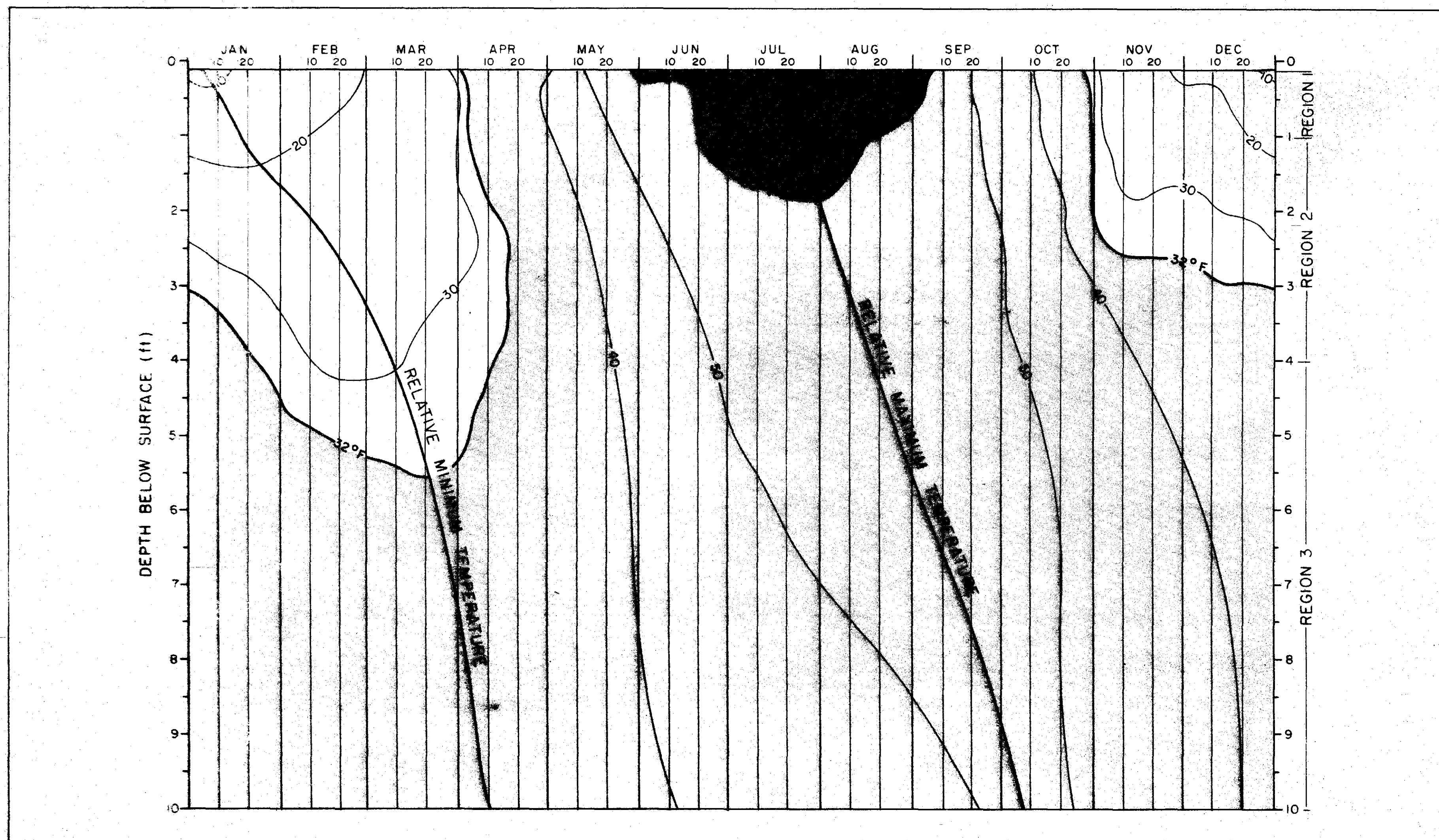
AFTER CHRISTIANSEN, 1970

FIGURE 4.13 DISTRIBUTION OF MEAN DAILY AND MEAN MONTHLY TEMPERATURES THROUGHOUT THE YEAR



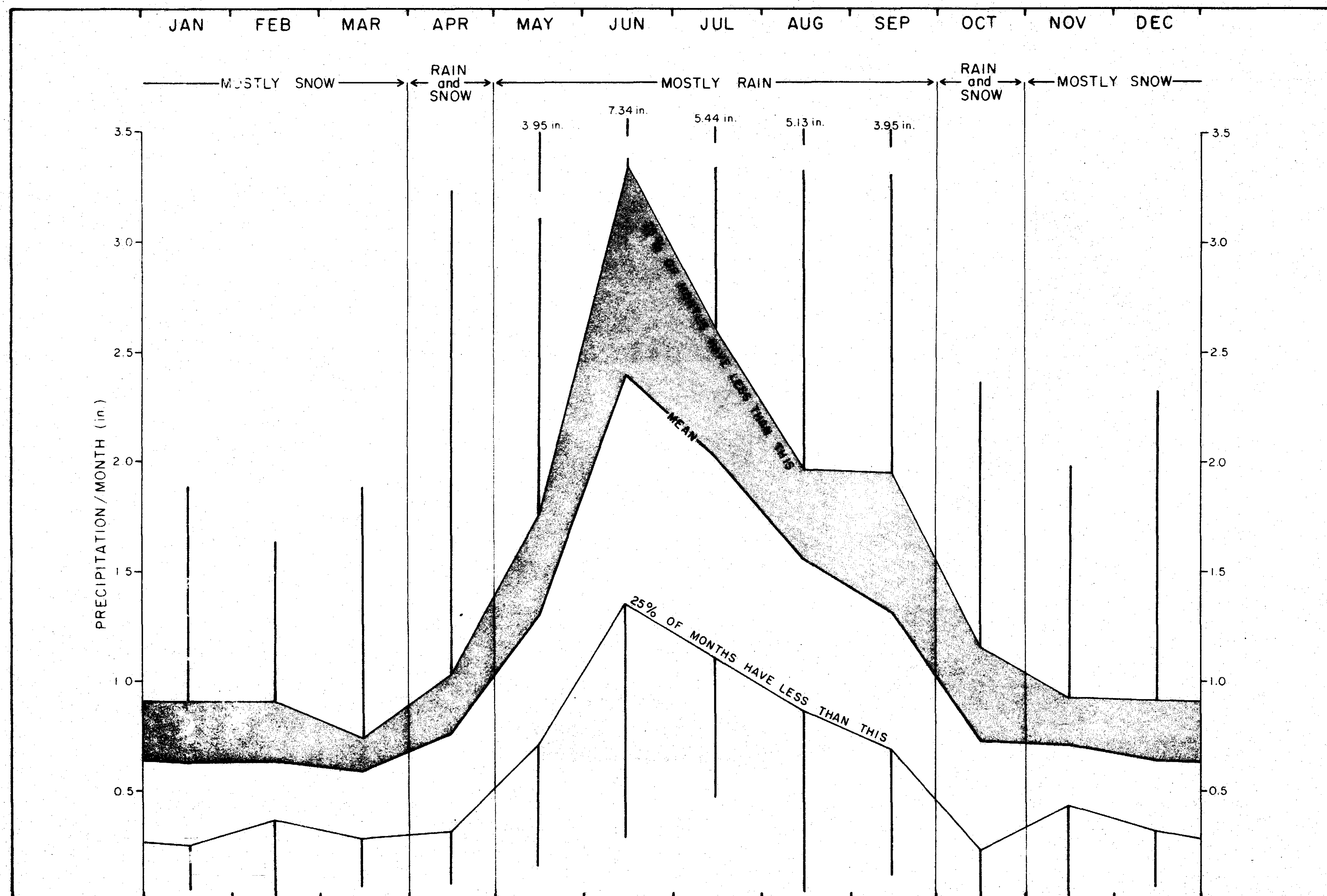
AFTER CHRISTIANSEN, 1970

FIGURE 4.14



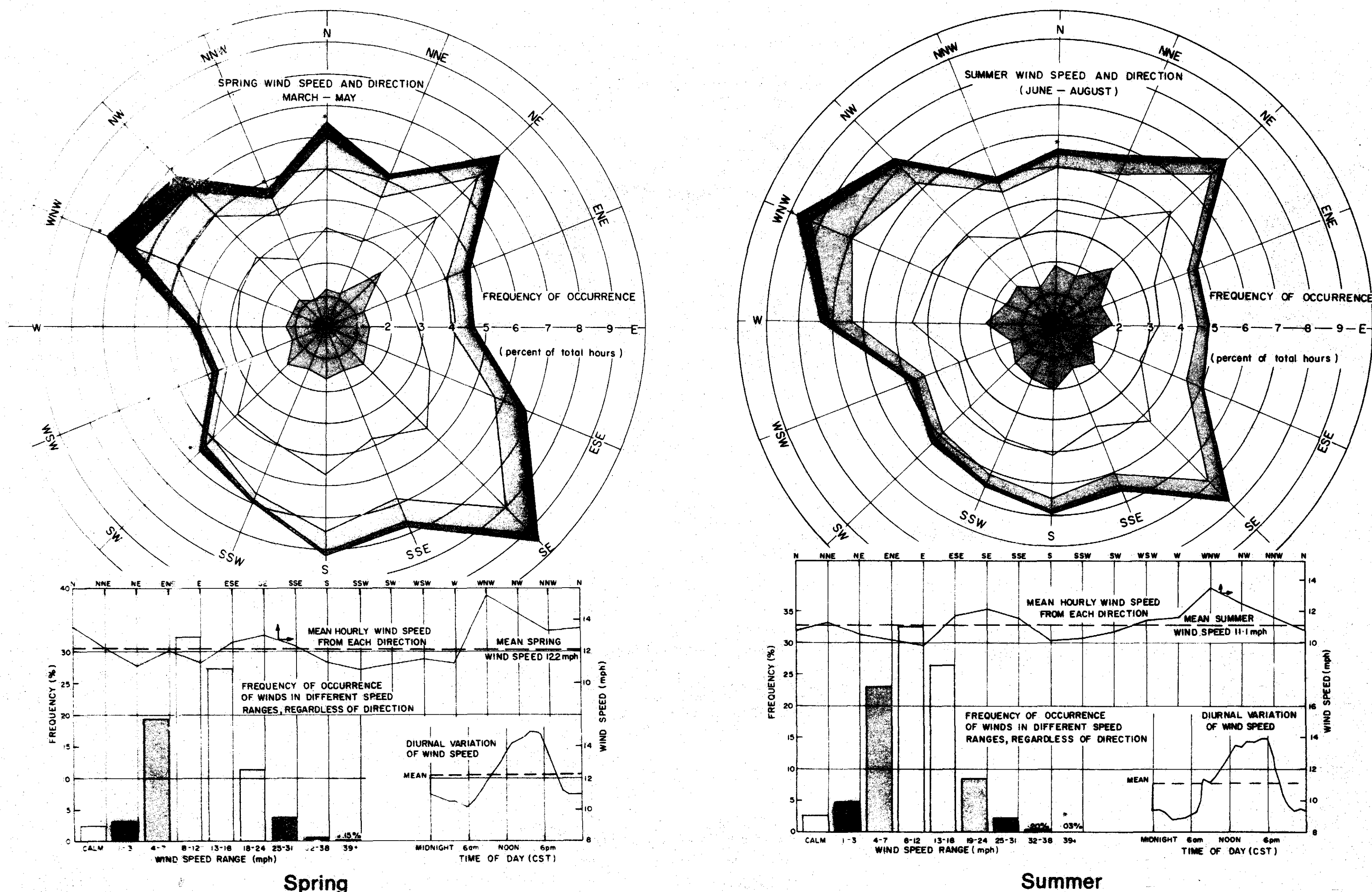
AFTER CHRISTIANSEN, 1970

FIGURE 4.15 ISOTHERMS OF MEAN SOIL TEMPERATURES THROUGHOUT THE YEAR



AFTER CHRISTIANSEN, 1970

FIGURE 4.16 MEAN MONTHLY PRECIPITATION TOTALS TOGETHER WITH EXTREME AND QUARTILE VALUES FOR EACH MONTH



AFTER CHRISTIANSEN, 1970

FIGURE 4.17 AVERAGE WIND SPEED AND DIRECTION DATA FOR SPRING AND SUMMER season* to the long term regional climatic averages in order to assess the normality of the 1970 vegetation in the Langham Study Area. Any large variation in temperature, precipitation or wind velocity from their long term averages in one growing season would be reflected by the condition of the vegetation. Accordingly, the meteorological records of the growing season, shown in Table IV-1 were examined for major climatic variations that may influence the vegetation.

Comparisons of 1970 meteorological monthly averages with long term averages indicated that the 1970 growing season experienced weather conditions very similar to the long term average conditions. The mean minimum monthly temperatures for 1970 were generally a few degrees lower than the long term average. Mean maximum monthly temperatures followed the same pattern. In spite of these generally lower temperatures, there were 115 frost-free days in the 1970 growing season as compared to the long term average of 112 days. The frost-free season was May 19th to September 11th, which again was close to the long term average dates of May 23rd to September 13th.

Another measure of temperature conditions is the number of degree-days below 65 degrees Farenheit. The 1970 growing season total of degree-days below 65 degrees was 1092, just less than the long term average of 1104. Although mean monthly temperatures during the 1970 growing season were slightly lower than the long term average

---

* The growing season was taken as being from May 1st to September 30th by this research.

TABLE IV-1

SUMMARY OF MONTHLY METEOROLOGICAL RECORDS AT THE SASKATOON AIRPORT WEATHER OFFICE FOR THE GROWING SEASON OF 1970

Month	Mean Temp.°F Min.	Max.	Total Precipitation Inches	Wind Speed (MPH)	Prevailing Wind Direction	Deg. day below 65°F	Days of Killing Frost	Comments
March	-1.7	21.2	1.23	10.2	SW	1712	31	cold,snowy
(Normal)	(8.3)	(27.1)	0.65	(11.0)	(SE)	(1466)		high snow-fall
April	27.3	44.6	0.60	10.9	NE	864	27	cool,cloudy
(Normal)	28.5	48.9	0.93	12.4	NW	789		dry
May	37.1	61.7	0.52	10.6	SE	477	4	clear,calm
(Normal)	40.3	64.3	1.34	12.4	SE	400	May 19	temperate
June	51.7	76.5	6.17	11.0	NW	78	0	warm,wet
(Normal)	48.0	71.4	2.04	11.9	NW	186		
July	54.4	78.1	1.79	9.2	W	33	0	warm, pleasant summer month
(Normal)	54.2	79.0	2.02	10.9	NW	59		
August	49.2	78.3	1.06	10.4	S	105	0	warm,sunny rapid maturing of crops
(Normal)	51.4	75.6	1.88	10.4	SE	90		
Sept.	38.6	64.4	0.12	9.3	W	399	6	dry with hot and cold weeks
(Normal)	41.8	64.0	1.32	11.7	NW	369	Sept.11	
Oct.	28.8	49.8	0.81	9.6	S	790	20	cold, first heavy snow
(Normal)	30.5	52.3	0.68	11.7	S	732		
Nov.	12.7	25.2	0.87	9.6	NW	1375	30	cold,cloudy calm
(Normal)	13.5	29.9	0.81	11.0	S&W	1299		

Numbers in brackets are long term averages for the month.

there was no significant departure from the long term averages in the frost-free season or number of degree-days below 65 degrees.

The mean monthly wind velocity for the 1970 growing season was one or two miles per hour less than normal. Predominant wind direction during each month did not vary appreciably from the normal. This slight reduction in mean wind velocity would tend to reduce evapotranspiration losses slightly.

Although temperature and wind conditions were slightly lower in 1970, it is unlikely that there was any vegetation response to these small variations. However, precipitation for the 1970 growing season was 1.5 inches more than normal. Furthermore, two-thirds of the 9.66 inches of precipitation for the season fell during June while the precipitation for the other months was normal except for a September drought. This heavy June precipitation would increase the soil moisture content before the hot summer months. In addition, a wet June would allow new vegetation to become well established. On the other hand, the September drought would accentuate the vegetational response to the inavailability of soil moisture in areas without a preferred moisture supply. This difference in vegetational response to dry autumn conditions was observed in the Langham Study Area. It will be discussed further under the heading "Wilting by Cooling" in Section 6.4..

In summary, the weather conditions of the 1970 growing season were normal. Temperatures and wind velocities were slightly lower than their long-term normals but precipitation was slightly higher than its long term average, especially for the month of June. The vegetation in the Langham Study Area therefore, had been exposed to near normal weather conditions during that growing season when it was examined during September, 1970. As a result, the condition of this vegetation was representative of normal vegetation in the Langham Study Area.

4.5. VEGETATION

In comparison to other elements of the physical environment, vegetation is relatively simple to assess, primarily because it can be seen and identified without the aid of any equipment. This simple assessment of vegetation is one of the reasons for the use of vegetation indicators of terrain conditions.

The species of the Langham Study Area represent three vegetation zones, the mixed prairie grasslands, the aspen grove, and the Boreal forest. The presence of grassland and aspen grove species is a result of the transition between these two zones passing through the study area. On the other hand, the Boreal forest species have invaded the study area by moving along the North Saskatchewan River from the Boreal forest which lies much farther north. Since the environment in the shelter of the valley slopes is very similar to their habitat in the north, species from the Boreal forest do well in mesic habitats in the Langham Study Area.

4.5.1. Aerial Infrared Photography for Vegetation Studies

Although vegetation can be examined easily in the field, additional information can be obtained from colour infrared photography which is sensitive to vegetation conditions not noticeable within the range of visible light. Vegetation which is suffering from moisture stress (wilting), disease or poor health loses its reflectance of infrared light (Heller, 1970). In this condition the vegetation appears a pale red or whitish on a colour infrared photograph, long before any visible change in vegetation colour takes place.

The green plant colour is present as long as chlorophyll is present whether the plant is in distress or not. However, it is the spongy mesophyll cells under the epidermis of the leaves that causes the high reflectance of infrared light from healthy plants (Colwell, 1970). Moreover, these mesophyll cells are the first to collapse when a leaf is in distress. Consequently, vegetation distress is detected by colour infrared photography before there is any visible signs of distress. This application of aerial colour infrared photography was useful in assessing the condition of the vegetation in the Langham Study Area.

4.5.2. Vegetation Description of a Generalized Site

Moving downslope at every vegetation study site, there was a change in vegetation caused by changes in microclimate. On the exposed upper slopes were grasses and forbs; moving downslope and out of the winds full force, short Roses *(Rosa spp.)* and Western snowberry *(Symphoricarpos occidentalis)* appeared. These shrubs became taller and more established in a downslope direction. Growing at the same slope position as the tall Rose and Snowberry were Wolf-willow *(Elaeagnus commutata)* and Canada buffaloberry *(Shepherdia canadenses)*. Yet further downslope, Choke cherry *(Prunus virginiana var. melanocarpa)* was usually present as well as Red-osier dogwood *(Cornus stolonifera)*.

There was no significant tree growth until approximately twenty feet below the top of the valley. Usually the trees highest on the slope were Trembling aspen *(Populus tremuloides)* with Birch *(Betula spp.)*, Balsam poplar *(P. balsamifera)* and Willow *(Salix spp.)* well down on the slope. Under these trees were the mesic herbs, many of which are Boreal forest species. At sites of ground-water discharge, sedges *(Carex spp.)* and other hygric species covered the wet ground surface.

This progression of vegetation on a slope is a generalization of all sites in the Langham Study Area. Usually the species appeared in this sequence on the slope; however the extent of distribution of any species varied from site to site. On the other hand, a few species occurred at all positions on a slope. For example, Rose was found in all but very wet habitats and Choke cherry was common to all xeric and mesic habitats.

4.5.3. Vegetation Description by Sites

4.5.3.1. Site I

In Site I there were several species whose presence may be of significance as vegetation indicators of terrain conditions. In particular the line of White birch at approximately the same elevation (1585) on the slope attracted attention since Birch have been associated with ground-water seepage. Further vegetation evidence of seepage was the presence of unusually tall Choke Cherry and Saskatoon bushes downslope from the Birch trees. Across the ravine from Site I, the Snowberry vegetation stopped abruptly at approximately the same elevation as the line of Birch trees. This abrupt change may be caused by changing edaphic factors.

4.5.3.2. Site II

The mesic and hygric character of the vegetation in Zones 3 and 4 is not typical of shallow prairie ravines like Site II. The presence of Balsam poplar and Willow around a Sedge meadow indicated an area of preferred soil moisture. Another indication of preferred soil moisture conditions was the abrupt change from mesic vegetation to xeric vegetation fifty feet to the east of Site II. Therefore, this vegetation indicated an area of significant ground-water discharge although the ground surface was dry at the time of the field study.

4.5.3.3. Sites III and IV

Both sites appeared xeric on the aerial photographs. In the colour aerial photographs, the vegetation at Sites III and IV appeared pale green, typical of xeric species. In both colour and colour infrared photographs, the affect of the first killing frost on the Manitoba maple *(Acer negundo var. iterius)* was visible, particularly in the colour infrared photographs which show a range of frost distress in the Manitoba maple (Figures 4-18 and 4-19). All other trees appeared healthy despite two nights of minimum temperatures of twenty-six degrees Farenheit.

4.5.3.4. Sites V and VI

Sites V and VI were beside Testhole V along a xeric section of the main valley slope. In Zone 2 of both sites there were some mesic species, the large White birch in Site VI being the most obvious of these species. The colour infrared aerial photograph (Figure 4-19) showed that the Trembling aspen on the topmost slide block were under distress whereas these trees showed no distress in

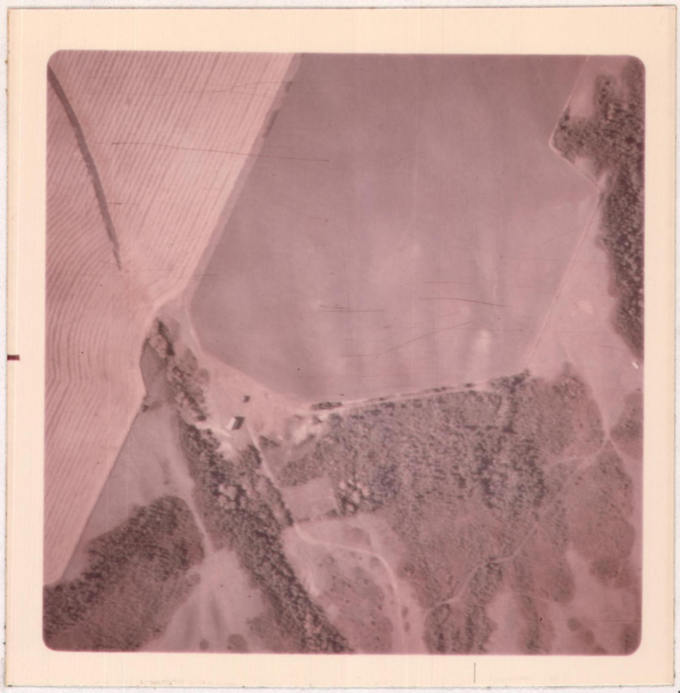


Figure 4-18: 70mm colour aerial photograph of Sites III and IV. The Manitoba maple trees appear grey after the first two killing frosts of the season. Notice the pale green colour of the xeric vegetation at Site III in the middle left of the photograph.

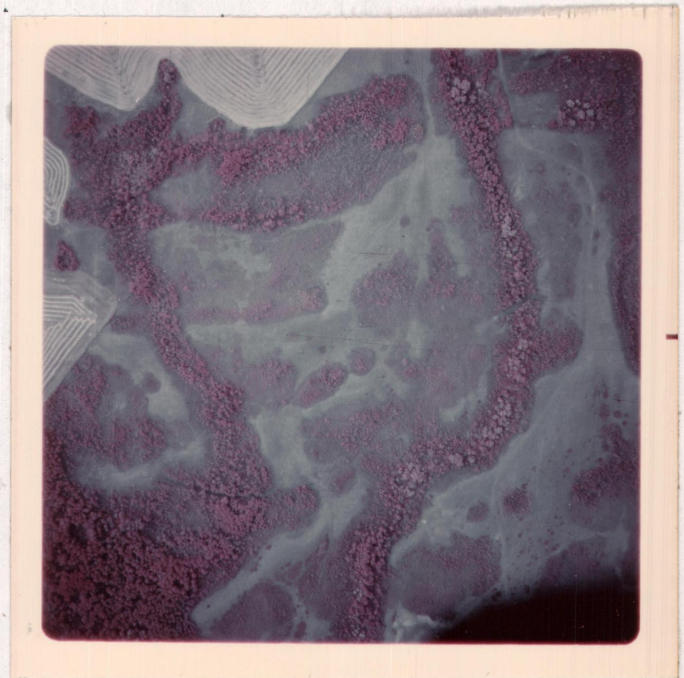


Figure 4-19: 70mm colour infrared aerial photograph of Site IV. Site IV is in the ravine in the upper right. The dying foliage of the Manitoba maples appears pale pink.

the colour aerial photograph (Figure 4-18). At the same time, the vegetation on the scarp showed no signs of distress in the colour infrared air photos.

4.5.3.5. <u>Sites VII through X</u>

At Sites VII through X the vegetation strongly suggested the hygric conditions associated with ground-water discharge areas. From the valley top the extensive canopy of large Balsam poplar was visible, suggesting an area of preferred soil moisture conditions. Moving towards the point of ground-water discharge, there was an increase in the incidence of hygric vegetation. It seemed that there was a much greater variety of species present in wet habitats than in dry habitats in the Langham Study Area.

The presence of boggy areas of ground-water discharge was more visible on colour infrared aerial photographs than on colour aerial photographs. This was a result of the difference in foliage between Willow in the bog and Balsam poplar beside the bog. On the colour infrared aerial photographs, all healthy vegetation with thick foliage appears dark pink such as the Balsam poplar grove in the middle left of Figure 4-21. On the other hand, the Willow in the bog have very small leaves and from the air, more branches than leaves are visible. Consequently, the Willow appeared much less pink than the Balsam poplar on the colour infrared aerial photography.

There is another difference between Balsam poplar and Willow that can be detected on stereo aerial photographs; that is their relative heights. The Pussy willow *(Salix discolour)* which is the Willow on these boggy areas, is a short tree. Comparison of tree heights therefore, further served to delineate the wet areas.

CHAPTER V

ANALYSIS OF VEGETATION INDICATORS OF TERRAIN CONDITIONS IN THE LANGHAM STUDY AREA

As has been pointed out previously, the arid climate in the Langham Study Area creates a narrow ecological margin of safety for vegetation; therefore the application of vegetation indicators of terrain conditions is quite effective. Consequently, many vegetation indicators previously discussed were successfully applied in the study area for the detection of terrain conditions that otherwise would require more sophisticated field investigation techniques. For example, vegetation indicators were used to identify a slightly brackish ground-water condition at two sites in the study area. Furthermore, at one of these sites, the approximate date at which the ground surface became dry in a ground-water discharge area was estimated on the basis of species composition. Similarly species distribution indicated seepage from a perched water table along the top of the main river valley. The location of this water table was subsequently confirmed by subsurface investigations. As a result of the successful application of vegetation indicators in the Langham Study Area for terrain evaluation purposes, this technique is recommended for other projects in southern Saskatchewan where the regional climate is generally arid such as that of the Langham Study Area.

5.1. SITE I

The top of the slope at Site I* is dry and exposed**. The soil is an eroded, very dry silty till. Zone I species, Pasture sage, Little Club-moss, Blue grama grass and June grass, are xeric in character. Three-flowered avens is common on the open prairie and Bearberry can be found on eroded upper slopes. Although this report has excluded the Bryophytes, the Bryophyte, Little Club-moss, is a consistent indicator of dry till soils in southern Saskatchewan. As such, it frequently covers much of the ground surface with other Dry Prairie*** vegetation.

