OCCASIONAL PAPER NO. 1

CROPP

Government of Canada   Gouvernement du Canada

Produced jointly by:
Environment Canada
Canadian Transportion Commission

PREFACE

CROPP, or Conformal Representation of the Prairie Provinces, was developed as one of the tools to meet the specific needs of two projects: the review of branch line abandonment applications by the Canadian Transport Commission, and the Whitemud River Watershed Resource Study undertaken in part by the Lands Directorate, Department of the Environment. These projects related agricultural statistics to individual parcels of farmland in the Prairie Provinces in order that they could be mapped on overlays for conformal maps and for calculation of distances by computer.

The acronym CROPP was chosen to stress one of the applications of the file rather than to describe the file. CROPP contains latitude and longitude coordinates of the centroids of quarter sections of land described by the Dominion Land Survey. The use of latitude and longitude coordinates enables each parcel of land to be expressed on any projection system.

CROPP represents the cooperative efforts of many persons from various government organizations. We wish to take this opportunity to express to all of them our sincere thanks. We are particularly grateful to Mr. Maurice Head, General Director of Management and Information Services, Canadian Wheat Board; Messrs. G. Moppett and P. Hibert, Computer Science Centre; Mr. C.E. Hoganson and Miss M. Brennan, Geodetic Survey Branch, Department of Energy, Mines and Resources; Messrs. B. Gill and W. Bell, Economics Branch of the Canadian Transport Commission; and

and Messrs. J. Brydges, Water Management Service, D. Johnston, Biometrics and Computer Sciences, and E. Beaudette, Lands Directorate, Department of the Environment.

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Ottawa, April, 1972.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The purpose of CROPP was to increase the usefulness of data banks that are based on land descriptions using the Dominion Land Survey (DLS). CROPP, a file of coordinate points of the centroids of sections and quarter sections in the DLS, was developed to spatially relate parcels of land in the Prairie Provinces and to permit, among other things, computer mapping. In designing the system, maximum flexibility was accomplished by assigning unique, universally recognized coordinates, that is, latitude and longitude correct to 5 decimal places, to the appropriate centroids. Because these coordinates can be readily transformed into any coordinate system, CROPP can be used with any computer mapping technique as well as merged into any data bank based on the DLS system.

An understanding of the DLS system is essential in order to comprehend CROPP. In brief, the DLS system is based on a township 6 miles square, which is divided into 36 sections (Figure 1) of 1 square mile or 640 acres each. The section is legally subdivided into four quarter sections of 160 acres each. Each parcel of land has its unique legal description. The sections are numbered 1 to 36 within a township according to the arrangement in Figure 1. Even if the entire section is not present, the numbering system remains constant for those sections that are present. Townships are numbered consecutively, northward from the 49th parallel of latitude and the ranges are numbered sequentially east and west of the principal meridian, $97^{\circ}27'28''$ west longitude, and west from the other five meridians. Meridians are separated by approximately 4^{o} of longitude. Thus, parcels of land are officially designated by quarter section compass location, that is, NE, NW, SE, SW, section, township, range and meridian numbers.

The townships were laid out along a base line, two townships on each side. The base lines were used as controls with correction lines inserted every fourth township to allow for the convergence of the lines of longitude. Thus, in a north-south direction, a jog occurs at every fourth township and some ranges completely disappear as they merge toward meridian lines. For example, the townships within Range 30 become progessively smaller and at Township 14, Range 30 completely disappears (Figure 2).

There are five different surveys, three of which incorporate the Prairie Provinces. Where the surveys meet, irregularly shaped townships can occur. For example, Township 18A, which contains less than 36 sections, occurs where the second and third surveys meet. Townships lying adjacent to a meridian may also contain less than 36 sections, for example, townships in Range 30 south of Township 14.

