THE DEVELOPMENT OF A COMBINATION SLOPE MAP AND ITS
APPLICATION TO THE STUDY OF LAND UTILIZATION
IN SELECTED AREAS OF MANITOBA

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CHAPTER I

INTRODUCTION

The topographical map presents much detailed, especially hypsometric information about terrain. It is, however, highly selective in what it shows, and often the detailed information that is given may not be in the desired form for direct use in geographical investigations. Particular elements of terrain, e.g. slope gradient, are important in studies of land-use, soil erosion, irrigation, flood control, transportation, economic planning and other aspects of human geography.

Sometimes, special methods of depicting terrain are required by geographers. The increasing demand for these special maps in varied geographical investigations has stimulated a search for more accurate, complete or effective representation of surface characteristics. In modern cartography, photographic and lithographic techniques have made valuable contributions to the search.

Concerning the relationship of human activities to relief, slope is one of the most influential elements. Therefore, the methods of slope determination and representation on maps have been the subject for much research, particularly by American geographers. The calculation of gradient between consecutive contours on a topographic map is easy, but the determination of average steepness of slopes and their representation on maps for areas of complicated relief requires much experimentation and critical analysis.

Slope analysis should be based on an objective or arbitrary system, applying methods such as random sampling or grid or uniform interval sampling. However, the choice of assessment of data completely depends upon one's purposes and propositions.

The Present Techniques of Slope Representation

In this thesis, the primary interest is the representation of the form of land on maps, not the methods of calculating average slope. Nevertheless, the basic unit of land form is the slope. Up to now, many techniques of average slope representation have been evolved by geographers. These are reviewed below.

1. Representation by Hachures.

It was early recognized as desirable to indicate all steep slopes on military maps. The idea of taking the line oriented in the direction of maximum slope and thickening it according to the surface gradient is attributed to Major G. J. Lehmann of the Saxon army.[1] In this method the slopes are indicated by parallel lines drawn perpendicular to the direction of contours. There should be constant frequency of lines, the thickness of each being proportional to the slope gradient and the spaces between lines therefore inversely proportional to the same. The ratio of the thickness of the lines to the space between each line should be as the angle of slope to the difference between that angle and 45 degrees, for a slope over 45 degrees is shown entirely black. The thickness of the lines can be mathematically determined as follows:

$$L : i = X^\circ : 45^\circ - X^\circ$$

Where L = width of hachure line,

i = width of interval between the lines,

X° = the angle of slope.

1 Cited by Captain H. G. Lyons, 'Relief in Cartography', Geography Journal, vol. 43, No. 3, 1914, pp. 246.

From the frequency of contour lines, the angles of slope can be determined, and hachures of various thicknesses inserted by hand.

The advantage of the Lehmann system of hachuring is that on such a map mountains can be visualized even by untrained persons. Theoretically, the angle of slope can be measured, but actually it cannot be read because of the difficulty of measuring line thickness. The hachure map is very laborious to construct, too. In modern times, hachures have been little used in presenting slope information, but constitute a visually effective technique.

An alternative hachure technique of maintaining line thickness, but varying line frequency according to gradient has also been employed by cartographers. The frequency is directly proportional to gradient. This technique has the same visual effect.

2. Representation by Choropleths.[2]

The tinted or shaded choropleth map is a very common technique used in showing average slopes. It shows the areal distribution of different groups or categories of slopes, and so by using a planimeter, the actual magnitude of each slope group can be evaluated.

E. Raisz and J. Henry[3] divided the large scale topographical map into small 'regions' within each of which the contour lines were approximately

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[2] E. Raisz, General Cartography, pp. 246 (1st ed. 1938, New York), emphasizes that the term choropleth need not be limited to administrative divisions, but that a map divided into squares for which a density could be calculated and then tinted or shaded would also be a choropleth map. He suggested that the term 'demopleth' be used for those maps based on administrative divisions.

[3] E. Raisz and J. Henry, 'An Average Slope Map of South New England', Geographical Review, vol. 27, 1937, pp. 467-72.

uniformly spaced. Six slope categories were chosen, according to the average density of the contour lines; with these as a guide, each region was carefully examined and classified. When the slope regions had been demarcated on the large-scale topographic sheets, their boundaries were transferred to small-scale maps, and choropleths were drawn.

Later, E. Raisz named this type of map a 'Slope-category map'.[4] This system emphasizes detail and shows the spatial associations of different slopes, as well as depicting important minor topographic features.

W. Calef and R. Newcomb[5] constructed an average slope map of Illinois, by following in general principles the Raisz and Henry method, though using the Wentworth equation[6] instead of delimiting areas of uniform contour spacing. Four slope classes were defined and represented by distinctive tints.

3. Representation by Isopleths.

A. N. Strahler introduced two types of slope maps, based on isotangents and isosines, in 1956.[7] A large number of slope values, in degrees, were converted into the values of tangent and sine, and these values were plotted at control points. Gradients can be obtained either by measuring

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4 E. Raisz, 'Principles of Cartography', pp. 87 (New York 1962).

5 W. Calef and R. Newcomb, 'An Average Slope Map of Illinois', Annals of the Association of American Geographers, vol. 43, 1953, pp. 304-16.

6 C. K. Wentworth, 'A Simplified Method of Determining the Average Slope of Land Surfaces', American Journal of Science, series 5, vol. 20 (New Haven, Conn., 1930). Wentworth's formula for average slope determination is

$$\frac{\text{Average number of contour crossings per mile} \times \text{contour interval}}{3361}$$

7 A. N. Strahler, 'Quantitative Slope Analysis', Bulletin of the Geological Society of America, vol. 67, pp. 571-596 (New York 1956).

contours on large-scale topographic maps, or by using an Abney Level in the field. With the values of tangent and sine on the base map, series of isotangents and isosines respectively were interpolated.

Furthermore, a percentage frequency distribution histogram was constructed and statistical parameters were deduced by measuring the areas between successive isotangents or successive isosines with a polar planimeter.

These two types of slope maps, which have a large potential value in engineering and military applications, have not been widely applied in geography.

Coefficient of Land Slope. E. Raisz developed a method of establishing an exact 'coefficient of land slope'.[8] The chosen topographic map is covered with rectangles whose dimensions are determined, arbitrarily, according to the degree of homogeneity of terrain; the more uniform the slope the larger the rectangles can be. Each rectangle is divided into areas of approximately constant slope by counting contour frequencies. Then the total area of all slope units within each category is measured with a planimeter. A horizontal line is drawn proportional in length to the total area of the rectangle, and the sum totals of areas in each slope category are represented to scale along this line (starting with the gentlest slopes at the left end). A series of connected lines in a slope sequence is drawn, each at the angle of slope corresponding to the appropriate vertical rise per mile, inclusive of the maximum slope occurring in the rectangle. The area bounded by the horizontal, vertical and connected sloping lines provides a coefficient of

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8 E. Raisz, 'General Cartography', pp. 273 (1st ed. New York, 1938).

Also see F. J. Monkhouse and H. R. Wilkinson, 'Map and Diagrams', pp. 107, figure 41 (2nd ed. 1963).

slope for the rectangle for which it has been drawn. This is calculated by simple geometry. Completely flat land will have a coefficient of zero. After the determination of coefficients for all rectangles, their respective values are plotted at the geometrical centres of the grid units; then selected isopleths can be drawn.

The Flatland-Ratio Map was introduced by E. Raisz,[9] and can be prepared in the following way. On the topographic sheet, used as base map, the land which is not too steep for farming is delimited, and described as 'flatland'. (The steepness of slope which can be farmed depends on local agricultural practices.) The map is divided up into small rectangles, in the geometric contres of which the respective percentages of flatland are plotted. Isopleths are then inserted.

4. Representation by Dots.

A. H. Robinson[10] produced a quantitatively accurate relief map from areal slope data. He divided the topographic sheets into squares each representing an area of 0.01 square miles. The average gradient within each square was estimated, and one dot for each degree of slope was placed within it. The dots were not placed symmetrically within each square; their positions were determined by reference to the contours on the topographic map.

In theory, the map is quantitatively precise, for the dots are countable. At the same time, the variation in relative dot density from one area

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9 E. Raisz, 'General Cartography', pp. 274 (ed. 1938).

10 A. H. Robinson, 'A Method for Producing Shaded Relief from Areal Slope Data', Surveying and Mapping, vol. 8 (Washington, 1948). Cited by F. J. Monkhouse and H. R. Wilkinson, Maps and Diagrams, pp. 107 (2nd ed. 1963).

to another gives an effective visual impression; but the map cannot give the areal values of slope units.

5. Slope Zone Technique.

The slope-zone device was first suggested in 1951 by O. M. Miller,[11] and maps were developed in 1960.[12] The aim of this technique is to emphasize slope rather than elevation, and to divide the map surface into a series of zones, which would reveal the detailed character of landforms. The zones can be reproduced in subdued tints. Miller and Summerson used the concept of A. Wood's fourfold classification of slope elements in the development of a hillside[13]: 'waxing slope', 'free face', 'constant slope' and 'waning slope'. In particular, they searched for a trigonometrical function of slope that would provide a gradient value that could be used to delimit valley floors from their sides. They considered the functions (1-cos x), x, sin x and $\sqrt{\sin x}$, where x is the angle of slope, and divided the ranges of values of each into 8 equal parts. Eventually, only four equal parts — separated by slope values of 3°35', 14°24', 34°14' — out of eight obtained from the $\sqrt{\sin x}$ function were chosen as the most suitable, thus giving four slope zones (0° - 3°35', 3°35' - 14°24', etc.). It is claimed that these four zones coincide with Wood's four slope elements. For more detailed maps, eight slope-zones categories can be adopted.

The compilation of a slope-zone map is easy if the region is covered with large-scale contoured topographic maps. The tinted map of slope zones

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[11] O. M. Miller, 'Relief on Maps and Models: Some Conclusions and a Proposal', The Ohio State University Research Foundation, Mapping and Charting Research Laboratory, Technical Paper No. 151, 1951. Cited in 'Slope-Zone Maps'.

[12] O. M. Miller and C. H. Summerson, 'Slope-Zone Maps', Geographical Review, vol. 50, 1960, pp. 196.

[13] A. Wood, 'The Development of Hillside Slopes', Proceedings of Geologists' Association, vol. 53, pp. 128-40 (London 1942). Cited by O. M. Miller and C. H. Summerson in 'Slope-Zone Maps'.

may be reproduced to the intended scale without loss of detail or clarity, as was demonstrated by Miller and Summerson in the production of a slope-zone map of the Appalachians at a scale of 1:2,000,000.

This kind of technique gives an excellent visual impression of the salient characteristics of slopes, and is particularly suitable for the morphological study of landscapes and in the determination of physiographical regions.

6. Slope Representation by Combined Techniques.

F. E. Elliot[14] introduced a technique of portraying slope gradients and relative relief on one map. He used a fine grid of squares to calculate values of relative relief. After these had been plotted, isopleths were drawn to show the spatial distribution of relative relief. Elliot then shaded the relative relief categories in various horizontal lines. A contour-spacing guide of the same contour map base was employed to secure the values of average slope, and three categories were recognized and vertical line-shaded. The superimposition of these two maps produced twelve composite slope and relative relief regions, which were outlined by pecked lines with the obvious identification of different intensities of cross-shading.

R. M. Glendinning[15] applied a simple technique to express slope conditions by using arrows to show the direction and steepness of slope and pecked lines to indicate the change of slope, for superimposing on land-

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14 F. E. Elliot, 'A technique of presenting Slope and Relative Relief on One Map', Surveying and Mapping, vol. 13, 1953, pp. 473-78. Cited by F. J. Monkhouse and H. R. Wilkinson, Maps and Diagrams, pp. 112 (2nd ed. 1963).

15 R. M. Glendinning, 'The Slope and Slope-Direction Map', Michigan Papers in Geography, vol. 7 (Ann Arbor, Mich., 1937). Cited by F. J. Monkhouse and H. R. Wilkinson in Maps and Diagrams, pp. 110 (2nd ed. 1963).

use and soil maps. This method can be used for correlating soil erosion, land suitability and slope.

7. Graphic Representations.

J. O. Veatch has devised a scheme for the graphic comparison of slopes and developed some ideas for comparing land on the basis of the number and areal extent of significant land components, of which he recognized three, 'highland', 'lowland' and 'slopes'.[16] Data may be obtained for constructing graphs from contour maps either by linear traverse measurements or by actual areal measurement. The 'slopes' component consists of classes of slopes, based on ranges of gradient. The function of the graph is to integrate these separate slope classes by expressing them as a single continuous sloping line. This line, which represents the integration of the slopes, has a gradient that is determined by a number obtained by multiplying the percentage frequency of each class of slope by its respective average gradient and taking one-quarter of the summation of these figures. The graph is constructed in the following way. A square is drawn, a side of which is equal to the total slopes percentage distance on the graph. A value that is equal to one-fourth of the highest gradient value times 100 is assigned to the combined right vertical and basal sides of the square. This is the integrated slope number and is represented by an inclined line joining the horizontal line depicting 'highland' at the upper left hand corner of the square. The horizontal line representing 'lowland' is added to the lower extremity of the inclined line afterwards. The lengths of these appended lines are proportional to the respective proportions of 'highland' and 'low-

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16 J. O. Veatch, 'Graphic and Quantitative Comparisons of Land Types', Journal of American Society Agronomy, vol. 27, 1935, pp. 505-510.

land' in the region.

The Clinographic Curve, first named by J. Hanson-Lowe,[17] shows the average gradient between any pair of contours. Its chief advantage is that it indicates both major breaks and sudden changes in the relief of any region, and it emphasizes uniform surfaces such as a peneplain.

Areas of land between pairs of successive contours are measured, and then represented by concentric circular zones. The average gradients between these pairs can be calculated, using the tangent function, tan @ (angle) = h/R-r, where @ is the average gradient of land between two successive contours, h is the contour interval, and R-r represents the difference in length between the radii of the respective circles.

After all the values of slope angle have been calculated, a clinographic curve can be drawn, using the contour intervals as vertical components and inserting each section of average slope gradient between each two contours with a protractor. If the clinographic curve possesses gentle slopes, then a vertical exaggeration may be used, by increasing each angle by a constant factor.

The Mean Slope Curve introduced by A. N. Strahler,[18] is a device for showing mean slope gradient by a curve. First, the length of each contour line is measured, and the average length of each pair of successive contours is calculated. The area between these contours is measured with a plani-

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17 J. Hanson-Lowe, 'The Clinographic Curve', Geological Magazine, vol. 72, pp. 180-4 (London 1935).

18 A. N. Strahler, 'Hypsometric (Area-Altitude) Analysis of Erosional Topography', Bulletin of the Geological Society of America, vol. 63, 1952, pp. 1117-42.

meter. The average width of each intercontour area is obtained by dividing this area by the mean length of the two successive contours. For the area above the highest contour, the mean width between each pair of successive contours is replaced by half the length of the highest contour. The tangent of the slope angle can be derived by dividing the contour interval by the mean width of each pair of successive contours. Then the curve, consisting of several straight-line segments, can be plotted.

In Strahler's method, ground slope distribution with respect to height can be depicted for direct visual analysis.

Slope-Height Curve. It was produced by F. Moseley[19] who determined the average slope value between each pair of contours at regular intervals. From these he was able to construct a slope-height curve, on which the average slope value between each pair of contours in each region was depicted. Uniform slopes were represented as straight lines parallel to the vertical axis of the graph, concave slopes with a uniform change of gradient were revealed as straight lines inclined to the right, whilst convex slopes were shown as straight lines inclined to the left.

This method can be utilized for analyzing slope values directly measured in the field, or for mean slopes of intercontour areas obtained by either the Hanson-Lowe or the Strahler methods.

The Columnar Diagram of Slope compiled by A.T.A.Learmonth,[20] in 1948, consists of a series of parallel bars whose lengths are proportional to the percentages of land of various inclinations.

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19 F. Moseley, 'Erosion Surfaces in the Forest of Bowland', Proceedings of the Yorkshire Geological Society, vol. 33, part 2, No. 9, pp. 173-96 (Hull, 1961). Cited by in Maps and Diagrams, pp. 122 (2nd ed. 1963).

20 A.T.A. Learmonth, 'The Floods of 12th August, 1948, in South-east Scotland' (circulated in manuscript form, 1951). Cited in Maps and Diagrams, pp. 110 (2nd ed. 1963).

8. Conclusion.

In all the methods described above, there are none that depict all types of slope information; in other words, every technique has its limitations. As a special technique, the slope map can emphasize what the compiler wants to show. So far, the few combined techniques of terrain representation can present more detailed and varied slope information than the others, therefore they are often more useful for geographical investigations.

In this thesis, a type of combined map and graph technique is proposed for presenting slope information for general use. It employs both choropleths and located line-graphs. The Raisz and Henry method was adopted for securing slope data from topographic sheets, because it can depict slope location in detail. The line-graph technique that is applied in this thesis broadly resembles E. Raisz's coefficient of land slope and J. O. Veatch's land components methods, but there are some important modifications that have been made with the aim of presenting more detailed slope information.

CHAPTER II

CONSTRUCTION OF THE COMBINATION SLOPE MAP

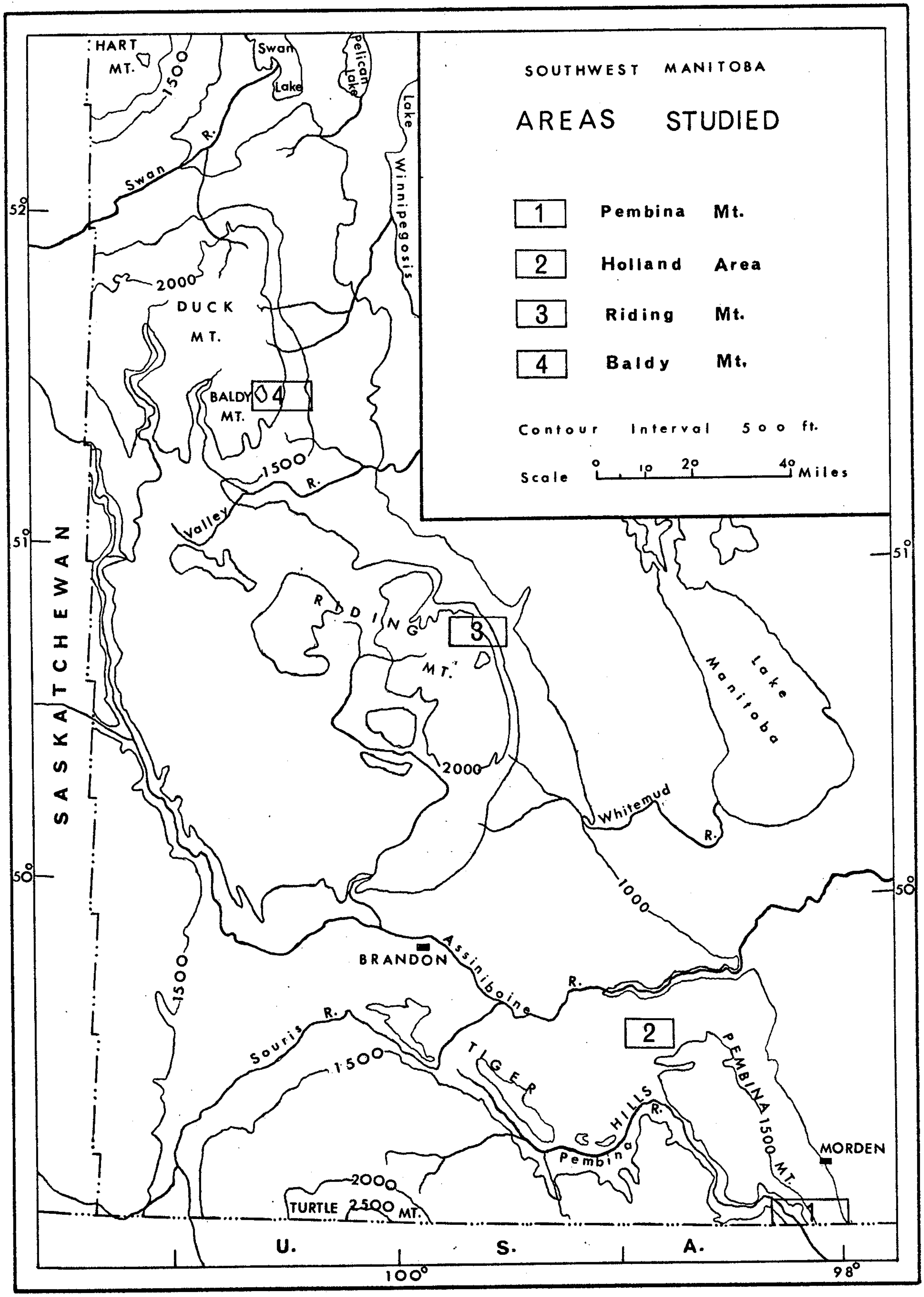
1. Choice of a Suitable Map Scale.