Moving downslope in Zone 2, the soil is also dry, silty till. The soil in this zone is as dry as in Zone 1 but as a result of the shelter afforded by its position on the slope, the microclimate is more favourable to vegetation. Consequently, the species which occur here form the ecotone between the prairie grasslands and the aspen grove in the study area. These species, Choke cherry, Snowberry and Rose, are found on upper slopes and adjoining wooded areas throughout the study area. Further downslope in Zone 2, Buffaloberry appears. It is associated with wooded areas, therefore it is an indication of

---

* See Figure 5-1 for this geobotanical profile.

** Exposed is descriptive of a habitat which has no shelter from vegetation or topography.

*** Dry Prairie is a habitat classification used in this report to designate areas of dry, open prairie.

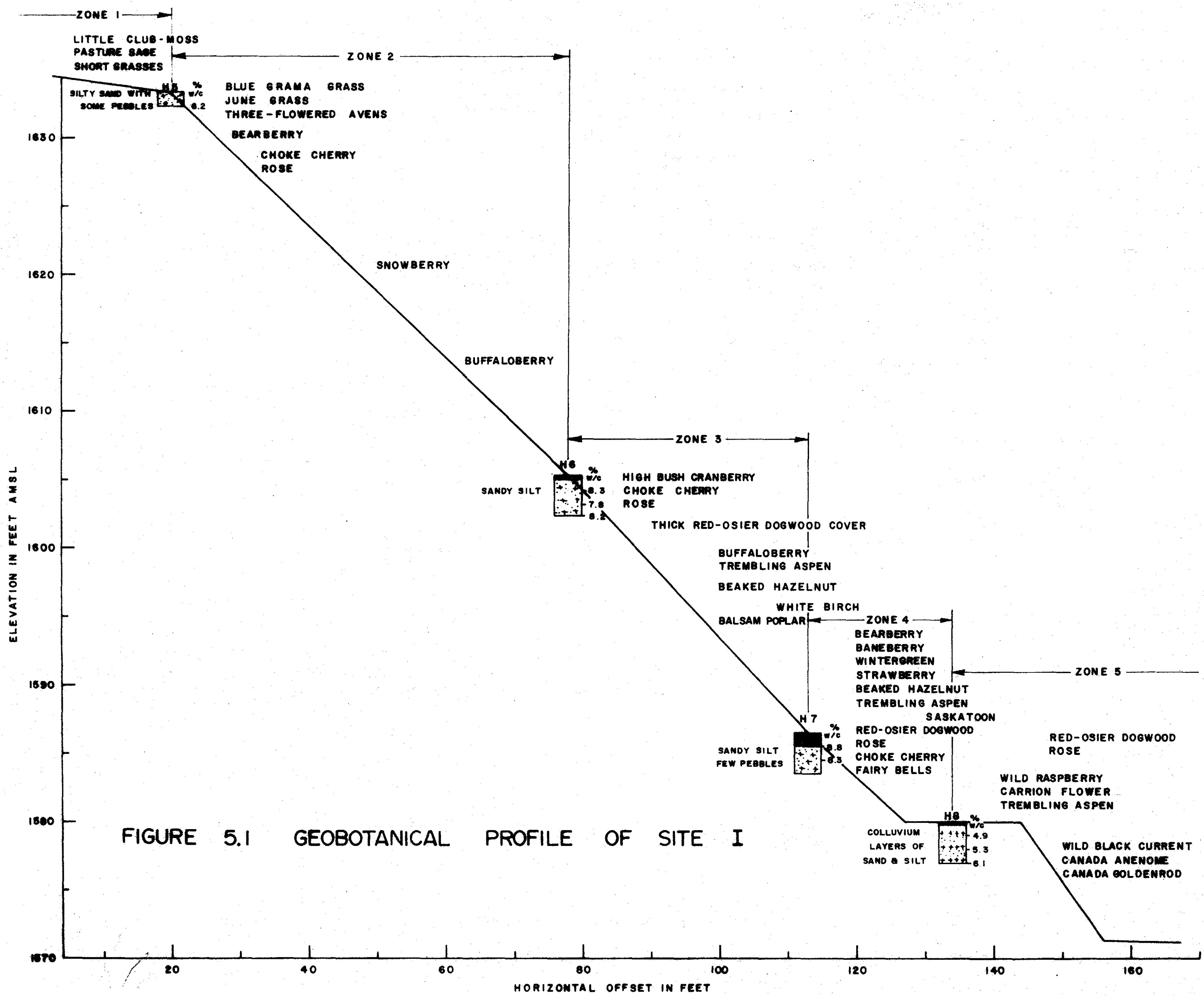


FIGURE 5.1 GEOBOTANICAL PROFILE OF SITE I

the microclimate on this part of the slope. None of these species, however, indicated any subsurface condition that would cause geotechnical problems during an excavation.

Species of the Moist Prairie* and Moist Woods** occur in Zone 3. The Red-osier dogwood is the dominant species. Also present are Balsam poplar, Beaked hazelnut, Trembling aspen and High bush cranberry. It is unlikely that precipitation and surface run-off could supply the moisture needs of these plants, therefore the moisture supply is from a subsurface source. There is, however, no geological evidence to substantiate the indication of moist soil conditions by the vegetation in Zone 3.

Zone 4 starts at a line of White birch trees at elevation 1585. Across the ravine there is a sharp vegetation change from grasses to shrubs, also at this elevation. Downslope from these Birch trees, the vegetation is mesic in character. Many of these species favour the Moist Woods habitat. Again there is a vegetation indicator of a moist soil condition. In this case there are two possible causes of the mesic vegetation. In the first place, the microclimate in Zone 4 is definitely cool and shaded in comparison to Zone 3. This change in microclimate may be enough climatic compensation for this Moist

---

* Moist Prairie is a habitat classification used in this report to designate prairie sites having some shelter from topography or other vegetation or having preferred soil moisture conditions.

** Moist Woods is a similar habitat classification. It designates a shaded, cool, moist woodland habitat.

Woods community to occupy a relatively dry soil. Secondly, there could be a subsurface moisture supply although it was not detected by the shallow borings in this site.

Zone 5 is located on sandy silt colluvium in the ravine bottom. This nutrient-rich soil can support very healthy vegetation. In addition, the soil moisture in this sandy soil is available to the plants, even at low water contents*. As a result of this nutrient-rich, moist soil, exceptionally large Choke cherry and Saskatoon bushes grow in this zone.

Vegetation indicators in Zones 3, 4 and 5 of Site I suggest a slightly preferred soil moisture condition. On the other hand at Site II on the same ravine and fifty feet above Sites I - 3,4,5, there is definite ground-water discharge. Furthermore, an extrapolation of the geological cross section from Testholes VII and V into Site I indicates that the bottom of Site I is at approximately the same elevation as the top of the Dalmeny aquifer. As a consequence of this analysis, the bottom of Site I should be an area of substantial ground-water discharge. In fact, it is not. Therefore, near Site I there is some stratigraphic irregularity which controls the ground-water regime and prevents significant ground-water discharge.

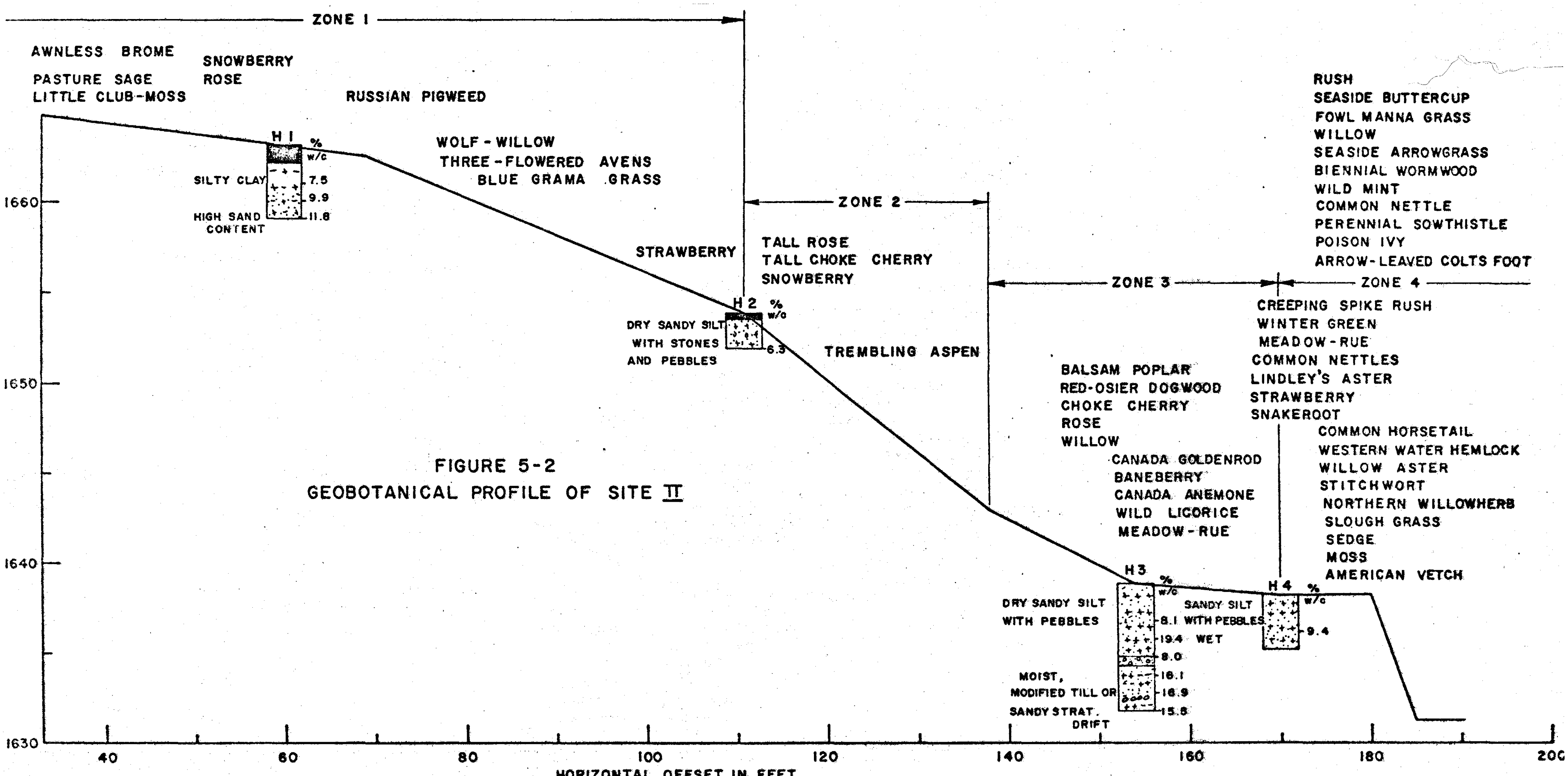
5.2. SITE II

Zone 1 of Site II** is very similar to Site I-1 in species composition. In fact the upper portions of most vegetation study

---

* Water consumption by plants and water retention characteristics of different soils is discussed in Section 6.6.2.

** See Figure 5-2 for this geobotanical profile.


ZONE 1
ZONE 2
ZONE 3
ZONE 4
AWNLESS BROME
PASTURE SAGE
LITTLE CLUB-MOSS
SNOWBERRY
ROSE
RUSSIAN PIGWEED
WOLF-WILLOW
THREE-FLOWERED AVENS
BLUE GRAMA GRASS
STRAWBERRY
TALL ROSE
TALL CHOKE CHERRY
SNOWBERRY
TREMBLING ASPEN
BALSAM POPLAR
RED-OSIER DOGWOOD
CHOKE CHERRY
ROSE
WILLOW
CANADA GOLDENROD
BANEBERRY
CANADA ANEMONE
WILD LICORICE
MEADOW-RUE
RUSH
SEASIDE BUTTERCUP
FOWL MANNA GRASS
WILLOW
SEASIDE ARROWGRASS
BIENNIAL WORMWOOD
WILD MINT
COMMON NETTLE
PERENNIAL SOWTHISTLE
POISON IVY
ARROW-LEAVED COLTS FOOT
CREEPING SPIKE RUSH
WINTER GREEN
MEADOW-RUE
COMMON NETTLES
LINDLEY'S ASTER
STRAWBERRY
SNAKEROOT
COMMON HORSETAIL
WESTERN WATER HEMLOCK
WILLOW ASTER
STITCHWORT
NORTHERN WILLOWHERB
SLOUGH GRASS
SEDGE
MOSS
AMERICAN VETCH
H1 % w/c
SILTY CLAY
HIGH SAND CONTENT
7.5
9.9
11.8
H2 % w/c
DRY SANDY SILT WITH STONES AND PEBBLES
6.3
H3 % w/c
DRY SANDY SILT WITH PEBBLES
8.1
19.4 WET
8.0
16.1
16.9
15.8
MOIST, MODIFIED TILL OR SANDY STRAT. DRIFT
H4 % w/c
SANDY SILT WITH PEBBLES
9.4
1660
1650
1640
1630
40
60
80
100
120
140
160
180
200
HORIZONTAL OFFSET IN FEET
FIGURE 5-2
GEOBOTANICAL PROFILE OF SITE II

sites are similar in their species composition as a result of their similar edaphic and climatic conditions. In Site II-1, Awnless brome, Blue grama grass, Pasture sage and Little Club-moss are Dry Prairie species. Also present is Snowberry and Rose. Both of these species seemed to occur at the edge of areas sheltered by either topography or other vegetation. Russian pigweed, which favours disturbed soils, abandoned land and waste places, was present in upper Zone 1. This zone has never been cultivated and is infrequently grazed, therefore it is waste land. Three-flowered avens is reported as a species of the open prairie (Budd and Best, 1964), but at both Sites I and II it occurs just below the crest of the ravine.

In lower Zone 1 there are Wolf-willow bushes. This shrub is reported to prefer moist, light textured soils (Budd and Best, 1964; Skoglund*, personal communication, 1970). The surficial soil description at the Wolf-willow bushes was silty clay, however, at a depth of three feet this soil had a "high sand content" and a natural water content of 11.8 per cent. The reported indicator significance of Wolf-willow is partially applicable in the Langham Study Area. In fact, Wolf-willow is more of an indicator of an Ecotone** area or Moist Prairie habitat than of moist, light textured soils.

---

* Mr. N.A. Skoglund is a botanist with the Department of Plant Ecology, University of Saskatchewan, Saskatoon.

** Ecotone is a habitat classification used in this report to designate areas of ecotone communities between the prairie grasslands and the aspen grove.

Zone 2 has a Moist Prairie habitat. Many species cannot be identified more precisely than by their genus without seeing their fruit or flowers. This was the case of the Strawberry in Zone 2. There are two species of Strawberry occurring in the part of the Province. Either species could live under the habitat conditions in Zone 2. On the basis of habitat, this Strawberry has been tentatively identified as the Smooth wild strawberry *(Fragaria glauca)*, which favours the moist prairie or open woodland habitats (Budd and Best, 1964).

Tall Rose and Choke cherry under a canopy of Trembling aspen are typical of the Moist Prairie habitat. The moist aspect of the habitat description, Moist Prairie, is as much a result of microclimate as of subsurface moisture supply. For example, Zone 2 is twenty feet below the crest of this north-facing slope. As a result of reduced insolation and locally high atmospheric humidity within the trees and shrubs, the microclimate is cool and moist. Accordingly, the vegetation is that of the Moist Prairie habitat although there is no appreciable difference in the natural water contents between soils in Zones 1 and 2.

It was the mesic character of the vegetation in Zone 3 that first attracted attention to Site II. Red-osier dogwood is commonly found in woodlands and moist hillsides but its presence may be as much a result of snow lodgement of moister microclimate as of improved soil moisture conditions. It was the Balsam poplar and the Willow, both of which grow in wet places, that indicated a distinct change in soil moisture conditions from Zone 2.

Species of the understory in Zone 3 are also mesic, however some species are more associated with cool, moist habitats rather than with high soil moisture contents. For example, Baneberry and Meadow-rue favour shaded, rich woodlands. Undoubtedly these conditions occur in Zone 3.

On the other hand, both Canada anemone and Wild licorice are associated with a Wet Meadow water regime*. These two species are herbs and together, as part of a community, they proved to be accurate indicators of the water regime of lower Zone 3. During a conversation on September 25, 1970, the landowner asked why his spring (Site II-3) went dry by the end of June when the springs on C.P. Epp's land (Site VII) did not. As part of his question he indicated that Site II-3 was wet until late June when the surface dried. His description of the seasonal position of the water table in Zone 3 closely resembles the water regime description for Wet Meadow. Moreover, Canada anemone and Wild licorice, common species in this zone, are also strongly indicative of a Wet Meadow water regime. Accordingly these two species give an accurate indication of the seasonal position of the water table at this site.

---

* Plant ecologists have a system of designating the water regime of a pond by position of the water's surface during the year. One of these systems (Walker, 1968) is shown by Table V-1. The Wet Meadow water regime has open water in the spring and a high water table to early July.

The habitat in Zone 4 was Wet Area *. During the field study in September 1970, the ground was dry but the vegetation indicated that the area was wet for most of the summer and that the water table was close to the surface. Natural water contents taken at depths of four to seven feet in Borehole 3 indicated a definite increase with depth but there was no evidence of the water table at the bottom of this borehole. However, in late spring of 1971, Zone 4 was an area of ground-water discharge with open pools of water draining into the small creek passing through this zone.

Many of the species in Zone 4 are Boreal forest invaders. Their presence indicates a cool, moist, shaded woodland more than an area of ground-water near surface. Species like this in Zone 4 are Wintergreen, Meadow-rue, Lindley's aster, Strawberry, Snakeroot, Poison ivy and American vetch.

On the other hand, three-quarters of the species in Zone 4 have known associations with wet habitats. Thus Zone 4 has plant communities indicating two habitat conditions. One indicates a cool, moist, shaded Moist Woods habitat while the other indicates a Wet Area habitat. In this zone both habitats exist. If, for example, all the trees and tall shrubs were removed from this zone, the Moist Woods species would die, but the Wet Area indicator community would not alter to the same extent.

---

* Wet area is a habitat classification used in this report to designate areas with ground-water at or near surface in either a prairie or woodland setting.

The Wet Area associated species indicate a water regime of Dry Meadow, Wet Meadow and Marsh Meadow* with the majority of species indicating the Wet Meadow regime. Of the nineteen Wet Area species, only Fowl mana grass is associated with a Shallow Marsh regime. Some species have a wide ecological amplitude with respect to water regime, and therefore are not as specific in their indication of soil moisture conditions as species with narrow amplitudes. For example, Creeping spike rush, Slough grass and Wild mint occupy habitats which range from Dry Meadow to Shallow Marsh water regimes. Moreover, Creeping spike rush and Slough grass have a similarly wide amplitude with respect to ground-water salinity (Walker, 1968).

Nevertheless, with a Wet Area plant community of twenty-eight species, the water regime and ground-water chemistry can be relatively well defined. Many of the species favoured slightly brackish** water; however there were a few species such as Seaside arrow-grass, Fowl mana grass and Western water hemlock that grow well in saline water. At the same time Zone 4 is surrounded by Willows which are definitely not tolerant to brackish ground-water. In fact, the specific conductivity of the water in this zone is 2.42 millimhos per centimeter. Zone 4, therefore, has a Wet Meadow water regime with a moderately brackish ground-water as indicated by the vegetation.

---

* These water regime classifications are described by Table V-1.

** Stewart and Kantrud (1969) defined slightly brackish water as having a conductivity of 0.3 to 2.2 millimhos per centimeter.

The specific conductivity of ground-water discharge at Site II is 2.42 millimhos per centimeter compared to 1.50 millimhos per centimeter for discharge from the Dalmeny aquifer. In consideration of this difference in specific conductivities and the geological conditions at Site II, the ground-water discharge at this site is probably from a near-surface aquifer system.

Other aspects of vegetation indicators are illustrated in Zones 3 and 4. The Balsam poplar trees, visible from the top of the ravine, indicated a preferred soil moisture supply. However, the position of the seasonal water level was determined by the herbs and shrubs. This is an example of the superior indicator quality of a community of herbs and shrubs as compared to a single tree species.

In spite of this, trees, as indicators of terrain conditions, should not be underrated. In the first place they are large and useful as markers of areas requiring closer investigation. Furthermore, a community of trees is a better indicator than any single species. For example, the Balsam poplar indicated a Wet Area. The Willows, found upon closer examination, indicated a Wet Area having relatively fresh soil water. On the initial indications by two tree species, the Zone 4 habitat was tentatively identified as wet with relatively fresh soil water. Therefore, as has been shown by others, herbs and shrubs are superior indicators and plant communities are better indicators than single species.

Site II contains examples of many aspects of vegetation indicators of terrain conditions discussed previously. Herbs and shrubs seem more sensitive to edaphic conditions than do trees. Clearly a plant community is a more reliable indicator of habitat conditions than any single species of that community. This was well illustrated by the example of the two trees, Balsam poplar and Willow, in Zones 3 and 4. The complexity of the vegetation's response is illustrated by the presence of species groups that indicate two or more different habitat conditions for the same site as was the case in Zone 4 where one group indicated a Moist Woods habitat and the other indicated a Wet Area habitat.

Also at Site II the ground-water chemistry and the seasonal position of the water surface in Zones 3 and 4 were accurately estimated on the basis of vegetation indicators. Estimating the seasonal position of water levels by vegetation indicators, as illustrated in Zones 3 and 4, could provide a reliable method of estimating dates of water levels in sloughs for highway engineering purposes in southern Saskatchewan.

5.3. <u>SITE III</u>

Site III was chosen for its xeric character. Accordingly, the species in this site are xeric or capable of tolerating drier conditions. The surficial soils investigation did reveal that the soil moisture contents were higher than what the vegetation seemed to indicate. Several years ago, a well excavated at this site one hundred feet deep was dry. It is possible, however,that a small amount of water is supplied to this site by seepage at the silt-till interface near the top of the main river valley. It is unlikely that the hydrostatic pressure in the Dalmeny aquifer is sufficient to cause ground-water movement through at least sixty feet of till to elevation 1625 at the bottom of Site III.

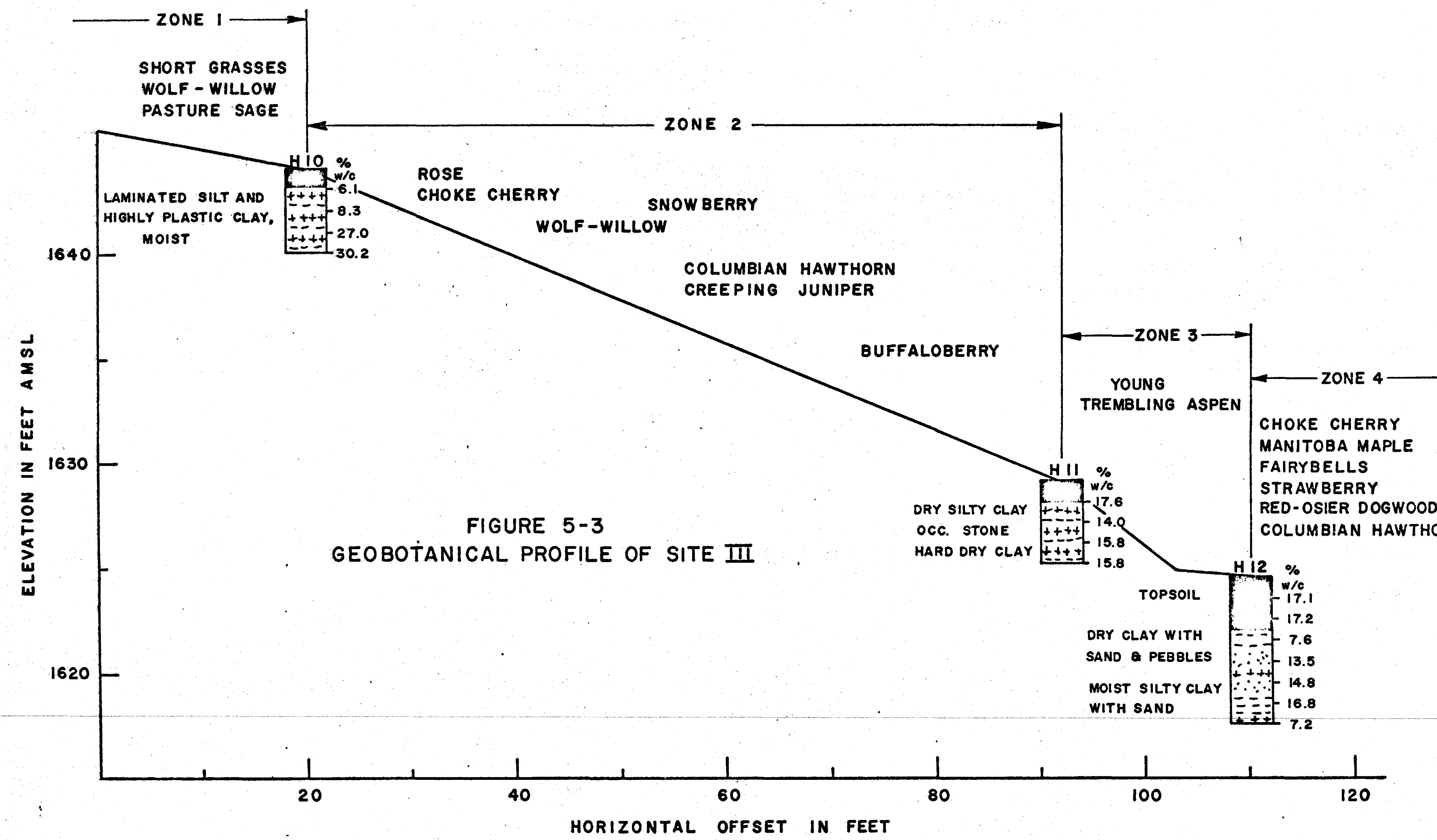


FIGURE 5-3
GEOBOTANICAL PROFILE OF SITE III

Zones 1 and 2 are typical of upper slope vegetation in the study area with the exception of one species. That is the Columbian hawthorn in Zone 2. This species prefers woodland habitats. All other species in Zone 2 are common species of the Ecotone habitat and as such provide no indication of soil moisture conditions.

Again Wolf-willow is on a moist, silty soil at Site III. The documented relationship between this species and moist, light textured soils seems to apply here, although the soil has a higher clay content and is not as moist as the soil in Site II-1.

Vegetation in Zones 3 and 4 belong to the Moist Prairie habitat although there is not as much shelter afforded to the vegetation by topography as in other sites. In view of the exposed nature of this site, the presence of this Moist Prairie community seems to indicate slightly preferred soil moisture conditions. This indication was confirmed by subsurface investigations. The natural water contents in the silty colluvial soil in the ravine bottom were of the order of 13 to 17 per cent. Most of the vegetation at this site is capable of removing water from a silty soil at these water contents.

In terms of engineering significance, the vegetation in Zones 3 and 4 indicate a slightly preferred soil moisture condition. Soils at these moisture contents can be handled by conventional earth moving equipment with no difficulty.

5.4. SITE IV

The preliminary assessment of Site IV was that this site was xeric but not as xeric as Site III. Subsequent field investigations confirmed this preliminary assessment. Whereas topographical shelter for vegetation is minimal at Site III,greater shelter is afforded the vegetation in Site IV where the ravine is deeper. In response to this increased shelter, the vegetation at Site IV is less xeric than at Site III.

Vegetation at the top of Site IV is Dry Prairie in character. Moving downslope, the habitat becomes Moist Prairie. There are some species in this site not yet discussed such as the Pin cherry trees that are common to hillsides and ravines.

In Zone 4, the ravine bottom is moist, sandy colluvium. This moist, nutrient-rich soil supports two species which strongly indicate mesic conditions. These are High bush cranberry and Green ash. The High bush cranberry prefers a heavily wooded woodland habitat whereas the Green ash is found on hillsides in southern Manitoba. The presence of these species indicated a preferred edaphic condition like the moist, sandy colluvium.