However, in spite of the variation in the number of sections within a township, the numbering system was consistent with that in Figure 1. This consistency was critical to the development of CROPP because it enabled the creation of hypothetical, regular-sized townships for those that contained less than 36 sections and it assigned coordinates to the existing sections without modifying the program.

METHODOLOGY

Development of CROPP

In the spring of 1971, a search was made to determine if a computer program existed that would assign coordinates to the legal land descriptions found in various data banks. As far as was determined, such a system had not been devised. During the summer, CROPP was developed in three steps: coding township corners, editing the coded data, and calculating the coordinates for the quarter section centroids.

The Geodetic Survey Branch, Department of Energy, Mines and Resources, provided a list of corrected latitude and longitude coordinates expressed in degrees, minutes, seconds and hundredths of seconds (a hundredth of a second is approximately 1 foot on the ground) for one corner, usually the northeast, of each township. This information was coded onto punched cards by first locating the approximately 12,000 corners on 1:250,000-scale national topographic series (NTS) maps. Assuming the coordinates of one township represented a corner of the adjacent township, the latitude and longitude coordinates were coded first and then the corner that had been recorded by the Geodetic Survey Branch and the adjacent corners on the topographic maps. For example, the coordinates for the NE corner of Township 3, Range 10 are also the coordinates for the SE corner, Township 4, Range 10; SW corner, Township 4, Range 9; and NW corner, Township 3, Range 9. Normally, the coordinates represented four corners, but in the case of jogs at correction lines they represented only two (Figure 4). The township corner identification for each set of coordinates were coded in a clockwise direction, that is NE, SE, SW, NW.

By this process, all known corners for each township were identified. In order to generate coordinates for the quarter sections, at least two corners for each township had to be known. In cases where only one township corner could be located a second hypothetical corner was created.

To check this coded data, an edit program was written to locate keypunch errors, incorrect record length, incorrect corner identification, and incorrect township indentification. The latitude and longitude coordinates were checked by generating theoretical coordinates correct to 5 decimal places and comparing these with the originally coded ones. If there was a discrepancy of more than 20 seconds, approximately 1/3 of a mile, an error was recorded and the record was checked manually.

When the coordinate data cards had been checked and corrected, their data were put onto tape and sorted by meridian, range, township, and corner. From this information, a program was written to assign latitude and longitude coordinates to the centroid of each section and quarter section by using three basic data manipulations: the identification of the sections and part sections by number and part, that is NE, NW, SE, SW; the calculation of the centroid of each section and quarter section from the township corners; and the creation of CROPP by combining the calculated coordinates with the appropriate section or quarter section identification.

The calculations for the centroid of each section were made by dividing the sides of each township into 12 equal parts and numbering them sequentially. In the case of the quarter sections, the township sides were divided into 24 equal parts (see Figure 5). The intersection of the odd-numbered lines formed the desired centroids.

The calculations of the centroid coordinates were done within a single township. Therefore, errors that may arise were contained within the township and are not cumulative. The coordinate file, CROPP, contains centroids of quarter sections, but by a simple modification of the program the centroid of any desired size of unit within a township can be calculated.

In summary, CROPP contains approximately 1,900,000 records sorted in order of meridian, range, township, section, and part-section. Each of these records contains the latitude and longitude coordinates correct to 5 decimal places.

Development of Data Banks

The purpose of CROPP was to increase the usefulness of existing data banks based on the DLS land descriptions. To date, CROPP has been successfully incorporated into copies of the Canadian Wheat Board records, the Manitoba Municipal Assessment Rolls, and the Manitoba Crop Insurance Corporation files. These records were sorted into the same order as CROPP and put through a match program that assigned latitude and longitude coordinates to the legal land descriptions in the data bank. When the two records did not match, zero latitude and longitude coordinates were assigned to the description to allow for later updating and the record was written in a no-match file for checking and correction. However, all of the records adequately described by the DLS system matched.