In this thesis, the scale of topographic sheets chosen as base maps is 1:50,000, the most widespread of the large scale maps obtainable in Canada, though their publication is not completed yet. The 1:50,000 maps of Manitoba have been produced with air photographs taken mainly between 1947 and the early 1950's. These maps are regarded as accurate. Another large scale series of topographic sheets is at 1:25,000, but its coverage is limited to a few small localities in Manitoba, excluding the areas arbitrarily chosen in this study.

The contour interval of the 1:50,000 Canadian maps is almost always 25 feet, a value which enables much detail of the surface configuration to be depicted. Fortunately, this scale is sufficiently large to show the degree of detail desired as a basis for this work. Another advantage of this scale is that the land use details on air photographs can be plotted quite accurately.

2. Size of Areas to be Studied.

Areas for cartographic analysis were arbitrarily chosen from an examination of topographic maps of types of terrain in Manitoba. Four areas were adopted for study, the size of each being between 60 and 100 square miles. Three areas lie astride the Manitoba Escarpment, but the remaining one extends from the northern margin of the Tiger Hills to


SOUTHWEST MANITOBA
AREAS STUDIED
1 Pembina Mt.
2 Holland Area
3 Riding Mt.
4 Baldy Mt.
Contour interval 500 ft.
Scale 0 10 20 40 Miles
HART MT.
Swan Lake
Pelican Lake
Lake Winnipegosis
Swan R.
DUCK MT.
BALDY MT.
Valley R.
RIDING MT.
SASKATCHEWAN
Lake Manitoba
Whitemud R.
BRANDON
Assiniboine R.
Souris R.
TIGER HILLS
Pembina R.
PEMBINA MT.
MORDEN
TURTLE MT.
U. S. A.
100°
98°
52°
51°
50°
2000
1500
1000
2500

Map 1

the Assiniboine Delta area (Map 1).[1]

All grid unit boundaries on sample sheets are section boundaries. The locations of the chosen areas can be identified by township (Tp) and range (R) numbers, indicated on the slope maps.

The 1:50,000 maps enable detailed cartographic analysis of these areas but are sufficiently small scale to permit the coverage of extensive tracts in a fairly short period of time.

3. Analysis.

(1) Delimitation of Slope Areas with Distinctive Gradients.

The delimitation process depends upon the initial identification on the topographic maps of slope areas with distinctive gradients. This method of delimitation is somewhat subjective, although training in topographic map analysis enables one to identify areas where there is virtual constancy of contour line frequency.[2] The delimitation is normally along a contour. This technique reveals important details such as average gradients and dimensions of slope units as well as their spatial distributions.

(2) Measurement.

a). Construction of a Slope Indicator.

Gradient can be calculated by the function: tan @ = h/D, where @ is the angle of the slope, h is the height, and D is the horizontal

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1 References of the topographic sheets used are:
Pembina Mt. Area -- 62 G/1 East and West
Holland Area -- 62 G-10 West
Riding Mt. Area -- 62 J/13 East and West
Baldy Mt. Area -- 62 N/7 (advance print) and 62 N/8 West

2 E. Raisz, 'Principles of Cartography', pp. 71 (ed. 1962).

distance. From this basic equation, an expression can be developed for the calculation of slope gradients.

Since the gradient of 1 degree = 1/57.3

$$\therefore \text{Slope Angle} = \frac{57.3 \times \text{Contour Interval (height)}}{\text{Horizontal Distance}}$$

As the scale of the topographic map used for base is 1:50,000 and the contour interval is 25 feet,

$$\therefore \text{Horizontal Distance} = \frac{57.3 \times 25' \times 1/50{,}000}{\text{Slope Angle}}$$

By this formula, the Horizontal Distance on the slope indicator can be calculated, and the results are as follows:

Slope Angle in Degrees	Length in inches on the Slope Indicator
½	.688
1	.344
2	.182
3	.114
4	.086
5	.069
6	.057
7	.049
8	.043
9	.038
10	.034
11	.031
12	.028
13	.025
14	.024
15	.022
16	.021

A strip of plastic was graduated according to the above values representing the slope angles.

b). Application of the Slope Indicator.

The average gradient of each facet[3] is determined by the use of the slope indicator. One problem is that of the number of measurements of slope steepness that should be taken with each spatially defined slope unit. If the measurements are far apart within a unit, then the average slope determination of that unit will not be reliable. If the measurements are frequent and evenly spaced, the greatest degree of objectivity is realized.

Measurements of gradient between each two consecutive contour lines were carried out at an interval of one reading per ¼ inch along the slope, wherever the gradient did not change appreciably within a unit. The small units or those with rapidly fluctuating values, were measured at greater frequencies.

A further problem is that the steeper slopes (i.e. 12 - 16 degrees of the slope indicator) possess such small linear differences -- approximately one thousandth of an inch -- that it is often well nigh impossible to decide the precise angle values from the slope indicator. But one can clearly distinguish the contour distance representing 12 degrees from that representing 16 degrees on the indicator. Therefore, in this thesis, areas where gradients exceed 12 degrees but are less than 16 degrees in average slope were placed in a single category with gentler slopes, the category of 8 - 16 degrees. The steepest slopes are in the 16 degrees and over category.

Finally the average gradient values of slope units were inserted in pencil on the base map, on which the units had already been delimited.

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[3] A '<u>facet</u>' is a unit of slope with fairly uniform characteristics.

(3) Choice of a Grid.

The construction of located line-graphs to enable the proportions of slope elements in different areas to be compared demands the choice of a grid system composed of uniform units. If the unit is arbitrarily chosen as one square mile, it presents many disadvantages. At the scale of 1:50,000, the space in each unit is so limited that it becomes impracticable to insert or to quantitatively interpret line symbols showing the proportions of the distinctive types of slope units.

A grid composed of units 2 miles square is advantageous in that it gives enough space for the insertion of a located line-graph symbol, even when the whole unit is classified as 'flat', and areal percentage within a slope class can be measured to within 1%. Furthermore, the scale is sufficiently large to distinguish the distinct units of slope and to measure angles with a protractor.

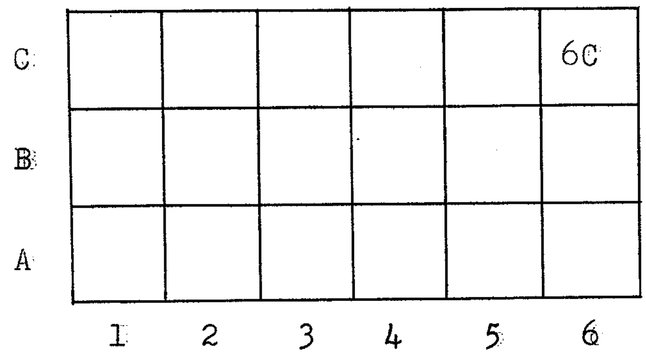
If the grid systems consists of units each exceeding 4 square miles, the final composite slope map would portray much less localized information in the form of located line-graphs than can be achieved by adopting a finer grid.

(4) The System of Grid Reference.

Each chosen area is divided into 4 square miles grid units that are 2 miles squares.

A system of numbering and lettering has been adopted for grid reference based upon the principle of the British Ordnance Survey reference system. In the text a grid unit is defined by reference to the numeral describing the number of squares from the left-hand side of the map (the easting). The northing reference (the letter describing the number of squares from the base of the map) is based on an alphabetical sequence of squares, the southernmost on each slope map being A.

For example, 6C :-



(5) <u>Areal Measurement of Facets</u>

The combination slope map reveals areally the percentages of slopes per grid unit, although the actual area of one category of slopes on the ground can be ascertained from the located line-graphs. It was not necessary to compute in absolute terms the areas of slope units from the measuring scales of the polar planimeter, since actual sizes can be derived from percentages of each 4 square miles grid unit.

As the slope units in a grid square representing 4 square miles at the 1:50,000 map scale are usually quite small, the planimeter is operated outside the area to be measured, therefore the accuracy is very high. However, the main factor in the determination of the accuracy of planimeter measurements is the care in manipulation of the instrument.

The map should be placed on a smooth and level surface. The polar bar of the planimeter should be set perpendicular to the pointer bar, before starting the measuring. The pointer should follow the boundaries exactly, and this is best achieved by slow, but uniform, movement of the pointer.

If the facet is long and narrow, the measuring wheel of the pointer bar should be located, more or less parallel to the longest dimension; if the instrument is not oriented in this way, the measuring wheel will slide along the surface of the paper as the pointer is being moved. This tends to produce less accurate readings on the dial. Initially, numerous measurements of the same unit are necessary to secure accurate results.

At least, three sets of planimeter readings per slope unit should be taken and the average areal value derived.

Many measurements of the area of one grid unit (i.e. 4 square miles) produced an average value of 424 planimeter units, which became the denominator for the calculation of the percentage value of any slope unit.

(6) Construction of Slope Symbol.

a). Definition of Slopeland and Flatland.

Since most of Manitoba consists of gentle slope and low local relief, an arbitrary value of 2 degrees was chosen to define the boundary between slopeland and flatland.[4] Areas where the average slope is 0 - 2 degrees are regarded as flatland; the category 0 - 2 degrees was used to delimit coastal flatlands by G. B. Cressey in 1938.[5] Those areas in which the average slope exceeds 2 degrees are classed as slopeland in this thesis.

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4 E. Raisz, 'General Cartography', pp. 274 (ed. 1938). Raisz implies that 'flatland' is 'possible farm land', that is, land that is not too steep for "farming" (presumably cultivation). The critical slope limit of cultivable land will depend on the methods employed and the type of farming economy.

5 G. B. Cressey, 'The Land Forms of Chekiang, China', A.A.A.G., vol. 28, 1938, pp. 259-76.

b). The Slope Symbol.

The total length of the slope-line symbol is two inches, representing 100% of the area of the grid unit (See the Combination Slope Maps). Flatland is represented by a horizontal line while inclined lines represent sloping land. A 4 square mile unit which is all horizontal land would be represented by a 2 inch line extending the full dimension of the grid unit. The steepness of a line on the graph is a fivefold exaggeration of the average gradient of all slopes that fall into that particular slope category within the grid unit.

Exaggeration aids vision. For without it, it is hard to distinguish one sloping line component from a contiguous one, especially when their values are close to each other. Furthermore, the exaggeration makes the slope angles easier to identify from protractor measurements.

c). Arrangement of the Slope Symbol .

The horizontal line (flatland representation) is succeeded by continuous inclined lines representing slopeland, starting from the representation of the lowest slope category present to the highest one.

The relative relief symbol is appended to the highest extremity of the line representing area.

(7) Choice of a System of Categories for a Classification of Slope Units according to Gradient.

The system adopted for the categories of slopes is a geometrical progression, with the first limiting value 2 degrees (the arbitrarily chosen maximum value for flatland) and 4, 8, and 16 degrees constituting the other limits. The advantage of this choice of a mathematical series is the conformity with the approximately inverse relationship of gradient and area -- the greater the gradient the smaller the area -- in the regions analyzed.

(8) Choice of Colouring of Slope Units.

The use of colouring is of great advantage in the slope map. It not only improves legibility and gives emphasis, but also adds attractiveness to the maps.

The shading employed in the categories on the Combination Slope Maps is the traditional colouring for hypsometric tinting on topographic maps -- a sequence of green, yellow and brown in order of ascending steepness of slope.

(9) Calculation of Relative Relief and Its Representation in the Slope Symbol.

In each grid unit, the difference between the maximum and the minimum elevations is the relative relief. Contour lines or spot heights are used to determine relative relief. Where there is only one contour line or spot height within a grid square, the relative relief of that unit is regarded as zero.

Manitoba is typified by areas of small to moderate relief, so a system of categories was chosen, based upon a 100 feet interval, except below 100 feet where there are two divisions, 0- 50 and 50 - 100 feet. In Manitoba many areas are quite flat, and these two lowest categories can depict more details.

There must be clarity of shading of the relative relief categories in the small rectangles portraying this and for this reason alone the distinctive patterns rather than varying intensities of shading were regarded as most important.

(10) The Function of the Relative Relief in the Combination Slope Map.

Relative relief gives an indication of the local vertical amplitude of landform and of the depth of dissection of terrain. Furthermore, areas of great relative relief possess steep slopes. Besides this relationship, there is a special function of the relative relief in this slope map. If the grid units in which all areasare under the category of flatland do not give additional information about the surface conditions themselves, the order of relative relief, depicted by distinctive line-shading, enables some quantitative assessment of the variation of gradient to be made.

(11) Summary of Characteristics of the Combination Slope Map.

The combination slope map therefore shows:-

(a). The locations and slope category associations of distinctive slope units (by choropleths).

(b). The respective percentages of groups of slopes of similar gradients in each grid unit, by the lengths of lines on the located graphs.

(c). The average gradients of types (groups) of slopes (on the slope symbol), measurable with a protractor, within each grid unit.

(d). The relative relief within a grid unit, both directly, by the line-shaded rectangle, and indirectly, by the height of the composite line on the slope symbol.

CHAPTER III

LAND USE STUDIES : AN APPLICATION OF THE COMBINATION SLOPE MAP

Analysis of Land Use

The main objective of the land use analysis here is to bring out the correlation, if any, of slope and land use, though slope is merely one of many determinants. Other factors are discussed where slope is regarded as locally insignificant.

The land use information was obtained solely from vertical air photographs, scale 4 inches to one mile, taken between 1948 and 1950. Land was arbitrarily classified into three types, (1) cultivated land, (2) used land, and (3) unused land.

1. Definitions of Terms.

Three terms are used in this land use analysis. (1) Cultivated land, that is land which has been ploughed. (2) Uncultivated but agriculturally utilized areas, termed 'used' land, e.g. grassland used for pasturing, woods or scrubland for sheltering livestock, planted wind-breaks, and farmstead lots. (3) Unused land, that is, land not agriculturally utilized, such as forest, bogs and some scrub land.

The identification of land-use from vertical air photographs has its limitations. This is especially so when the Seelyscope is employed to reduce the scale of the photographs to that of the slope maps, as in this study. There is no difficulty in delimiting the cultivated land, but there is in the distinction of used and unused, particularly in wooded areas. When removed from farmstead lots, the latter possessing no signs of dugouts for watering livestock are regarded as unused, except where there is evidence of stream flow. Often the boundary between used and unused land follows a section limit, indicating the importance of the individual farmer's preference in the determination of land use.

A reconnaissance survey of land use which can give more substantial evidence of identification of land use patterns, especially the used and unused land, has not been conducted. Land use patterns may have changed somewhat since the air photographs were taken in 1948 - 1950, so a reconnaissance ground survey at present could lead to false conclusions concerning the interpretation of land use on these photographic prints.

2. Analyses of Chosen Areas.

Topographical names of local regions are used wherever possible. Each land use map (transparency) was superimposed first upon the related combination slope map and later upon the appropriate topographic sheet in the analysis of relationships.

(1) The Pembina Mountain Area.

Statistical analysis of the chosen area.

The chosen area has the following characteristics of use (as revealed by Table I and Fig. I):-

A high proportion (67.5%) of land under cultivation exists, with a very high percentage of this occurring on flatland. Most of the remaining cultivated land is found on 2-4 degrees slopes.

A very large proportion of the uncultivated but agriculturally used land, which comprises 14.3% of the chosen area, is situated on flatland, and most of the rest occurs on slopes gentler than 8 degrees.

Agriculturally unused land comprises 18.2% of the area, and more than one-quarter of this element is found on flatland.

TABLE I

PERCENTAGE AREAS OF LAND-USE TYPES IN EACH SLOPE CATEGORY IN THE PEMBINA MT. AREA.