In both Sites III and IV there were few low growing herbs and shrubs. Herbaceous vegetation probably occurs in these sites; however, grazing and trampling by cattle destroys it during the growing season. Without these herbs and shrubs the sensitivity of vegetation indicators of edaphic conditions is limited to the sensitivity of the trees. Consequently, it is not possible to expect much terrain information from the vegetation in areas that have been heavily grazed by cattle.

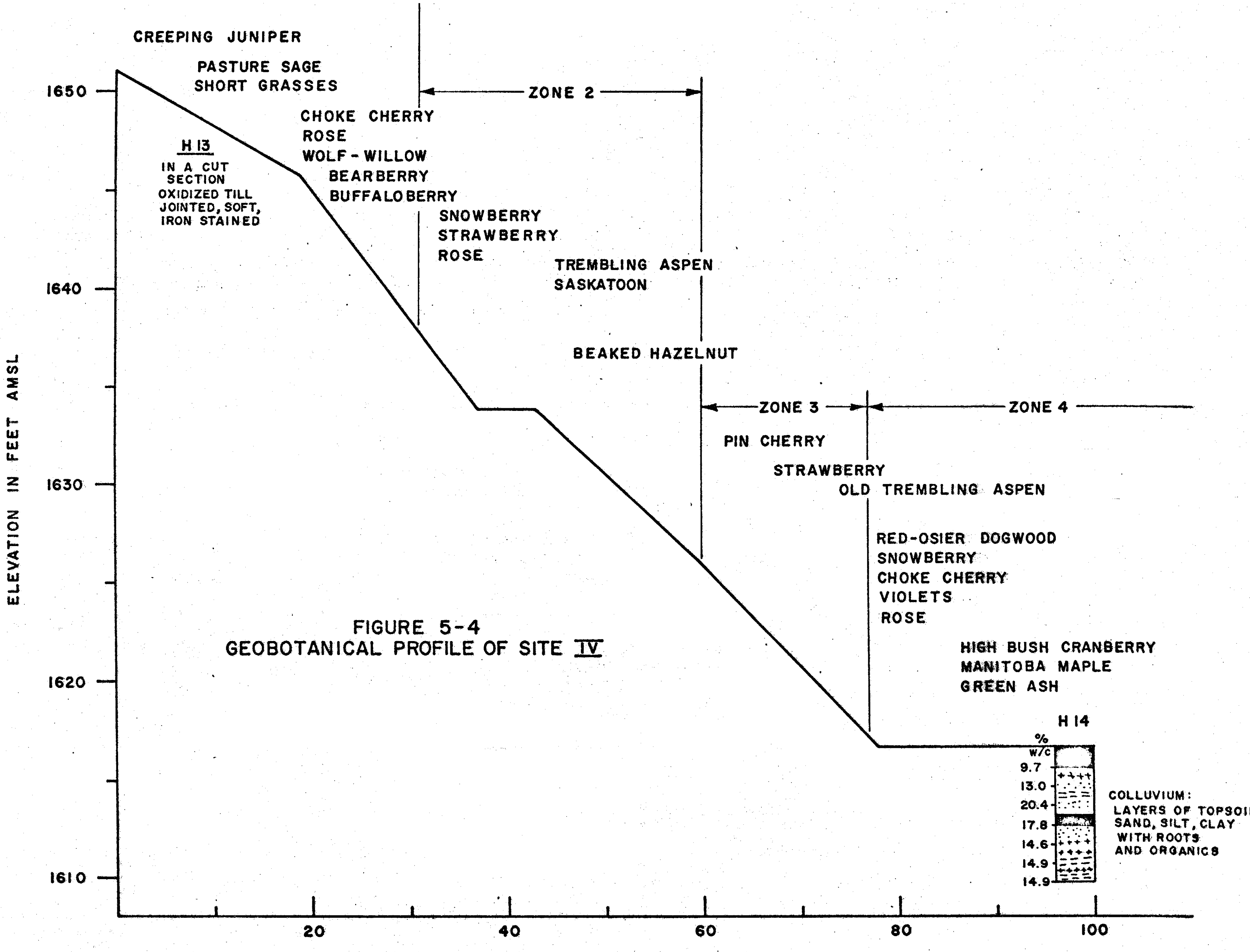


FIGURE 5-4
GEOBOTANICAL PROFILE OF SITE IV

5.5. SITE V

For the most part, the vegetation in Site V is typical of dry valley slopes in the Langham vicinity. As a result of the xeric nature of the vegetation at this site, in contrast with the hygric vegetation at Site VII, Testhole V was located at the top of this site.

Geomorphologically, this site is on the most recent landslide scarp and part of the topmost slump block. The changes in vegetation seem related to changes in microclimate since edaphic conditions do not vary significantly from the top to the bottom of the site.

Site V is unique in the Langham Study Area in that the vegetation at both the top and bottom of the site has a Dry Prairie character, yet the vegetation in the middle is Moist Prairie in character. This vegetation in the middle showed no signs of moisture stress on the colour infrared aerial photographs whereas the vegetation at the top and bottom did. At the top and bottom of this profile, the microclimate is very similar. The slump block at the bottom of this site is exposed almost to the same extent as the pasture at the top. Only the vegetation on the scarp in the middle of the site has shelter by topography and other vegetation. In addition, there are vegetation indicators of seepage along this part of the scarp in Site VI. Although there was no subsurface evidence of seepage at the time of the field study, some seepage may occur during the wetter parts of the season.

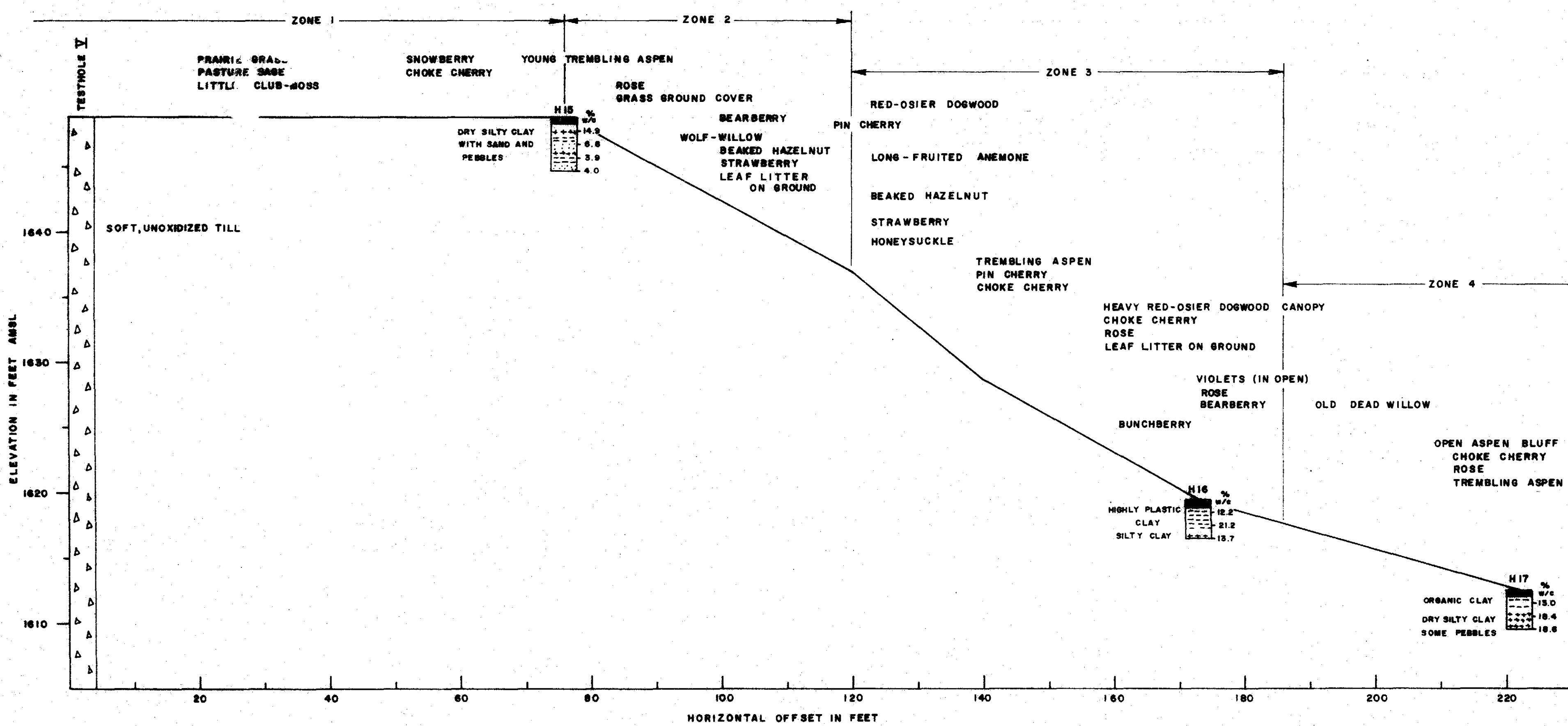


FIGURE 5.5 GEOBOTANICAL PROFILE OF SITE V

At the top of the landslide shear zone in upper Zone 4, there are some old but dead Willow. The Willow, being a Wet Area species, is out of place here. Near the dead Willow is a very dense growth of Red-osier dogwood, normally an indicator of good soil moisture conditions when found in dense stands. At some time in the past, soil conditions around these dead Willows were wet. At present the vegetation also indicates preferred soil moisture conditions. This extra soil moisture may have come as seepage from the Dalmeny aquifer along the landslide shear zone. Present stratigraphic information,however, does not support this hypothesis. Nevertheless, the presence of old, dead Willow and dense growths of Dogwood, along a landslide shear zone at an elevation twenty feet below the present head in the Dalmeny aquifer, is cause for speculation.

As an empirical observation in the Langham Study Area, there is an approximate correlation between the moisture content of soil and the number of different species growing on that soil. The typical Dry Prairie habitat species are few in number. On the contrary, the number of different species is much greater in Wet Areas. This correlation between the number of species present and the moisture content of the soil is an example of a general indicator because a terrain condition is indicated by vegetation in general, without reference to a particular species.

5.6. SITE VI

Site VI has a vegetation pattern similar to that of Site V with some exceptions. As in Site V, the upper slope Dry Prairie vegetation changes to Moist Prairie mid-slope then back to Dry Prairie on the slump block.

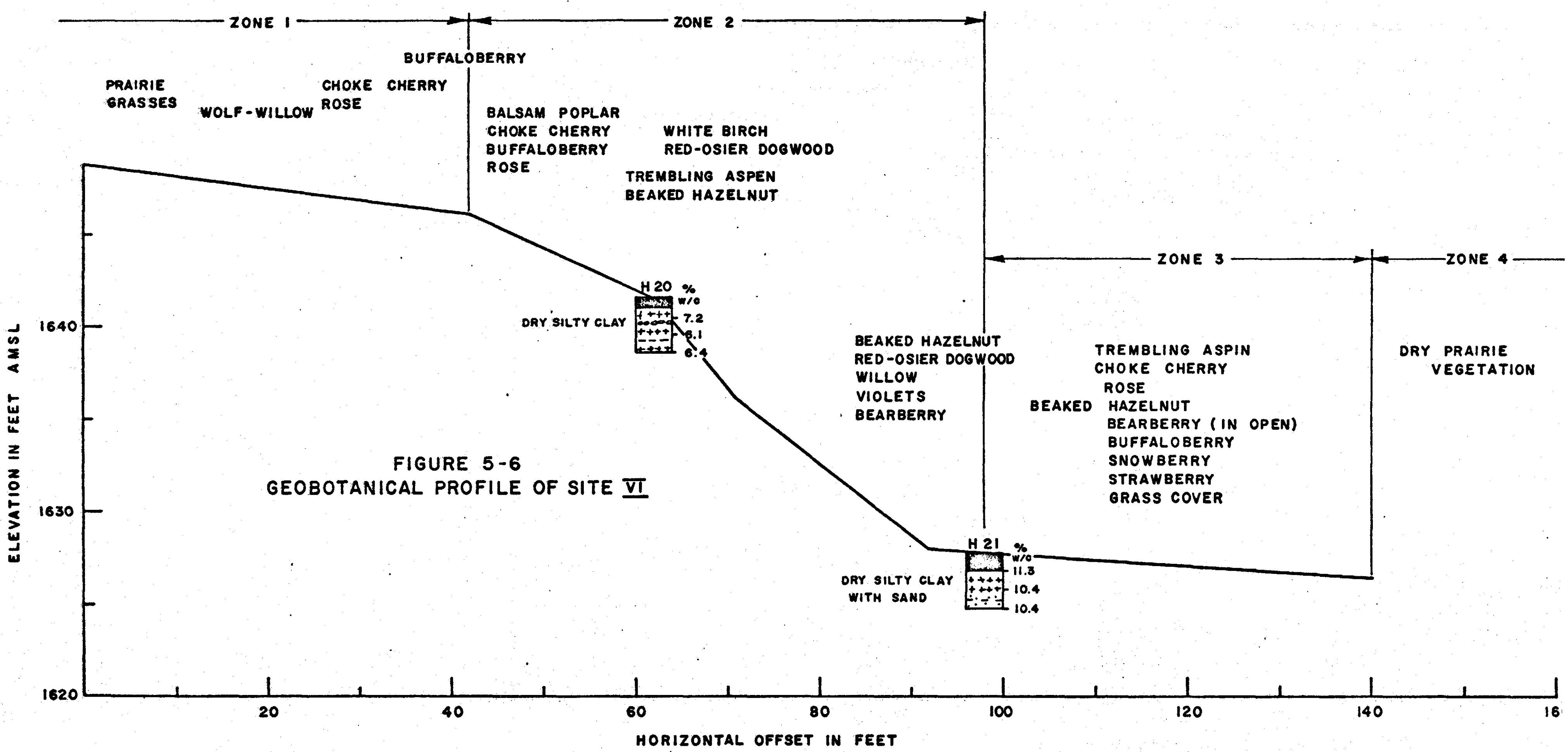


FIGURE 5-6
GEOBOTANICAL PROFILE OF SITE VI

One exception is the Balsam poplar in upper Zone 2. Another is the largest White birch tree in the study area at mid-Zone 2. There are also Willow along the top of the landslide shear zone. As was discussed, Willow along the top of the shear zone are common in the study area, particularly when there is seepage along the shear zone. Consequently, the presence of Willow in lower Zone 2 implies seepage from the Dalmeny aquifer along the shear zone. Another possible cause of increased soil moisture along Zone 2 is the additional water supplied by snow melt from the snow lodgement just below the crest of the valley. However, extra moisture from snow melt is not likely to sustain Willow through the growing season at Site VI.

Both Balsam poplar and White birch require adequate moisture supplies. Since it appeared on the colour infrared aerial photographs that these trees were doing well in a very dry September, they probably have an adequate soil moisture supply such as might be provided by seepage at a stratigraphic boundary. Although there is no evidence of such a boundary near the surface in nearby Testhole V, the vegetation indicates a small amount of seepage. Before any construction at Site VI, further subsurface investigations are needed to confirm the nature of the seepage indicated by the vegetation.

5.7. SITE VII

A standard geobotanical profile was not established for Site VII. The profile followed an overgrown path across the valley slope. Plotting this path on a profile would result in an unwanted distortion. In its place the species distribution is shown with vertical control data only in Figure 5-7.

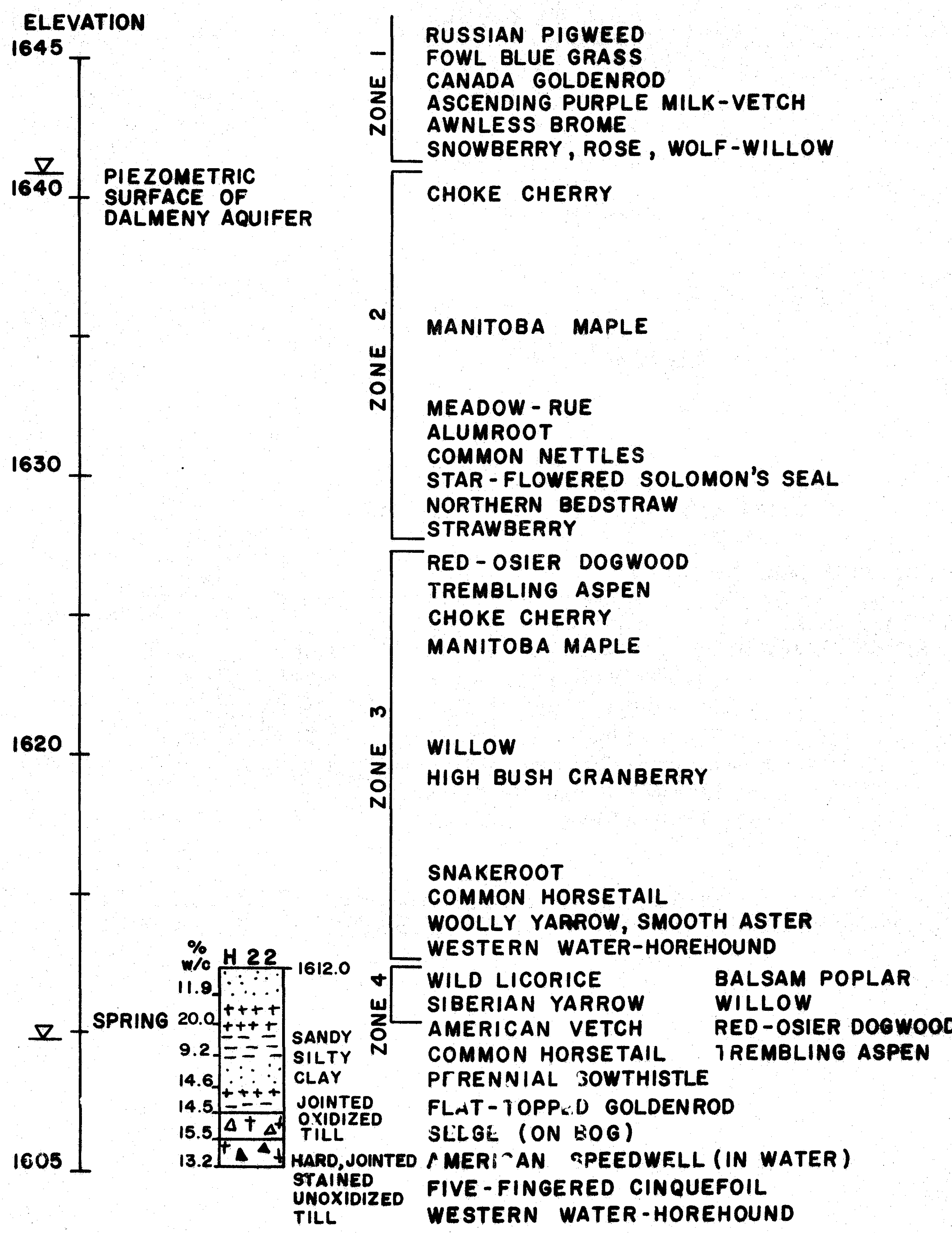


FIGURE 5-7. DISTRIBUTION OF SPECIES BY THEIR SLOPE POSITION IN SITE VII

Zone 1 has a variety of species not representative of the Dry Prairie habitat. This departure in species composition is caused by man's disturbance of the vegetation in what is now an abandoned farm yard. The vegetation in Zone 1 resembles the vegetation of other abandoned farm yards in southern Saskatchewan, particularly the large quantities of Russian Pig weed. This species is a good indicator of abandoned areas.

In Zone 2, the canopy of Manitoba maple and Trembling aspen provide shade, which in combination with the shelter provided by topography, creates a shaded, cool Moist Woods habitat. Accordingly, most of the species in this zone are associated with the Moist Woods habitat. These species like Meadow-rue, Northern bedstraw, Star-flowered Solomon's seal, Strawberry and Common nettle (Stinging nettle) are associated more with moist, cool, shaded areas than with Wet Areas. Common nettle is a partial exception because it can grow in sunny locations and is often found along small drainage courses and depressions, that are dry for most of the year.

In Zone 3 vegetation indicates a water table near the surface. In particular, Balsam poplar and Willow indicate ground-water nearby. High bush cranberry indicates a mesic habitat. Such a habitat can occur as a result of shelter or as is the case here, as a result of water table near the surface. Therefore, High bush cranberry is an indirect indicator of wet subsurface conditions in Zone 3.

Species associated with Wet Areas start to appear in lower Zone 3. Some of these species are more reliable indicators than others. Accordingly, more significance is attached to these indicator species.

For example, of the five herbs in lower Zone 3, only two, Horsetail and Wetsern water-horehound, are associated with Wet Areas. Two others, Snakeroot and Woolly yarrow, prefer Moist Woods habitats. The last, Smooth aster, is a Wet Meadow or Moist Prairie species. Nevertheless, the area is designated as being wet on the basis of the presence of Horsetail and Western water-horehound. Unless the water table was near the surface, these two species would not likely be present. The presence of the other three species does not negate the indication of a Wet Area although they could live in drier habitats, whereas Horsetail and Western water-horehound could not.

There is an open, level area around the spring at Site VII. This area is Zone 4. It supports a large variety of herbs. Most are associated with wet places but there are also species associated with cool, shaded woodlands. Species indicating a Wet Area in this Zone are Wild licorice, Western water-horehound, Horsetail, Flat-topped goldenrod, Sedge of several species, Balsam poplar and Willow. American speedwell, which is known for growing in streams at springs (Budd and Best, 1964), was growing in the spring pool in Zone 4.

In Zone 4 the indicator significance of vegetation associated with Wet Areas is lessened by the open spring water. However, all of the Wet Area species listed grow in soils where the water table is near the surface. For example, many of these species are present in Site II-4 where the ground surface dries in early July. By studying the vegetation around an open spring pool, direct indicator relationships are established between vegetation and wet soils. Then at other locations where the wet soil condition is not immediately visible, these established indicator relationships can be applied.

5.8. SITE VIII

There are two significant variations in the vegetation pattern of Site VIII in comparison to other hygric vegetation study sites. The first variation is that there are fewer hygric species in the wet zones of Site VIII than in other wet zones in the study area despite the large ground-water discharge volumes. Not only are there fewer hygric species but the total number of species in this site is less than in other hygric sites. At the same time, Site VIII seemed much more exposed than neighboring hygric sites. As a result there is much more exposure to sun and wind in Site VIII. Although the topography allows similar shelter at each site, a large variety of species is unable to occupy Site VIII because the microclimate is too dry even though the soil is moist. The vegetation on moist soils has compensated for the drier microclimate. The result is the presence of Moist Prairie species at slope positions normally taken by Moist Woods species.

The second significant variation is a band of Moist Prairie species at the boundary between Zones 2 and 3. This band is unique because both upslope and downslope from it the vegetation is definitely mesic. As a result of the very dry laminated silt and heavy clay underlying this band the vegetation is more xeric in composition than the vegetation above and below it on the slope.

The soil underlying the mesic vegetation above the xeric band is wet sand. Consequently, the small amount of seepage from this layer of sand, near the bottom of the lacustine surficial soil, provides adequate moisture to support a mesic community of Balsam poplar,

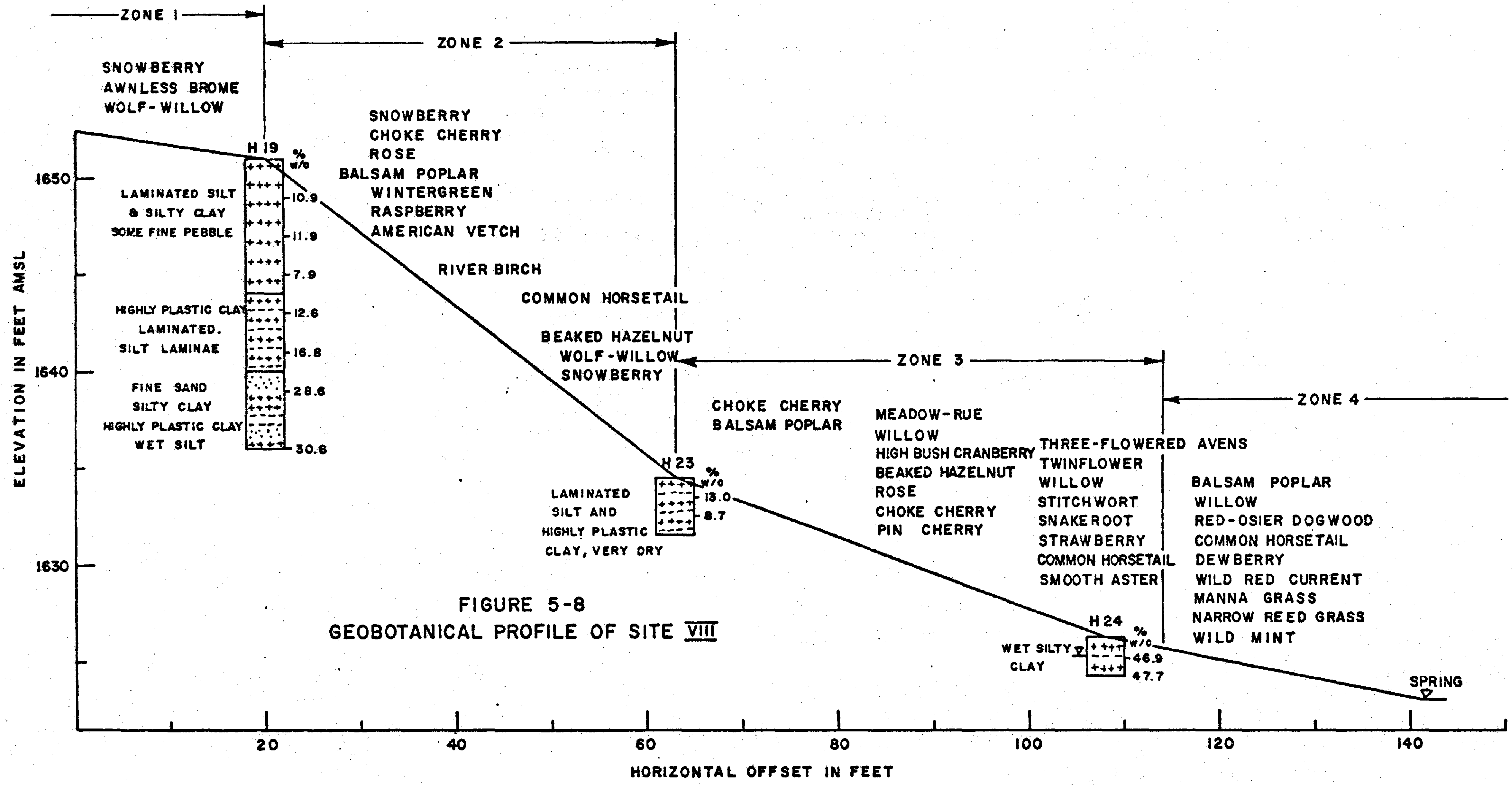


FIGURE 5-8
GEOBOTANICAL PROFILE OF SITE VIII

Raspberry and Wintergreen along with the less mesic species of Snowberry, Chokecherry, American vetch and Rose.

Any unexpected change in the character of vegetation on a slope is an indicator of changes in edaphic conditions as was the case in Site VIII. Other than by vegetation indicators, it is unlikely that subtle changes in subsurface conditions could be detected without subsurface investigations.

5.9. SITE IX

Vegetation in Zone 1 is an ecotone community between the cultivated field and the aspen grove downslope. Consequently those species common to the Ecotone habitat, such as Rose, Snowberry and Choke cherry dominate this Zone. Wolf-willow is also present although the soil is dry silt. Observations in the study area suggest that Wolf-willow is as much associated with light textured soils in the Ecotone habitat as it is with moist, light textured soils. Therefore no aspect of the Zone 1 vegetation indicated other than the expected dry, exposed conditions.