Not all of the parcels of land are described by quarter sections or sections, which were the only units for which centroid coordinates were calculated. Two alternative measures were used to overcome this problem; any description for a parcel greater than a quarter section was assigned to coordinates of the section, or all units greater than a quarter section were broken into quarter sections. For example, if the northern half of a section was described, it was divided into the NE and NW quarter sections. The particular method used depended upon the type of output that was desired.

Once data banks with coordinates exist various manipulations, such as calculating distances and mapping, can be carried out.

APPLICATIONS

Non-mapping Applications

The CROPP coordinates enable easy and accurate calculation of distances. For example, from the Canadian Wheat Board file containing the legal land description of individual parcels of land, the distance from a given parcel of land to a delivery point can be calculated. To compute the road distance, it was assumed that this distance approximates the distance east-west and north-south to the delivery point. That is, the distance traveled by a farmer on prairie roads that are laid out on a grid would be the distance along two sides of a right angle rather than the straight-line distance. The formula used to calculate this road distance in nautical miles is:

$$\text{distance} = \left| \text{lat}_1 - \text{lat}_2 \right| + \left| \text{long}_1 - \text{long}_2 \right| \left(\cos \left[\frac{\text{lat}_1 + \text{lat}_2}{2}\right]\right)$$

where latitutde and longitude are in minutes and the argument of the cosine is in degrees.

Road distances were also calculated by using the Lambert Conic Conformal projection. The latitude and longitude coordinates were converted into X, Y coordinates measured in feet for this projection. Using the same assumption, that road distance is the right angle distance, the distance was calculated as:

$$\text{road distance} = \left| X_2 - X_1 \right| + \left| Y_2 - Y_1 \right|$$

Mapping Applications

In addition to the calculation of distances, the created data banks enabled the production of accurate maps on an off-line plotter. The process used to produce the maps is described schematically in Figure 7.

Maps were produced on both flatbed and drum plotters by various plotter software packages. When using the flatbed plotter, actual parcels of land were plotted on an UTM (Universal Transverse Mercator) projection so that they could be overlain on NTS maps.

As previously noted, two methods were used to overcome the problem of having only the centroids of sections and quarter sections on the coordinate file. For the grain hinterland maps (Figure 8), each quarter section was plotted, whereas on the other maps this accuracy was not required.

To produce the grain hinterland maps, each parcel of land described on the legal land description file of the Canadian Wheat Board was broken into quarter sections and coordinates assigned to each quarter section. Each parcel of land was then assigned a symbol corresponding to the delivery point to which grain from that parcel was delivered. These records were then sorted by coordinate to make the plotting more efficient.

The main mapping program, written in FORTRAN, handled the titles, border, and grid systems needed to produce the final plot. It read the data, converted the coordinates to UTM, checked for coordinates outside the map boundary, scaled the coordinates to plotter inches, allocated the correct symbols to coordinates. The program included a subroutine that created plotter instructions to handle all titles, character strings, and punctuation. As many as 26 alphabetics and 14 special characters in strings of up to 50 characters can be drawn to any size.

The output of this program was a set of instructions for the flatbed plotter, which drew the maps on sheets of cronaflex. These, in turn, were overlain in NTS maps. These overlays confirmed the accuracy of CROPP. Maps of publication quality were then produced either photographically or cartographically.

Less detailed maps were produced to show selected farm characteristics. For example, maps were produced to show farm sizes in six categories: 0 to 160 acres, 161 to 320 acres, 321 to 480 acres, 481 to 640 acres, 641 to 800 acres, and over 801 acres, (Figure 9). For these maps, the farm size was read on the legal land description file and the first parcel of land described for an individual farm assigned to the appropriate category. If the description was for a unit larger than a quarter section, the coordinate for the appropriate section was assigned to it. Thus, each farm was assigned the coordinate location of the first parcel of land listed on the legal land description file.

This new record was then put through the same mapping program as the grain hinterland records. Instead of plotting the map on a sheet of clear cronaflex, the plot was made on a cronaflex base map. This was accomplished by lining up the coordinate points of the map border with the corresponding points on the base map.