Slope-category		Land-use			
		Cultivated	Used	Unused	Total
0°–2°	A	64.3%	12.4%	4.9%	81.6%
2°–4°	B	2.1%	0.5%	2.0%	4.6%
4°–8°	C	0.5%	0.9%	2.3%	3.7%
8°–16°	D	0.4%	0.2%	6.2%	6.8%
16°	E	0.2%	0.3%	2.8%	3.3%
Total		67.5%	14.3%	18.2%	

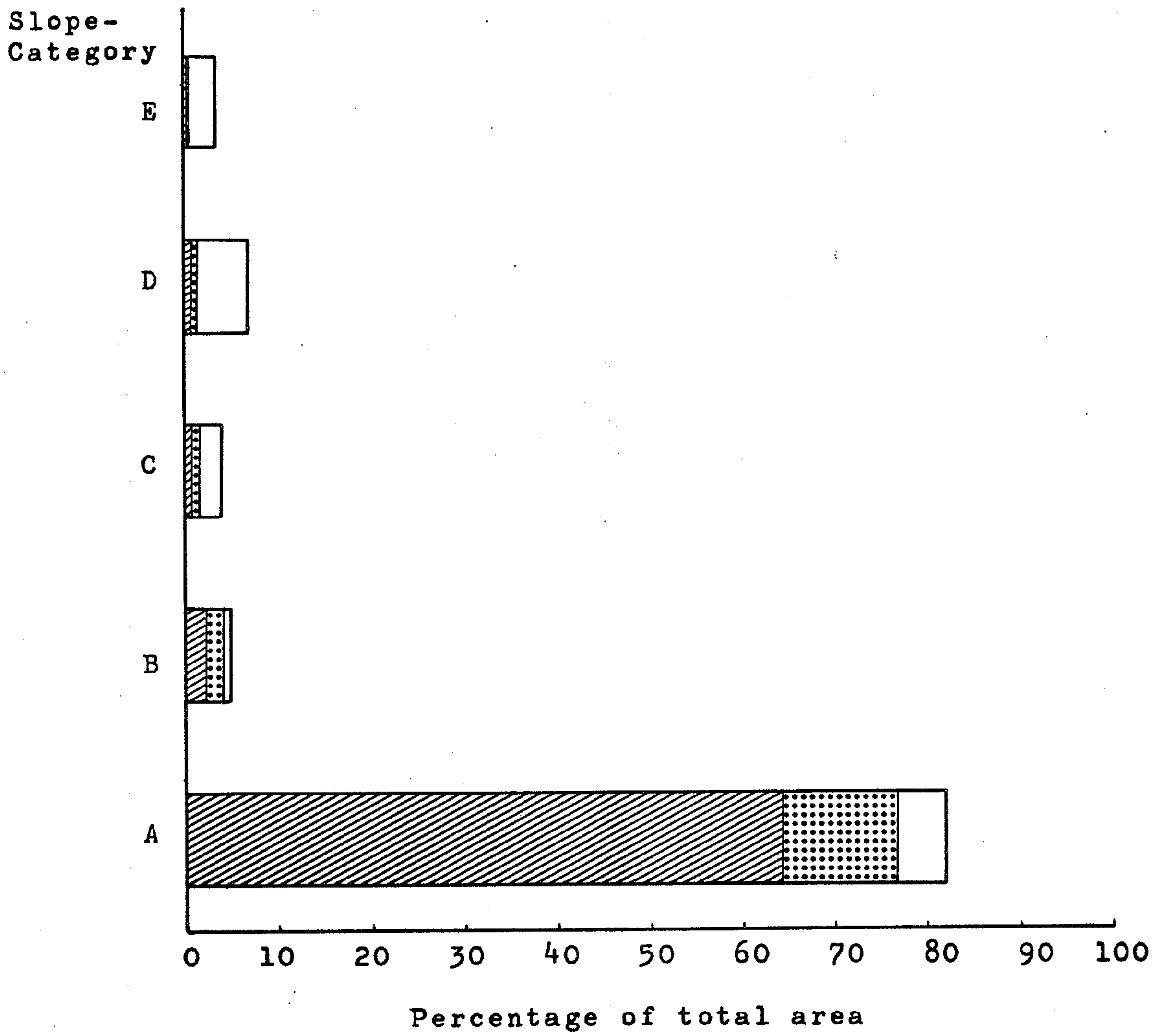
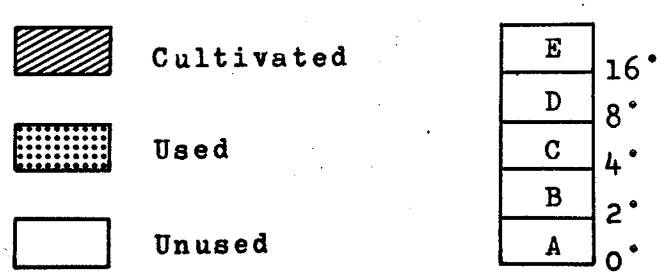


FIGURE 1

Slope - Land Use Relationship
in the Pembina Mt. Area.



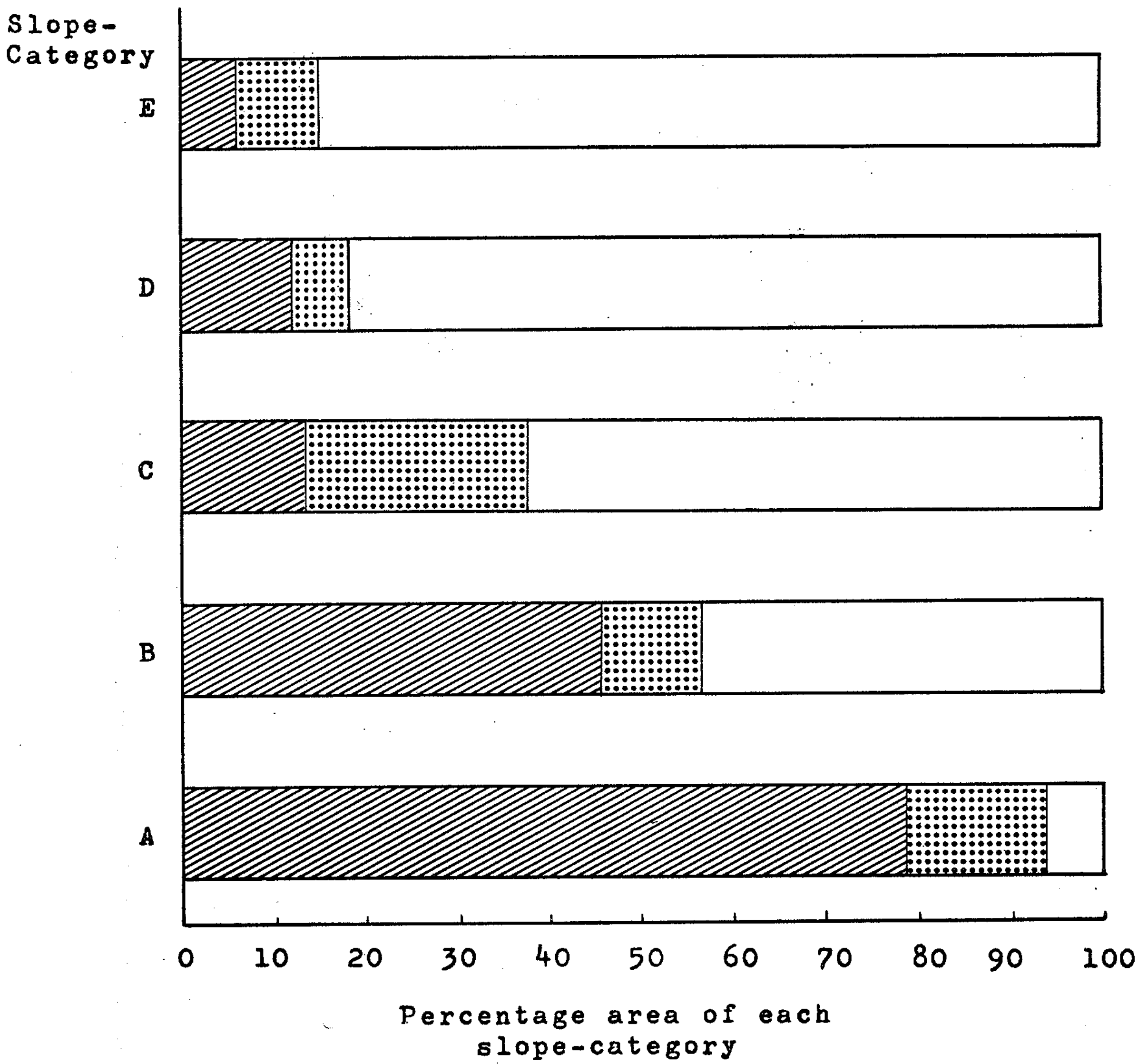
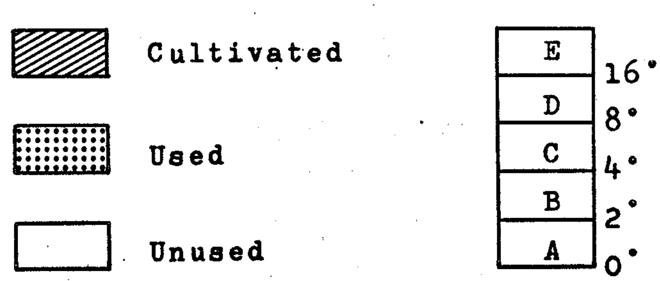


FIGURE 2

Percentage comparison of the land-use compositions of slope categories in the Pembina Mt. Area.



The following characteristics are revealed by analysis of Fig. 2:-

There is a progressive decrease in the proportion of cultivated land with increasing slope gradient; this is especially noteworthy in the lowest three slope categories.

A positive correlation between the proportion of unused land within a slope category and the gradient values of that category exists, although Group D (8-16 degrees) slopes have a percentage of unused land that is almost as high as Group E slopes.

On a proportional basis, uncultivated agriculturally used land is most significant in 4-8 degrees areas (it occupies 24% of these areas), although approximately 16% of all flatland is classified as 'used' land. Slope does not appear to be a determinant of the distribution of this land-use element in the Pembina Mountain Area.

Local Determinants of the Land Use Pattern.

From the combination slope map, Map 2, it is evident that the chosen area includes several distinctive types of terrain. Each of these tracts is described below in terms of its physiographic characteristics and land use pattern, and the factors determining the utilization of the land are evaluated.

Lake Agassiz Lowlands (8A, 8B, 8C, 7C and part of 7B). The combination slope map indicates the universality of 'flatland', and the gently increasing gradient towards the foot of Manitoba escarpment (depicted by a zone of 4-8 degrees slopes) is evidenced by a low but increasing relative relief in that direction.

On the lowlands most of the land is cultivated, but a considerable amount of the area is non-cultivated agriculturally used land. There is great variety in the size of 'used' lots, although the majority of larger ones occur within a mile and half of the escarpment. Most of the larger units are narrow but elongated in a direction parallel to the escarpment.

The most pronounced example of this orientation is the virtually continuous zone of used land between the 1050 and 1075 feet contours. Nearly all the farmsteads are situated within the used zone rather than beyond its margins.[1] Three intermittent lakes account for only a small fraction of the used land in this belt. In the south, the belt is narrow, and appears to coincide with closely-spaced contours representing the degraded cliff at the back of the highest Campbell beach (altitude 1040 feet in the vicinity of the international boundary[2]). In the north, the 'used' belt is broad and although at the same altitude, part of the element appears to coincide with this particular beach, and the remainder with the bluff at the rear of it. The coarseness of the beach deposit may account for the absence of cultivated land on this strandline, whereas the gradient of the degraded cliff behind would preclude ploughing there.

Most of the east-west oriented patches of used land coincide with intermittently stream-occupied gullies. These are generally woodland (topographic map), although in a few cases their presence is due to swampy conditions. The smallest parcels of used land are farmsteads and farm yards.

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1 In the classification of 'used' land, farm buildings, feed lots, orchards, etc. are included.

2 J. H. Ellis, 'The Soils of Manitoba', 1938, pp. 112.

Near the U.S.A. border two sizeable units of unused land occur, both of which are completely wooded and which are related to a long deep gully dissecting the piedmont slope. A part of the unused land, is however, not explainable in terms of apparent physical characteristics.

Manitoba Escarpment (extends from 6C to 7A) is fairly linear in plan, although it is dissected by occasional deep gullies and small steep-sided valleys. Most of the escarpment appears to have a simple profile with dominantly 4-8 degrees slopes, although in area 7B it is locally steeper near the top (with gradients exceeding 16 degrees) between two very steep gullies. The relative relief in the escarpment area is normally 200-300 feet, although the escarpment itself has an amplitude of less than 200 feet.

More than a half of the escarpment is uncultivated used land, nearly all this being in the northern part. This land use characterizes adjoining gentle slopes (e.g. 2-4 degrees) as well as the typical 4-8 degrees slopes. Farther south, all the steepest slopes and most of the 4-8 degrees slopes comprising the escarpment towards the U.S.A. border are agriculturally unused. But in grid unit 7B some of the lower part of the escarpment, even where fairly steep, is cultivated land contiguous with that on the Agassiz lowlands. There is no apparent explanation for this, although it is clear that slopes of 4-8 degrees are not considered too steep and therefore too prone to soil erosion by runoff to be brought under the plough.

Referring to the topographic sheet, virtually all the land classified as 'used' and 'unused' is woodland. The air photos, however, revealed two important differences between the wooded escarpment in the north and that in the south. Firstly, the southern area is thickly wooded whereas the northern continuation is not. Secondly, only the northern part appears to possess dugouts for cattle watering. All minor gullies in the northern part of the escarpment were used but uncultivated, those in the south were forested.

The abrupt change between used and unused land midway along the escarpment occurs at a section boundary. The same type of change occurs along the same section line in the minor valley behind the escarpment. The change of use reflects different degrees of farming intensiveness on the same quality of land.

Summarily, there does not appear to be a causal relationship between slope and used, as distinct from unused, land along the escarpment. Drainage does not appear to be an important factor, but the thin soils on steeper slopes will be rapidly eroded when cultivated. Consequently, the general avoidance of the escarpment by ploughed land.

Rolling land on top of Pembina Mountain (5C, 6C, 6B, 7A) is defined by a western limit of a narrow zone of 2-4 degrees slopes increasing southwards to 4-8 degrees slopes, and the Manitoba escarpment as the eastern limit. Most of the area appears to be well dissected by small gullies and intermittent stream-occupied incised valleys. The relative relief in this area is usually 200-300 feet.

A large proportion of the flatland in the area is cultivated. Some of the uncultivated used land has a dendritic pattern of distribution which reflects the locations of small intermittent gullies (6B). In the south (6A), a long strip of used woodland is located on east-facing

4-8 degrees slopes at 1375-1425 feet above sea level. The slope is developed on the ground moraine immediately east of the low and moraine ridge. In the northern section of this belt of sloping land, the gradient falls into the 2-4 degrees category, and most of the area is cultivated except for the largest gullies whose utilization falls into the 'used' category. Much fairly well dissected terrain and even medium sized linear depressions, are ploughed in this area.

There are three large areas that are agriculturally unused, all coinciding with three independent dendritic networks of steep-sided incised valleys. Most of these areas are wooded and on 4-8 degrees slopes, although some flatland is incorporated.

As a whole in this area, slope appears to be an important determinant of land use.

<u>Ground moraine and End moraine plain</u> (3B, 3C, 4B, 4C, 5A, 5B and parts of 2B, 2C, 4A and 6A) has an amplitude of relief that is less than 50 feet. The whole area is dominated by flatland, except one elongated area with over 16 degrees slope, located in grid unit 6A. It is a deeply incised tributary valley of the Pembina valley.

There is very little clear expression of the local end moraine on the topographic map. The trend of the 1500 feet contour reveals a low narrow northwest-southeast ridge, and the distinctive shallow depressions and seasonal lakes on the map reveal the knob and kettle topography of the end moraine. This moraine is much less pronounced in this area than further north, near Altamont.

Cultivated land dominates this whole morainic area. The clay-loam soils are generally favourable for agriculture, although the soils of the

Snowflake association that are found on the flat southwestern part of the till plain are badly drained and salinized in some places (see soil map[3] and topographic map). Although in some areas, there are 15-20 examples of this kind of small intermittent lakes within one square mile, yet it has surprisingly little effect on the land use pattern. Only the larger ill-drained patches, for instance the biggest one in 4B, have remained uncultivated, although these are usually unimproved grassland probably used for livestock pasturing. Sometimes artificial drainage has enabled cultivation to extend. For instance, a small marshy area in 4C, is connected by a drainage ditch to a gully; the area is now cultivated.

In this area, many small plots of 'used' land are centred on farmsteads, and some of the medium size ones are associated with drainage elements, not necessarily steep-sided gullies. Some of the 'used' land is woodland, but a few areas are presumably grassland, associated with imperfect drainage and small depressions (especially in the hummocky end moraine tract).

The only trace of unused land is located in the incised valley and its tributary gullies in 6A. The steep slopes are forested, but the headward part of the valley which has much gentler sides is uncultivated but agriculturally used land, mainly grassland.

<u>Pembina Valley</u> (1C, 2B, 3A and parts of 1A, 1B, 2A, 2C and 4A) has high relative relief, 300-400 feet in the north and 400-500 feet downvalley. The average width of the valley is two miles. It appears to

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3 J. H. Ellis and W. H. Shafer, 'Soil Map, Reconnaissance Survey of South-Central Manitoba', Soils Report No. 4, 1943, Manitoba Department of Agriculture.

possess a concave valley-side profile, with over 16 degrees slopes typical in the upper part of valley, below which is a broad 8-16 degrees slope element. The basal part of the valley possesses a narrow belt of flatland or 2-4 degrees slopes. Occasional 2-4 degrees terraces occur, and a very large cultivated 0-2 degrees terrace cut in outwash fill occurs in 1C[4].

The north side of the lower valley possesses a midslope element of 4-8 degrees, below and above which are much steeper slope elements. The valley sides are embayed by small gullies and punctuated by fairly deep tributary valleys. These minor valleys possess sides that decrease in gradient towards their heads, although the average slope of each side is usually equal to or greater than 16 degrees.

This segment of the Pembina Valley on the Pembina Mountain sheet is almost completely characterized by unused land, apparently due to the steepness of slopes. There are many small areas of cultivated land located on the bottom flatland (a narrow floodplain), and one extends from flatland on to slopes of 2-4 degrees. Almost as many cultivated patches exist on 2-4 degrees terraces, sometimes well above the valley floor, and occasionally on gently inclined colluvial slopes. The cultivated fields on the terraces are usually larger than those on the restricted and more vulnerable flood plain. Some of the cultivated patches (e.g. in 3A, 1C) extend on to the adjacent slopes of 8-16 degrees. On the 8-16 degrees valley sides a few small and narrow isolated units of cultivated land

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4 E. C. Halstead, 'Surficial Geological Map of Brandon Area (Map 1067A)', in Geological Survey of Canada, Memoir 300, 1959.

occur. These (when located on the topographic map) appear to be sited either on small dissected old terraces or on spurs whose axes have slopes of category 8-10 degrees.

There are a few large patches of non-cultivated agriculturally used land, of which most are situated at the heads of tributary valleys with the slope equal to or greater than 16 degrees, except one of 2-8 degrees (in 1A). Two others constitute the extension of used land on the Boissevain till plain. The 'used' units located on the steep sides of tributary valleys are not too steep for livestock grazing, but prohibitively steep for the plough.

In this section of the Pembina Valley there are very few farmsteads, and only one, in 3A, is situated on the 4-8 degrees slopes of the valley sides. It reflects the insignificance of the valley as an agricultural producer. The air photographs present no evidence of usage for livestock grazing, although there is pasturing on some of the scrubby lower slopes (open range) during the summer months.

In conclusion, slope gradient in the Pembina Valley has a positive correlation with the unused land and an inverse correlation with the cultivated land.

The Ground moraine plain to south-west of Pembina Valley (1A, 1B and parts of 1C, 2A, 3A) has a low relief, but its margin is dissected by gullies and tributary valleys of Pembina Valley. Flatland is very characteristic (no undulation is observed on the slope map, although this is apparent on the topographic sheet).

Referring to the topographic sheet, this till plain is full of small swales that are intermittently occupied by water, yet most of them are cultivated. Much of the uncultivated agriculturally used land.

TABLE II

PERCENTAGE AREAS OF LAND-USE TYPES IN EACH SLOPE CATEGORY IN THE HOLLAND AREA.