The ground surface slopes gently towards the valley in both Zones 1 and 2. Therefore Zone 2 is not afforded the same protection from sun and wind by topography as Zone 2 in other sites. Furthermore, the tree canopy is thin and there are no tall shrubs. In general, Zone 2 is very open with ample space between trees. As a result of its open exposure the vegetation should be xeric in character. On the contrary,there is a large number of different species common to the Moist Woods habitat. Therefore, moist subsurface conditions must compensate for the exposed-location climate of Zone 2 to allow a

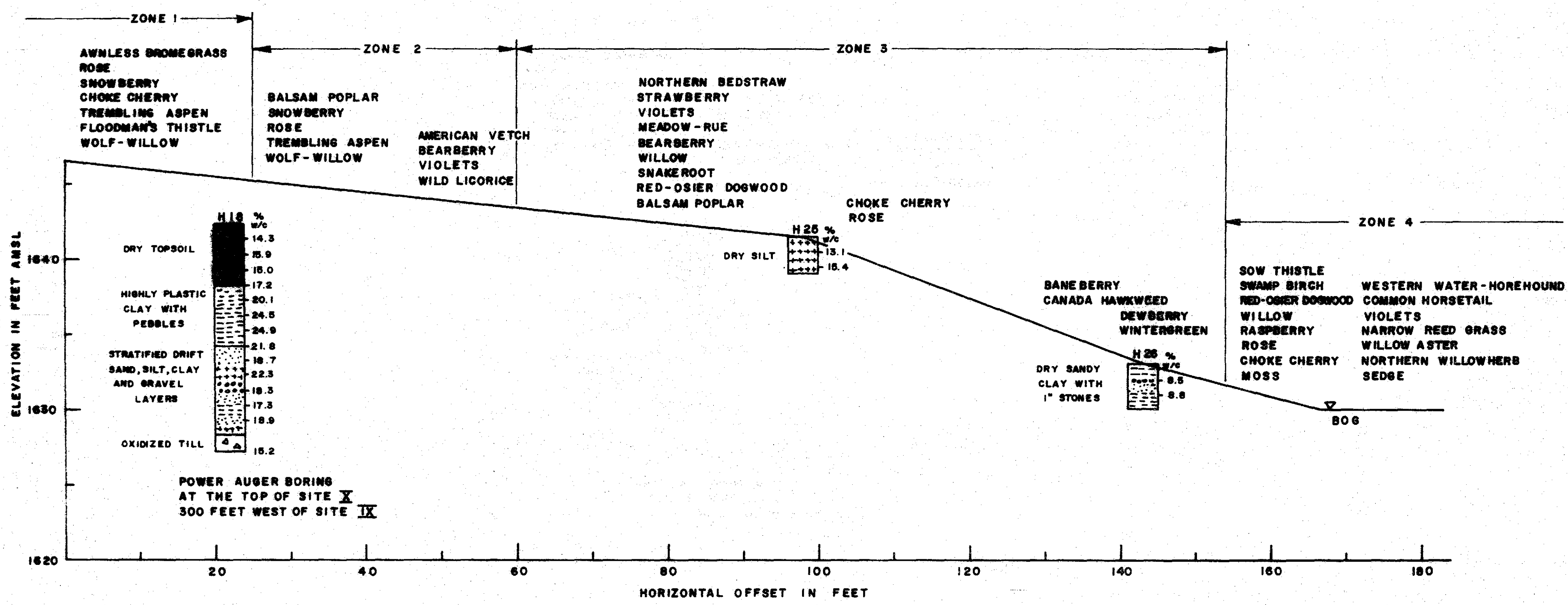


FIGURE 5.9 GEOBOTANICAL PROFILE OF SITE IX

mesic community to grow.

There are several possible explanations for the mesic community in Zone 2. The first is that the interconnected root system of the Balsam poplar, which can reproduce vegetatively, moves water from roots near the spring in Zone 4 up to trees in Zone 2. This, however, does not explain the presence of other species like American vetch and Wild licorice.

The second explanation of this mesic community in Zone 2 involves the movement of water in the silt soil. By capillary rise, water can move upwards in a silt soil as much as sixteen feet under ideal conditions. The surface of Zone 2 is only fourteen feet above the spring level in Zone 4. Yet, in view of the statement by Pierre et al. (1966) that water movement in unsaturated soils is too slow to be an important factor in supplying the requirements of a rapidly transpiring plant, it is unlikely that capillary rise of water in this silt can supply sufficient water for the mesic vegetation in Zone 2.

The third explanation incorporates the second and seems to be the most probable of the three offered. At Borehole 18 at the top of Site X there is a layer of wet stratified drift in the lacustrine surficial deposit between elevations 1629 and 1634. This layer is ten feet below the ground surface in Zone 2. A combination of capillary rise and root penetration would bring the plant roots within reach of a permanent water supply. At the time of this field study, a more skillful interpretation of vegetation indicators of ground-water at a depth of ten feet in Zone 2 would have led to a more complete sub-surface investigation at the top of Site IX.

Upon moving into Zone 3 the vegetation becomes more mesic. The Willow in upper Zone 3 indicates adequate subsurface moisture. Undoubtedly the wet stratified drift which was the moisture supply to Zone 2 also supplies Zone 3. Although there are no signs of ground-water discharge from this near-surface aquifer other than the vegetation, this ground-water flow system is worth of investigation prior to any excavation near Site IX.

Site IX-4 is a wet bog with open water. The vegetation on this bog has a very similar species composition as the meadow in Site II-4. As in most bogs, the trees grow on hummocks because very few trees can grow when their roots are submerged. Several species in this zone indicate the Wet Area habitat. They are Swamp birch, Willow, Western water-horehound, Horsetail and Narrow reed grass. Willow aster, Northern willowherb and Sow thistle are growing near but not in the water.

The absence of tall trees in an otherwise wooded area probably indicates an area of very high water table. If in addition the treeless area is also a sedge* meadow, then the water table is definitely near the surface. These areas are readily identified from the air by their flat meadow-like appearance and lack of tall trees.

---

* Sedge *(Carex spp.)* looks like coarse grass. It is easily identified by its triangular stem cross section as compared to the circular cross section of grass stems.

Site IX-4B is the travertine mound immediately north-east of the bog in Zone 4. The vegetation on and around the mound is similar to that of Zone 4 with the exceptions of Fleshy Stitchwort and a heavy growth of Algae in the water. The Pussy willow here have some irregular characteristics but these are more likely caused by hybridization than the calcium carbonate soil. There was no vegetation response that could be attributed to the chemical composition of the mound.

5.10. SITE X

At the top of Site X* there is no Ecotone habitat. Instead, large Balsam poplars grow at the edge of the cultivated field. Originally it was these Balsam poplars which led to the selection of Site X for further vegetation studies.

As part of these studies, Borehole 18 at the top of Site X penetrated very wet stratified drift at the eight foot depth. This stratified drift is no doubt the water source which allows the growth of large Balsam poplars in an exposed zone such as this.

As has been discussed, the mesic zone starts at the edge of a cultivated field and continues downslope to the bog at the top of the most recent landslide shear zone. The bog in Site X-4 was drier than the bog in Site IX-4 yet not as wet as the meadow in Site II-4.

---

* Because of the similarity in vegetation patterns between Site X and other hygric study sites, no geobotanical profile is given for Site X.

Nevertheless, several species in Site X-4 indicate a water permanence throughout the year. These are Mana grass, Western water-horehound, Rush aster, Western water hemlock and Water sedge; the last three species being associated with Wet Brackish* habitats. In fact, the water in the bog has a conductivity of 1.50 millimhos per centimeter and is therefore moderately brackish.

Vegetation indicators are valuable in that they draw attention to subtle terrain conditions which are not otherwise detectable without elaborate techniques or equipment. In Site X, the bog is clearly an area of ground-water discharge. However, the vegetation at the edge of the cultivated field indicated wet subsurface conditions above the bog. Subsequent investigations discovered a layer of wet stratified drift, just eight feet below the surface. Similarly, the vegetation at the bog indicated a brackish water condition that could not have been analyzed without additional equipment.

5.11. SUMMARY OF SIGNIFICANT INDICATOR SPECIES

As a result of the analysis of vegetation indicators of terrain conditions in the Langham Study Area, several documented vegetation-terrain relationships were found to be applicable. In addition, some vegetation-terrain relationships, not yet documented, were found

---

* Wet Brackish Area is a habitat classification used in this report to designate areas of brackish ground-water at or near surface in either prairie or woodland settings.

applicable. A summary of all these relationships is presented in Table VII-1

Known relationships were taken from Budd and Best (1964), Walker (1968), Stewart and Kantrud (1969) and Millar (1969). Walker and Millar each examined a large number of prairie potholes for species-habitat relationships in southern Saskatchewan. Stewart and Kantrud conducted similar studies in central North Dakota. Budd and Best conducted field studies of species found in the Canadian prairies. Millar (1969) stated that his work and that of Walker (1966), and Stewart and Kantrud (1969) "have shown the general composition of the wetland vegetation in the Northern Great Plains Region to be quite similar over a large area". Therefore, vegetation-terrain relationships in wetland areas can be extrapolated throughout southern Saskatchewan with a degree of reliability.

Forty-two species which were considered significant indicators of different terrain conditions in the Langham Study Area, were organized into groups with respect to habitat classifications already discussed. These species-terrain relationships are shown by Table VII-1.

In Table VII-1 the water regime associated with species is taken from Walker (1968), Stewart and Kantrud (1969) and Millar (1969). Each author has a system of classifying water regimes. Millar and Walker use the same system shown by Table V-1. The system used by Stewart and Kantrud is shown by Table V-3.

Similar to the classification systems of water regimes, Walker and Stewart and Kantrud classified water salinity shown by Tables V-2 and V-4 respectively. Millar did not include water salinity considerations in his tables of species habitats although water salinity

TABLE V-1

WATER REGIME CLASSIFICATION

PRAIRIE POTHOLES

(used by Walker, 1968 and Millar, 1969)

WATER REGIME	DESCRIPTION
Aquatic	More than 20 cm of water present in the autumn
Deep Marsh	Just containing water in the autumn
Shallow Marsh	Water present for most of the summer but drying out before autumn
Marsh Meadow	Water present in spring but dry by early July
Wet Meadow	Water present in spring and a high water table until early July
Dry Meadow	Flooded briefly during the spring but relatively dry by July

TABLE V-2

WATER SALINITY CLASSIFICATION FOR PRAIRIE POTHOLES (Walker, 1968)

DESCRIPTIVE CONDITION	CONDUCTIVITY (mmhos/cm)
Non-saline	less than 1.0
Lightly saline	1.0 - 2.5
Moderately saline	2.5 - 7.5
Saline	7.5 - 20
Very saline	20 - 50
Extremely saline	more than 50

TABLE V-3

WATER REGIME CLASSIFICATION FOR PRAIRIE POTHOLES

(Stewart and Kantrud, 1969)

WATER REGIME	DESCRIPTION
Low-prairie	Flooded briefly in the spring but drains as soon as the subsurface ice seal melts in late spring
Wet-meadow	Flooded for a few weeks in the spring after snow melt. Heavy rains will produce a water surface for a few days during summer or autumn
Shallow-marsh	Water present for an extended period in spring and early summer but frequently dry during late summer and autumn
Deep-marsh	Water present throughout spring and summer extending into autumn and frequently into winter

TABLE V-4

WATER SALINITY CLASSIFICATION FOR PRAIRIE POTHOLES

(Stewart and Kantrud, 1969)

DESCRIPTIVE ASSOCIATION	CONDUCTIVITY (mmhos/cm)
Fresh	0.04 - 0.7
Slightly brackish	0.3 - 2.2
Moderately brackish	1.0 - 8.0
Brackish	1.6 - 18.0
Subsaline	3.5 - 70
Saline	20 - 100+

TABLE V-5

EQUIVALENT ENGINEERING DESCRIPTIONS OF BOTANICAL DESCRIPTIONS OF SOIL MOISTURE CONDITIONS

BOTANICAL DESCRIPTION	ENGINEERING DESCRIPTION
DRY SOILS:	
Soils in which water is available to plants at relatively high osmotic potentials	Soils with relatively high soil suctions; soils at water contents below the standard AASHO optumum water content
PREFERRED SOIL MOISTURE:	
Soils in which water is available to plants at moderate osmotic potentials	Soils with moderate soil suctions; soils having a water content approximately equal to the standard AASHO optimum water content.
MOIST SOILS:	
Soils in which water is freely available to plants at relatively low osmotic potentials	Soils with relatively low soil suctions; soils having water contents greater than the standard AASHO optimum water content but less than 100% saturation
WET SOILS:	
Saturated soils	Soils with 100% saturation; soils below the water table

was considered as part of his investigations.

Budd and Best (1964) compiled a Flora of the Canadian prairies. Their work was primarily involved with giving botanical descriptions of all species found on the prairies. As part of the botanical description for each species, they have given the habitat for each.

CHAPTER VI

OTHER ASPECTS OF VEGETATION-TERRAIN RELATIONSHIPS OF ENGINEERING SIGNIFICANCE

Mechanical properties of soil, such as stability, volume change characteristics and permeability, are a function of soil type and environment. Soil type refers to the textural composition; for example, clay, silt or sand. With respect to mechanical properties of soil, environment means the soil moisture environment. Although there are many factors in the environment which determine the moisture content of a soil, only the soil moisture parameter itself affects the mechanical properties.

The distribution of vegetation is also a function of soil type and environment. In the case of vegetation distribution, environment includes all aspects of the total physical environment, yet the soil moisture parameter is frequently dominant in determining vegetation distribution, especially in arid regions.

As can be seen, the parameters determining the mechanical properties of a soil are very similar to those determining the distribution of vegetation. Therefore, this research investigated the relationship between mechanical properties of soil and distribution of vegetation. In most cases the distribution of vegetation was determined primarily by a combination of soil type and soil moisture. These same parameters, soil type and soil moisture, determine the mechanical properties of soil. Vegetation, therefore, can serve as an indirect indicator of mechanical properties of soil.

The relationships between vegetation and environment have been shown as having applications of vegetation indicators developing from these relationships. Subsequently the application of vegetation indicators in southern Saskatchewan was evaluated using the Langham Study Area. It seems meaningful at this point to discuss, in detail, some of the aspects of soil physics which relate vegetation indicators to the mechanical properties of soil.

Many habitats are not well suited to vegetation. Plants, however, have been able to occupy areas of adverse conditions by developing specialized characteristics. It is from these specialized vegetation-terrain relationships that vegetation indicators are derived. Several types of specialized adaptations by vegetation can be used to illustrate the distribution of species in response to conditions of soil type and soil moisture.

The change in soil stability and soil volume with decreasing soil moisture as a result of water consumption by vegetation is an example of suction-effective stress relationships in soils. Water extraction from soil by vegetation is a factor that is often omitted from the design of structure foundations in spite of its influence on the proposed foundation. Soil desiccation by vegetation has caused foundation damage as a result of soil shrinkage (Skempton, 1954; Legget and Crawford, 1956). On the other hand, Metz* (personal

---

* Mr. D.G. Metz is the Materials Engineer with the Yorkton District of the Saskatchewan Department of Highways.

communication, 1970) found that soil desiccated by vegetation in an alfalfa pasture allowed excavation for highway embankment construction; whereas high soil moisture contents in an adjoining fallow field prevented any excavation. By applying studies of osmotic potentials of plants, it is possible to be more quantitative about the influence of water removal from soil by vegetation for foundation design purposes.

6.1. EDAPHIC FACTORS

Often the same aspect of soil physics influences both the vegetation and the mechanical properties of the soil. For example, cation exchange capacity is related to soil texture. To the geotechnical engineer a high cation exchange capacity is an indication of a soil that will likely be subject to volume changes associated with soil moisture changes. To the plant physiologist, a high cation exchange capacity is an indication of a nutrient-rich soil (Clifton, 1966). It is, therefore, possible to use plants with high nutrient requirements as indicators of a soil or ground-water regime that has a high cation exchange capacity. These plants then serve as indirect indicators of soils that are subject to volume changes.

6.1.1. Nutrient Selection

A species will favor habitats in which its nutrient requirements are well met. There are seven elements (nitrogen, phosphorus, sulphur, potassium, calcium, magnesium and iron) which are universally essential for plant growth, although trace quantities of other elements are needed for a complete supply of plant nutrients (Sutcliffe, 1962). However, plants have selective nutrient absorption

(Rorison, 1969); therefore, individual plants can have salt contents which are relatively independent of the composition of the medium in which they are grown (Sutcliffe, 1962). Accordingly, only species with a very narrow ecological amplitude with respect to nutrients will respond to changes in the nutrient supply.

In a study of the influence of soil nutrients on species distribution in the salt deserts of Utah, Gates et al., (1956), found that there were significant differences between species distribution and the following factors: total soluble salts, saturation extract conductivity*, exchangeable sodium, soluble sodium and field capacity**. In spite of the relationship between species distribution and nutrient supply, vegetation indicators of terrain conditions associated with nutrient supply are more likely to confuse than to assist those without botanical training.

6.1.2. Soil Temperature

Soil temperature determines the time at which vegetation will begin to grow in the spring. Moreover, retention of soil water is greater in cooler soils, and although soil water is present it is not available to the plants. Soil temperature, as a function of

---

* Saturation extract conductivity is the electrical conductivity of water extracted from a soil at 100 per cent saturation.

** Field capacity is the moisture content of a soil, expressed as percentage of oven-dry weight after the gravitational water has drained away (Hanson, 1962).

insolation, varies with the slope aspect. For example, Ashby (1969) found a difference of five degrees Centigrade in surface soils between south-facing and north-facing slopes in the United Kingdom. Accordingly, vegetation starts growing on south-facing slopes first.

Another factor affecting soil temperature is the presence of ground-water. In areas of ground-water discharge or ground-water close to the surface, the heat from the subsurface water reduces the affects of atmospheric cooling on soils. As a result vegetation in these areas is the first to grow in the spring and the last to die in the autumn (Figure 6-1).

On the contrary, in soils far removed from the water table, vegetation on dry soils appears before vegetation on moist soils in response to the different thermal properties of soil and water systems. Mineral particles of soil have a specific heat of 0.2 calories per gram per degree Centigrade, and water has a specific heat of 1.0 calories per gram per degree Centigrade. Moist soils, therefore, require more heat to raise the soil temperature than dry soils. Conversely, moist soils cool more slowly than dry soils in the same climate. Differences in the dates of beginning and ending of growth are an indicator of soil temperature which is in turn related to the soil moisture conditions. Therefore differences in dates of vegetative activity is an indicator of soil moisture conditions.

6.1.3. Organic Decomposition and Soil Acidity

According to Leach (1956) there are two possible processes for the decomposition of dead plants, oxidation decomposition and humification. Oxidation decomposition occurs at soil temperatures of

Figure 6-1: Photograph taken near Site II-4. Heat from the ground-water reduces the effects of atmospheric cooling on soils. The first snow-fall has melted where the water table is nearest the surface. There is also a change in species composition along this line of snow melt.

thirty-five to forty degrees Centigrade in calcareous soils with good aeration and moderate water content. By this process, all organic matter is reduced to inorganic compounds. As a result of the decomposition of organic matter, the water retention capacity of the soil is reduced.

Humification is an anaerobic decomposition which produces organic acids in calcium-poor soils. Even without humification, calcium-poor soils become acidic when carbon dioxide from respiring plant roots combines with soil water to form a weak acid (Clements, 1928). Accumulations of humus are associated with acidic soil conditions, and therefore indicate wet or calcium-poor soils.

Many plants are definitely selective with respect to soil acidity (Leach, 1956); moreover, germination is particularly sensitive to soil pH (Rorison, 1969). In terms of terrain conditions, species sensitive to soil pH differentiate alkaline soils associated with areas of ground-water discharge having high evaporation rates from acidic soils associated with wet areas having a high organic content.

6.2. ROOT SYSTEMS

If a plant is considered an indicator of subsurface conditions, its above ground parts signal conditions as detected by its development below ground. Root systems are influenced by prevailing conditions but the pattern of root growth is determined primarily by heredity and is characteristic of each plant species (Ashby, 1969). As a result of the heredity limitations of root systems, most species are confined to soil conditions in which their root systems can be functional.

6.2.1. Vegetative Reproduction*

Plants which reproduce vegetatively can be a source of confusion to vegetation indicators as in the case of the Balsam poplar *(Populus balsamifera)*. On the other hand vegetative reproduction by aquatic plants is a reliable indicator of recent changes in slough water levels. In any case an individual not trained in botany can ascertain vegetative reproduction by uprooting a young plant. If the root leads to another plant the species propagates vegetatively, and the indicator significance of that species must be evaluated within the context of the total environment.

For example, the Balsam poplar prefers a moist habitat. However, in Site IX-2 of the Langham Study Area, Balsam poplar is the tree cover in an exposed area that is fifteen feet above the water table. There is insufficient soil moisture to support Balsam poplar in a habitat like Site IX-2, therefore the water is supplied via interconnecting roots with Balsam poplar near the water table in Site IX-3, or these trees have roots which penetrate to the water table.

In the case of recent changes in slough water levels, aquatic plants reproduce vegetatively to follow the shore line as the water level rises, and new plants establish relatively quickly. However, when the water level falls, the aquatic plants die, leaving the ground bare, since land plants near the slough usually propagate by seed.

---

* Vegetative reproduction is the propagation of a species from the original plant by vegetative extensions such as runners or rhizomes.

Land plant invasion into the recently emersed land is slow although abundant ungerminated seed is in the ground from previous seasons (Walker, 1968).

6.2.2. Root Configurations

Root systems vary in depth of penetration, spatial distribution and adaptations to submersion or drought to provide water and nutrient uptake, respiration and anchorage for the plant. Many plants, because of their distinctive rooting characteristics are reliable indicators of terrain conditions. For example, phreatophytes, whose roots reach into the water table, have been used by geotechnical engineers as ground-water indicators. With the exception of aquatic plant roots, which have a modified respiration process, most plant roots respire as well as take up water and nutrients. Therefore, these roots try to strike a compromise between aeration and adequate moisture.

In arid regions common grasses, forbs and shrubs have a dense mat of roots immediately below the ground surface. Any infiltration from light rains is taken by these roots before evaporation can draw the water from the surface soil. For example, Blue grama grass *(Bouteloua gracilis)*, which is the most xerophytic grass in the Canadian prairies, has eighty-four per cent by weight, of its underground parts in the top fifteen centimeters (Coupland and Johnson, 1965). Group II forbs*, which have a deep tap root with abundant

---

* J.E. Weaver classified species of forbs into four groups by their root configurations. Each group is referred to by a Roman numeral.

spreading laterals near the surface, remained vital during the great drought of the 1930's where other shallow rooted forbs and grasses died (J.E. Weaver, 1958). Deep roots are typical of dry prairie plants.

6.3. WILTING BY DRYING

As part of the photosynthesis process the plant opens its stomatae to draw carbon dioxide from the air. When the stomatae are open, the plant loses water by transpiration. Most of the water taken up by the roots is lost to the atmosphere by this process. In very hot, windy locations, water loss by transpiration may exceed water supply by the roots; when this happens, the plant dehydrates and wilts.

Adaptation by species has produced a spectrum of drought resistance with each species having its own drought tolerance. As an example of drought tolerant species, xerophytes have several adaptations to reduce their transpiration losses. First, they have fewer stomatae and the size of each stomata can be reduced during drought. Next, there are fine hairs around the stomata to reduce wind velocity and thus reduce evaporation losses. In severe drought the leaves curl to further protect the stomatae from drying winds, and finally in very severe drought the plant becomes dormant until moisture conditions improve (Maximov, 1935).

Xerophytes are capable of withstanding very high osmotic potentials to extract needed water. Spear grass *(Stipa comata)* can tolerate osmotic potentials of sixty atmospheres (J.E. Weaver et al., 1935). Furthermore, the xerophyte root system is structured to remove as much water as possible from the soil. Although xerophytes do well in moist habitats, mesophylous species are stronger competitors in these habitats. Consequently the xerophytes are forced onto the drier sites where the mesophytes would wilt as a result of excessive transpiration losses.

6.4. WILTING BY COOLING

6.4.1. Field Observations

During the cool weather of September and October, 1970, it was noted that areas of favourable moisture conditions supported healthy, green vegetation; whereas, drier areas showed dying, brown vegetation. This phenomenon was observed in several locations shown in Figure 6-2: at Site II of the Langham Study Area; in the median of highway No. 11 on the north side of the Qu'Appelle Valley; in the west ditch of highway No. 2 between the east hunction of highways No. 2 and 11, and the Arm River Valley; and on the west side of Kelfield Coulee (Eagle Creek Spillway) on highway No. 51.

Stratigraphic information was available for the Kelfield Coulee site which is a highway cut section. A structural testhole located at the top of the cut section showed Floral Till was present to a depth of two hundred feet except for the top twenty feet where there was severe stratigraphic disorder. The approximate sequence of stratigraphic units in the top twenty feet is lacustine silty clay on Battleford Till on Floral Till with large pockets of coarse, granular, water-bearing stratified drift in both tills.

The water-bearing stratified drift supported a healthy, green growth of Yellow sweet clover *(Melilotus officinalis)* and Willowherb *(Epilobium sp.)* both species being common to the prairie roadside

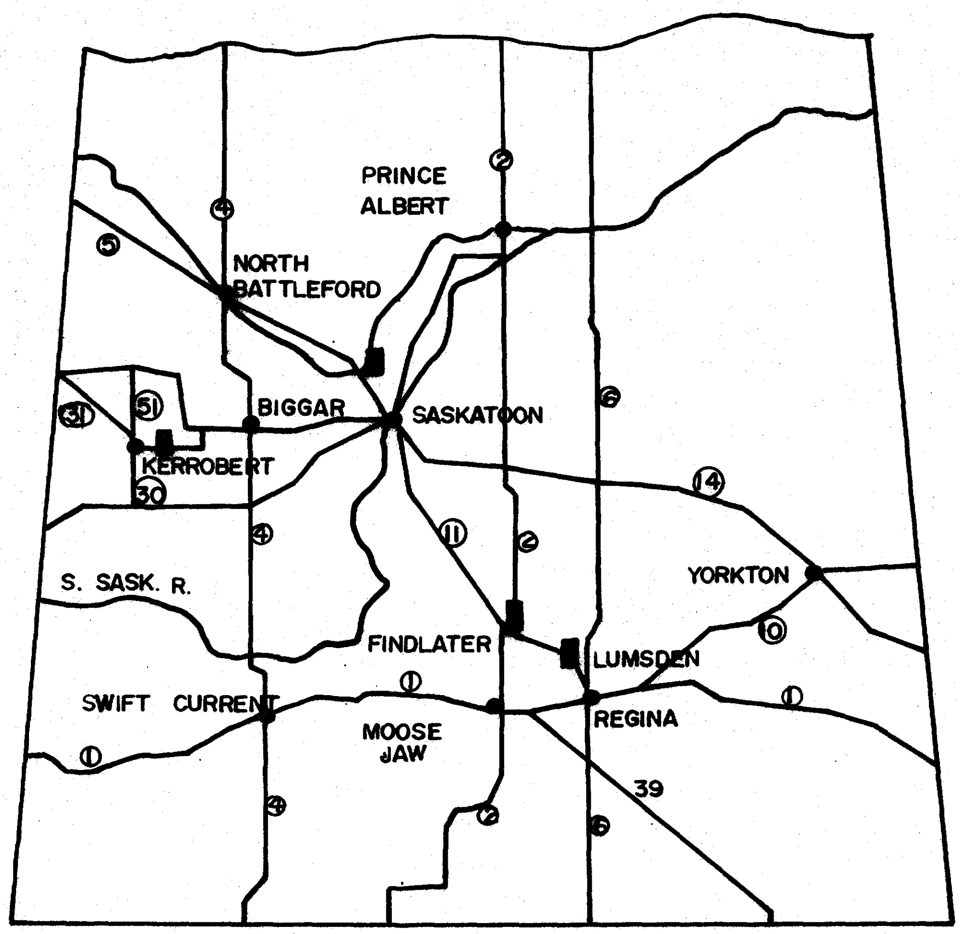


FIGURE 6.2 LOCATION OF OBSERVED WILTING BY COOLING IN SOUTHERN SASKATCHEWAN

(Budd and Best, 1964). On the other hand the silty clay and tills supported the dying, brown Smooth brome grass *(Bromus inermis)** (Figures 6-3 and 6-4).