In addition to the plotting programs for the flatbed plotter, contour maps were produced on the drum plotter by GPCP (General Purpose Contouring Program) developed by Calcomp. These maps also used the UTM grid, enabling overlays on NTS maps at a scale of 1:250,000. Information obtained from all of the developed data banks provided input for this program.

GPCP required X, Y and Z coordinates as inputs. The X and Y coordinates were the latitude and longitude locations, which had been transformed into UTM coordinates. The Z value was the value to be mapped according to calculations based on the data banks. For example, cropping indexes were derived from the Canadian Wheat Board records and mapped by this program. The cropping index was used as a measure of the intensity of land use for crops and is defined by the following formula:

$$\frac{\text{acreage in crops/farm}}{\text{total farm acreage}} \times 1000$$

The processing of this map occurred in a number of distinct stages (Figure 7). First, the prime number on the legal land position file was matched with the prime number on the detailed acreage summary file to produce a tape containing coordinates and the acreage summary. Second, the latitude and longitude coordinates were converted to northing and easting values and put on tape in a format acceptable to GPCP. Finally, the Z value was computed and put on the same tape in an acceptable format. This output tape could then be used as input to GPCP.

The GPCP program calculates the contour lines by generating values for the mesh points of a regular grid. These values are estimated from a tangent plane approximated at each data point from the weighted values of a number of neighboring data points.

The overlays produced by GPCP were combined photographically with a base map by lining up the border points on the GPCP output with the corresponding locations on the base map (Figure 10).

The Manitoba Municipal Assessment Rolls were also put through this procedure. The only calculation needed on these data was to combine the parcels of land that were smaller than quarter sections into quarter sections. The assessed value listed for each quarter section was used as the Z value for GPCP.

The assessment rolls contained approximately 12,000 points, which could not be handled by GPCP in one computer run. To overcome this problem, five overlapping overlays were made and joined manually (Figure 11).

CONCLUSION

In summary, it has been shown that CROPP, a coordinate file based on the DLS system, was successfully added to the Canadian Wheat Board records, the Manitoba Crop Insurance Corporation files, and the Manitoba Municipal Assessment Rolls. All of these files contain the legal land descriptions of individual parcels of land, and any data banks that contain these descriptions can be merged with CROPP.

There are several uses for a data bank containing CROPP. Distances can be calculated, individual parcels of land can be plotted, and isolines can be drawn. Latitude and longitude coordinates were used since these are universal and can be readily converted to any type of coordinates desired by the user. In the applications, both the Universal Transverse Mercator and the Lambert Conformal projections have been used.

The maps, which were done by several different programs, were produced both on a flatbed and a drum plotter. They were then reproduced photographically with good results. Thus, the user can obtain satisfactory results using whatever equipment or software that is available.

CROPP is not restricted to mapping applications, or to one mapping system. Although the applications listed in this report are social science oriented, the system is also a potential tool for the physical scientist.