Slope-category		Land-use: Cultivated	Used	Unused	Total
0°–2°	A	69.5%	13.3%	1.3%	84.1%
2°–4°	B	5.4%	2.6%	0.7%	8.7%
4°–8°	C	2.1%	2.1%	1.6%	5.8%
8°–16°	D	0.3%	0.8%	0.3%	1.4%
16°–	E	/	/	/	/
Total		77.3%	18.8%	3.9%	

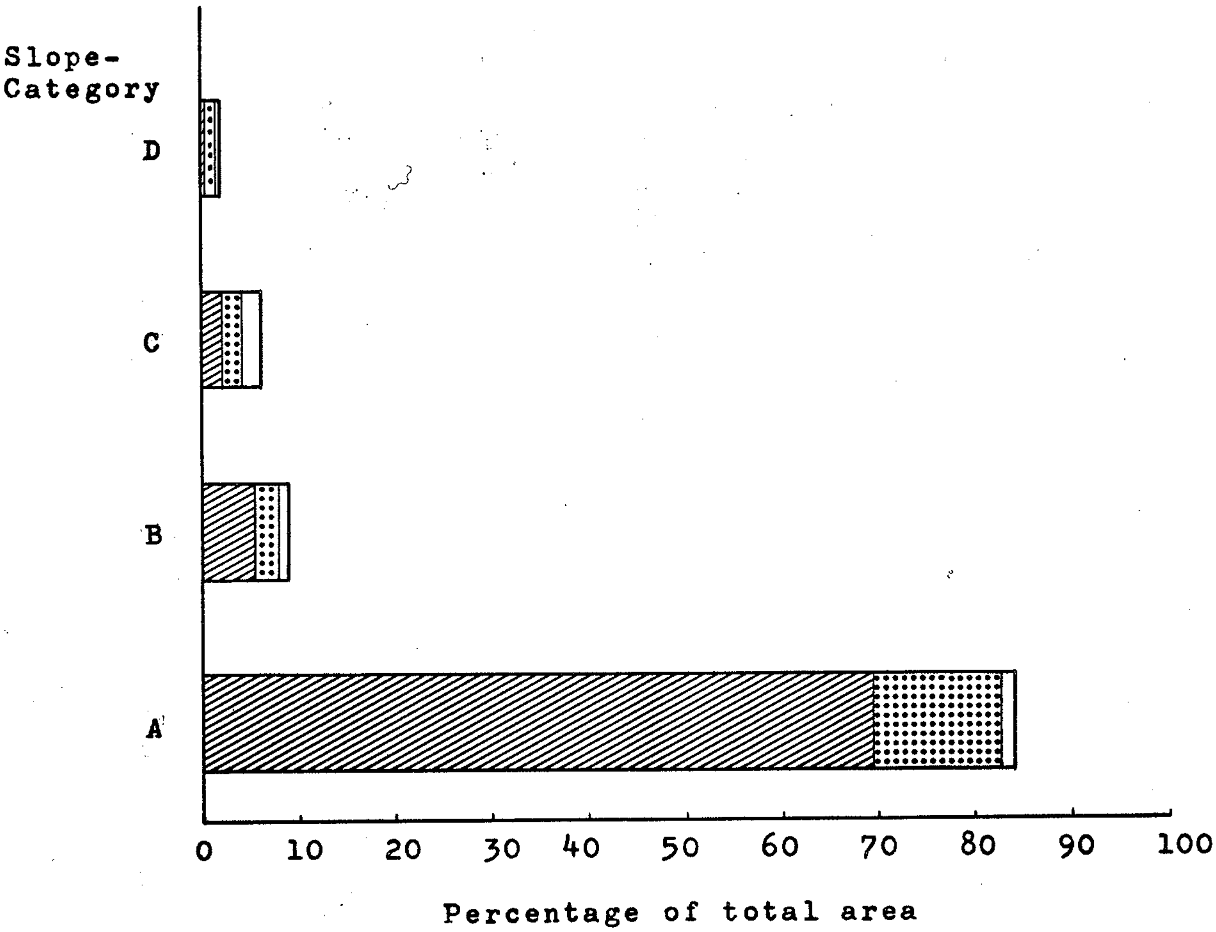
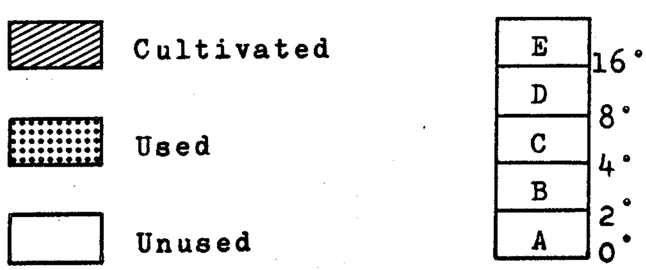


FIGURE 3

Slope - Land Use Relationship
in the Holland Area.



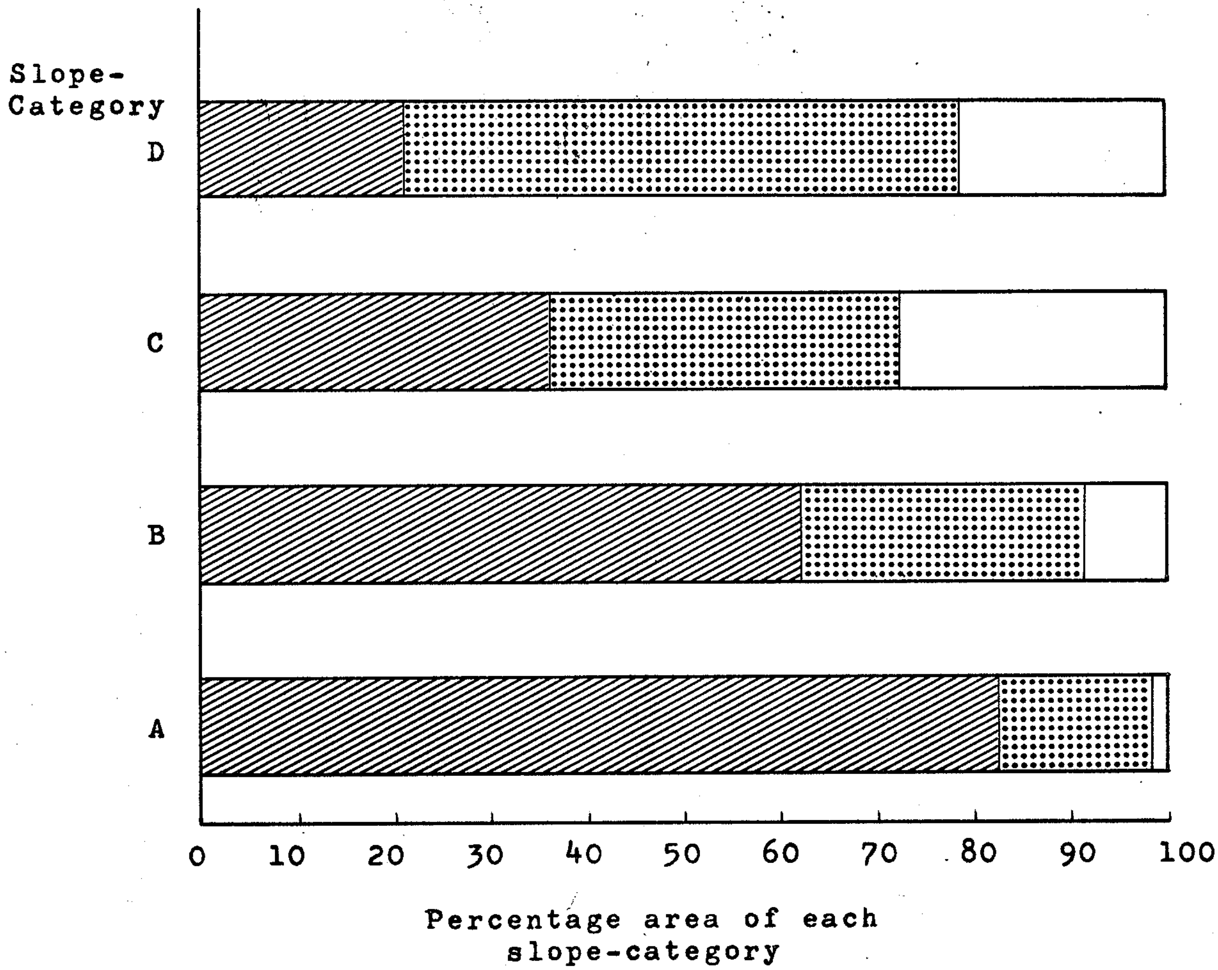
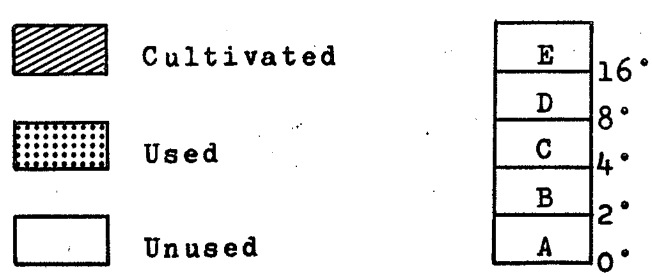


FIGURE 4

Percentage comparison of the land-use compositions of slope categories in the Holland Area.



occurs on this ill-drained land or is related to farmsteads and yards. Some is found on gentle slopes adjacent to the steep valley-sides. Nevertheless part of the 'used' land appears to be potentially cultivable, but is at present woodland or scrubland in rectangular lots.

(2) Holland Area.

Statistical analysis of the chosen area.

This chosen area has the following characteristics of land-use (as shown on Table II and Fig. 3):-

A very high proportion (77.3%) of the area is under cultivation, and most of this land use element is on flatland. Most of the remaining cultivated land is located on gentle slopes.

More than two-thirds of the uncultivated agriculturally used land, (which occupies 18.8% of the total Holland area) is situated on flatland, and most of the rest is on slopes gentler than 8 degrees. Only 3.9% of the chosen area is agriculturally unused, and one-third of this land use is found on flatland.

The following characteristics are indicated by analysis of Figure 4:-

There is a uniformly progressive decrease in the proportion of the cultivated land with increasing slope gradient, although approximately 20% of the steepest local slopes are cultivated.

A positive correlation exists between the proportion of agriculturally used land within a slope category and the gradient values of that category.

Concerning unused land, Group C (4-8 degrees) slopes have a higher percentage of this land use type than do Group D slopes. Therefore, slope is not a prime determinant of the distribution of unused land, even though there is apparently a direct relationship between slope gradient and unused land on 0-8 degrees land.

Local Determinants of the Land Use Pattern.

The Holland Area depicted on the combination slope map, Map 3, may be divided broadly into two topographic entities, based on slope unit associations and relative relief:-

The Tiger Hills morainic area (1A, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B, 5C, and parts of 1B, 4C), as shown on the combination slope map, consists of a complex association of slope units that are linear or rounded in plan with intervening flatland areas. The relative relief is characteristically 100-200 feet. From the irregular distribution of slopes it is apparent that there is accidented relief, with locally hilly areas. The sub-parallel linear slopes in the eastern area are the well-defined sides of the flat-floored Boyne valley. The area is largely composed of ground moraine, although the flatter parts consist of 'lag concentrate', that is, the coarser fraction of glacial drift that was reworked by lake water action, when Lake Agassiz existed[5].

On the flatland, a fairly low proportion (13.3%) of the area is uncultivated agriculturally used land, although almost all the remainder is under cultivation. 'Used' land is a highly characteristic feature of the whole morainic area in this locality. Yet there is a substantial fraction of all gently sloping (2-8 degrees) land that is cultivated.

5 Map 1067A accompanying Geological Survey of Canada Memoir 300 by E. C. Halstead.

The pattern of land use in this morainic region reveals that the dominant control of utilization is drainage, not slope gradient.

There are two very large elongated tracts of 'used' land. One is an east-west belt, about three miles long, located on flatland (2A), the other commences one mile to the east and extends down the Boyne valley for approximately three miles (4B). These large tracts are located on imperceptibly sloping ground in a linear depression connecting the Cypress and Boyne rivers, and separating masses of exposed ground moraine. Referring to the topographic sheet, they are the two largest intermittent lakes in this chosen area. The linear depression in which they both occur was probably a spillway. Ditches extend almost the full length of the southern marshy area. The other one has natural drainage via the Boyne river when it is flooded.

Narrow sinuous zones of used land in 2A, 3A, 4A, 4B are coincident with intermittently occupied gullies, although they are commonly woodland or pasture. Many patches of 'used' land occur on the steeper sides of morainic knobs; these are nearly all scrub or woodland, utilized by livestock. Small plots of 'used' land on the 'flatland', which is mostly very gently undulating in this area, appear to reflect the distribution of farmsteads, farm buildings and attached small wood lots, not impeded drainage. In 5A, a large patch of wooded but used land is situated in an area of knobs and intermittently occupied shallow depressions, representing the only sizeable piece of end moraine and associated ice contact stratified drift in the Holland map area. Some smaller rectangular 'used' lots are not explainable in terms of physical determinants, and they appear to be cultivable.

Seemingly, a high proportion of gently-sloping (2-8 degrees) land is cultivated, even on the varied soils of the morainic ridges (4B, 5C). The upper (and gentler) slopes of some of the tributary valleys of the Boyne and the south-facing side of its valley (4B, 5C) are cultivated. A narrow strip of cultivated land is found on the 8-16 degrees slopes of the north-facing valley side of the Boyne. The ploughed unit, however, appears to be near the lower limit of slope gradient in this category. Many of the small areas that are depicted as ill-drained on the topographic map are nevertheless cultivated.

Agriculturally unused land is fairly significant in this area. A large elongated patch in 4B and 5B, coincides with the steep (8-16 degrees) south side of the Boyne valley and the incised gullies and tributary valleys, as well as the downvalley part of the intermittently flooded flat floor drained by the Boyne river. The 'unused' character of these areas appears to reflect the occurrence of the steepest slopes in the area and the worst drained part of this section of the Boyne valley.

There are some medium-sized tracts of unused land located on moderate slopes of knobs (1A, 2A, 4B). Similar terrain in other parts of this area are cultivated, indicating the importance of the individual farmer's preference in the determination of land use.

The knob and kettle topography appears to be less settled than the areas of flatland within the Tiger Hills region of the Holland map area.

Assiniboine Delta Area (1C, 2C, 3C, and parts of 1B, 2B and 3B) is an area that is almost completely 'flatland', with a relative relief of 0-150 feet. The Tiger Hills morainic country in the south, merges northwards with the Assiniboine delta.

A very high proportion of cultivated land characterizes this area and there is no agriculturally unused land, with the exception of the settlement of Holland (which, by error, has been depicted on the land-use transparency as 'used' land). A considerable amount of uncultivated agriculturally used land exists. Two elongated tracts of used land coincide with the two small zones of 8-16 degrees slopes which are the sides of incised, intermittently occupied gullies joining the Cypress River. Although they are mostly wooded, the slopes are not too steep for live-stock grazing. In the north-east of 3C, a tract of one-quarter of a square mile is agriculturally used because of a few small intermittent lakes which occupy part of the floor of a long depression connecting two tributary valleys of the Cypress river. Many of the larger tracts of used land are occupied by pasture due to impeded drainage. The smallest units are, however, simply farm buildings and yards in the essentially cultivated areas.

In conclusion, slope elements have no significance in correlation of land use pattern except in the areas of 8-16 degrees slopes. In flatland, the dominant control is drainage.

(3). Riding Mountain Area.

Statistical analysis of the chosen area.

From Table III, Figures 5 and 6, there is no indication of a relationship between gradient and land use pattern, the reason being that about 77% of the chosen area falls within the Riding Mountain National Park, in which all of the slopeland and most of the flatland of the chosen area are located.

TABLE III

PERCENTAGE AREAS OF LAND-USE TYPES IN EACH SLOPE CATEGORY IN THE RIDING MT. AREA.

Slope-category		Land-use			
		Cultivated	Used	Unused	Total
0°–2°	A	15.9%	3.1%	50.0%	69.0%
2°–4°	B	/	/	8.0%	8.0%
4°–8°	C	/	/	12.4%	12.4%
8°–16°	D	/	/	8.1%	8.1%
16°–	E	/	/	2.5%	2.5%
Total		15.9%	3.1%	81.0%	

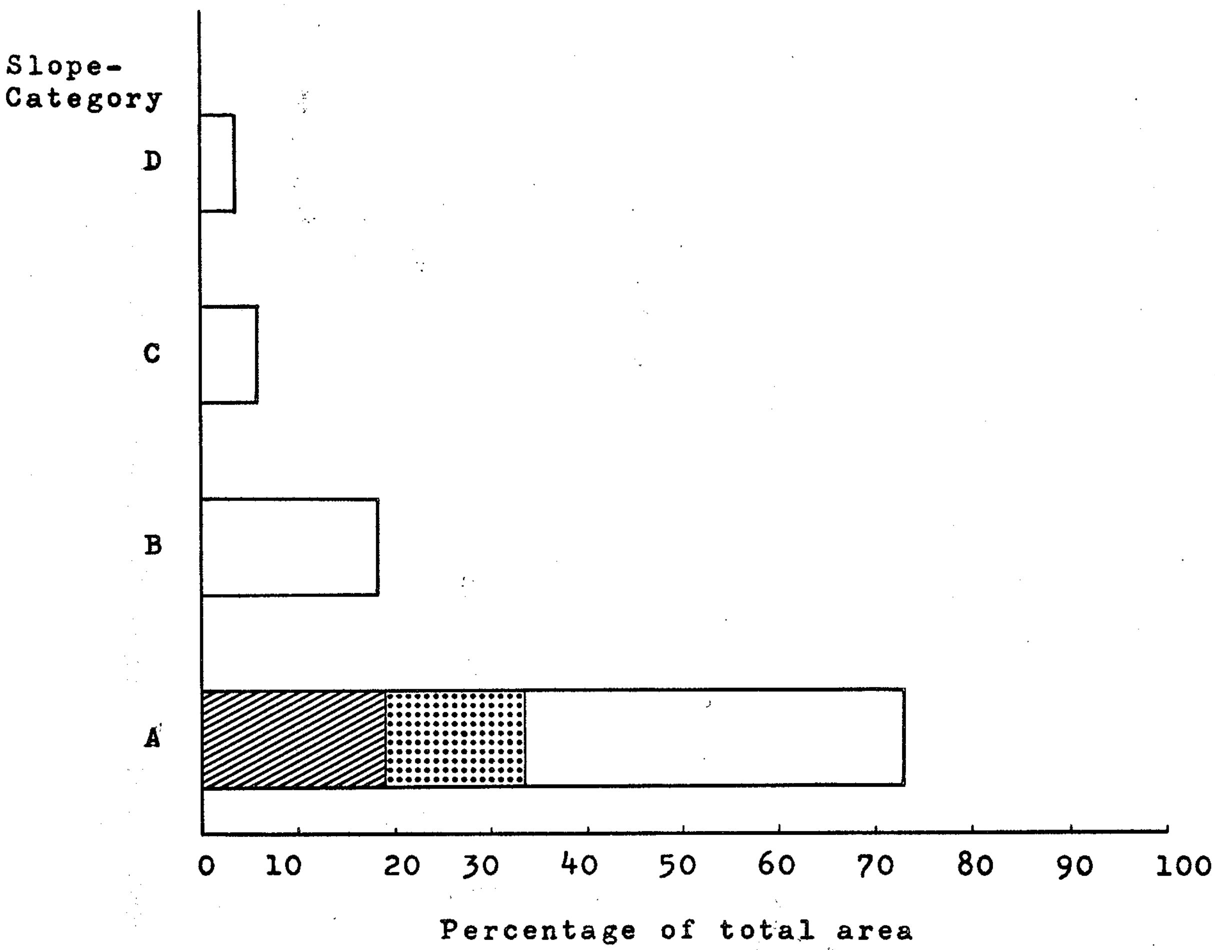
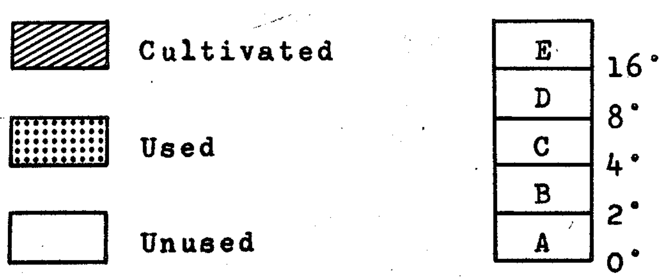


FIGURE 5

Slope - Land Use Relationship
in the Riding Mt. Area.