6.4.2. Theory

Upon the first analysis of these field observations, the cause of the difference in vegetation condition seemed to be the difference in soil water content. However, the silty clay and tills at Kelfield Coulee had a water content greater than field capacity**. Likewise, the soil under the dying vegetation at Site II was wet, albeit not as wet as the identical soil under the healthy vegetation. Although adequate soil water was present, the dying plants suggest that this water was not available to them.

Daubenmire (1957) reported that the slow increase in temperature of mountain soils makes water available to plants continuously throughout the summer. Conversely, a plant will show signs of moisture stress (wilting) when the soil is chilled. Herein lies the explanation of wilting by cooling which can be explained in terms of plant physiology and soil physics relationships.

Plant physiologists know that there is a decrease in botanical activity, in general, at lower temperatures. Shorter days in the

---

* *Bromus inermis* was called Smooth brome. More recent publications index *Bromus inermis* as Awnless brome.

** The plastic limit of a soil is easily identified in the field by hand rolling a small sample of wet soil. Moreover, there is an empirical correlation between the plastic limit and the water content of unsaturated soil below the zone of seasonal moisture variation. By definition field capacity is the water content of a soil after all gravitational water has been drained. Therefore, the plastic limit and field capacity occur at approximately the same water content.

Figure 6-3: Photograph of vegetation which has experienced wilting by cooling at Kelfield Coulee. The green vegetation is on wet stratified drift and the brown vegetation is on moist till.

Figure 6-4: Photograph of the highway cut section at Kelfield Coulee. Notice the change in vegetation colour at the boundary of soil types. The newly repaired road surface is another indicator of a high soil moisture content.

autumn result in less sunlight for photosynthesis which is essential for plant growth. The reduced photosynthesis activity subsequently results in reduced water consumption. In general, all plants place less demands on the soil for water and nutrients at lower temperatures.

The decrease in botanical activity during autumn is greater in dry soils than in wet soils. As a result of the greater quantity of heat stored in wet soils by virtue of the high specific heat of water, wet soils cool more slowly than do dry soils in the autumn. Consequently, the decrease in botanical activity takes place slightly later in the season in wet soils.

Of the combination of mechanisms acting to cause wilting by cooling, those related to the soil are more influential. Clay minerals, particularly montmorillonite, will take on more absorbed water at lower temperatures because the reduced thermal-kinetic movement of water molecules allows the attractive forces of a clay particle to absorb a greater thickness of water (Yong and Warkentin, 1966).

Definitely the most influential mechanism in limiting the amount of soil water available to plants in chilled soils is the increase of surface tension at lower temperatures. Capillary water that was previously available to plants is held in the capillaries of a chilled soil at suction potentials greater than those developed by the plants.

Wilting by cooling causes a bold differentiation in the colour of the vegetation in early autumn. Without reference to species, this wilting affects all herbaceous vegetation that do not have a preferred soil moisture environment. Any indicator of small wet areas is useful to highway engineers and others, for anticipation of wet area construction problems.

6.5. HALOPHYTES

Halophytes are specially adapted for saline conditions and, as such, are good indicators of alkaline ground-water discharge areas. Ground-water hardness is descriptive of the local stratigraphy; often separate aquifer systems are distinguished by the chemical composition of their respective ground-waters. Moreover the presence of halophytes in a ground-water discharge area is a strong indicator of hard water which in turn indicates a long ground-water flow path (Meyboom, 1966b).

Osmotic effects are the most detrimetal factor to vegetation in saline areas (Bolen, 1964). Halophytes, therefore, have the ability to develop high internal osmotic potentials to counter the chemical potential of saline soil water. For example, Red samphire *(Salicornia rubra)* develops osmotic potentials from 450 to 1000 pounds per square inch (Salisbury and Ross, 1969). In order to draw water and nutrients from the soil, the halophyte must raise the concentration of its internal solutions above the concentration of the saline soil water. Accordingly the key mechanism for halophytes is the selective transport of ions (Rorison, 1969).

6.6. WATER CONSUMPTION BY VEGETATION

Plants with high rates of photosynthesis consume large quantities of water, most of which is lost to transpiration. Some plants, for example, can replace all the water within their leaves within one hour (Maximov, 1935). By comparison relatively little water is used chemically in photosynthesis.

Biedeman (1961), in a study of the influence of plants on the dynamics of ground-water, found that shallow rooted plants exert no marked influence on water consumption. Similarly, soil scientists, Pierre et al., (1966), reported that water movement in unsaturated soils is too slow to be an important factor in supplying the requirements of rapidly transpiring plants. As might be expected, the greatest amount of water removed from the ground by plants is from below the water table.

6.6.1. Previous Studies

Seasonal changes in the water table are related to transpirational activities of plants (Beideman, 1961; Meyboom, 1966a). Mayboom (1966a) installed an observation well beside a Willow-ringed slough near Saskatoon where he found the average daily drawdown was 0.2 feet per day; the nightly recovery was 0.1 feet per day. This net drawdown rate of 0.1 feet per day results in a monthly drawdown of 3.0 feet from the open ground-water system in Meyboom's study.

Trees use more water than herbaceous vegetation because they are bigger. Trees or woody plants can also exert greater osmotic potentials to ensure their high water demands are met. The following table illustrates the range of osmotic potentials of groups of vegetation in the Arizona deserts.

TABLE VI-1

OSMOTIC POTENTIALS OF PLANTS GROUPED BY SIZE, IN POUNDS PER SQUARE INCH (Maximov, 1935)

Trees and shrubs	398
Dwarf shrubs and undershrubs	305
Perennial herbs	232
Winter Annuals	209

Clements (1928) reported a study in Germany where one acre of a 115 year old oak forest absorbed from 2,200 to 2,600 gallons of water per day. This corresponds to a rainfall of three to four inches per month. The removal of these quantities of water from the soil and soil suctions of the order of three hundred pounds per square inch represent design factors toolarge to be classified as negligible for the design of civil engineering structures.

6.6.2. Engineering Applications

Geotechnical engineers as applied scientists, have a preference for quantitative data. Purely qualitative data, such as the affect of vegetation on removing water from the ground, cannot be calculated; and therefore tends to receive marginal consideration. With the development of new electronic equipment, research in plant physiology is becoming more quantitative. It is now possible to apply results from research in plant physiology to numerical solutions in geotechnical engineering. To illustrate these numerical solutions, two applications of plant physiology to civil engineering construction are presented.

The first application is a calculation of the amount of water removed from a soil by prairie vegetation in a proposed borrow pit area*. This example considered a landscaped borrow pit of 32,000 cubic yards and covering approximately six acres to an average depth of four feet in a soil with a dry density of one hundred pounds per cubic foot.

For the purposes of this example, the vegetation is Little bluestem grass *(Andropogon scorparius)*, a fairly common grass on silty to sandy soils in southern Saskatchewan. J.E. Weaver et al. (1935), found that one square foot of Little bluestem grass consumed 1.5 pounds of water during a hot and windy day on the Nebraska prairie. Although the mean daily temperature during the study in Nebraska is ten degrees Farenheit higher than the mean daily temperature in southern Saskatchewan, there is a greater average daily wind velocity in Saskatchewan; and therefore, atmospheric conditions favouring evaporation are probably very similar in the two areas.

At a rate of water consumption of 1.5 pounds per square foot per day, Little bluestem grass could reduce the natural water content of the borrow soil by 0.45 per cent per day if the soil is wet. As a soil becomes drier, it is more difficult for plants to extract water. As a result, water consumption by plants decreases with

---

* Frequently, in construction of highway embankments, more earth is needed to raise the embankment than is excavated within the highway right of way. Consequently, additional earth is excavated from small areas outside the right of way. These excavations are called borrow pits. There are basically two types of borrow pits, deep and landscaped. Deep pits are dug-outs, whereas landscaped pits are shallow and excavated to blend with the topography.

decreasing water contents in soil. Nevertheless, a loss of natural water content from a proposed borrow area at the rate of one to two per cent per week is definitely worth consideration in the design of highway embankments.

The second application is a quantitative description of the limits to which vegetation can extract water from the soils of various textures. Graphs, called moisture retention curves by botanists, show the relationship between suction and water content of a soil. These graphs indicate that soil suction increases with decreasing water content. Since plants cannot develop osmotic potentials greater than soil suction associated with lower water contents, the plants cannot draw water; and therefore they wilt. The water content at which the osmotic potential of a plant equals the soil suction is called its wilting point. A wilting point of fifteen atmospheres is commonly stated for cultivated plants. By plotting the wilting points of common plants on the moisture retention curves for till, clay and silt, it is possible to state the limits of water extraction by vegetation from each of these soils.

With reference to Figures 6-5, 6-6 and 6-7, the limits of water extraction by vegetation from till, clay and sandy loam can be assessed with respect to soil properties used in earthwork construction. The till, which has an optimum water content* of 16.5 per cent can be dried to 11 per cent water content by most species and further

---

* All optimum water contents referred to by this report are taken from the Standard AASHO compaction test. The water content at which the maximum soil density can be obtained by a constant compaction effort is the optimum water content.

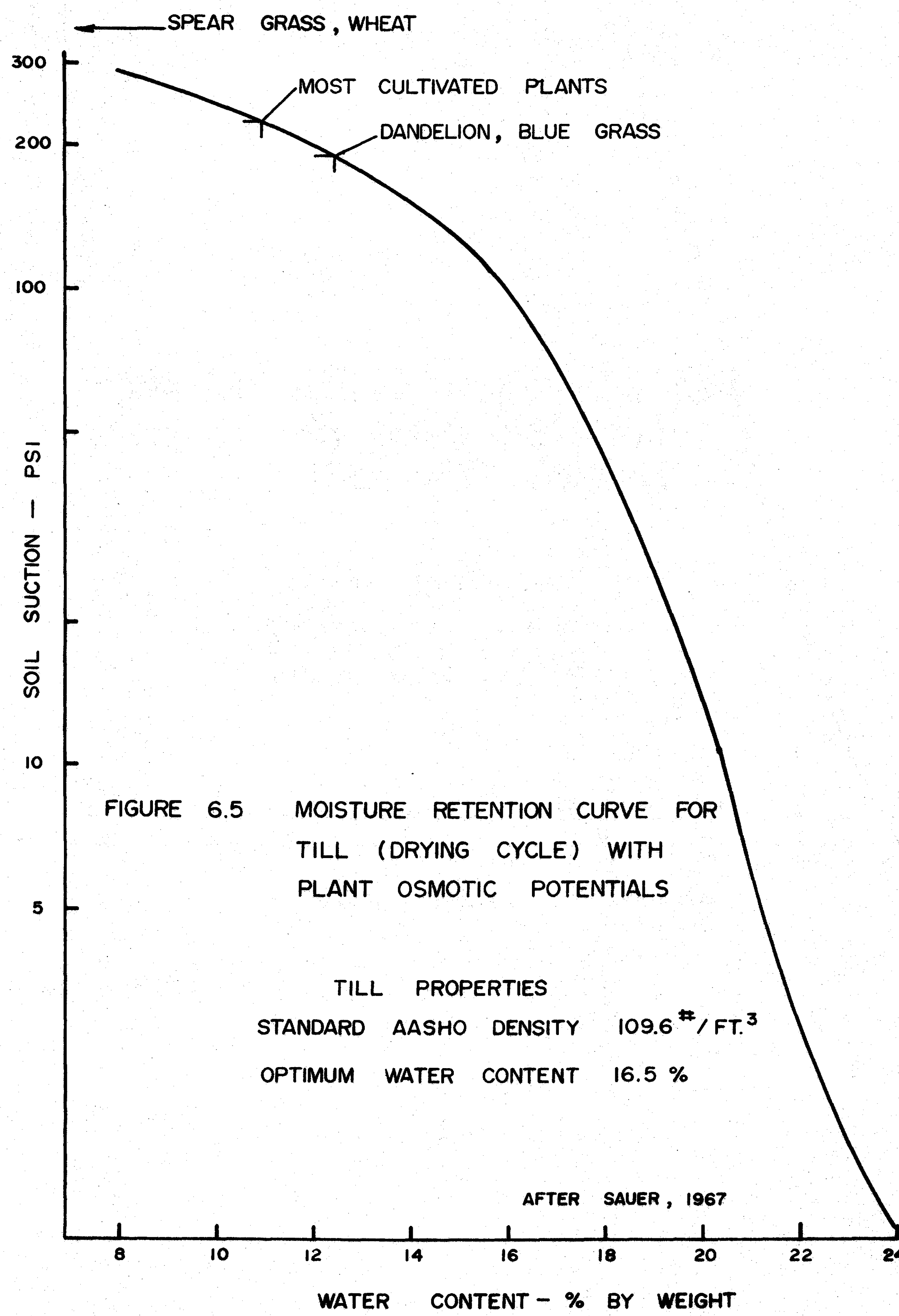


FIGURE 6.5 MOISTURE RETENTION CURVE FOR TILL (DRYING CYCLE) WITH PLANT OSMOTIC POTENTIALS

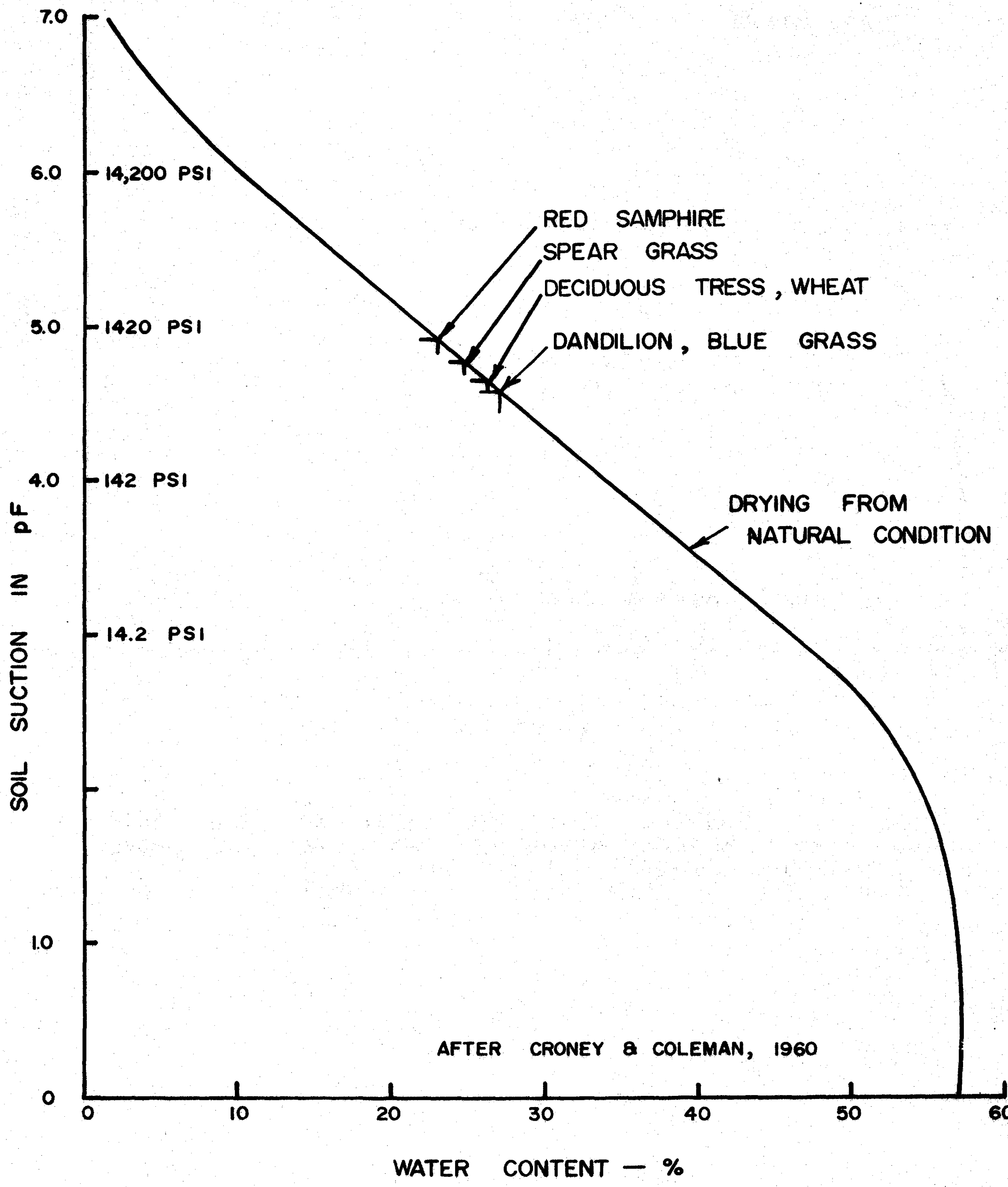


FIGURE 6.6 MOISTURE RETENTION CURVE FOR GAULT CLAY WITH PLANT OSMOTIC POTENTIALS

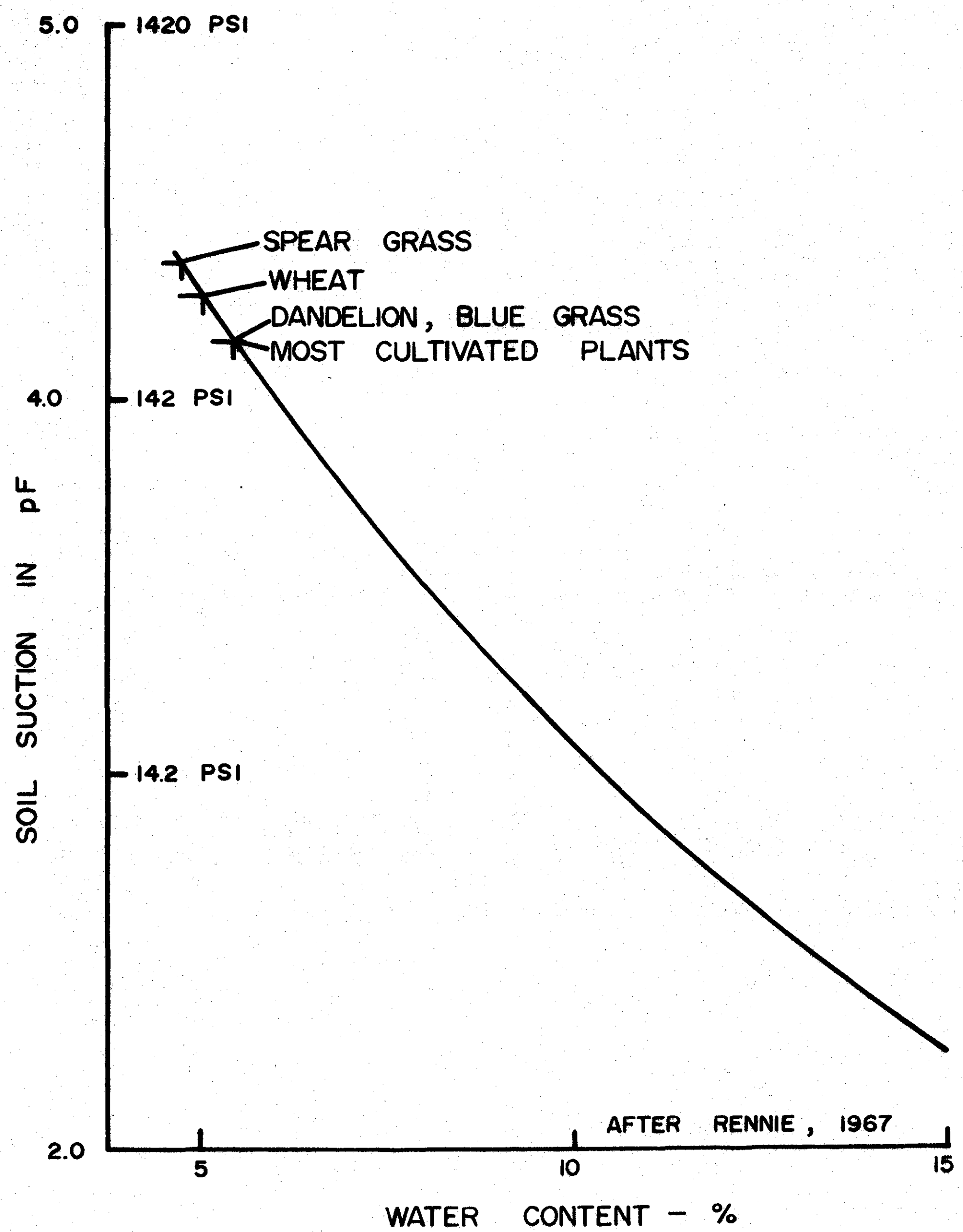


FIGURE 6.7 MOISTURE RETENTION CURVE FOR SANDY LOAM WITH PLANT OSMOTIC POTENTIALS

dried to 5 to 8 per cent water content by trees, halophytes and xerophytes.

Croney and Coleman (1960) do not give the soil properties for the Gault clay, however their moisture retention curve for Gault clay is similar to the moisture retention curve for Regina clay (Mickleborough, 1970) at lower suction values. Therefore, assuming similar soil properties between Regina clay and Gault clay, the optimum water content of Gault clay is approximately 30 per cent. Consequently, most species are able to dry clay to the optimum water content. Wheat (deJong and Rennie, 1967), trees and xerophytes can, with difficulty, further dry the clay to about 5 per cent below optimum water content. As can be seen, vegetation has little effect on drying clay below optimum water content.

Soil desiccation by vegetation is greatest in silty and sandy soils as a result of their inability to develop high soil suctions. Most species can easily exert osmotic potentials to draw water from the sandy loam shown in Figure 6-7 down to 5 per cent water content. This sandy loam is approximately ten per cent clay, twenty per cent silt and seventy per cent sand. This soil would have an optimum water content of approximately 10 to 12 per cent. As in the case of the till shown in Figure 6-5, sandy loam can be readily desiccated more than 5 per cent below optimum water content.

The reduction of natural water contents in soil in borrow areas relates directly to the cost and quality of earthwork construction. Soils at water contents greater than optimum water content, particularly silt, tend to displace under the weight of compaction equipment. On the other hand soils at water contents below optimum water content require extra compaction effort to obtain an acceptable degree of compaction. Therefore, earthwork construction is best done with soils near their optimum water content. However, wetting or drying operations in earthwork construction increase the total construction cost. For these reasons there is merit in encouraging plant growth in soils above optimum water content and discouraging plant growth in soils below optimum water content.

6.7. SUMMARY

This chapter has not provided the complete list of mechanisms causing vegetation indicators of terrain conditions. Nevertheless, the mechanisms discussed illustrate the intimate and complex relationships between vegetation and environment. As a result of these mechanisms, species distribution follows established rules; and therefore, vegetation can be a reliable indicator of terrain conditions.

Adaptations by some species equip them to occupy areas where environmental conditions exclude all other vegetation. Information was presented about the adaptations of xerophytes and halophytes. As a result of adaptations, or more so, lack of adaptations, many species are limited to a very narrow range of environmental conditions. For example, phreatophytes must have their roots reach into a permanent water supply in order to grow. The phreatophyte's inability to reduce its water losses to transpiration limits its growth to areas where the water table is within reach of its roots. Consequently, vegetation indicators of terrain conditions are based on adaptations or lack of adaptations which limit species distribution to a very narrow range of environmental conditions.

In knowledge of the limited distribution of some species, it is possible to develop vegetation-terrain relationships as a result of empirical observations. The relationship between healthy, green vegetation and areas of preferred moisture supply during cool autumn weather was developed from empirical observations. This relationship was further developed by taking plant samples for later identification by botanists. Many botanists will be able to describe the preferred habitat of species and thereby provide an explanation of the botanical aspects of the vegetation-terrain relationship. With the addition of the geotechnical explanation of the environmental conditions, there can be a synthesis of these two explanations to produce an understanding of the vegetation-terrain relationship and the limitations of its use as a vegetation indicator of terrain conditions.

As a result of information put forward in this Chapter regarding water consumption by vegetation, civil engineers could become more cognizant of vegetation's influence as a design factor in planning their structures. In the case of foundation design, the possibility of settlement from soil desiccation by vegetation can be assessed by plotting the osmotic potentials of the local vegetation on the moisture retention curves for the foundation soil. If the local vegetation has the ability to remove enought water to cause soil shrinkage, then the foundation design should anticipate shrinkage settlement.

Similarly, water consumption by vegetation can be controlled in soils designated for borrow excavation in earthwork construction. As a result of soils investigations before construction, it is possible to select a known moisture retention curve for a soil with similar soil properties. As in the case of foundation design, the osmotic potentials of the local vegetation is plotted on the moisture retention curve for the borrow soil. Then, early in the growing season, the proposed borrow soil is tested for natural water content. If the soil moisture is over optimum water content, then the vegetation growth should be encouraged in order to bring the natural water content towards the optimum water content. On the other hand, vegetation growth on soils which are dry of their optimum water content should be discouraged by clearing, grubbing or summer-fallowing. By this management of vegetation to modify natural water contents of proposed borrow soils, it is possible, in some cases, to control the soil moisture parameter which previously was considered a natural condition to be accepted.

CHAPTER VII

CONCLUSIONS

7.1. INTRODUCTION

This report deals with the terrestrial applications of vegetation indicators of terrain conditions for engineering purposes in southern Saskatchewan. As a result of its arid climate, this region has a narrow ecological margin of safety. Consequently, this region is well suited for the application of vegetation indicators of terrain conditions. The field study conducted in the Langham Study Area found vegetation an excellent indicator of subtle terrain conditions that otherwise could only be detected by more elaborate techniques. Accordingly, the use of vegetation indicators for terrain evaluation is recommended.

7.2. CHARACTERISTICS OF VEGETATION INDICATORS

The terrain evaluation of an area should consider as many aspects of the total environment as possible because these aspects are intimately interrelated parts of the total. Vegetation is an expression of some of the aspects of the dynamic total environment and as such is an indicator of environmental conditions for those who understand plant ecology.

Many plant species have highly specialized adaptations which equip them to survive under unique terrain conditions. These specialized vegetation-terrain relationships form the basis for vegetation indicators of terrain conditions.

Good indicator species have narrow ecological amplitudes; in addition, they are distinctive and dependable.

Both vegetation and the mechanical properties of soil are functions of soil type and environment. As an indicator of soil type and environment, vegetation is also an indicator of the mechanical properties of soil.

Vegetation indicators of terrain conditions are well suited for application during the initial terrestrial reconnaissance of an area. Essentially this application is an interpretation of the vegetation's response to prevailing environmental conditions.

Vegetation indicators, like any other indicator of terrain conditions, draw attention to terrain conditions that are subsequently confirmed in the field. To expect direct, positive identification of a terrain condition from vegetation indicators is to exceed the purpose for which vegetation indicators are intended. That purpose is to draw attention to subtle terrain conditions that otherwise would not be detected during the initial terrestrial reconnaisance of an area.

7.3. APPLICATIONS OF VEGETATION INDICATORS

Herbs and shrubs are more reliable indicators of edaphic conditions than either trees or low-growing annuals. Unfortunately, heavy grazing removes these reliable indicator species from some areas.

A plant community is a better indicator of terrain conditions than any single species of that community.

In the Langham Study Area, the number of different species in an area is proportional to the water content of the soil. Dry habitats have few different species whereas wet habitats have many different species.

The general well-being of vegetation is an indicator of the suitability of the habitat for that vegetation.