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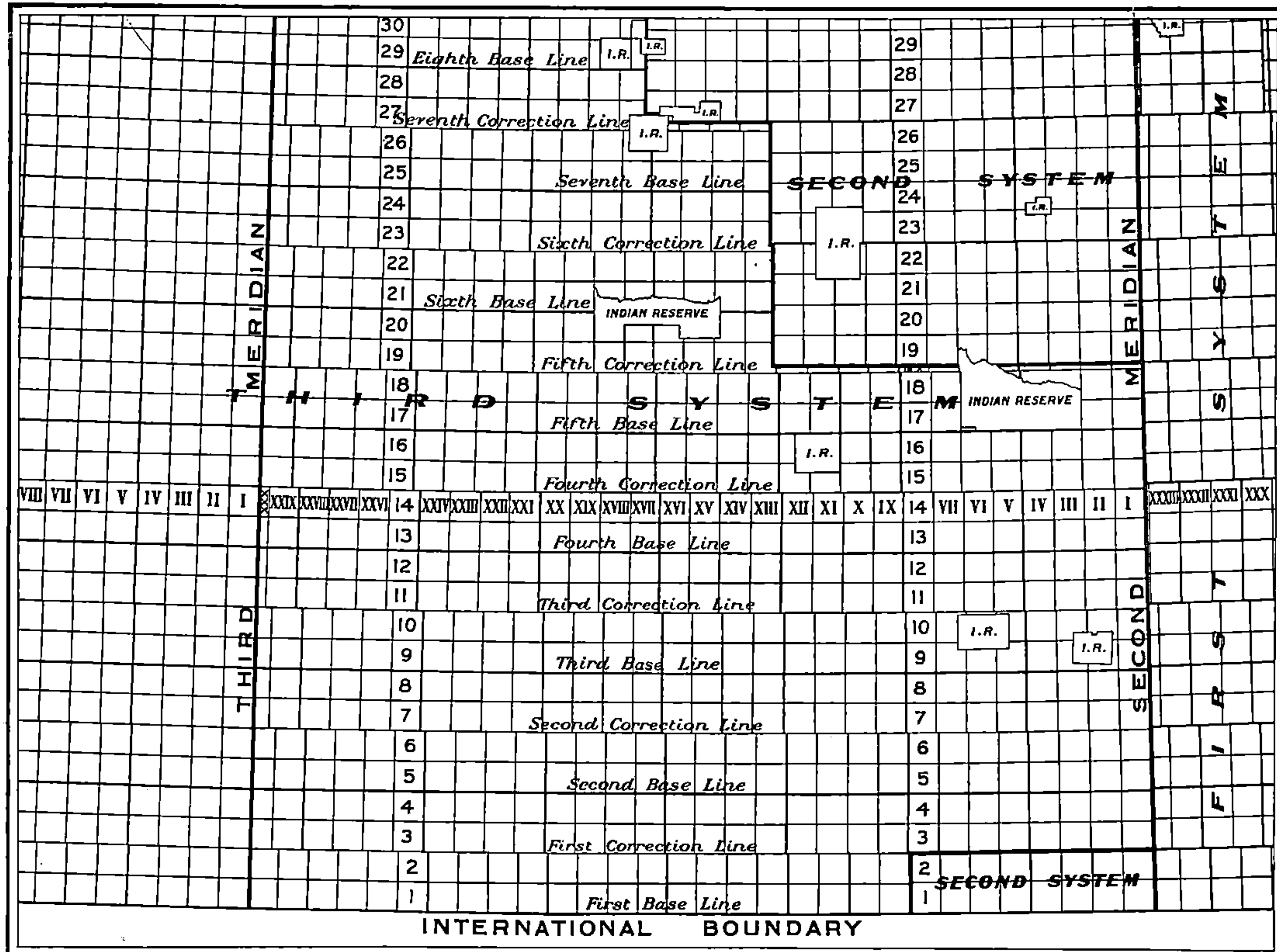
California Computer Products Inc. GPCP General Purpose Contouring Program. Anaheim, California, 1968.

SECTION PLAN OF A TOWNSHIP

31	32	33	34	35	36
30	29	28	27	26	25
19	20	21	22	23	24
18	17	16	15	14	13
7	8	9	10	11	12
6	5	4	3	2	1

Figure 1

DOMINION LAND SURVEY SYSTEM



SOURCE:
BOND, COURTNEY C. J. SURVEYORS OF CANADA 1867 TO 1967
OTTAWA, CANADIAN INSTITUTE OF SURVEYORS, 1966. P. 21.