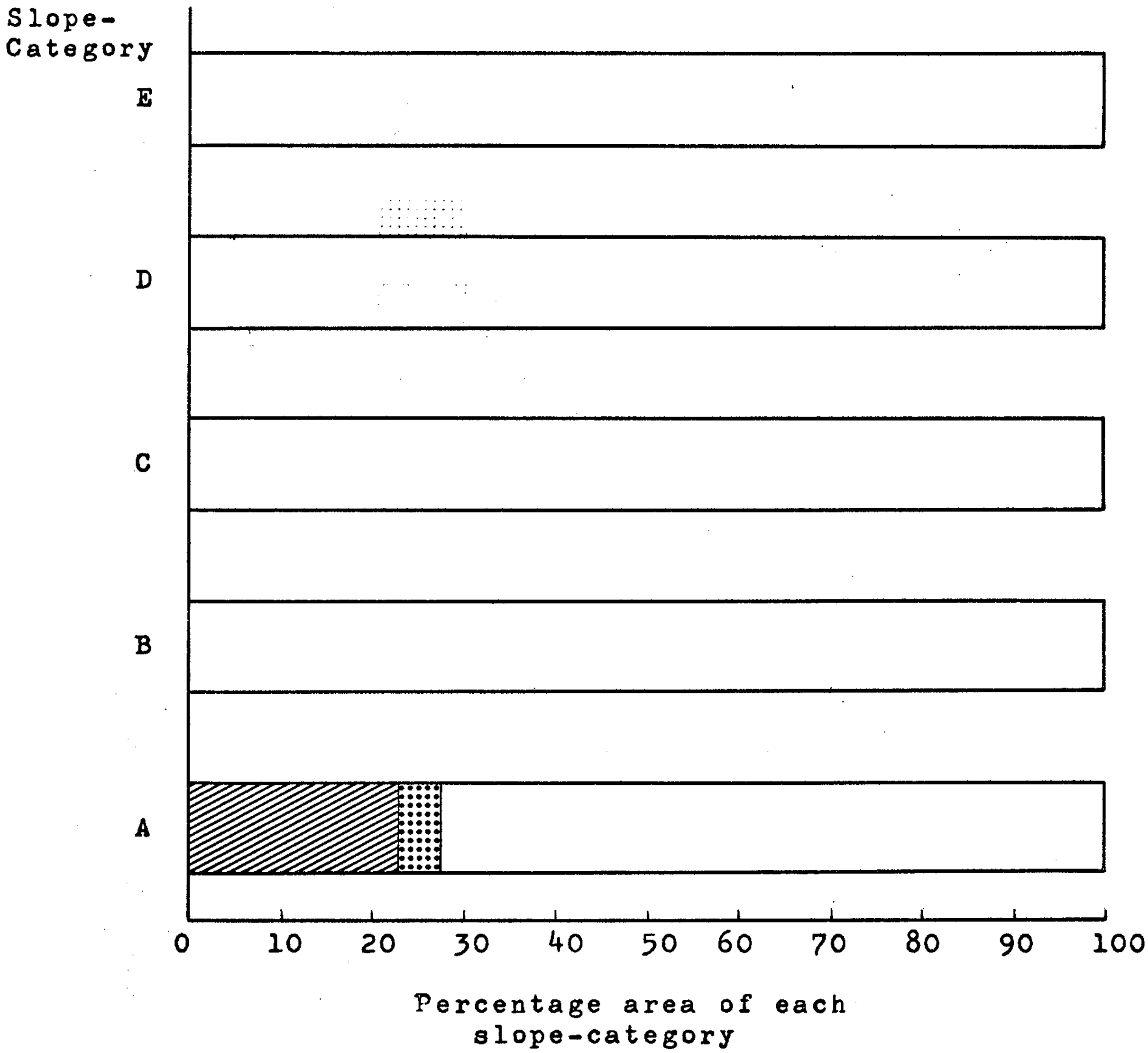
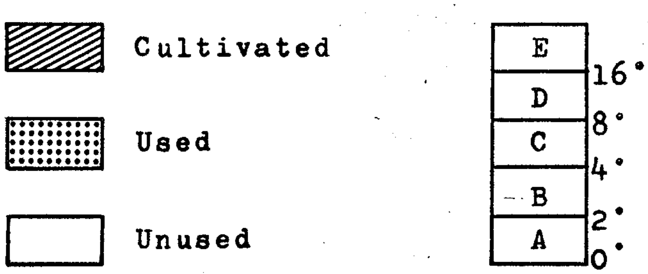


FIGURE 6

Percentage comparison of the land-use compositions of slope categories in the Riding Mt. Area.



Local Determinants of the Land Use Pattern (Map 4).

The Manitoba Lowlands (6A, 6B, 6C, and parts of 5B, 5C) have a smooth, level to very gently sloping topography. The relative relief is about 50 feet in the east, increasing to approximately 200 feet in dissected areas towards the foot of the escarpment. The western part, the piedmont region, is characterized by lake-bed deposits and beach deposits of prominent strandlines.[6]

All cultivated land is located on flatland. Creeks such as McKinnon and Scott are joined by ditches on the flatland to help drainage, and there appears to be adequate drainage throughout the area.

The non-cultivated agriculturally used land comprises a small portion compared with the ploughed area. In 6A, there is an elongated tract of 'used' land about two miles long and mostly wooded parallel to the escarpment. The southern part of this tract coincides with a small tributary of McKinnon Creek ending at a marshy area, that appears to be an elongated swale behind a beach ridge. The unwooded parcels of used land are kept for livestock pasturing. The smaller 'used' patches are nearly all farmsteads and yards. The remaining used land is wooded, but there is evidence of pasture for livestock in the form of clearings.

Most of the agriculturally unused land is located near the boundary of the Park and is thickly forested. The large patch of unused land in 5C is outside the Park, and could be cultivated if drainage of three elongated swales behind the beach ridges was accomplished.

Within the Riding Mountain National Park farmsteading was prohibited, so all the land is classified as agriculturally unused, although there is variety of land use depending on the state of drainage, as exemplified by numerous non-wooded but marshy tracts.

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6 W. A. Johnston, 'Surface Deposits and Ground-water Supply of Winnipeg Map-area, Manitoba', Geological Survey of Canada, Memoir 174, 1934. W. A. Ehrlich and others, 'Reconnaissance Soil Survey of West-Lake Map Sheet Area', Soils Report No. 8, 1958, Manitoba Soil Survey.

(4). Baldy Mountain Area.

Statistical analysis of chosen area.

Most of the slopeland in the chosen area falls within the Duck Mt. Forest Reservation. Figure 7 and Table IV shows the complete restriction of all agriculturally used land to the flatland areas.

Local Determinants of the Land Use Pattern (Map 5).

The Manitoba Lowlands (5A, 5B, 5C, 6A, 6B, 6C and parts of 4A, 4B, 4C) are an area of undulating land that slopes gently eastwards from the Duck Mountain escarpment. The relative relief of 50-200 feet increases towards the west.

A fairly high proportion of land outside the Reservation in the sample area is cultivated. There are two significant features concerning cultivated land. Elongated cultivated tracts, parallel to the escarpment, in 5C, 6B and 6C are situated on well-drained low Agassiz beach ridges and the intervening sandy loams. To the east of these ridges there is a belt of Meharry clay loam[7] that is largely cultivated, whilst peat deposits to the south are uncultivated. West of the belt of beach ridges, there is a zone of Meharry clay loam that is badly drained in some places. This zone is essentially uncultivated, although the best drained sites have been brought under the plough.

In the west contiguous areas of cultivated land extend north-south at the base of the escarpment. Most of the belt possesses gentle slopes developed on well-drained Grifton sandy loams, derived from ground moraine.

[7] Soil Map accompanying Manitoba Soil Survey, Report No. 9 by W. A. Ehrlich and others.

TABLE IV

PERCENTAGE AREAS OF LAND-USE TYPES IN EACH SLOPE CATEGORY IN THE BALDY MT. AREA.

		Land-use			
Slope-category		Cultivated	Used	Unused	Total
0°–2°	A	18.9%	14.6%	39.2%	72.7%
2°–4°	B	/	/	18.2%	18.2%
4°–8°	C	/	/	5.7%	5.7%
8°–16°	D	/	/	3.4%	3.4%
16°–	E	/	/	/	/
Total		18.9%	14.6%	66.5%	

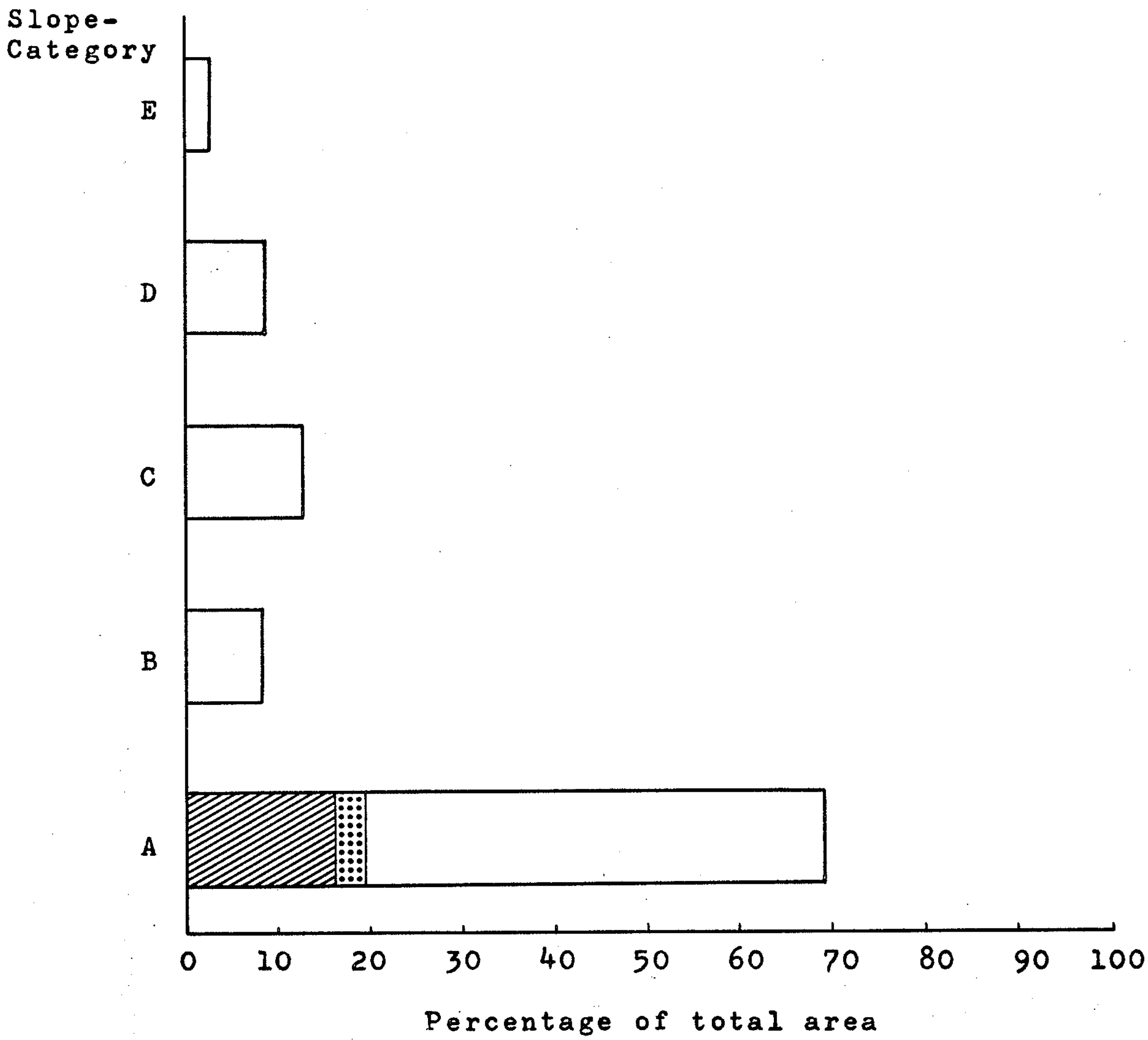
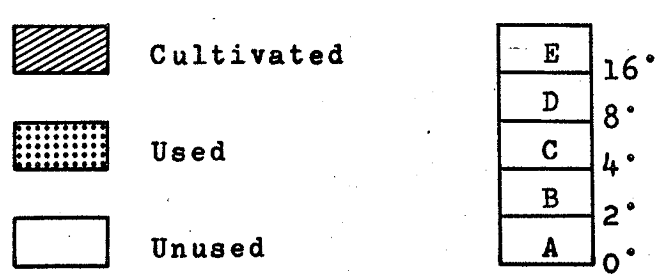


FIGURE 7

Slope - Land Use Relationship
in the Baldy Mt. Area.



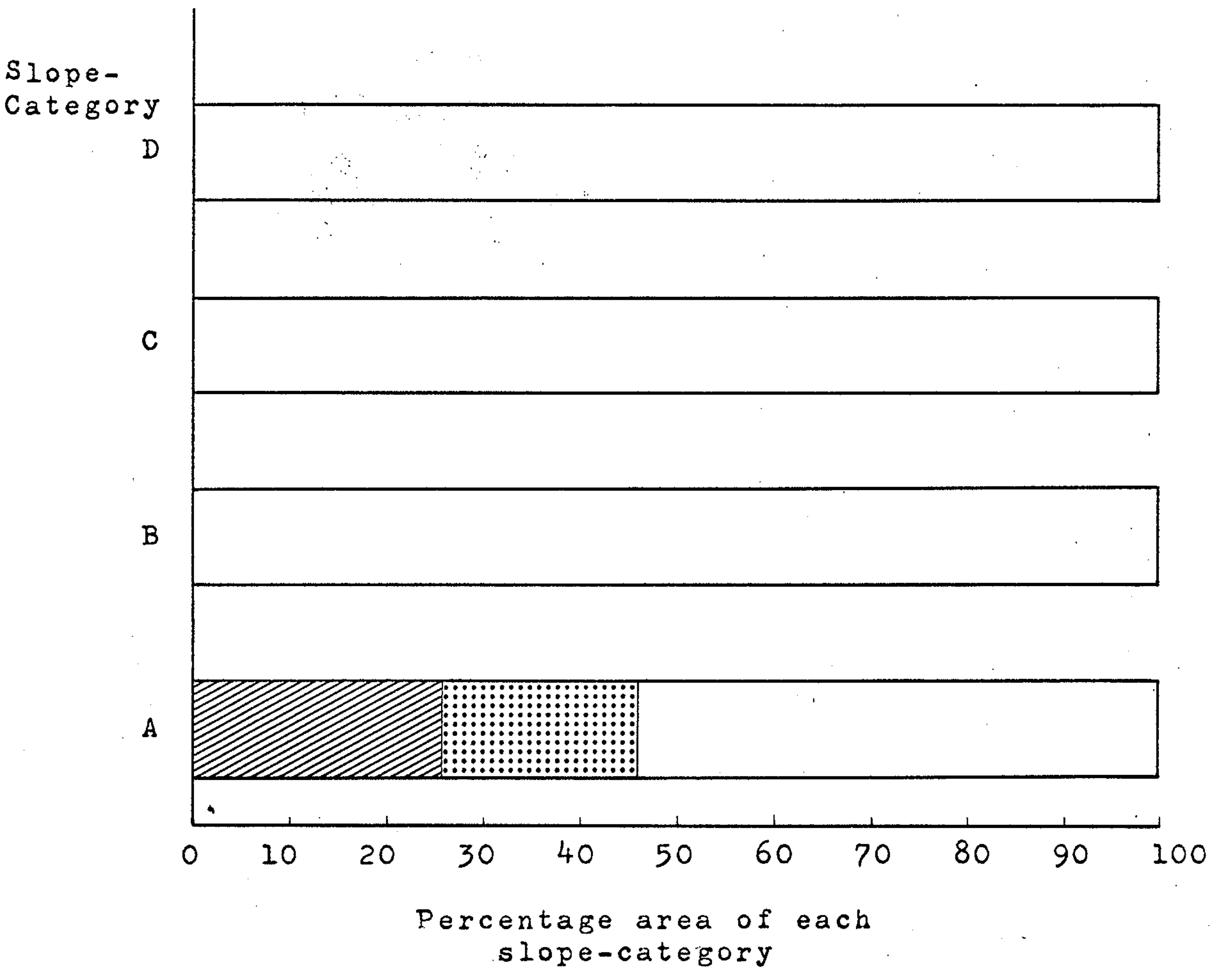
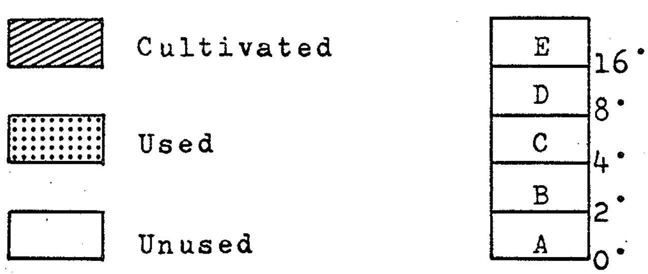


FIGURE 8

Percentage comparison of the land-use compositions of slope categories in the Baldy Mt. Area.



There is a high proportion of 'used' land on the flatland outside the Reservation. Most the patches of used land in 6A, 6B and 6C are wooded, and probably reflect poorer drainage than in the belt of beaches and Gilbert sandy loam soils.