Changes in soil moisture, ground-water chemistry or soil texture often occur as sharp boundaries. The corresponding sharp change in the species composition in the vegetation can be identified readily without training in species identification.

The species-moisture regime relationships for wetlands are applicable through the Northern Great Plains Region which includes southern Saskatchewan.

Vegetation-terrain relationships are subject to many exceptions as a result of compensation by edaphic and climatic factors.

7.4. INTERDISCIPLINE COMMUNICATIONS

Communications amongst persons in the different disciplines included in this project were much better than anticipated at the beginning of the project. A mutual understanding of basic sciences was the medium for discussion, whereas technical terminology, peculiar to each discipline, was a barrier to smooth communications. On the basis of the experience in this project, a lack of knowledge of another discipline's work and the fear of the inability to communicate are not valid arguments for the lack of interdisciplinary approaches to problems of the environment.

7.5. THE LANGHAM STUDY AREA

Vegetation indicators were successfully applied as one of the terrain evaluation techniques used in the Langham Study Area. Vegetation indicated soil moisture conditions, soil texture and soil boundaries, dates of water levels in ponds, ground-water chemistry and disturbed areas. Furthermore, several very good indicator species are present in the study area. These species are shown in Table VII-1. As a result of the satisfactory application of vegetation indicators in the Langham Study Area, their more extensive use is recommended.

7.6. FURTHER STUDIES

There is insufficient evidence to support the statement that there is a relationship between vegetation and the stratigraphic boundaries between till units in southern Saskatchewan. There are, however, field observations of this relationship. Further studies would establish if the subtle differences in edaphic factors across these stratigraphic boundaries cause abrupt vegetation changes and if this relationship is generally applicable in southern Saskatchewan.

Another project for study has immediate economic ramifications to highway engineering. This project would assess the sensitivity of the Canadian Wildlife Survey method of dating slough water levels by vegetation for designating water levels for highway embankment design.

7.7. VEGETATION AS A DESIGN FACTOR IN CIVIL ENGINEERING

A method of predicting potential foundation settlement problems caused by soil shrinkage upon desiccation by vegetation has been shown. It involves comparing plant wilting point osmotic potentials with moisture retention characteristics of the foundation soil.

A similar procedure is used to manage the vegetation on areas of proposed borrow pits for highway embankment construction in order to partially control the moisture content of the borrow soil to acceptable levels for highway construction.

TABLE VII-1

SUMMARY OF VEGETATION-TERRAIN RELATIONSHIPS FOR SIGNIFICANT INDICATOR SPECIES IN THE LANGHAM STUDY AREA

SPECIES	Site Location	Terrain Condition in the Langham Study Area	DOCUMENTED TERRAIN CONDITION Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
DRY PRAIRIE:						
Little Club-moss *(Selaginella densa)*	I,II	Dry silty soil, open prairie	Dry and open prairie, dry, light soils			
Three-flowered avens *(Geum triflorum)*	I,II	Dry prairie, just below crest of ravine	Plentiful on open prairie			
ECOTONE:						
Buffaloberry *(Shepherdia canadensis)*	I,II,III, IV,VI	In areas sheltered by vegetation or topography	River banks and wooded areas			
Chokecherry *(Prunus virginiana var. melanocarpa)*	I-IX	In areas sheltered by vegetation or topography	In bluffs, ravines and hillsides			
Rose *(Rosa spp.)*	I-X	In areas sheltered by vegetation or topography	In bluffs, ravines and hillsides			
Snowberry (Western) *(Symphoricarpos occidentalis)*	I-X	In areas sheltered by vegetation or topography	Open prairie, ravines and woodlands. Most wide spread shrub		Common to Low-prairie	
Wolf-willow *(Elaeagnus commutata)*	I-IX	Equally, sheltered areas and moist, light soils	Moist, light soils			

Table VII-1: Continued

SPECIES	Site Location	Terrain conditions in the Langham Study Area	DOCUMENTED TERRAIN CONDITION			
			Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
MOIST PRAIRIE:						
American vetch *(Vicia americana)*	II,VII, VIII,IX	Sheltered areas with preferred soil moisture area	Very common around bluffs and shady parts of prairie			Wet Meadow
Balsam Poplar *(Populus balsamifera)*	I, II	Preferred soil moisture areas and wet areas, with or without shelter	Near water and wet ground			
Buffaloberry *(Shepherdia canadensis)*	I-IV, VI	In areas sheltered by vegetation or topography	River banks and wooded areas			
Chokecherry *(Prunus virginiana var. melanocarpa)*	I-IX	In areas sheltered by vegetation or topography	Bluffs, ravines and hillsides			
Common nettles *(Urtica dioica var. procera)*	VII, X	Moist disturbed areas	Around sloughs, moist places and in bushes			Wet Meadow
Dogwood (Red-osier) *(Cornus stolonifera)*	I-X	Sheltered hillside areas of snow lodgement,slightly preferred soil moisture conditions or above wet areas	Woodlands and coulees in eastern portion of Candian prairie			

Table VII-1: Continued

SPECIES	Site Location	Terrain conditions in the Langham Study Area	DOCUMENTED TERRAIN CONDITION			
			Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
MOIST PRAIRIE (Cont.)						
Hazelnut (Beaked) *(Corylus cornuta)*	I,IV-VI VIII	Well sheltered area of slightly preferred soil moisture conditions	Woodlands and moist hillsides			
Pin cherry *(Prunus pensylvanica)*	IV,V,VII	Well sheltered area of slightly preferred soil moisture conditions	Bluffs, ravines, and hillsides			
Rose *(Rosa spp.)*	I-X	In areas sheltered by vegetation or topography	Bluffs, ravines and hillsides			
Saskatoon *(Amelanchier alnifolia)*	I	Open woodlands on moist, nutrient-rich soils	Coulees, bluffs and open woodlands			
Snowberry (Western) *(Symphoricarpos occidentalis)*	I-X	In areas sheltered by vegetation or topography	Open prairie, ravines and woodlands. Most wide spread shrub			
Strawberry *(Fragaria spp.)*	I,III-IX	Sheltered and shaded areas with slightly preferred soil moisture conditions	Moist woods or moist prairie depending on species		Occasional in Low-prairie	
Wild licorice *(Glycyrrhiza lepidota)*	II,VII	Wet areas, near open water	Low spots on prairie, slough margins, coulees		Common in Low-prairie	Wet Meadow

Table VII-1: Continued

SPECIES	Site Location	Terrain conditions in the Langham Study Area	DOCUMENTED TERRAIN CONDITION			
			Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
MOIST PRAIRIE (Cont.)						
White Birch *(Betula papyrifera)*	I,VI	Hillsides at locations of minor amounts of seepage	Along streams and river banks			
Wolf-willow *(Elaeagnus commutata)*	I-IX	Equally, sheltered areas and moist, light soils	Moist, light soils			
<u>MOIST WOODS</u>:						
Dogwood (Red-osier) *(Cornus stolonifera)*	I-X	Sheltered hillside areas of snow lodge -ment, slightly preferred soil moisture conditions or above wet areas	Woodlands and coulees in eastern portion of Canadian prairie			
Hazelnut (Beaked) *(Corylus cornuta)*	I,IV-VI	Well sheltered areas of slightly preferred soil moisture conditions	Woodlands and moist hillsides			
High bush cranberry *(Viburnum trilobum)*	I,IV,VII VIII	Moist, shaded wood-lands with nutrient rich soils (colluvium)	Woodlands in heavier wooded parts			
Meadow-rue *(Thalictrum sp.)*	II,VII-IX	Cool,moist,shaded woods	Moist woodlands			
Northern bedstraw *(Galium boreale)*	VII,IX	Cool, moist, open woods	Openings in wood-lands, along the roadside, moister places on prairie			Wet meadow

Table VII-1: Continued

SPECIES	Site Location	Terrain conditions in the Langham Study Area	DOCUMENTED TERRAIN CONDITION			
			Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
MOIST WOODS (Cont.)						
Pin cherry *(Prunus pensylvanica)*	IV,V, VIII	Well sheltered areas of slightly preferred soil moisture conditions	Bluffs, ravines and hillsides			
Snakeroot *(Sanicula marilandica)*	II, VII, VIII	Cool, moist shaded woods, just above bogs	Moist, rich woodlands			
Strawberry *(Fragaria spp.)*	I, III-IX	Sheltered, shaded areas	Moist prairie, moist woods, depending on species		Occasionally in Low-prairie	
Wintergreen *(Pyrola spp.)*	II, IX	Cool, moist, shaded woods	Moist woodlands and bluffs			
Wood's rose *(Rosa woodsii)*	II	Cool, moist shaded woods	Bluffs, ravines and sand hills		Common in Low-prairie	
<u>WET AREAS:</u>						
Balsam poplar *(Populus balsamifera)*	I, II VI-X	Preferred soil moisture areas and wet areas, with or without shelter	Near water and wet ground			
Creeping spike rush *(Eleocharis palustris)*	II	Slightly brackish wet area	Wet places and slough margins	Dry Meadow to Aquatic, non-saline to moderately saline water	Shallow-meadow, fresh to brackish water	Shallow Marsh

Table VII-1: Continued

SPECIES	Site Location	Terrain conditions in the Langham Study Area	DOCUMENTED TERRAIN CONDITION			
			Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
WET AREAS (Cont.)						
"Feather moss"	II, VII-X	Shaded moist areas and wet areas				
Horsetail (Common) *(Equisetum arvense)*	II, VII-IX	Just above open water. Excellent indicator	Wet places, on sandy soils			Wet Meadow
Narrow reed grass *(Calamagrostis neglecta)*	VIII, IX	Bogs or beside open water	Wet and marshy site			
River birch *(Betula occidentalis)*	VIII	Sheltered hillside with small amounts of seepage	Low places, stream bank and depressions in sand hills			
Sedge *(Carex spp.)*	II, VII-X	Wet areas, bogs	Depends on species, most prefer wet areas			
Water sedge *(Carex aquatalis)*	IX-4B X	Slightly brackish bogs	Wet places, swamps and marshes		Frequent in alkaline bogs	
Slough grass *(Beckmannia syzigachne)*	II	Slightly brackish bogs. Excellent indicator of wet places	In water in sloughs and moist places	Dry meadow to Shallow Marsh, non-saline to moderately saline water	Shallow-marsh, fresh to brackish water	Shallow Marsh
Sow thistle *(Sonchus arvensis)*	II, VII IX, X	Wet areas, beside open water, fresh to slightly brackish water	Very common in moister districts and wet places	Dry Meadow, non-saline to moderately saline water	Wet-meadow, fresh to slightly brackish water	Wet Meadow

Table VII-1: Continued

SPECIES	Site Location	Terrain conditions in the Langham Study Area	DOCUMENTED TERRAIN CONDITION			
			Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
WET AREAS (Cont.)						
Swamp birch *(Betula glandulifera)*	IX	In a wet bog	Swamps and bogs			
Western water-horehound *(Lycopus asper)*	VII,IX X	On bogs and permanently wet places	Wet places and swamps	Dry Meadows, slightly saline water	Wet-meadows, slightly brackish to brackish water	Wet Meadows
Wild mint *(Mentha arvensis var. villosa)*	II, VIII	On bogs and beside open water	Sloughs and wet places, often in water	Dry Meadow to Shallow Marsh, non-saline to moderately saline water	Wet-meadow, fresh water	Wet Meadow
Willow *(Salix spp.)*	II, V-X	In wet areas, or beside open water	Most species found in distinctly wet places such as bogs marshes and beside sloughs			Wet Meadow
WET BRACKISH AREA:						
Fowl manna grass *(Glyceria striata)*	II, VII	Wet places, II is slightly brackish; VII is fresh water	Wet and marshy places		Common on alkaline bogs	Shallow Marsh
Seaside arrow grass *(Triglochin maritima)*	II	Wet area,slightly brackish water	Marshy and wet places	Dry and Wet meadow, moderately saline water	Wet-meadow, brackish to sub-saline water. Common on alkaline bogs	Wet Meadow

Table VII-1: Continued

SPECIES	Site Location	Terrain conditions in the Langham Study Area	DOCUMENTED TERRAIN CONDITION			
			Budd & Best (1964)	Walker (1968)	Stewart and Kantrud (1969)	Millar(1969)
WET BRACKISH AREA (Cont.)						
Slough grass *(Beckmannia syzigachne)*	II	Wet area, slightly brackish water	In water, in slough and moist places	Dry Meadow to Shallow Marsh, non-saline to moderately saline water	Shallow-marsh, fresh to moderately brackish water	Shallow Marsh
Water sedge *(Carex aquatalis)*	II, IX-4B, X	Wet areas, slightly brackish water	Wet places, swamps and marshes		Frequent on alkaline bog	
Western water hemlock *(Cicuta douglasii)*	II, X	Wet area, slightly brackish water	Wet marshy places, stream banks, lake shores	Dry Meadow very saline		Wet Meadow
<u>DISTURBED AREAS</u>:						
Awnless brome *(Bromus inermis)*	II, VIII IX	Dry waste places	Roadsides and waste places, pasture seeding			
Common nettles *(Urtica dioica var. procera)*	VII, IX X	Disturbed areas with a slightly preferred soil moisture condition	Around sloughs, moist places and in bushes			Wet Meadow
Russian pigweed *(Axyris amaranthoides)*	II, VII	Dry disturbed or waste areas	Abandoned lands, waste places, cultivated land and shelter belts			

7.8. MAN'S INFLUENCE ON VEGETATION

As a result of the intimate relationship between vegetation and the environment, vegetation is used by civil engineers as an indicator of terrain conditions. It is, therefore, exigent that civil engineers apply these same relationships to predict the affect on vegetation of their manipulations of the natural environment.

However, the prediction of the impact of civil engineering works on the vegetation is not enough. Often, violations of the rules of ecology have had undesirable ramifications to these works as well as to the environment. Vegetation-terrain relationships should be used to design projects such that they will be more in harmony with the natural environment. Moreover, the aesthetic quality of these projects would also improve if the revegetation of denuded areas was planned at the design stage.

Good engineering practice requires correcting problems before they occur. There is no reason why good engineering practice could not be extended to planning a modified environment conducive to revegetation.

REFERENCES CITED

Acton, D.F., Clayton, J.S., Ellis, J.G., Christiansen, E.A., Kupsch, W.O., 1960. Physiographic Divisions of Saskatchewan. Established by the Saskatchewan Soil Survey in cooperation with the Geology Division, Saskatchewan Research Council, and Geology Department, University of Saskatchewan, Saskatoon.

Allread, B.W., and Clements, Edith S., 1949. Dynamics of Vegetation. Selections from Writings of Fredric E. Clements. The H.H. Wilson Company, New York.

Anderson, D.H., 1971. Terrain Evaluation of the Waskesiu. Term Project. Civil Engineering course 864A, University of Saskatchewan, Saskatoon.

Ashby, Maurice, 1969. Introduction to Plant Ecology, Second Edition: The MacMillan Company, Toronto.

Ayyad, M.A.G., and Dix, R.L., 1964. An Analysis of Vegetation-Microenvironmental Complex on Prairie Slopes in Saskatchewan: Ecological Monographs, Volume 34.

Biedeman, I.N., 1965. The Significance of Coedificators in the Indicator Properties of Plant Communities. Plant Indicators of Soils, Rocks and Subsurface Waters. Edited by A.G. Chikishev: Consultant's Bureau, New York.

Bolen, Eric G., 1964. Plant Ecology of Spring-Fed Salt Marshes in Western Utah: Ecological Monographs, Volume 34.

Buck, Paul, 1964. Relationships of the Woody Vegetation of Witchita Mountains Wildlife Refuge to Geological Formations and Soil Types: Ecology, Volume 45.

Budd, Archibald C., and Best, Keith F., 1964. Wild Plants of the Canadian Prairies: Queen's Printer, Ottawa.

Chikishev, A.G., 1965. Relationship of the Vegetation Cover to Climatic and Soil-Lithological Conditions in the Central Urals. Plant Indicators of Soils, Rocks and Subsurface Waters, Edited by A.G. Chikishev: Consultant's Bureau, New York.

Christiansen, E.A., 1968. Pleistocene Stratigraphy of the Saskatoon Area, Saskatchewan, Canada: Canadian Journal of Earth Sciences, Volume 5.

Christiansen, E.A., (editor), 1970. Physical Environment of Saskatoon Canada: Saskatchewan Research Council, N.R.C. Publication Number 11378, Ottawa.

Clements, Fredric E., 1928. Plant Succession and Indicators: The H.H. Wilson Company, New York.

Clifton, A.W., 1966. Highway Engineering in Northern Saskatchewan: Unpublished M.Sc. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Colwell, Robert N. 1970. Determining Crop Vigor. Remote Sensing with Special Reference to Agriculture and Forestry: National Academy of Sciences, Washington, D.C.

Concise Oxford Dictionary of Current English, 1964. Fifth edition. H.W. Fowler and F.G. Fowler (editors): Clarendon Press, Oxford.

Coupland, R.T., 1950. Ecology of Mixed Prairie in Canada: Ecological Monographs, volume 20.

Coupland, R.T., and Johnson, R.E., 1965. Rooting Characteristics of Native Grassland Species in Saskatchewan: Journal of Ecology, volume 53.

Coupland, R.T., and Rowe, J.S., 1969. Natural Vegetation of Saskatchewan. Atlas of Saskatchewan: J. Howard Richards (editor), University of Saskatchewan, Saskatoon, Modern Press.

Croney, D., and Coleman, J.D., 1961. Pore Pressure and Suction in Soil. Pore Pressure and Suction in Soil. Butterworths, London.

Daubenmire, R., 1957. Influence of Temperature upon Soil Moisture Constants and its Possible Ecological Significance. Ecology, volume 38.

deJong, E., 1967. Soil Moisture Retention. Soil Plant Nutrient Report, compiled by D.A. Rennie: Saskatchewan Institute of Pedology, Report No. M6 (mimeographed).

deJong, E., and Rennie, D.A., 1967. Physical Soil Factors Influencing the Growth of Wheat: Proceedings of the Canadian Centennial Wheat Symposium, K.F. Nielsen (editor).

Dodd, J.D. and Coupland, R.T., 1966. Vegetation of Saline Areas in Saskatchewan: Ecology, volume 47.

Ellis, J.G., 1969. An Evaluation of Saskatchewan Soils Maps and Reports. Saskatoon Wetlands Seminar: Canadian Wildlife Service Report Series No. 6., Queen's Printer, Ottawa.

Gates, Dillard H., Stoddart, L.A., and Cook, C. Wayne, 1956. Soil as a Factor Influencing Plant Distribution on Salt Deserts of Utah: Ecological Monographs, volume 26.

Hanson, Herbert C., 1962. Dictionary of Ecology: Philosophical Library Inc., New York.

Heller, Robert C., 1970. Imaging with Photographic Sensors. Remote Sensing with Special Reference to Agriculture and Forestry: National Academy of Sciences, Washington, D.C.

Hilgard, E.W., 1860. Report on the Geology and Agriculture of the State of Mississippi, volume 2, p. 202 (Reprinted by Clements, 1928).

Hullet, G.K., 1962. Species Distribution Patterns in Dune Sand Areas in the Grasslands of Saskatchewan: Unpublished Ph.D. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Küchler, A.W., 1967. Vegetation Mapping. The Ronald Press Company, New York.

Leach, William., 1956. Plant Ecology, Fourth Edition: John Wiley and Sons Inc., New York.

Legget, R.F., and Crawford, C.B., 1965. Trees and Buildings. Canadian Building Digest, Division of Building Research, National Research Council, Ottawa, CBD 62.

Lynch, Daniel, 1955. Ecology of the Aspen Groveland in Glacier County Montana: Ecological Monographs, volume 25.

MacDonald, A.B., 1969. Drift Stratigraphy in Terrain Evaluation. Unpublished M.Sc. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Mason, H.L., 1946. The Edaphic Factor in Narrow Endemism. No. 1, The Nature of Environmental Influences: Madorno, volume 8.

Maximov, N.A., 1935. The plant in Relation to Water (A translation): George Allen and Unwin Limited, London.

Metz, D.G., 1970. Personal Communications.

Meyboom, Peter, 1966a. Unsteady Ground-water Flow Near a Willow Ring in Hummocky Moraine: Journal of Hydrology, volume 4.

Meyboom, Peter, 1966b. Ground-water Studies in the Assiniboine River Drainage Basin, Part I. The Evaluation of a Flow System in South-Central Saskatchewan: Geological Survey of Canada, Bulletin 139.

Mickleborough, B.W., 1970. An Experimental Study of the Effects of Freezing on Clay Subgrades: Unpublished M.Sc. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Millar, J.B., 1969. Some Characteristics of Wetland Basins in Central and Southwestern Saskatchewan. Saskatoon Wetlands Seminar. Canadian Wildlife Service Report, Series No. 6., Queen's Printer, Ottawa.

Mitchell, John., Moss, H.C., Clayton, J.S., 1944. Soil Survey of Southern Saskatchewan from Township 1 to 48 Inclusive. Saskatchewan Soil Survey, Report No. 12.

Morrison, B., 1969. A Sidewall Sampler. Canadian Geotechnical Journal, Volume 6, No. 4.

Moss, E.H., 1932. The Vegetation of Alberta IV., The Poplar Association and Related Vegetation of Central Alberta. Journal of Ecology, volume 20.

Ostrovskii, V.N., 1965. The Zonal Distribution of Subsurface Waters in the Southwestern Part of the Zaisonsk Depression and its Reflection in the Plant and Soil Cover. Plant Indicators of Soil, Rocks and Subsurface Waters, Edited by A.G. Chikishev. Consultant's Bureau, New York.

Peterson, R., Jaspar, J.L., Rivard, P.J. and Iverson, N.L., 1960. Limitations of Laboratory Shear Strength in Evaluating Stability of Highly Plastic Clays. ASCE Research Conference on Shear Strength of Cohesive Soils, Boulder, Colorado.

Pierre, W.H. (editor), 1966. Plant Environment and Efficient Water Use. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin.

Popova, T.A., 1965. Hydrologic Indicator Properties of the Vegetation in Zones of Inadequate Moisture and Their Representation in Aerial Photographs. Plant Indicators of Soils, Rocks and Subsurface Waters, Edited by A.G. Chikishev, Consultants Bureau, New York.

Rorison, I.H. (editor), 1969. Ecological Aspects of the Mineral Nutrition of Plants. A Symposium of the British Ecological Society. Blackwell Scientific Publications, Oxford.

Rowe, J.S., 1956. Uses of Undergrowth Plant Species in Forestry. Ecology, volume 37.

Rowe, J.S., 1959. Forest Regions of Canada. Bulletin 123, Department of Northern Affairs and Natural Resources, Forestry Branch, Canada.

Rowe, J.S., 1968. The Ecology of Some Important Forest Species. Forest-Soils Workshop Proceedings. Saskatchewan Institute of Pedology Publication M10, University of Saskatchewan, Saskatoon (Mimeographed).

Salisbury, F.B., and Ross, Cleon, 1969. Plant Physiology. Wadsworth Publishing Company, Belmont, California.

Sauer, E.K., 1964. Landform Analysis in Saskatchewan Highway Engineering. Unpublished M.Sc. Thesis, Cornell University, Ithica, New York.

Sauer, E.K., 1967. Application of Geotechnical Principles to Highway Engineering. Unpublished D. Eng. Thesis, University of California, Berkely, California.

Shavyrina, A.V., 1965. On the Possibility of Using the Geobotanical Method in the Search for Fresh Water in Southern Deserts. Plant Indicators of Soils, Rocks and Subsurface Waters. Edited by A.G. Chikishev, Consultants Bureau, New York.

Skempton, A.W., 1954. A Foundation Failure Due to Clay Shrinkage Caused by Poplar Trees. Proceedings, Institute of Civil Engineers, volume 1.

Skoglund, N.A., 1970. Personal communication.

Sloan, C.E., 1967. Ground-Water Movements as Indicated by Plants in the Prairie Pothole Region. Glacial Geology of the Missouri Coteau and Adjacent Areas (18th Annual Field Conference of the Midwest Friends of the Pliestocene). North Dakota Geological Survey Miscellaneous Series 30, Bismark, North Dakota.

Stanley, Oran B., 1938. Indicator Significance of Lesser Vegetation in the Yale Forest near Keene, New Hampshire. Ecology, volume 19.

Sutcliffe, J.F., 1962. Mineral Salts Absorption in Plants. Pergammon Press, London.

Tsatsenkin, I.A., 1966. The Elaboration of Ecological Scales for Pasture and Hay Meadow Plants of the U.S.S.R. (translated). Transactions of the Moscow Society of Naturalists, volume 27, Moscow.

Vereiskii, N.G., and Vostokova, E.A. (editors), 1963. Guidebook for Determining Lithological Composition of Surface Deposits and Depth of Occurrence of Ground Waters. Moscow. Translated by A. Gourevitch, Israel Program for Scientific Translations, Jerusalem, 1966.

Viktorov, S.V., Vostokova, Ye.A., and Vyshivkin, D.D., 1964. Short Guide to Geo-Botanical Surveying. Translated by J.M. MacLennan. The MacMillan Co., New York.

Viktorov, S.V., Vostokova, Ye.A., and Yvshivkin, D.D., 1965. Some Problems in the Theory of Geobotanical Indicator Research. Plant Indicators of Soils, Rocks and Subsurface Waters. Edited by A.G. Chikishev, Consultants Bureau, New York.

Vinogardov, B.V., 1965. Ecological Compensation and Replaceability and the Extrapolation of Plant Indicators. Plant Indicators of Soils, Rocks and Subsurface Waters. Edited by A.G. Chikishev, Consultants Bureau, New York.

Voronkova, L.F., 1965. Geobotanical Features of the Evolution of the Mineralization of Fresh-Water Lenses in the Sam Sands. Plant Indicators of Soils, Rocks and Subsurface Waters. Edited by A.G. Chikishev, Consultants Bureau, New York.

Walker, B.H., 1966. The Vegetation of Non-Saline Sloughs in South Central Saskatchewan. Unpublished M.Sc. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Walker, B.H., 1968. Ecology of Herbaceous Wetland Vegetation in the Aspen Grove and Grassland Regions of Saskatchewan. Unpublished Ph.D. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Walker, B.H., and Coupland, R.T., 1970. Herbaceous Wetland Vegetation in the Aspen Grove and Grassland Regions of Saskatchewan. Canadian Journal of Botany, volume 48.

Weaver, J.E., 1958. Classification of Root Systems of Forbs of Grassland and a Consideration of their Significance. Ecology, volume 39.

Weaver, J.E., Stoddart, L.A., and Noil, William, 1935. Response of the Prairie to the Great Drought of 1934. Ecology, volume 16.

Woeslander, A.E., and Storie, R.E., 1953. Vegetational Approach to Soil Surveys on Wildland Areas. Proceedings of Soil Science Society of America, volume 17.

Yong, R.N., and Warkentin, B.P., 1966. Introduction to Soil Behavior. The MacMillan Company, New York.

APPENDICES

APPENDIX A

GLOSSARY OF BOTANICAL AND ECOLOGICAL TERMS

APPENDIX A

AMPLITUDE

See ECOLOGICAL AMPLITUDE

ANAEROBIC

Refers to life or activity in the absence of free oxygen (Hanson, 1962).

ASPEN GROVE SECTION

A natural vegetation region that crosses Saskatchewan diagonally from north-west to south-east. This vegetation region lies between the prairie grasslands to the south and the BOREAL FOREST to the north. In a local sense, an aspen grove is a bluff in which the dominant tree is the Trembling aspen.

ASSOCIATION

See PLANT ASSOCIATION

BIOTIC FACTORS

Environmental influences caused by plants or animals such as shading by trees or trampling by animals (Hanson, 1962).

BOREAL FOREST

A natural vegetation region characterized by cool, moist forests of Black spruce, White spruce, Jack pine and Trembling aspen. In Saskatchewan this region lies north of Prince Albert.