In 5A, 5B and 5C, a long tract, nearly one mile in width, of mostly wooded land, extends from north to south, and appears to be related to the rather ill-drained Meharry clay loams, which occur on a very gentle slope behind the beaches. Along the banks of Fishing river, used land is also found, since the slopes are probably too steep for cultivation. At the foot of the escarpment substantial areas of 'used' land can almost without exception be correlated with poorly drained elements, such as intermittent lakes and marshes. Occasionally, moderate slopes that are well-drained have remained as natural pastureland after forest clearance.

The agriculturally unused land is significantly contained by section boundaries. Two areas of unused land are surrounded by agriculturally used land. The largest patch, in 5A, is forest on poorly drained peat soils. The other one in 5C of half square mile in size is wooded but evidence indicates cultivation by clearance is possible. All the area at the base of and on the lower part of the escarpment is 'unused' forest except for one patch of cultivated land in the south of 4A.

Manitoba Escarpment and the Morainic Area West of It. The escarpment is dominated by the slopes of 2-4 degrees in the extreme south, but in the northern part there is an alternation of 4-8 degrees slopes and gentler units. The width of this composite escarpment varies from two miles in the north to approximately four miles in the south. The amplitude of relief of the escarpment area is almost 1,000 feet.

The Fishing river is deeply incised into the Duck Mountain plateau, and its valley sides are 8-16 degrees. In units 3A and 4A is a small almost level ill-drained morainic plain dominated by unused woodland. It contains two isolated patches of cultivated land found on better drained sites.

The top of the plateau, completely within the Reservation, consists of rolling end moraine with numerous small permanent lakes punctuating forests and swamps. Baldy Mountain stands out as a steeper area, with characteristic 8-16 degrees slopes and gullies radiating from it.

In conclusion, most of the chosen area of Baldy Mountain Area lies within the Duck Mountain Forest Reservation, and consequently it is only the eastern portion of the area that can be examined with the view to determining the relationship between agricultural land use and physical determinants, such as slope, drainage and soils.

CHAPTER IV

CONCLUSION

1. The Combination Slope Map.

The combination slope map has been produced, in this thesis, by utilizing combined diagram and map techniques. Raisz and Henry's method of determining slope units was adopted, and J. O. Veatch's quantitative line-graph technique of depicting land types provided the concept of representing diagrammatically the association of slope components in any area. However, the construction of the located diagrams in this thesis is quite different from Veatch's method.

The major limitation of the technique lies in the difficulty of representing slope characteristics adequately when there are many complex minor variations in slope gradients as revealed by contour positions. The slope maps, therefore, do present a generalized represenation of terrain.

2. Application to Land Use Studies.

The emphasis in this work has been to determine the type of relationship that exists between slope and land use. Other physical determinants of the land use pattern have been considered as well.

On a broad scale, slope does play an important role in determining the incidence of cultivated land, but in gently sloping areas the particular land use reflects drainage and soil conditions rather than minor variations in gradient. Generally, the steepest slopes in a locality are agriculturally unused, although some escarpment and incised valley slopes are woodland or pasture used for supporting livestock. Agriculturally used, but uncultivated, land normally consists of open woodland with intervening pastures, and is found on a variety of slopes, although mainly where there are gentle gradients.

3. The employment of the combination slope map in the analysis of land use patterns in four small areas of Manitoba provides a satisfactory method of examining some of the major associated physical and human elements of the landscape. Its application to other areas could enable regional comparisons to be made.

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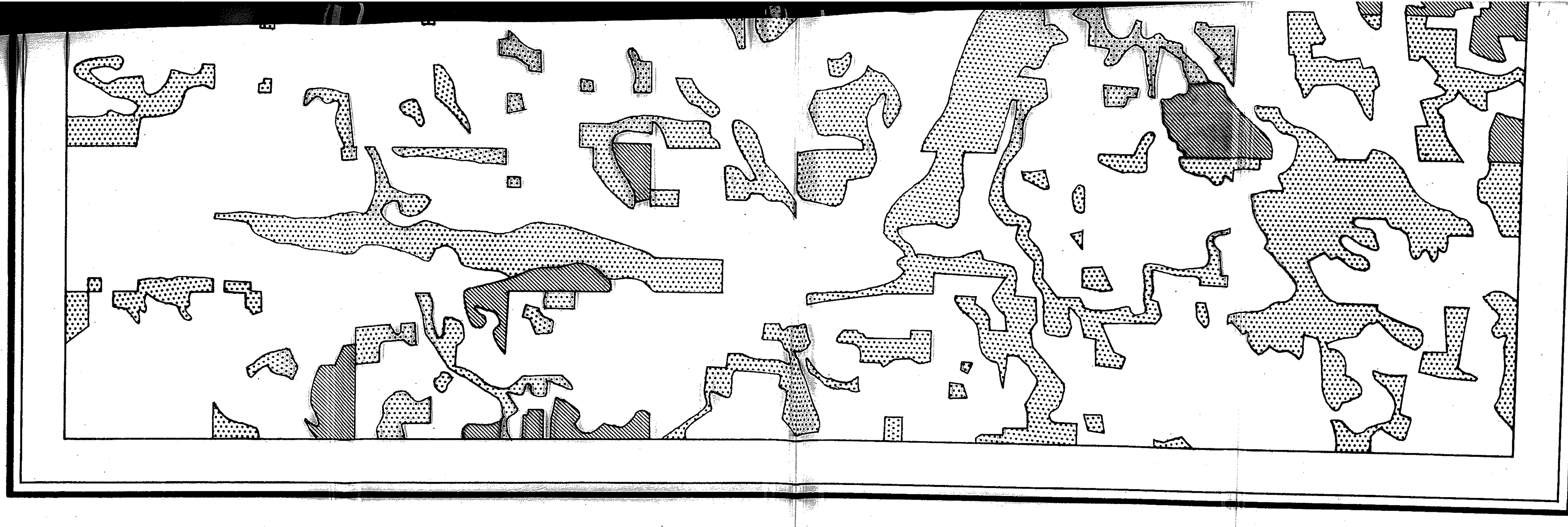
HOLLAND AREA

MANITOBA

LAND USE MAP



LAND USE TYPES

Cultivated

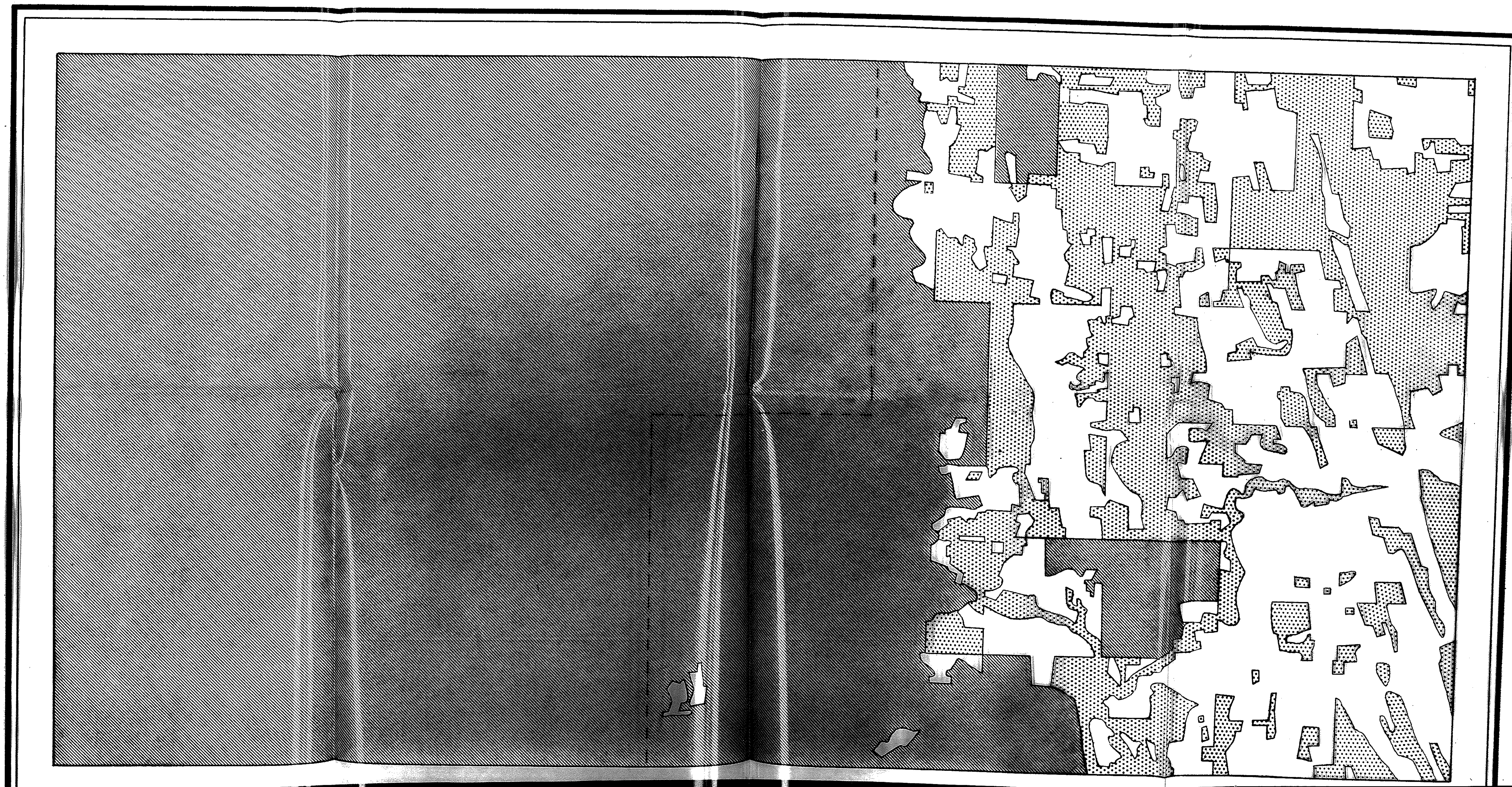
Used

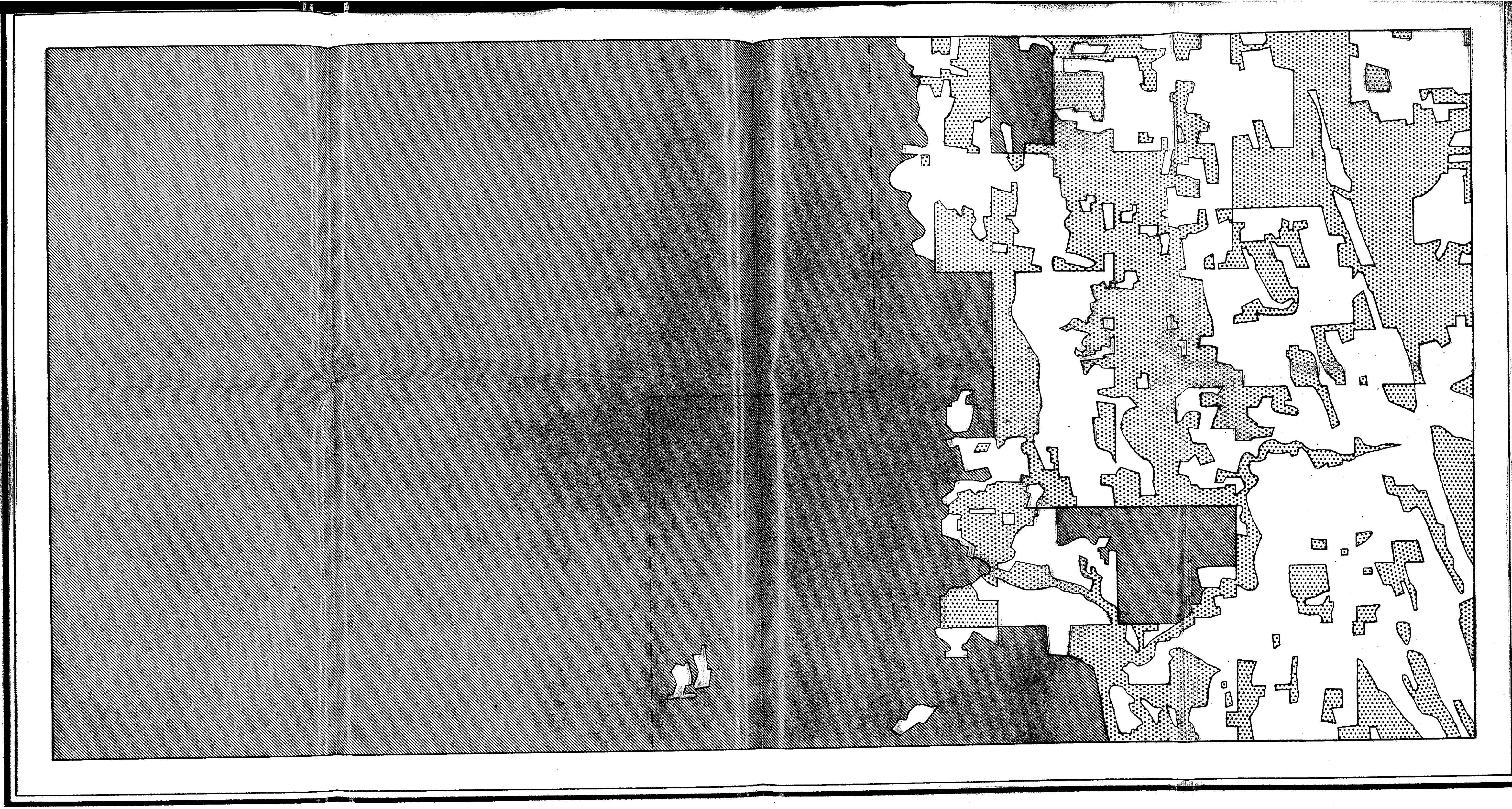
Unused

BALDY MT. AREA

MANITOBA

LAND USE MAP





LAND USE TYPES

Cultivated

Used

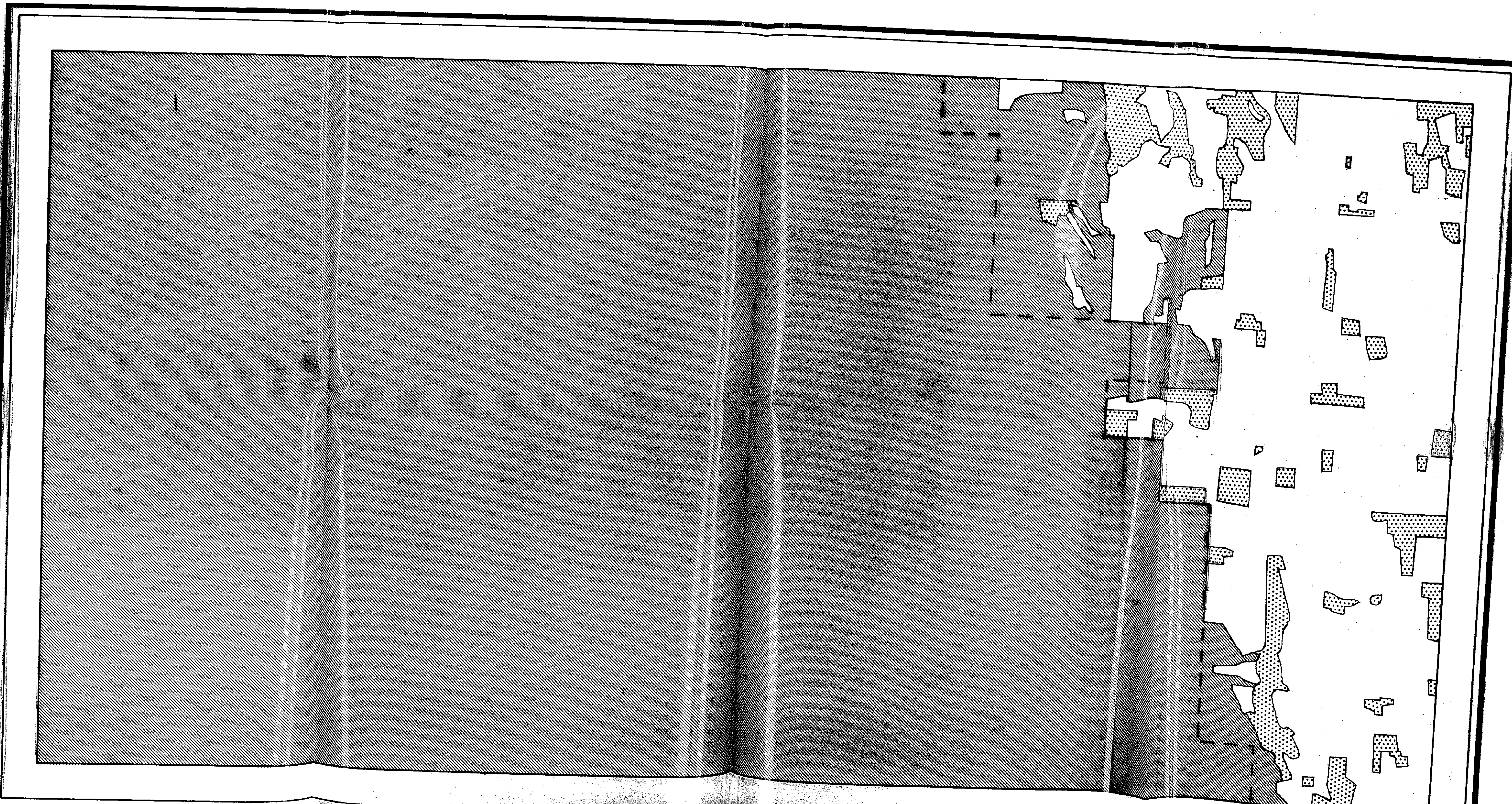
Unused

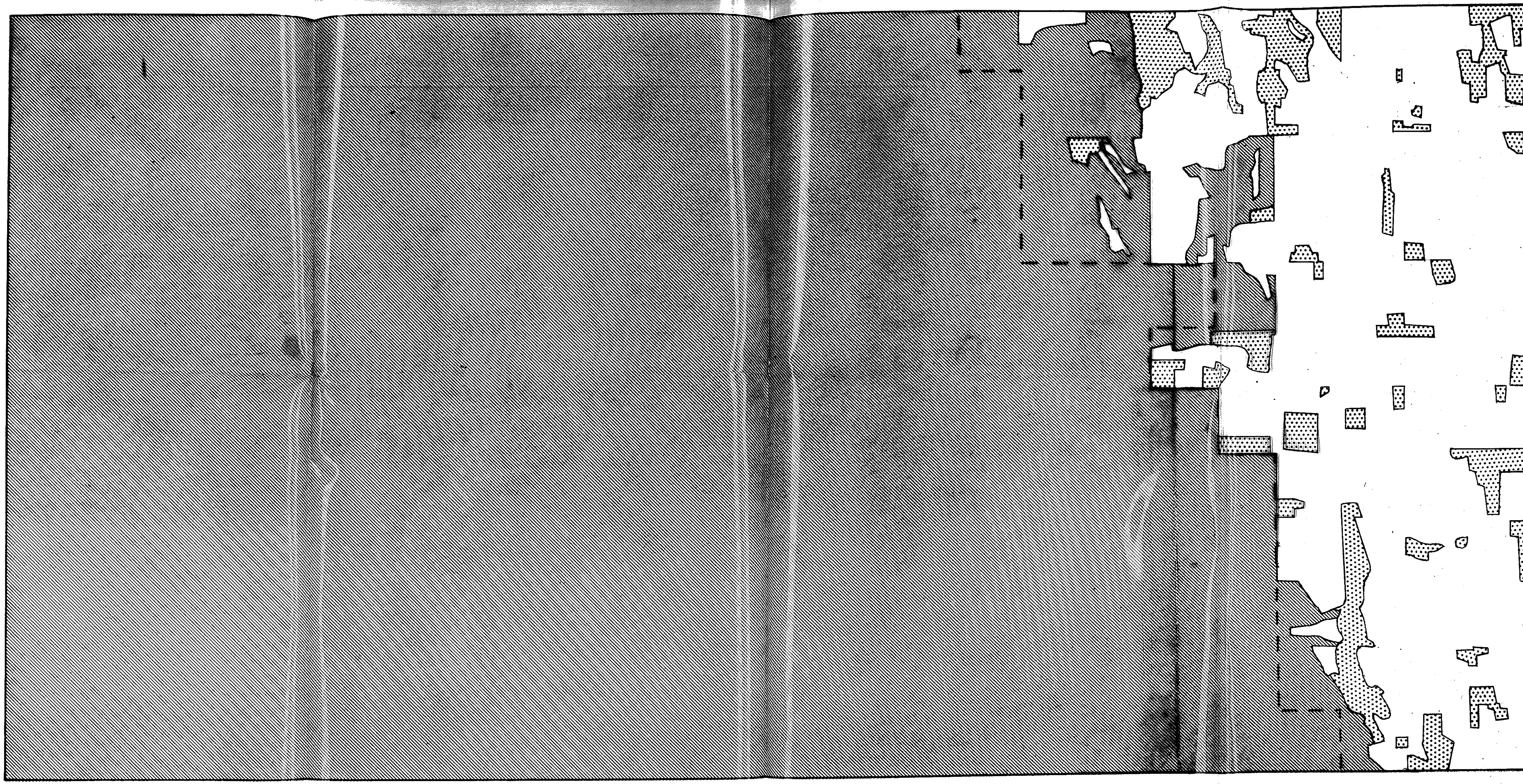
- - - - Boundary Of Duck Mt. Forest Reservation