BRYOPHYTES

Plants in the phylum Bryophyta comprising mosses, liverworts, and hornworts (Hanson, 1962).

CANOPY

The uppermost layer of vegetation consisting of crowns of trees or shrubs in a forest or woodland (Hanson, 1962).

CHLOROPHYLL

The green pigments contained in plants. This substance synthesises carbohydrates from carbon dioxide and water using light as energy in PHOTOSYNTHESIS.

CLIMAX

The kind of community capable of perpetuation under the prevailing climatic and edaphic conditions; the terminal stage of a SERE (series) under the prevailing conditions (Hanson, 1962).

COMMUNITY

See PLANT COMMUNITY

COMPENSATION

Similar vegetation may be found in different habitats as a result of compensation amongst the ecological factors to, in effect, produce the same environmental influence on a community despite a difference in habitats. For example, a species may be able to extract brackish water from a sandy soil but the soil water would have to be fresh for the same species to draw water from a clay soil.

DRY PRAIRIE

A habitat classification used in this report to designate prairie sites that are dry and without any shelter from wind or sun.

DISTURBED

A habitat classification used in this report to designate areas disturbed by man's activities and then abandoned.

ECOLOGICAL AMPLITUDE

The range of one or more environmental conditions in which an organism or a process can function (Hanson, 1962).

ECOLOGY

The study of the interrelationships of organisms to one another and to the environment (Hanson, 1962).

ECOTONE

1. A transitional line or strip of vegetation between two communities which has characteristics of both kinds of neighboring vegetation as well as characteristics of its own (Hanson, 1962).
2. A habitat classification used in this report to designate areas of ecotone communities between the prairie grasslands and the aspen grove.

EDAPHIC FACTOR

A condition or characteristic of the soil, physical, chemical or biological that influences organisms (Hanson, 1962).

EVAPOTRANSPIRATION

The sum total of water lost from the land by evaporation and plant TRANSPIRATION (Hanson, 1962).

EXPOSED HABITATS

Descriptive of habitats which are not protected from sun and wind by shelter from topography or vegetation.

FIELD CAPACITY

The moisture content of a soil, expressed as a percentage of oven-dry weight after the gravitational water has been drained away (Hanson, 1962).

FLORA

The sum total of the kinds of plants in an area at one time (Hanson, 1962).

FORB

A herbaceous plant that is not a grass or grasslike, such as sedge (Hanson, 1962).

GENUS

A group of related species, or occasionally only one species, used in the classification of organisms (Hanson, 1962). For example, Balsam poplar and Aspen poplar belong to the genus *Populus*.

GEOBOTANICAL PROFILE

A graphical presentation of the shape of the land's surface on which soil data and species present are plotted at their relative position on the profile. This graphical technique is often applied when assessing vegetation-terrain relationships in an area.

GEOBOTANY

As a result of the study of the relationships between botany and topography and geology, this combined discipline was formed from botany, geography and geology. The term, geobotany, appears primarily in Russian publications.

GERMINATION

The process of growth renewal of a seed or spore (Hanson, 1962).

GRAMINOID

Refers to a herb with long, narrow leaves (Hanson, 1962). For the purposes of this report, it means grass.

HABITAT FACTOR

Any one factor of the sum total of environmental conditions of a specific place that is occupied by an organism, by a population or by a community (Hanson, 1962).

HALOPHYTE

A plant growing in saline soil (Hanson, 1962).

HERB

A plant with one or more stems that die back to the ground each year; grasses and FORBS as distinct from shrubs and trees (Hanson, 1962).

HERBACEOUS VEGETATION

Refers to vegetation with characteristics of a herb (Hanson, 1962).

HYBRIDIZATION

The crossing or breeding of unlike individuals to produce hybrids (Hanson, 1962). For the purposes of this report hybridization refers to the crossing of genetically similar species to produce a hybrid with some of the characteristics of each parent species.

HYGRIC

Refers to a wet or moist condition of habitat (Hanson, 1962).

HYGROPHYTE

A plant which grows in moist or wet places (Hanson, 1962).

INSOLATION

Solar radiation received by the earth and other planets from the sun, or exposure to rays of the sun (Hanson, 1962).

MESIC

Refers to environmental conditions that are medium in moisture supply (Hanson, 1962).

MESOPHYLOUS

A characteristic of plants which seek MESIC habitats.

MESOPHYTE

A plant that grows in environmental conditions that are medium in moisture conditions.

MICROCLIMATE

The climate in a small area of the order of twenty feet or smaller in dimensions. This area may also be confined to a vertical layer in the vegetation.

MOIST PRAIRIE

A habitat classification used in this report to designate prairie sites having some shelter from sun and wind by topgraphy or other vegetation or having preferred soil moisture conditions.

MOISTURE STRESS

A plant condition whereby the plant cannot draw water from the soil and wilting is incipient.

MOIST WOODS

A habitat classification used in this report to designate woodland sites that are shaded, cool and moist.

ONE THIRD ATMOSPHERIC PERCENTAGE

See FIELD CAPACITY

OSMOTIC POTENTIAL

The suction pressure generated by the process of osmosis in plants for the transport of water and nutrients from the soil to the plant.

PHOTOSYNTHESIS

The synthesis of carbohydrates from carbon dioxide and water by CHLOROPHYLL using light as energy with oxygen as a by-product (Hanson, 1962).

PHREATOPHYTE

A plant that absorbs its water from a permanent supply in the ground (Hanson, 1962).

PHYSIOLOGY

The branch of biology that deals with the functions and processes carried on by plants and animals (Hanson, 1962).

______PHYTE

A suffix meaning plant. For example, a <u>PHREATO</u>PHYTE is a plant that is associated with a phreatic surface.

PIONEER COMMUNITY

A plant community that first invades a bare area (Hanson, 1962).

PRAIRIE POTHOLE

A shallow depression on the glaciated prairies that fills with water either temporarily or permanently.

REACTION

The effects which one or more organisms produces upon its habitat (Hanson, 1962).

RESPIRATION

The complex series of chemical reactions in all living organisms by which the energy in foods is made available for use (Hanson, 1962). In this report, respiration refers to the taking on and release of gases as the by-products of photosynthesis by plants.

RHIZOME

An underground stem that produces shoots and roots at the nodes (Hanson, 1962).

RUNNER

A stem of a plant that has all the characteristics of above ground stems of that plant but grow underground and away from the main plant before coming to the surface to establish a new above ground stem away from the original plant.

SATURATION EXTRACT CONDUCTIVITY

The electrical conductivity of soil water extracted from a soil at 100% saturation.

SERAL

Refers to SERE.

SERE

The series of stages that follow one another in an ecological SUCCESSION (Hanson, 1962).

SHELTERED

Descriptive of habitats which are protected from sun and wind by shelter from topography or vegetation.

SHRUB

A perennial woody plant that differs from a tree by its low growth and the possession of several stems arising from the base (Hanson, 1962).

SPECIES

A unit of classification of plants and animals, consisting of the largest and most inclusive array of sexually reproducing and cross-fertilizing individuals which share a common gene pool (Hanson, 1962).

SP.

An abbreviation used to designate one unknown species when used with the genus name. For example, *Rosa sp.*

SPP.

An abbreviation used to designate more than one species, known or unknown, when used with the genus name. For example, *Rosa spp.*

STOMATA

A minute pore and two surrounding guard cells occurring in the epidermis of leaves, young stems and fruits, and other organs, through which diffusion of gases occurs.

STORY

A vertical layer of vegetation which is spatially distinct from other layers of vegetation above or below.

SUCCESSION (ECOLOGICAL)

The replacement of one kind of COMMUNITY by another kind; the progressive changes in vegetation and in animal life which may culminate in the CLIMAX.

TAXONOMY

The science of classification of organisms; the arrangement of organisms into systematic groupings such as VARIETY, SPECIES, GENUS, family and order (Hanson, 1962).

TRANSPIRATION

The loss of water in vapor form from a plant, mostly through the stomata and lenticels (Hanson, 1962).

TURGID

The condition of a cell or a tissue when it is swollen with water causing the actual pressure of sap within a cell against the cell wall resulting from the intake of water by osmosis (Hanson, 1962).

UNDERGROWTH

Collectively the shrubs, seedlings and sapling trees and all HERBACEOUS PLANTS in the forest (Hanson, 1962).

UNDERSTORY

Collectively the trees in a forest below the upper canopy cover (Hanson, 1962). In this report understory also includes UNDERGROWTH.

VARIETY

A TAXONOMIC group within a SPECIES (Hanson, 1962). For example, Black-fruited choke cherry is *Prunus virginiana var. melanocarpa*. That is the genus *Prunus*, the species *virginiana* and the variety *melanocarpa*.

VEGETATIVE REPRODUCTION

The propagation of plants by use of vegetative parts such as RHIZOMES or RUNNERS (Hanson, 1962).

WATER ABSORPTION

The process by which water is taken from the soil by a plant's roots.

WET AREAS

A habitat classification used in this report to designate areas with water at or near the ground's surface in either prairie or woodland settings.

WET BRACKISH AREAS

A habitat classification used in this report to designate areas with brackish water at or near the ground's surface in either prairie or woodland settings.

WILTING

The temporary or transient loss of TURGIDITY in a plant caused by a rate of transpiration in excess of the rate of absorption of water. Permanent wilting: wilting to such degree that plants do not recover unless water is added to the soil soon after wilting occurs (Hanson, 1962).

WILTING POINT

The water remaining in the soil in percentage of dry weight of the soil when the plants are in a condition of permanent wilting (Hanson, 1962).

XERIC

Refers to a dry habitat (Hanson, 1962).

XEROPHYTE

A plant that can grow in dry places (Hanson, 1962).

APPENDIX B

COMMON NAMES TO SCIENTIFIC NAMES

LIST OF ALL SPECIES IN THE LANGHAM STUDY AREA

APPENDIX B

COMMON NAME	SCIENTIFIC NAME
Algae *	*Algae, spp.*
Alumroot	*Heuchera richardsonii*
American speedwell	*Veronica americana*
American vetch	*Vicia americana*
Anemone, Canada	*Anemone canadensis*
______, Long-fruited	*Anemone cylindrica*
Arrow-grass, Seaside	*Triglochin maritima*
Arrow-leaved colt's foot	*Petasites sagittatus*
Ascending purple milk-vetch	*Astragulus striatus*
Ash, green	*Fraximus campestris*
Aspen poplar	*Populus tremuloides*
_____, trembling	*Populus tremuloides*
Aster, Lindley's	*Aster, ciliolatus*
_____ rush	*Aster, junkiformis*
_____ smooth	*Aster, laevis*
_____ willow	*Aster, hesperius*

---

* Common names were taken from Budd and Best (1964). Other Flora were used for the few species that were not included by Budd and Best.

Avens, Three-flowered	*Geum triflorum*
Awnless brome	*Bromus inermis*
Balsam poplar	*Populus balsamifera*
Baneberry, Red	*Actaea rubra*
Basket willow	*Salix petiolaris*
Beaked hazelnut	*Corylus cornuta*
Bearberry	*Arctostaphylos uva-ursi*
Bedstraw, Northern	*Galium boreale*
________, sweet-scented	*Galium triflorum*
Biennial wormwood	*Artemisia biennis*
Birch, River	*Betula occidentalis*
_____, Swamp	*Betula glandulifera*
_____, White (Paper)	*Betula papyrifera*
Black current	*Ribes americanum*
Black-fruited choke cherry	*Prunus virginiana var. melanocarpa*
Blue grama grass	*Bouteloua gracilis*
Blue grass, Fowl	*Poa palustris*

Box elder (Manitoba maple)	*Acer negundo var. interius*
Brome, Awnless	*Bromus inermis*
Brook grass	*Catabrosa aquatica*
Buffaloberry, Canada	*Shepherdia canadensis*
Bunchberry	*Cornus canadensis*
Buttercup	*Ranunculus sp.*
Buttercup, Celery-leaved	*Ranunculus sceleratus*
________, Seaside	*Ranunculus cymbalaria*
Canada anemone	*Anemone canadensis*
Canada buffaloberry	*Shepherdia canadensis*
Canada hawkweed	*Hieracium canadense*
Canada thistle	*Cirsium arvense*
Carrionflower	*Smilax lasionevra*
Celery-leaved buttercup	*Ranunculus sceleratus*
Choke cherry (black-fruited)	*Prunus virginiana var. melanocarpa*
Cinquefoil, Five-fingered	*Potentilla quinquefolia*
Club-moss, Little	*Selaginella densa*

Colt's foot, Arrow-leaved	*Petasites sagittatus*
Columbian hawthorn	*Crataegus columbiana*
Common horsetail	*Equisetum arvense*
Common nettles	*Urtica dioica var. procera*
Cranberry, High bush	*Viburnum trilobum*
Creeping juniper	*Juniperus horizontalis*
Creeping spike rush	*Eleocharis palustris*
Current, Wild black	*Ribes americanum*
Dewberry	*Rubus pubescens*
Dogwood, Red-osier	*Cornus stolonifera*
Five-fingered cinquefoil	*Potentilla quinquefoil*
Flat-topped goldenrod	*Solidago graminifolia var. major*
Fleshy stitchwort	*Stellaria scrassifolia*
Floodman's thistle	*Cirsium flodmanii*
Fowl blue grass	*Poa palustris*

Fowl manna grass	*Glyceria striata*
Goldenrod	*Solidago canadensis*
________, flat-topped	*Solidago graminifolia var. major*
Green ash	*Fraxinus campestris*
Hawkweed, Canada	*Hieracium canadense*
Hawthorn, Columbian	*Crataegus columbiana*
Hazelnut, Beaked	*Corylus cornuta*
High bush cranberry	*Viburnum trilobum*
Honeysuckle	*Lonicera sp.*
Horsetail, Common	*Equisetum arvense*
________, Marsh	*Equisetum palustre*
June grass	*Koeleria cristata*
Juniper, Creeping	*Juniperus horizontalis*
Licorice, Wild	*Glycyrrhiza lepidota*
Linley's aster	*Aster ciliolatus*
Liverwort	*Marchantia sp.*
Long-fruited anemone	*Anemone cylindrica*
Low juniper	*Juniperus communis var. depressa*
Lungwort, Tall	*Mertensia paniculata*

Manitoba maple (Box elder)	*Acer negundo var. interius*
Manna grass	*Glyceria spp.*
__________, Fowl	*Glyceria striata*
Many-flowered yarrow	*Achillea sibirica*
Marsh horsetail	*Equisetum palustre*
Meadow-rue	*Thalictrum sp.*
Milk-vetch, Ascending purple	*Astragulus striatus*
Mint, Wild	*Mentha arvensis var. villosa*
Moss (Little Club-moss)	*Selaginella densa*
Narrow reed grass	*Calamagrostis neglectra*
Nettles, Common	*Urtica dioica var. procera*
Northern bedstraw	*Galium boreale*
Northern bog violet	*Viola nephropylla*
Northern willowherb	*Epilobium glandulosum var. adenocaulon*
Pasture sage	*Artemisia frigida*
Perennial sow thistle	*Sonchus arvensis*
Pigweed, Russian	*Axyris amaranthoides*

Pin cherry	*Prunus pensylvanica*
Poison ivy	*Rhus radicans*
Poplar, Aspen	*Populus tremuloides*
______, Balsam	*Populus balsamifera*
Pussy willow	*Salix discolor*
Raspberry	*Rubus sp.*
Red baneberry	*Actaea rubra*
Red-osier dogwood	*Cornus stolonifera*
Reed grass, Narrow	*Calamagrostis neglecta*
River birch	*Betula occidentalis*
Rose	*Rosa sp.*
Rose, Wood's	*Rosa woodsii*
Rush aster	*Aster junkiformis*
Russian pigweed	*Axyris amaranthoides*
Saskatoon	*Amelanchier alnifolia*
Seaside arrow-grass	*Triglochin maritima*
Sedge, water	*Carex aquatalis*
______	*Carex deweyana*

_____	*Carex foenea*
_____	*Carex interior*
_____, woolly	*Carex lanuginosa*
Selaginella, Prairie	*Selaginella densa*
Siberian yarrow	*Achillea sibirica*
Silverberry	*Elaeagnus commutata*
Slender wheat grass	*Agropyron trachycaulon*
Slough grass	*Beckmannia syzigachne*
Smooth aster	*Aster laevis*
Smooth brome	*Bromus inermis*
Snakeroot	*Sanicula marilandica*
Snowberry, Western	*Symphoricarpos occidentalis*
Solomon's seal, Star-flowered	*Smilacina stellata*
Sow thistle, Perennial	*Sonchus arvensis*
Speedwell, American	*Veronica americana*
Spike-rush, Creeping	*Eleocharis palustris*
Star-flowered Solomon's seal	*Smilacina stellata*
Stinging nettles	*Urtica dioica var. procera*

Stitchwort, Fleshy	*Stellaria scrassifolia*
Strawberry	*Fragaria sp.*
Sweet-scented bedstraw	*Galium triflorum*
Tall lungwort	*Mertensia paniculata*
Thistle, Canada	*Cirsium arvense*
_______, Floodman's	*Cirsium flodmanii*
Three-flowered avens	*Geum triflorum*
Torchflower	*Geum triflorum*
Trembling aspen	*Populus tremuloides*
Twinflower	*Linnaea borealis var. americana*
Vetch, American	*Vicia americana*
Violets	*Viola spp.*
Water-horehound, Western	*Lycopus asper*
Western snowberry	*Symphoricarpos occidentalis*
Western water hemlock	*Cicuta douglasii*
Western water-horehound	*Lycopus asper*
Wheat grass, Slender	*Agropyron trachycaulon*
Wild black current	*Ribes americanum*

Wild licorice	*Glycyrrhiza lepodita*
Wild mint	*Mentha arvensis var. villosa*
Willow aster	*Aster hesperius*
Willow, Basket	*Salix petiolaris*
______, Pussy	*Salix discolor*
Willowherb, Northern	*Epilobium glandulosum var. adenocaulon*
Wintergreen sp.	*Pyrola sp.*
Wintergreen, One-sided	*Pyrola secunda*
Wire rush	*Juncus sp.*
Wolf-willow	*Elaeagnus commutata*
Wood's rose	*Rosa woodsii*
Yarrow, Siberian	*Achillea sibirica*

APPENDIX C

SCIENTIFIC NAMES TO COMMON NAMES

LIST OF ALL SPECIES IN THE LANGHAM STUDY AREA

APPENDIX C

SCIENTIFIC NAME	COMMON NAME
*Acer negundo var. interius**	Manitoba maple, Box elder
Achillea lanulosa	Woolly yarrow
_______ *sibirica*	Siberian yarrow, Many-flowered yarrow
Actaea rubra	Red baneberry
Agropyron trachycaulum	Slender wheat grass
Algae sp.	Algae
Amelanchier alnifolia	Saskatoon
Anemone canadensis	Canada anemone
_______ *cylindrica*	Long-fruited anemone
Arctostaphylos uva-ursi	Bearberry
Artemisia biennis	Biennial wormwood
_______ *frigida*	Pasture sage
Aster ciliolatus	Lindley's aster
_____ *hesperius*	Willow aster
_____ *junciformis*	Rush aster

* Common names were taken from Budd and Best (1964). Other Flora were used for the few species that were not included by Budd and Best.

SCIENTIFIC NAME	COMMON NAME
Aster laevis	Smooth aster
Astragulus striatus	Ascending purple milk-vetch
Axyris amaranthoides	Russian pigweed
Beckmannia syzigachne	Slough grass
Betula glandulifera	Swamp birch
______ *occidentalis*	River birch
______ *papyrifera*	White birch, Paper birch
Bouteloua gracilis	Blue grama grass
Bromus inermis	Awnless brome, Smooth brome
Calamagrostis neglectra	Narrow reed grass
Carex aquatilis	Water sedge
_____ *deweyana*	Sedge
_____ *foenea*	Sedge
_____ *interior (Bailey)*	Sedge
_____ *lanuginosa*	Woolly sedge
Catabrosa aquatica	Brook grass

SCIENTIFIC NAME	COMMON NAME
Cicuta douglasii	Western water hemlock
Cirsium arvense	Canada thistle
______ *flodmanii*	Floodman's thistle
Cornus canadensis	Bunchberry
______ *stolonifera*	Red-osier dogwood
Corylus cornuta	Beaked hazelnut
Crataegus columbiana	Columbian hawthorn
Disporum trachycarpum	Fairybells
Elaeagnus commutata	Wolf-willow, Silverberry
Eleocharis palustris	Creeping spike-rush
Epilobium glandulosum var. adenocaulon	Northern willowherb
Equisetum, arvense	Common horsetail
________, *palustre*	Marsh horsetail
Fragaria sp.	Strawberry
Fraxinus campestris	Green ash

SCIENTIFIC NAME	COMMON NAME
Galium boreale	Northern bedstraw
______ *triflorum*	Sweet-scented bedstraw
Geum triflorum	Three-flowered avens
Glyceria pulchella	Manna grass
Clyceria sp.	Manna grass
________ *striata*	Fowl manna grass
Glycyrrhiza lepidota	Wild licorice
Heuchera richardsonii	Alumroot
Hieracium canadense	Canada Hawkweed
Juncus sp.	Wire rush
Juniperus horizontalis	Creeping juniper
Koeleria cristata	June grass
Linnaea borealis var. americana	Twinflower
Lonicera sp.	Honeysuckle
Lycopus asper	Western water-horehound
Marchantia sp.	Liverwort

SCIENTIFIC NAME	COMMON NAME
Mentha arvensis var. villosa	Wild mint
Mertensia paniculata	Tall lungwort
Petasites sagittatus	Arrow-leaved colt's foot
Poa palustris	Fowl blue grass
Populus balsamifera	Balsam poplar
Populus tremuloides	Aspen poplar, Trembling aspen
Potentilla quinquefolia	Five-fingered cinquefoil
Prunus pensylvanica	Pin cherry
______ *virginiana var. melanocarpa*	Black-fruited choke cherry, choke cherry
Pyrola secunda	One-sided wintergreen
______ *sp.*	Wintergreen
Ranunculus cymbalaria	Seaside buttercup
__________ *sp.*	Buttercup
__________ *sceleratus*	Celery-leaved buttercup
Rhus radicans	Poison ivy
Ribes americanum	Wild black current

SCIENTIFIC NAME	COMMON NAME
Ribes triste	Wild red current
Rosa sp.	Rose
____ *woodsii*	Wood's rose
Rubus sp.	Raspberry
_____ *pubescens*	Dewberry
Salix discolor	Pussy willow
_____ *petiolaris*	Basket willow
Sanicula marilandica	Snakeroot
Selaginella densa	Little Club-moss, Prairie Selaginella
Shepherdia canadensis	Russet buffaloberry
Smilacina stellata	Star-flowered Solomon's-seal
Smilax lasioneura	Carrion flower
Solidago canadensis	Canada goldenrod
________ *graminifolia var. major*	Flat-topped goldenrod
Sonchus arvensis	Perennial sow thistle
Stellaria scrassifolia	Fleshy stitchwort

SCIENTIFIC NAME	COMMON NAME
Symphoricarpos occidentalis	Western snowberry
Thalictrum sp.	Meadow-rue
Triglochin maritima	Seaside arrow-grass
Urtica dioica var. procera	Common nettles, Stinging nettles
Veronica americana	American speedwell
Viburnum trilobum	High bush cranberry
Vicia americana	American vetch
Viola spp.	Violets
Viola nephrophylla	Northern bog violet