RIDING MT. AREA

MANITOBA

LAND USE MAP





LAND USE TYPES

Cultivated

Used

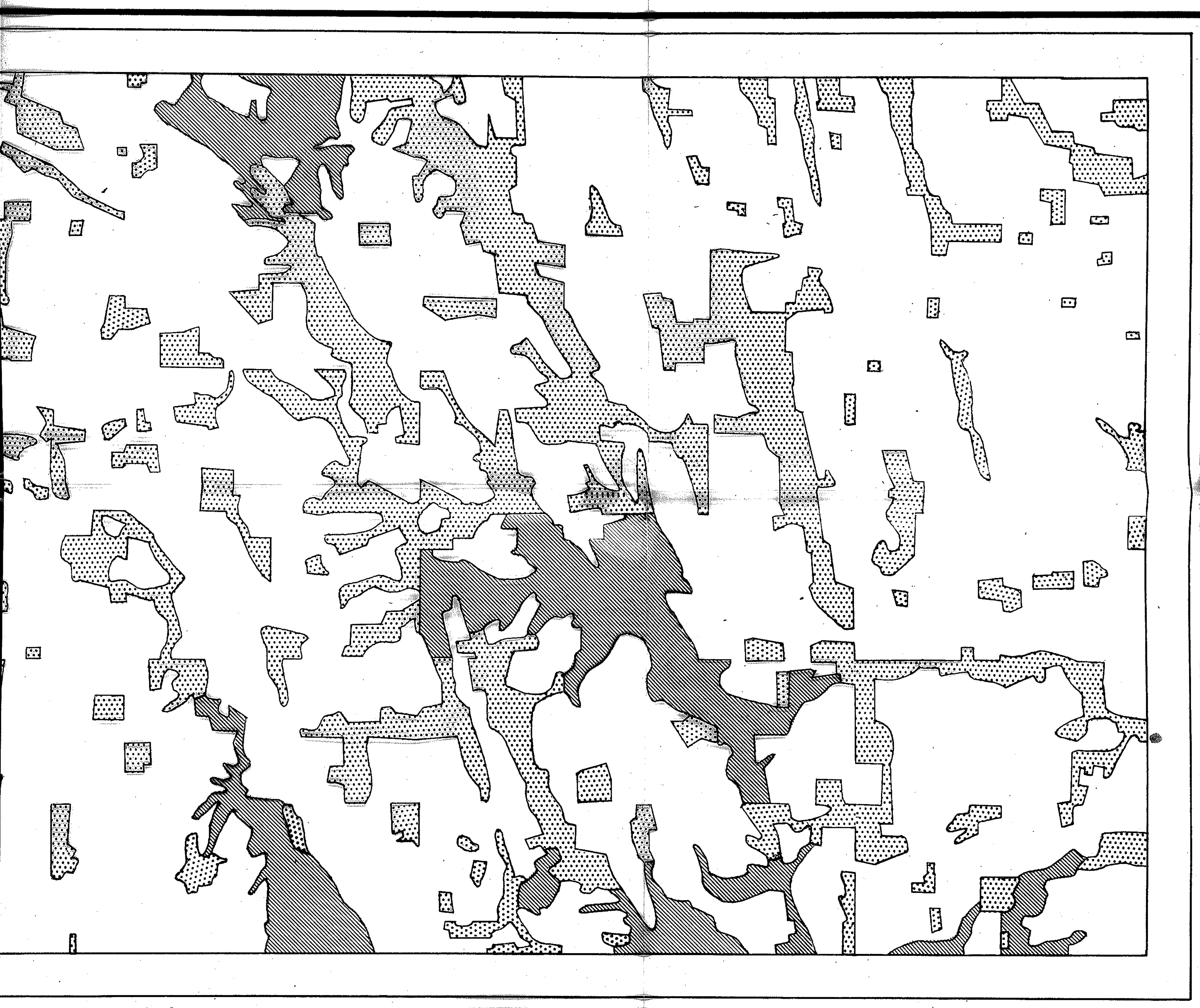
Unused

– – – – Boundary Of Riding Mt. National Park

MT. AREA

OBA

E MAP



TYPES

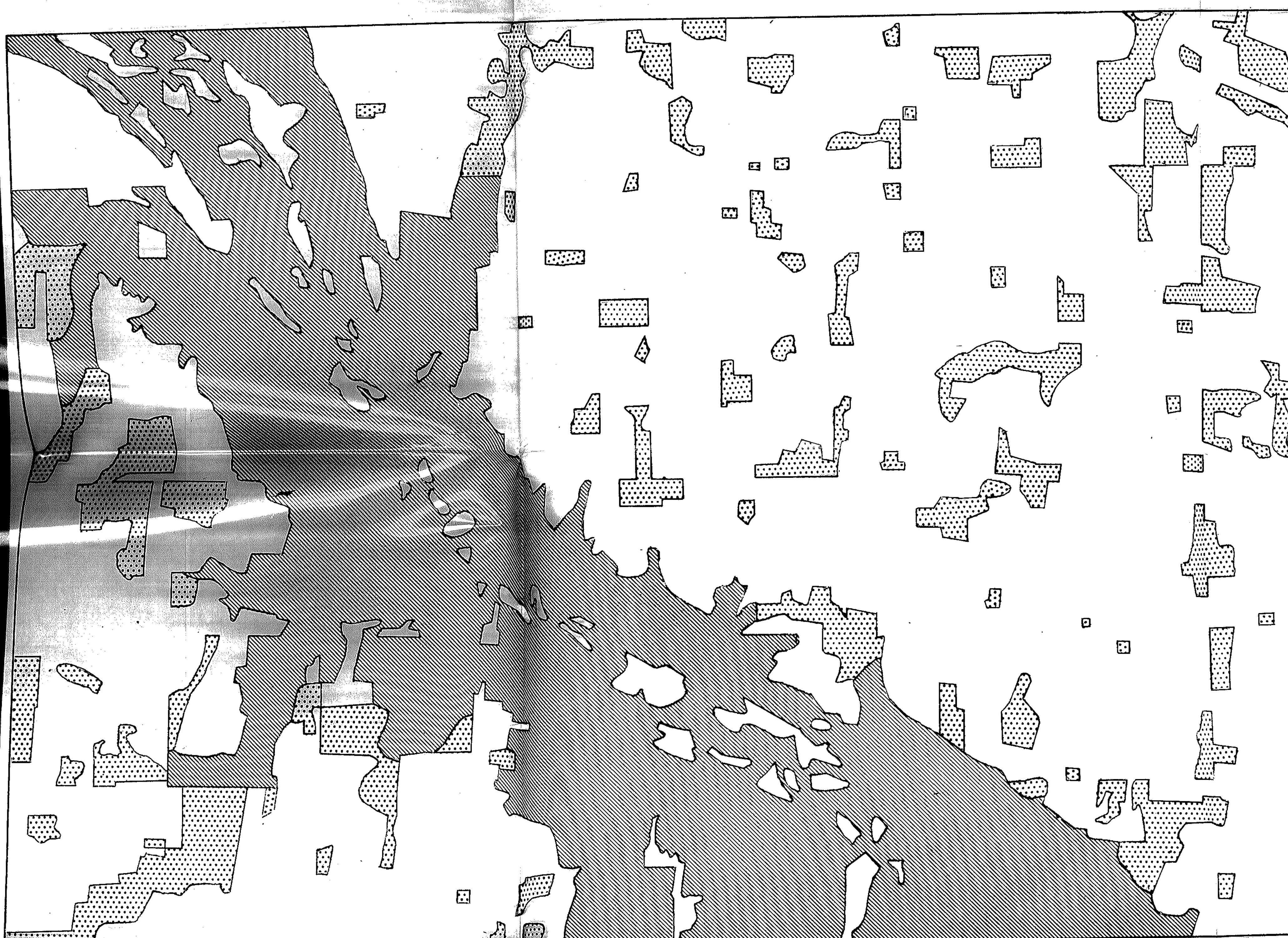
Used

Unused

PEMBINA MT.

MANITOBA

LAND USE



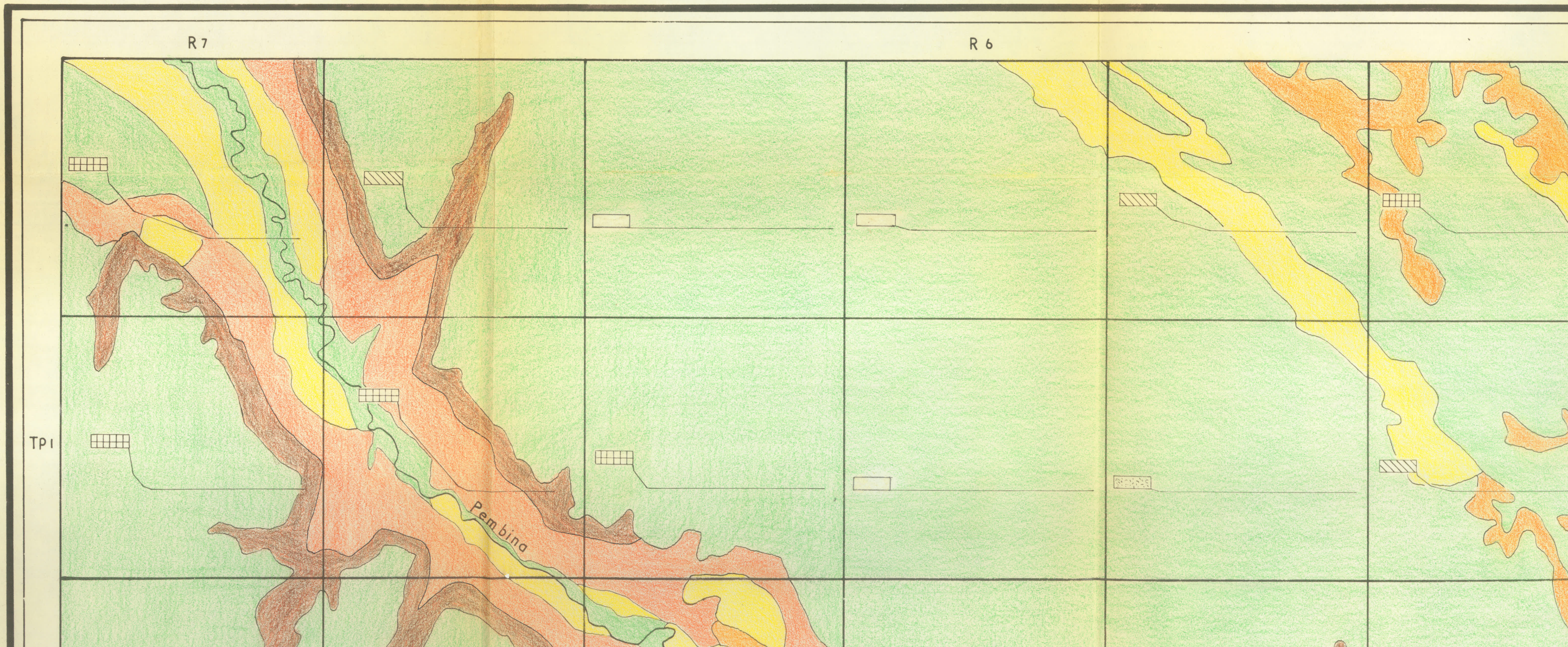
LAND USE

Cultivated

PEMBINA MT. AREA

MANITOBA

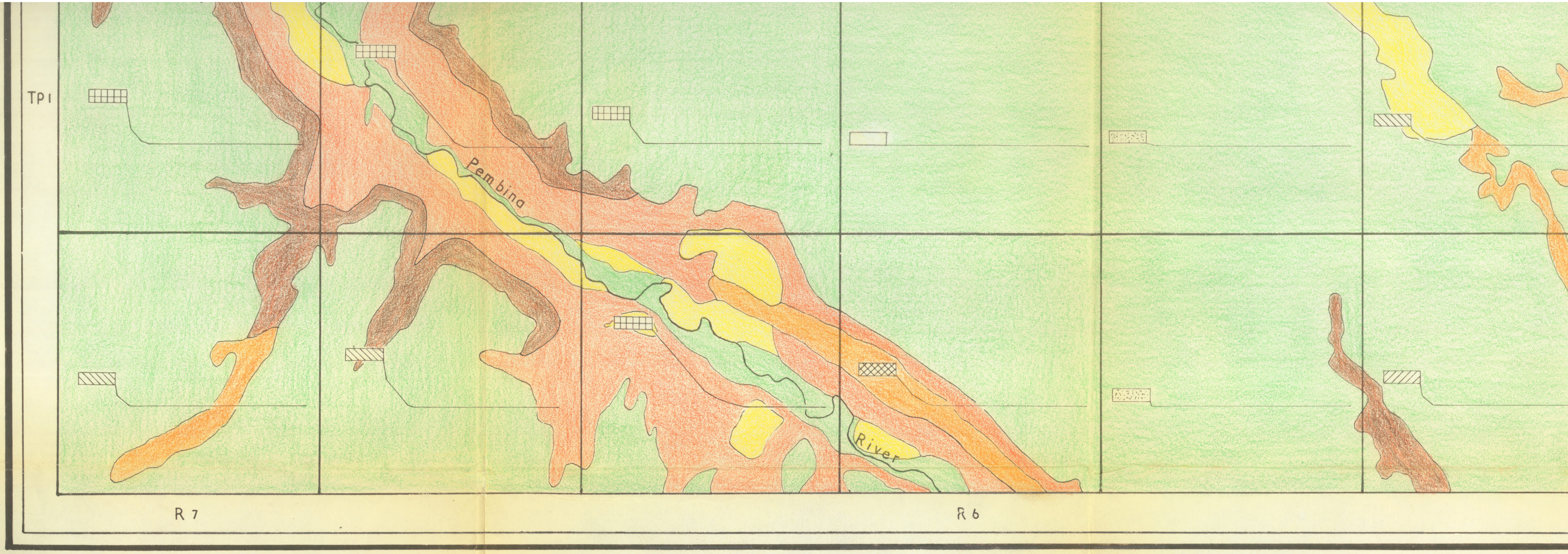
COMBINATION SLOPE MAP



PEMBINA MT. AREA

MANITOBA

COMBINATION SLOPE MAP



LEGEND

RELATIVE RELIEF

Feet

0 50 100 200 300 400 500 & over

SLOPE SCALE

0 50 100%

For measuring the percentage of each rectangular area in a given slope, as indicated by the angle of slope