APPENDIX D

EXPERIMENTAL RESULTS

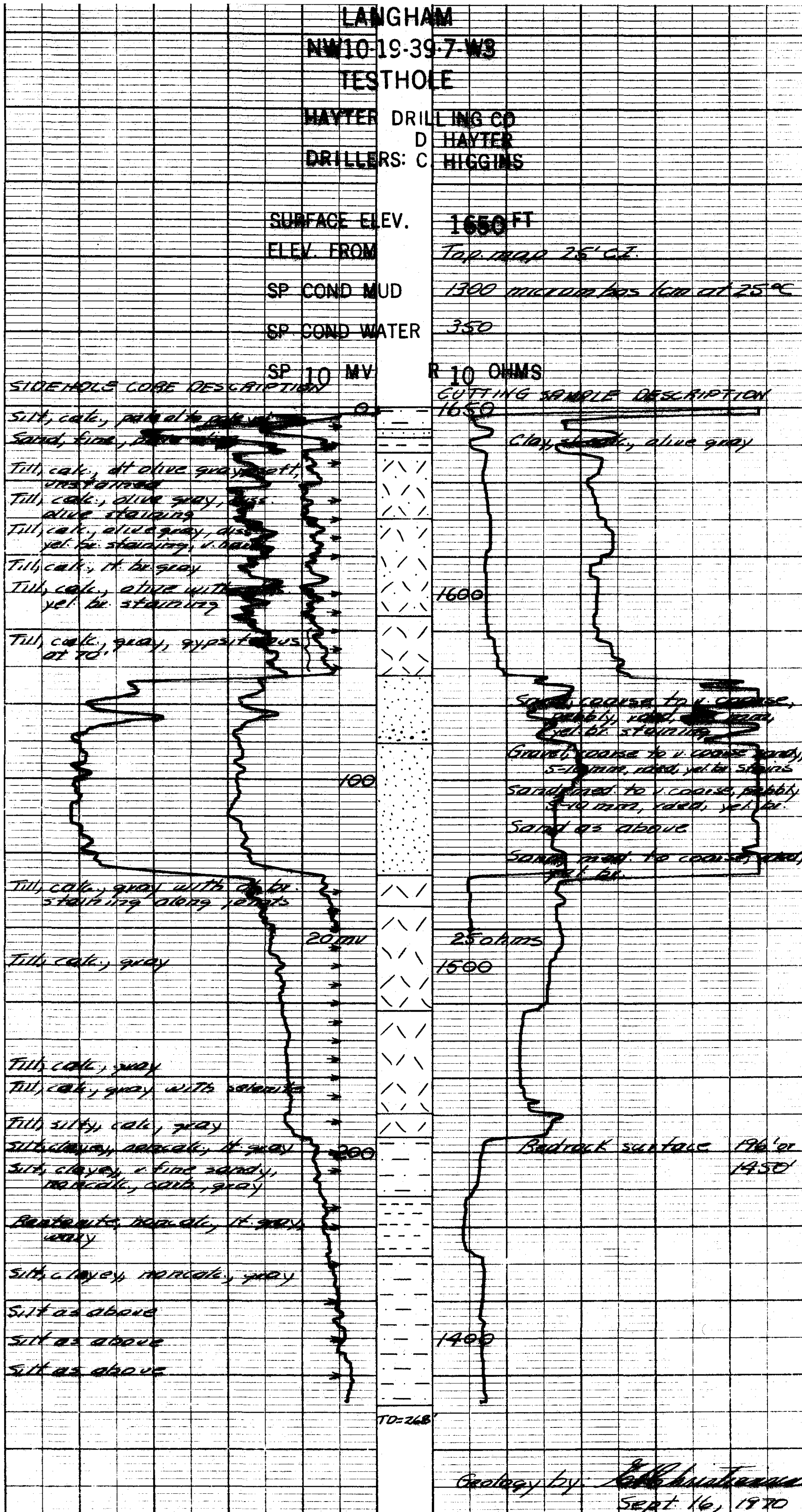


FIGURE D-1 ELECTRIC LOG OF TESTHOLE VII

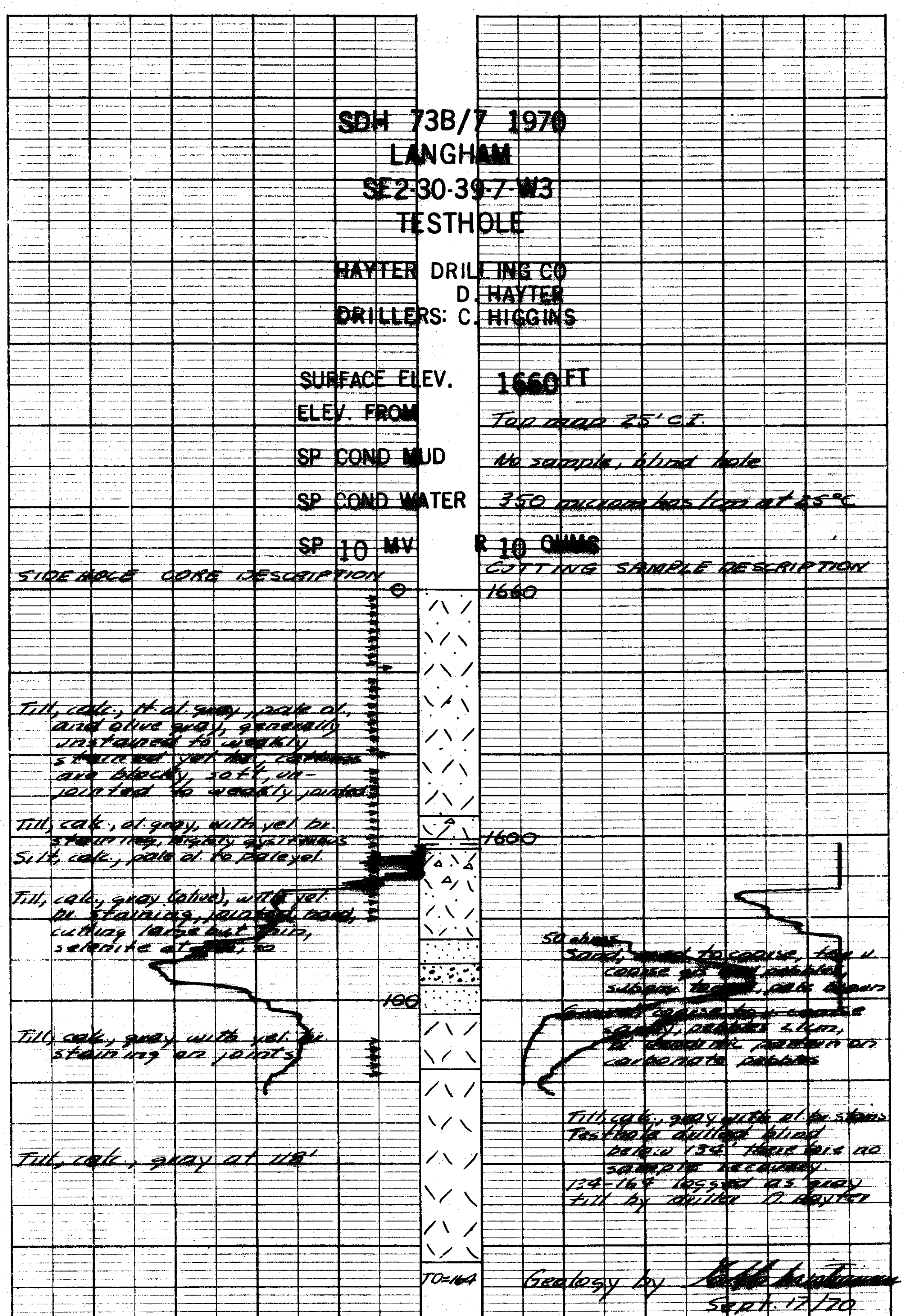


FIGURE D-2 ELECTRIC LOG OF TESTHOLE V

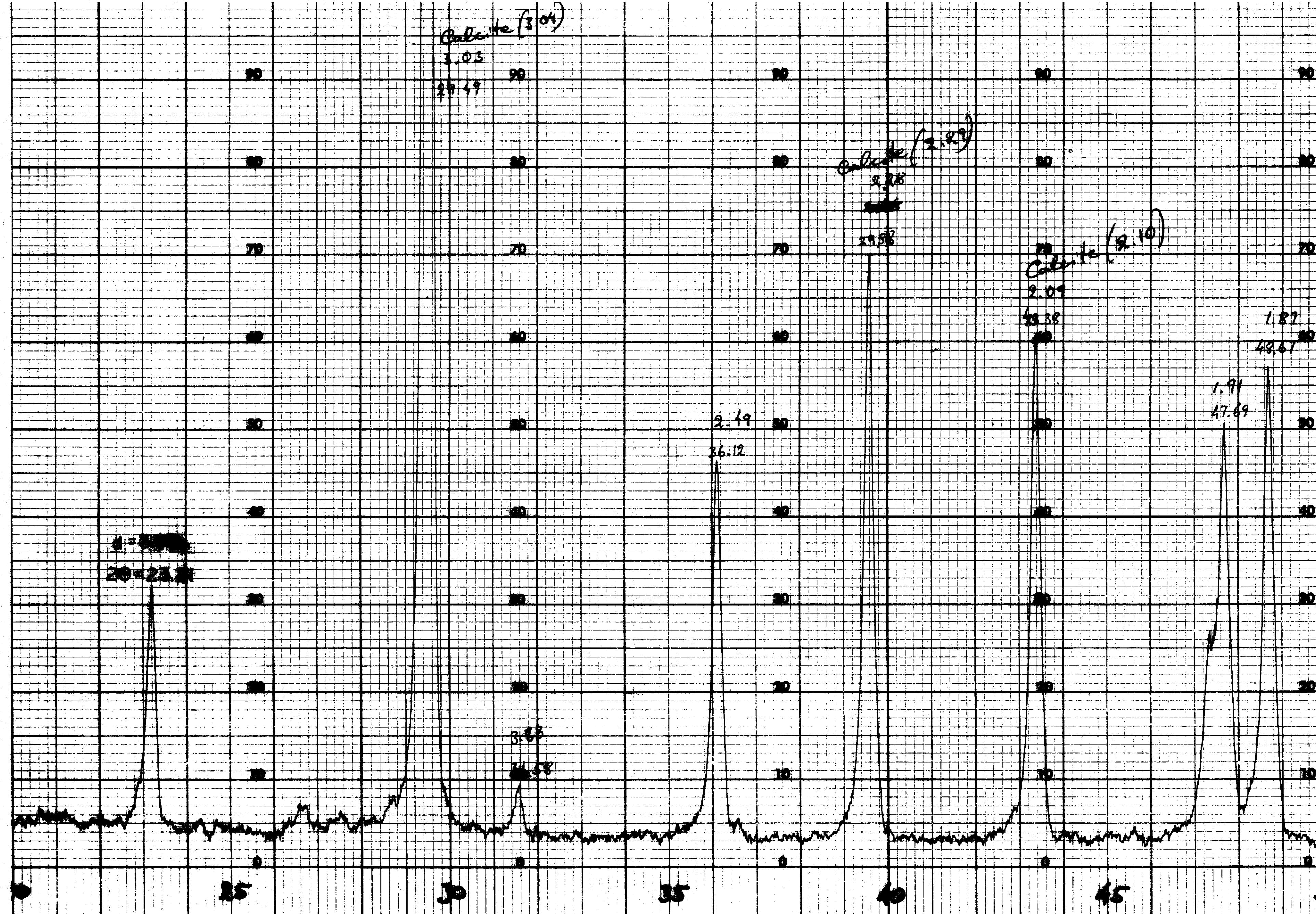


FIGURE D-3 X-RAY DIFFRACTION TRACE FOR TRAVERTINE MOUND MATERIAL

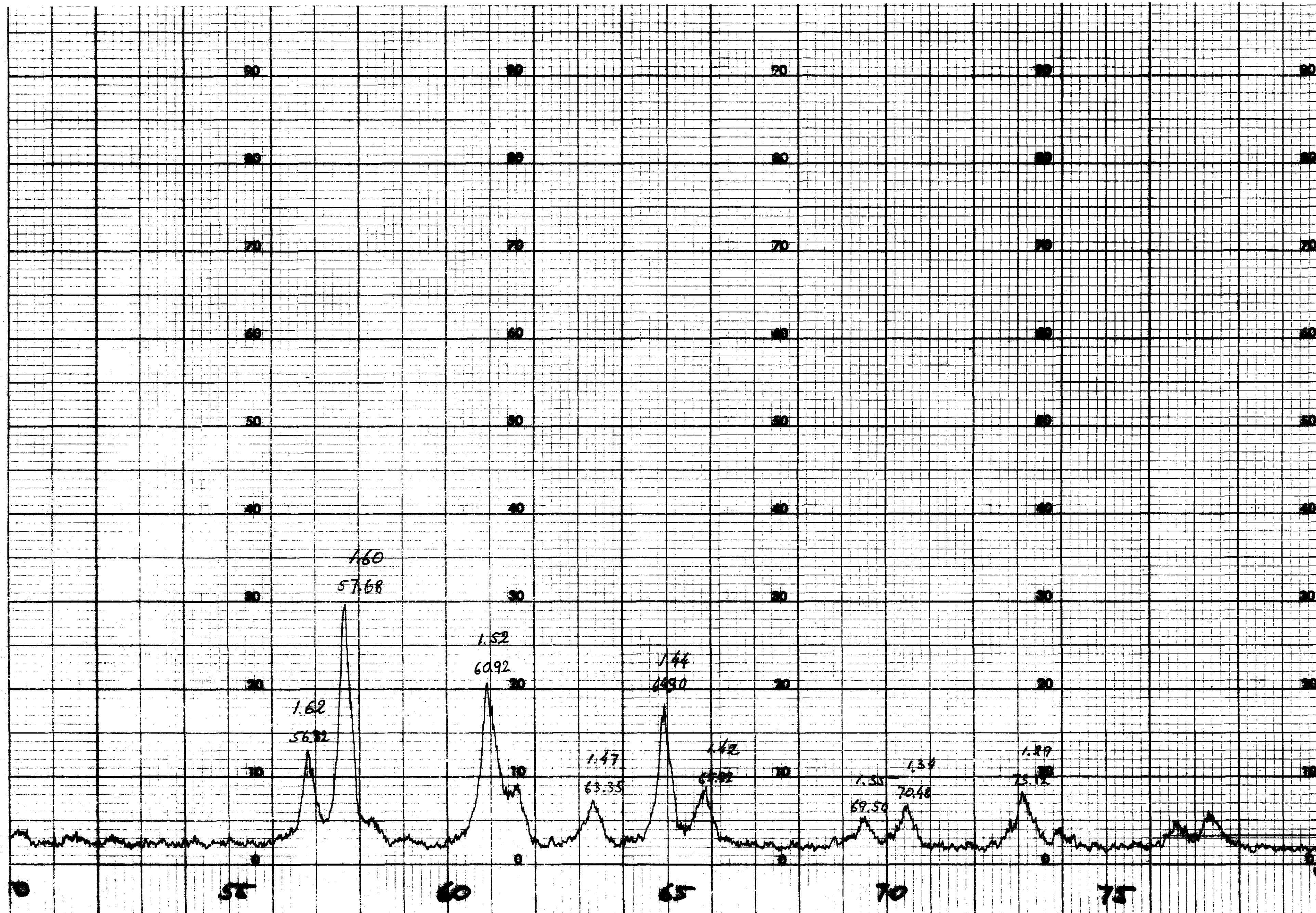


FIGURE D-4 X-RAY DIFFRACTION TRACE FOR TRAVERTINE MOUND MATERIAL

TABLE D-1

SUMMARY OF LABORATORY SOIL TESTING RESULTS

Borehole No.	Depth (ft.)	Sieve Analysis %-10	%-40	%-200	Natural Water Content (%)	Liquid Limit (%)	Plasticity Index (%)	Unified Classification
H1	2'	97.0	86.0	56.0	7.5	28.4	13.3	CL
H2	2'	96.0	85.0	54.0	6.3	28.7	7.3	CL
H3	4'	58.0	44.0	22.0	8.0	21.4	6.1	Sm-Sc
H3	6'	91.0	81.0	53.0	16.9	24.8	9.5	CL
H5	1'	95.0	85.0	53.0	6.2	31.4	12.7	CL
H6	3'	95.0	85.0	55.0	8.2	28.1	11.9	CL
H10	3'			+75	27.0	50.8	25.4	CH
H11	3'			+75	15.8	46.8	21.7	CL
H12	3'			+75	7.6	46.1	21.2	CL
H12	7'			+75	7.2	43.5	23.2	CL
H13	Cut	96.0	86.0	57.0		24.1	9.3	CL
H14	2'	100	93.0	67.0	13.0	34.3	15.1	CL
H14	7'	97.0	85.0	63.0	14.9	34.2	16.4	CL
H15	3'	92.0	78.0	47.0	3.9	23.1	9.7	SL
H16	2'			+75	21.2	75.4	44.2	CH
H17	3'			+75	18.6	61.5	33.5	CH
H18	5'			+75	20.1	50.3	26.2	CH
H18	10'	98.0	90.0	70.0	22.3	28.6	13.0	CL
H18	15'	95.0	83.0	53.0	15.2	24.8	11.7	CL
H19	4'			+75	11.9	74.6	45.9	CH
H19	8'			+75	12.6	72.2	44.3	CH
H19	12'			+75	28.6	48.5	25.2	CL
H19	15'			+75	30.6	46.3	22.8	CL
H20	2'	96.0	84.0	55.0	6.1	26.6	11.6	CL
H21	3'	100	81.0	63.0	10.4	36.0	15.4	CL
H22	2'			+75	20.0	48.8	22.1	CL
H22	4'	93.0	83.0	52.0	14.6	25.2	11.7	CL
H22	7'	96.0	86.0	53.0	13.2	24.2	11.6	CL
H23	3'			+75	8.7	67.5	37.9	CH
H24	2'			+75	47.7	62.5	31.8	CH
H25	2'			+75	15.4	46.3	19.1	CL
H26	2'	94.0	82.0	53.0	8.8	26.1	11.4	CL
H27	2'	94.0	84.0	53.0	19.2	27.2	10.7	CL
H27	4'	95.0	86.0	56.0	17.9	27.2	13.1	CL
H27	7'	98.0	88.0	57.0	17.5	24.5	11.1	CL

TABLE D-2

RECORD OF PIEZOMETER READINGS AT SITE VII (NW19-39-7-W3)

Date	Time	Depth (ft)	Elevation of Water Table (ft. AMSL)	Comments
Sept.29/70				Piezometer installed
Sept.29/70	5:00 pm	0		Full and falling
Sept.30/70	5:00 pm	18.0	1642.0	
Oct. 1/70	11:30 am	18.5	1641.5	
Oct. 8/70	2:00 pm	18.5	1641.5	
Nov. 4/70	2:15 pm	19.0	1641.0	
Nov.11/70	12:00 am	19.0	1641.0	
Apr. 4/71	5:00 pm	19.5	1640.5	
May 16/71	1:15 pm	19.0	1641.0	
May 16/71	1:20 pm			Pour 3 gallons of water into piezometer
May 16/71	1:25 pm	19.0	1641.0	
June 5/71	1:30 pm	19.0	1641.0	

APPENDIX E

PHOTOGRAPHIC GLOSSARY

OF

SIGNIFICANT INDICATOR SPECIES

IN THE

LANGHAM STUDY AREA

Bark Detail

Full Tree

WHITE BIRCH (PAPER BIRCH) *Betula papyrifera*

Leaf Detail

Bark Detail

Full Tree

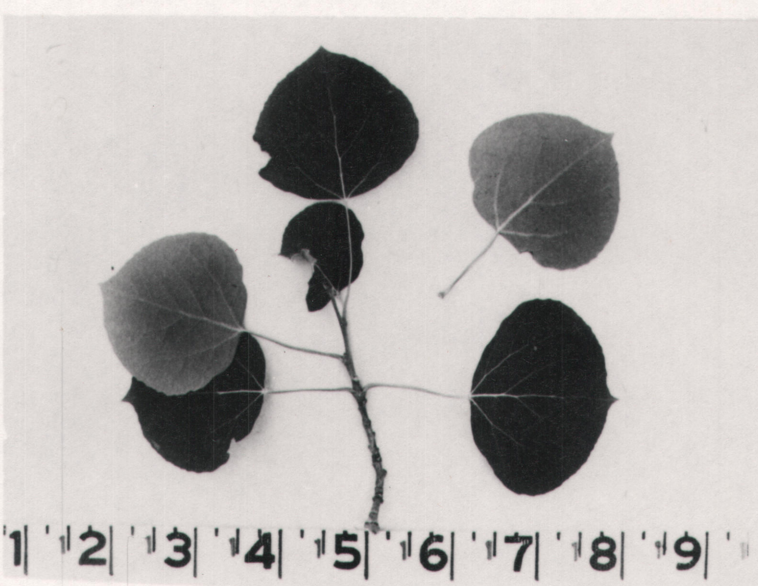
BALSAM POPLAR *Populus balsamifera*

Leaf Detail

Bark Detail

Full Tree

TREMBLING ASPEN (ASPEN POPLAR) *Populus tremuloides*



Leaf Detail

Full Tree

PUSSY WILLOW *Salix discolour*

Leaf Detail

Full Shrub

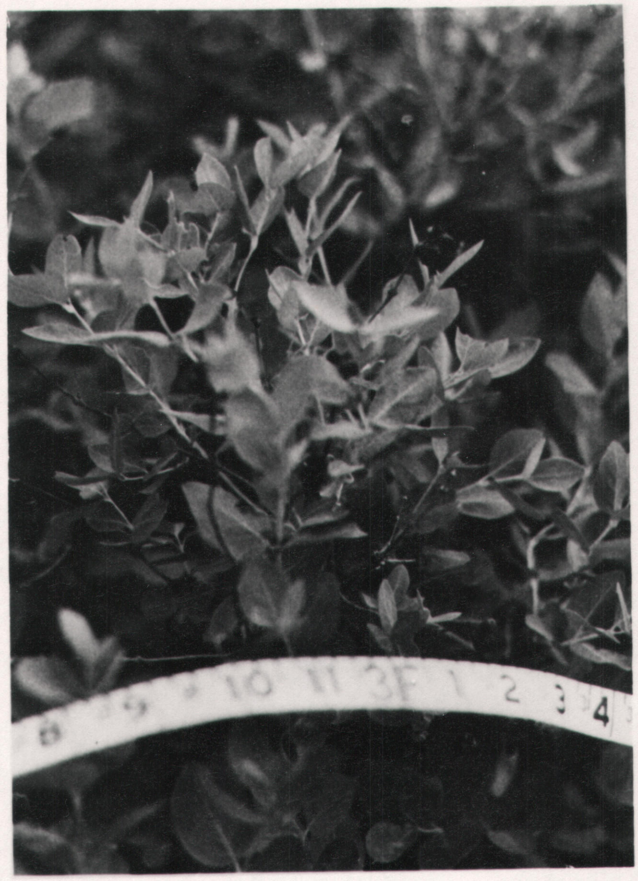
Leaf Detail

HIGH BUSH CRANBERRY *Viburnum trilobum*

Full Shrub

Leaf Detail

WOLF-WILLOW (SILVERBERRY) *Elaeagnus commutata*



Leaf Detail

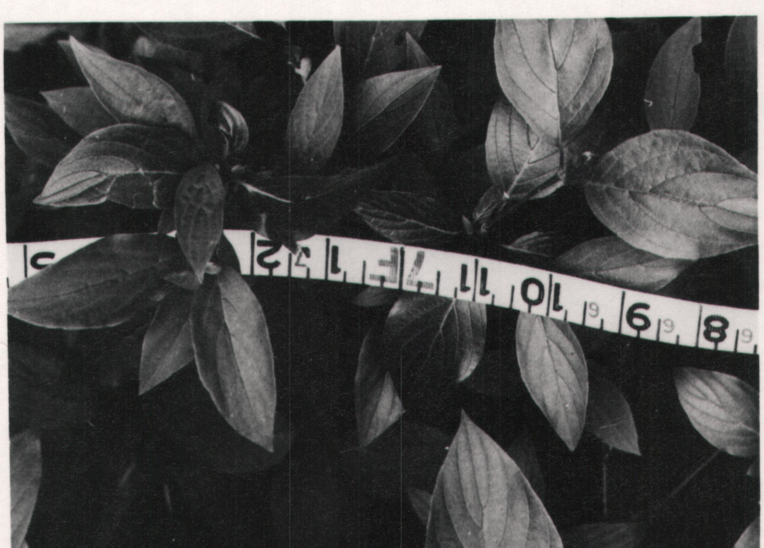
WESTERN SNOWBERRY *Symphoricarpos occidentalis*

Full Shrub

Bark Detail

Full Shrub

RED-OSIER DOGWOOD *Cornus stolonifera*



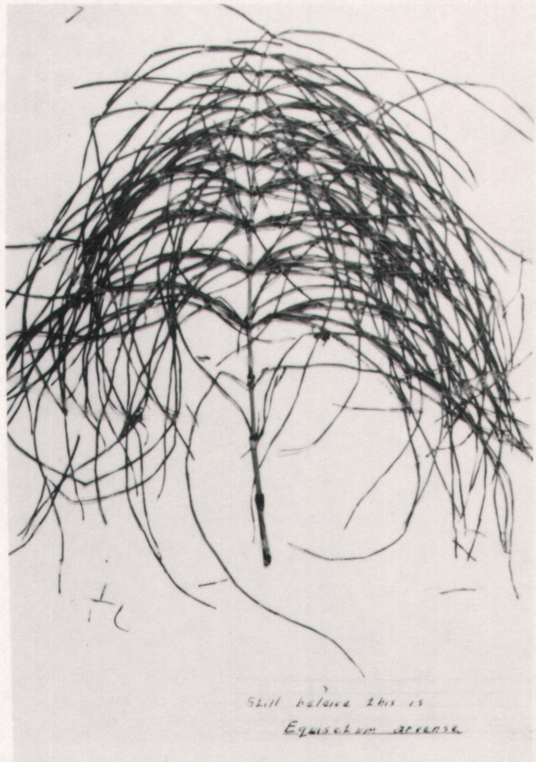
Leaf Detail

BUFFALOBERRY *Shepherdia argentia*

BEAKED HAZELNUT *Corylus cornuta*

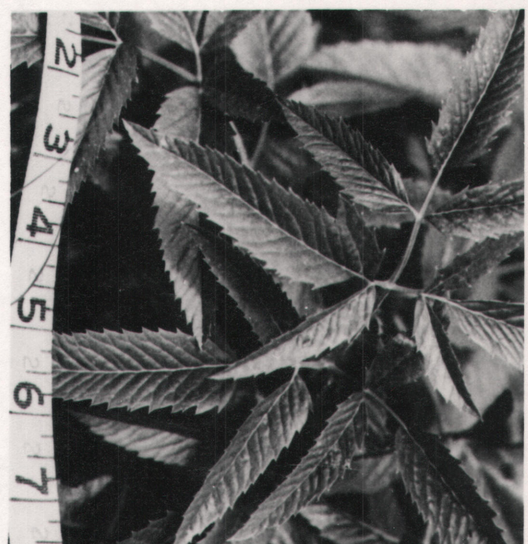
CANADA BUFFALOBERRY *Shepherdia canadensis*

Young Plant



Mature Plant

COMMON HORSETAIL *Equisetum arvense*



WESTERN WATER HEMLOCK *Cicuta douglasii*

ARROW-LEAFED COLT'S FOOT

Petasites sagittatos

PERENNIAL SOW THISTLE

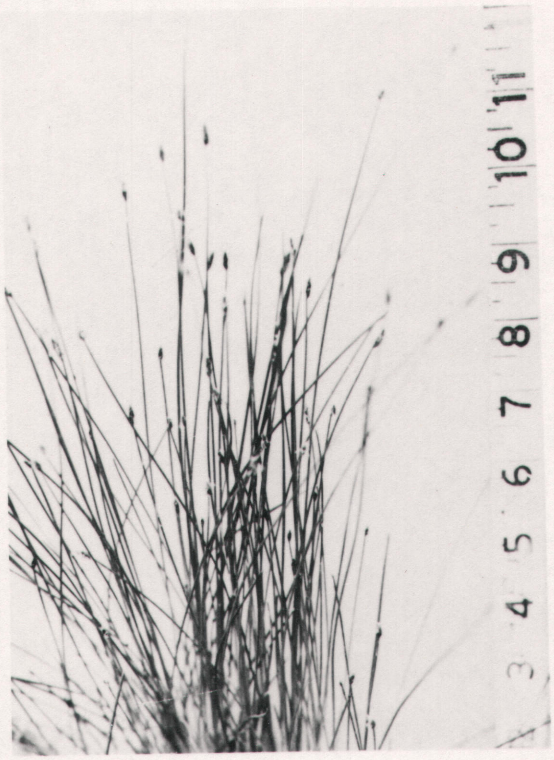
Sonchus arvensis

WESTERN WATER-HOREHOUND

Lycopus asper

NORTHERN WILLOWHERB

Epilobium glandulosum var. adenocaulon



CREEPING SPIKE RUSH
Eleocharis palustris

FOWL MANNA GRASS
Glyceria striata

SEDGE
Carex sp.

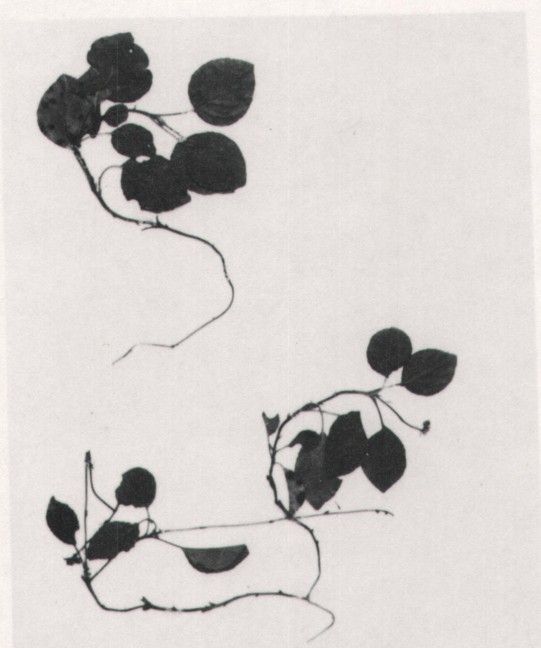
SLOUGH GRASS
Beckmannia syzigachne

WILD MINT *Mentha arvensis var. villosa*

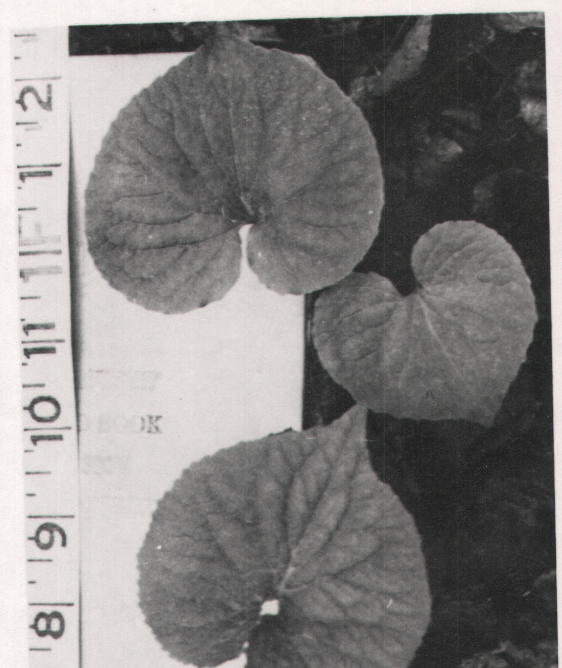
WILD LICORICE *Glycyrrhiza lepodita*

MEADOW-RUE
Thalictrum sp.

NORTHERN BEDSTRAW
Galium boreale



ONE-SIDED WINTERGREEN
Pyrolea secunda



WESTERN CANADA VIOLET
Viola rugulosa

COMMON NETTLE
Urtica dioica var. procera

RUSSIAN PIGWEED
Axyris amaranthoides

LITTLE CLUB-MOSS (PRAIRIE SELAGINELLA)
Selaginella densa