SLOPE SYMBOL

Relative relief

Slope Area measured on slope scale

Flatland

Slope angles in degrees according to the average slope and exaggerated 5 times

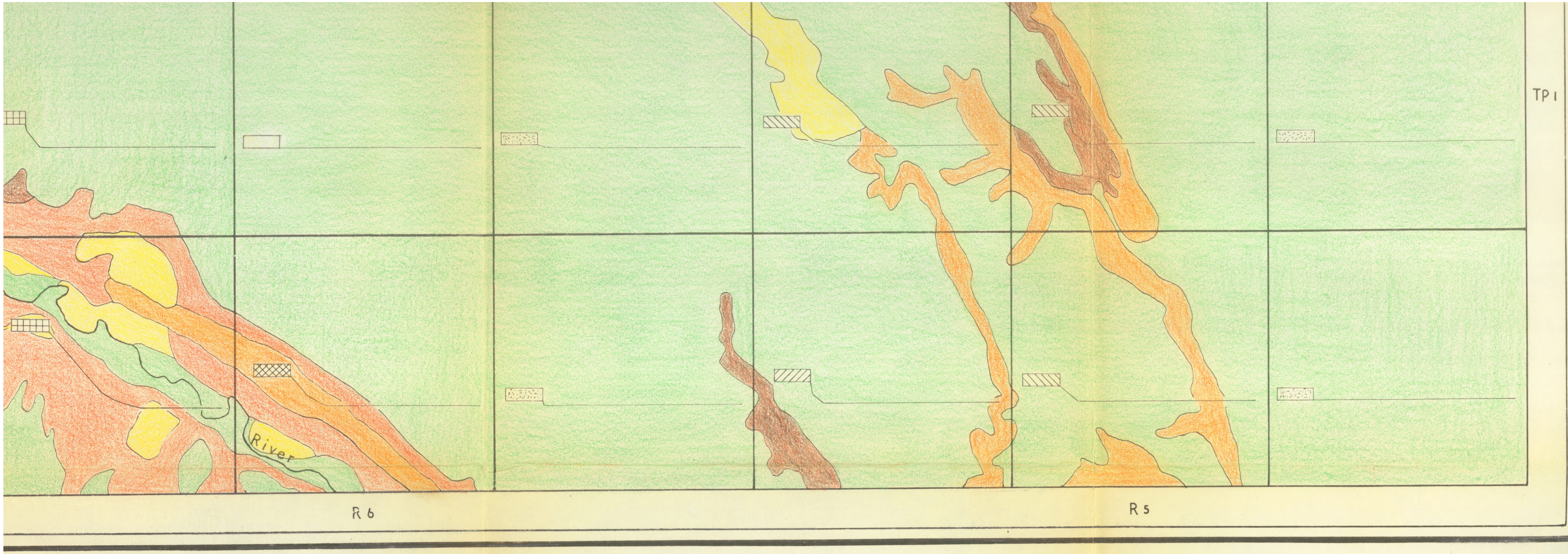
AREAS OF AVERAG

De

Slopeland above 2°

Flatland below 2°

0



LEGEND

Feet
oo & over

Relative relief

each rectangular area
y the angle of slope

%

SLOPE SYMBOL

Slope Area
measured on slope scale

Flatland

Slope angles in degrees according to the average slope and exaggerated 5 times

AREAS OF AVERAGE SLOPE

Degrees

16
8
4
2
0

Slopeland above 2°
Flatland below 2°

Lake & river

Town

Railway

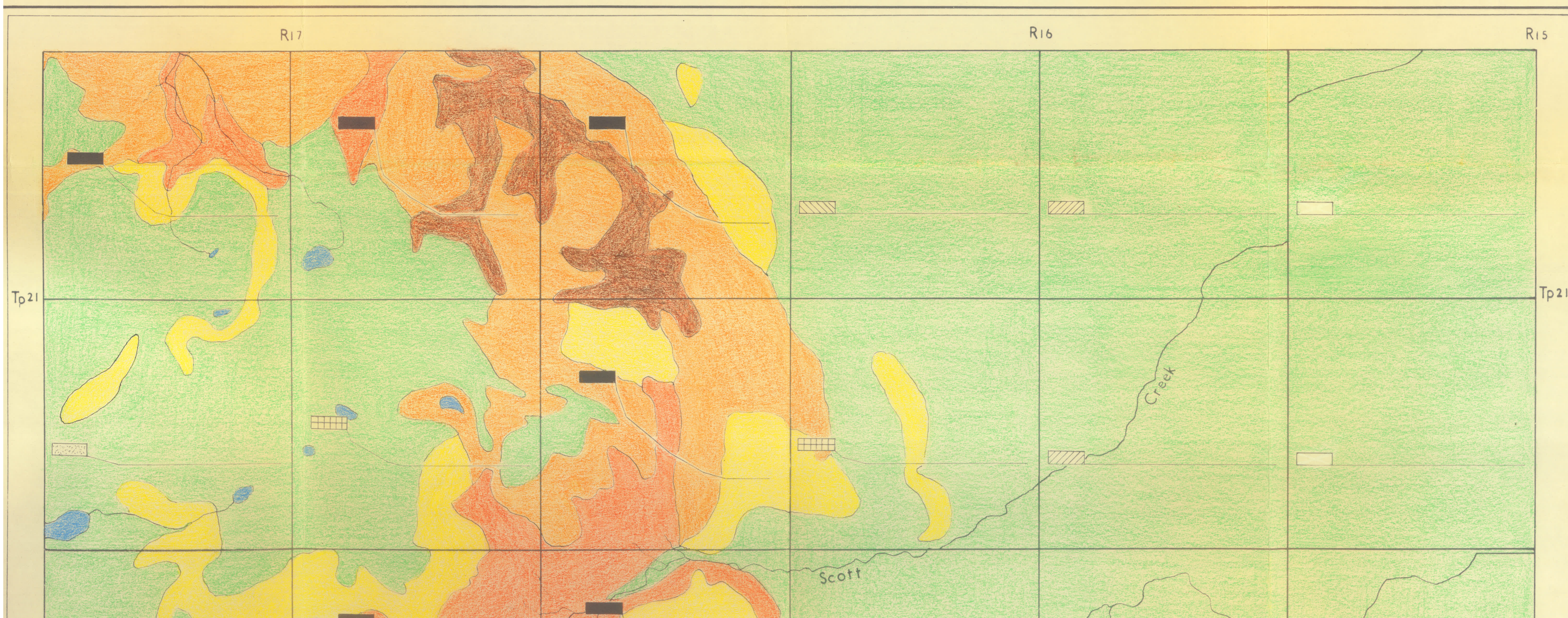
SCALE

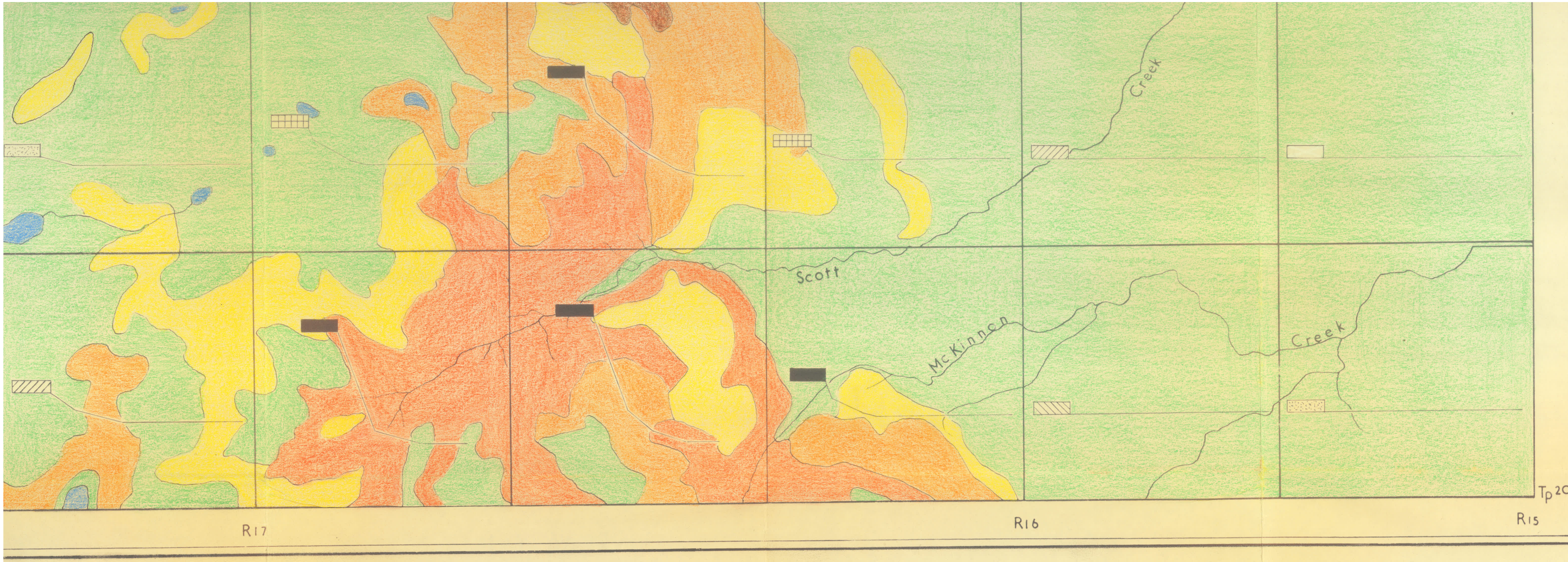
0 1 2 Miles

RIDING MT. AREA

MANITOBA

COMBINATION SLOPE MAP





LEGEND

RELATIVE RELIEF

Feet

50 100 200 300 400 500 & over

SLOPE SCALE

0 50 100%

r measuring the percentage of each rectangular area
n a given slope, as indicated by the angle of slope

SLOPE SYMBOL

Relative relief

Slope Area measured on slope scale

Flatland

Slope angles in degrees according to the average slope and exaggerated 5 times

AREAS OF AVERAGE SLOPE

Degrees

16
8
4
2
0

Slopeland above 2°

Flatland below 2°

Lake & river

Town

Railway

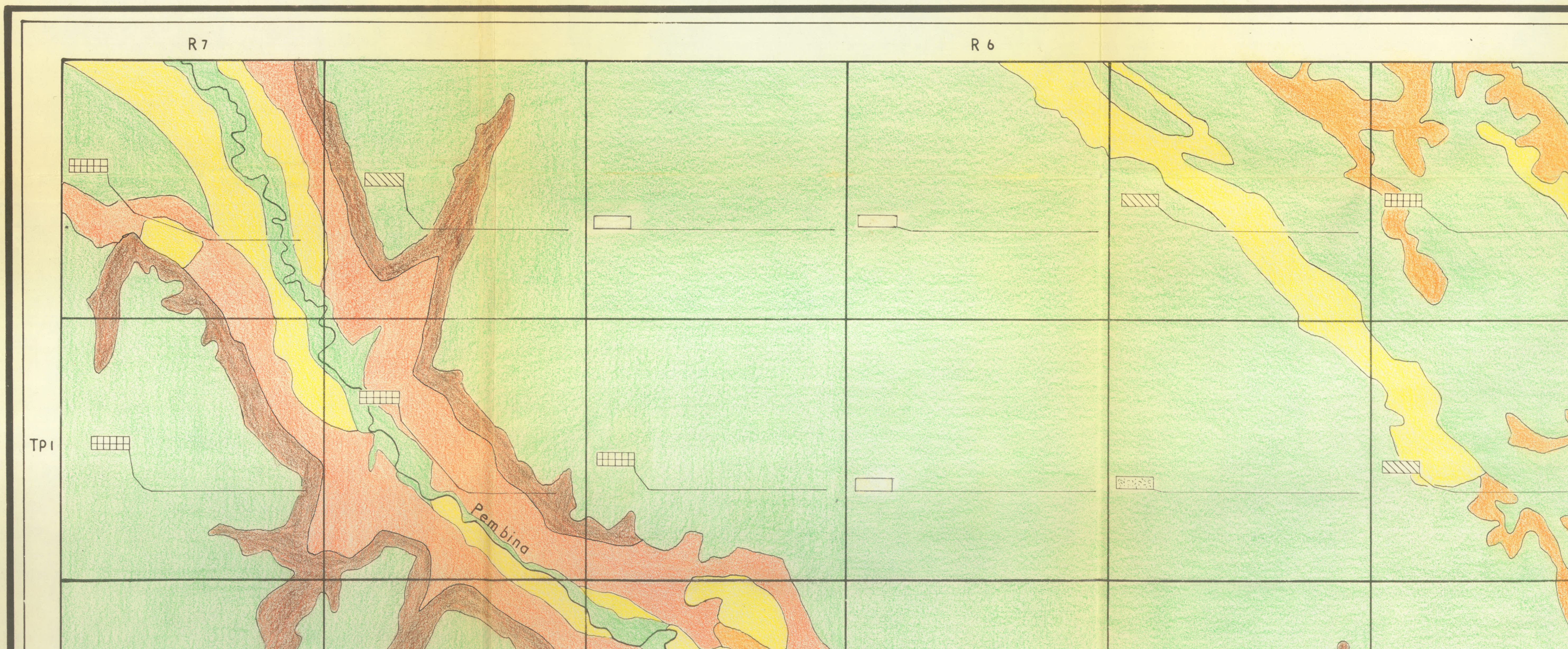
SCALE

0 1 2 Miles

PEMBINA MT. AREA

MANITOBA

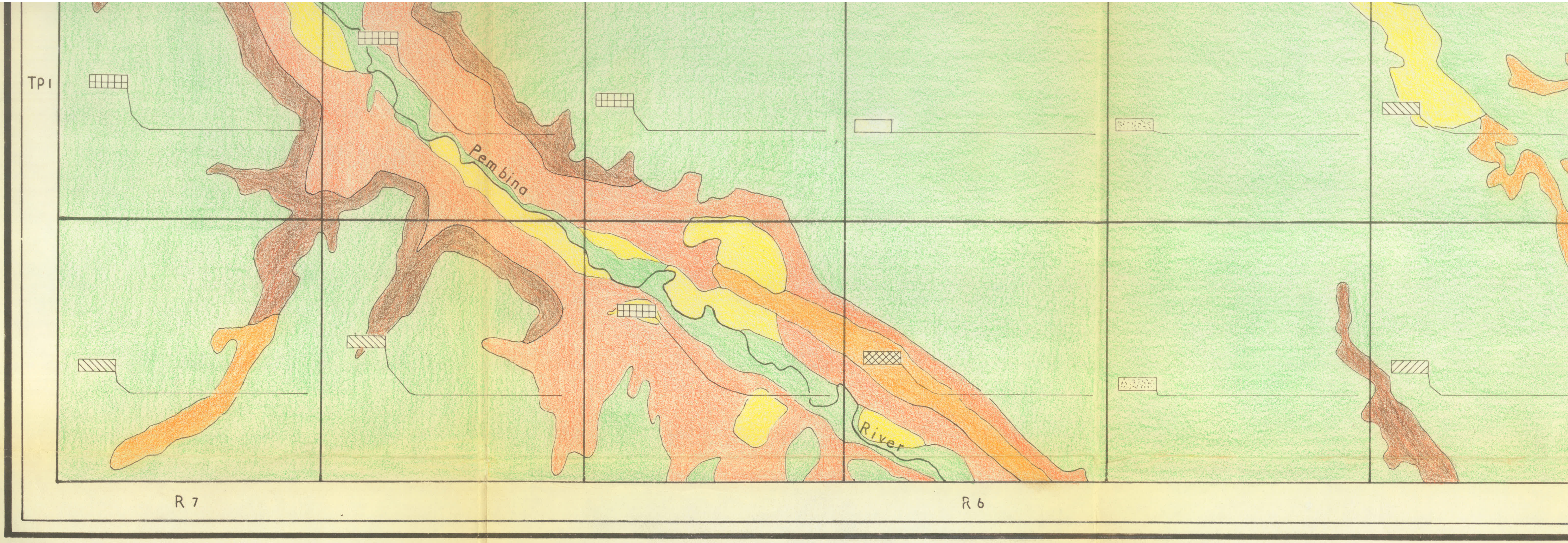
COMBINATION SLOPE MAP



PEMBINA MT. AREA

MANITOBA

COMBINATION SLOPE MAP



LEGEND

RELATIVE RELIEF

Feet

0 50 100 200 300 400 500 & over

SLOPE SCALE

0 50 100%

For measuring the percentage of each rectangular area in a given slope, as indicated by the angle of slope

SLOPE SYMBOL

Slope Area measured on slope scale

Relative relief

Flatland

Slope angles in degrees according to the average slope and exaggerated 5 times

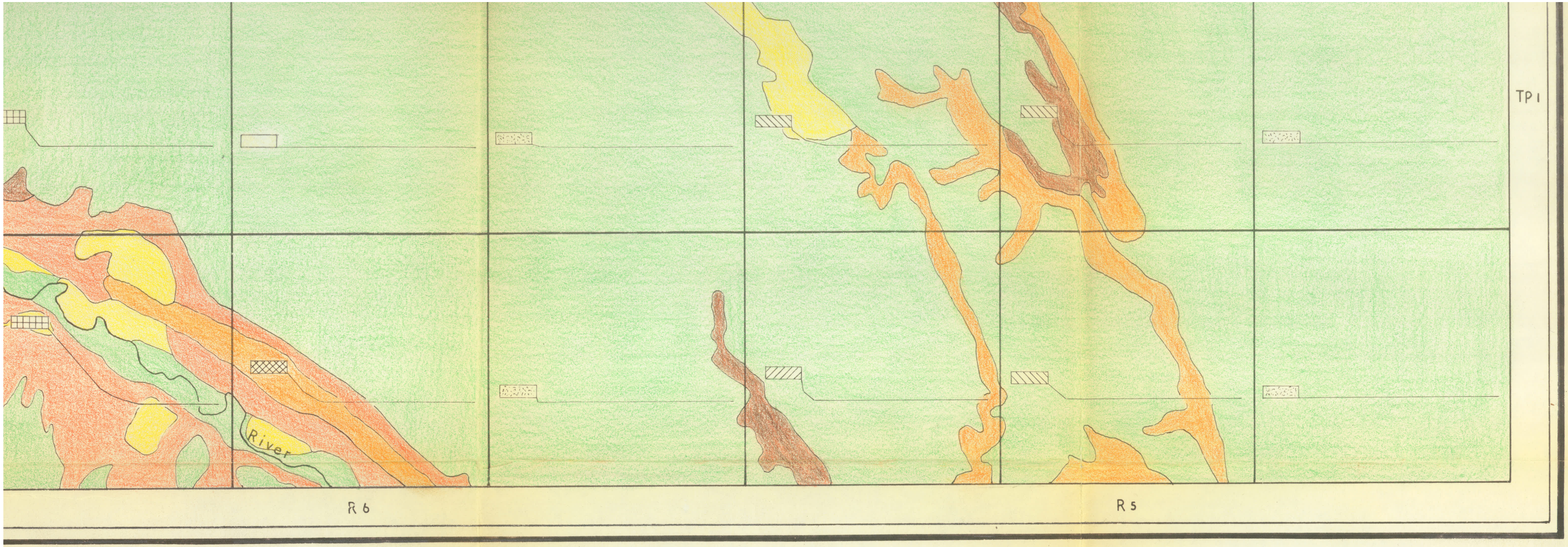
AREAS OF AVERA

De

Slopeland above 2°

Flatland below 2°

0



LEGEND

Feet

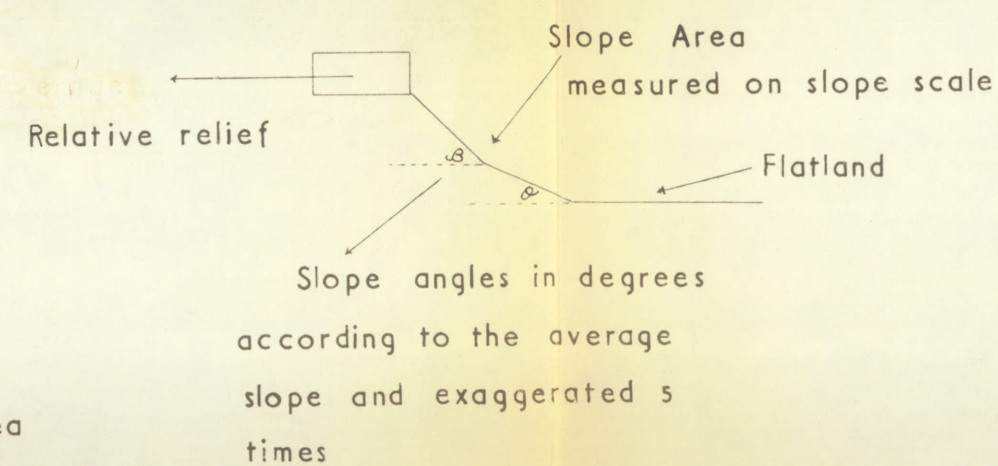
00 & over

%

each rectangular area

y the angle of slope

SLOPE SYMBOL



AREAS OF AVERAGE SLOPE

Degrees

16

8

4

Slopeland above 2° — 2

Flatland below 2° — 0

Lake & river

Town

Railway

SCALE

0 1 2 Miles