Figure 2

STEPS IN THE DEVELOPMENT OF CROPP

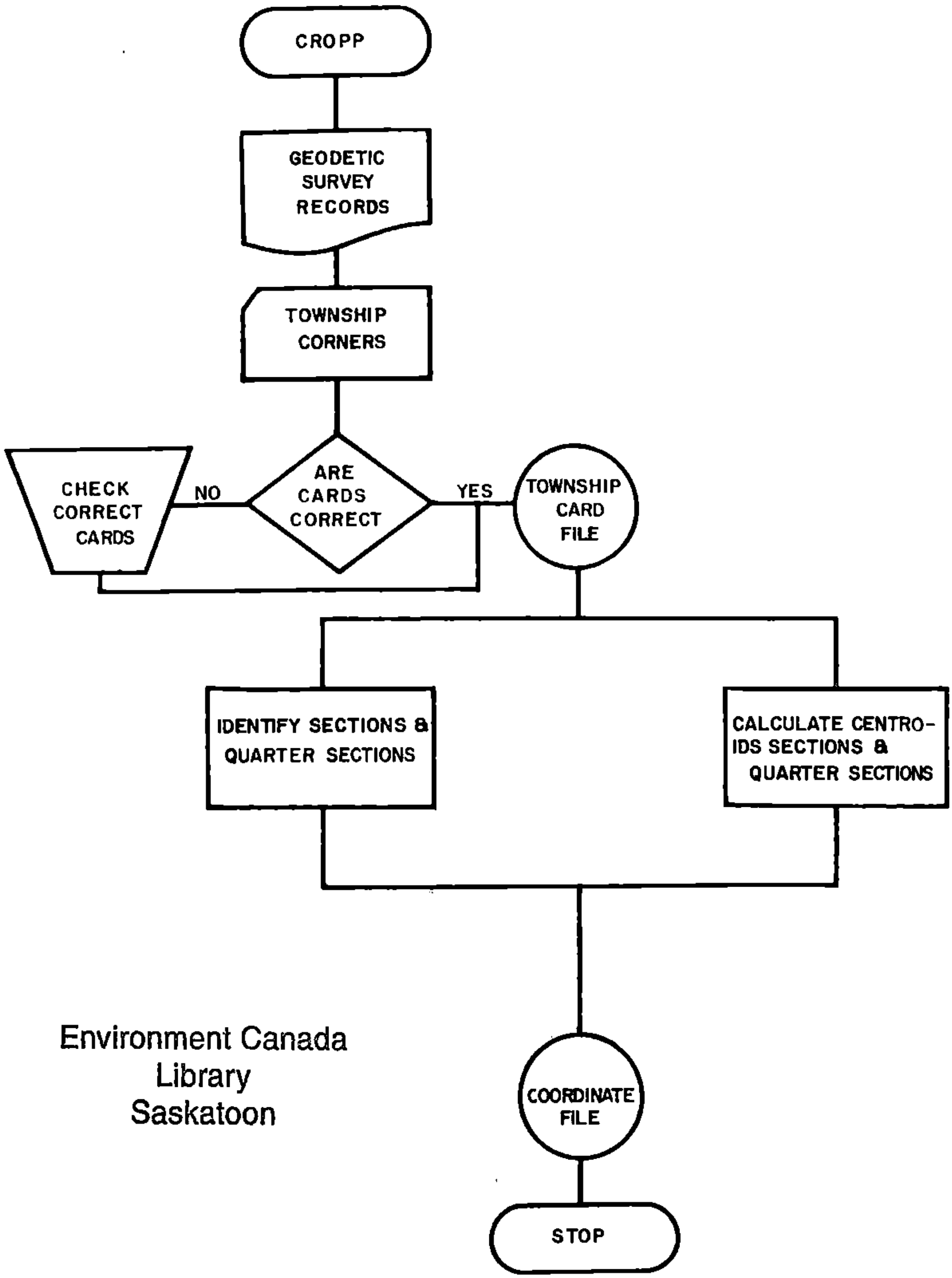


Figure 3.

TOWNSHIP LAYOUT

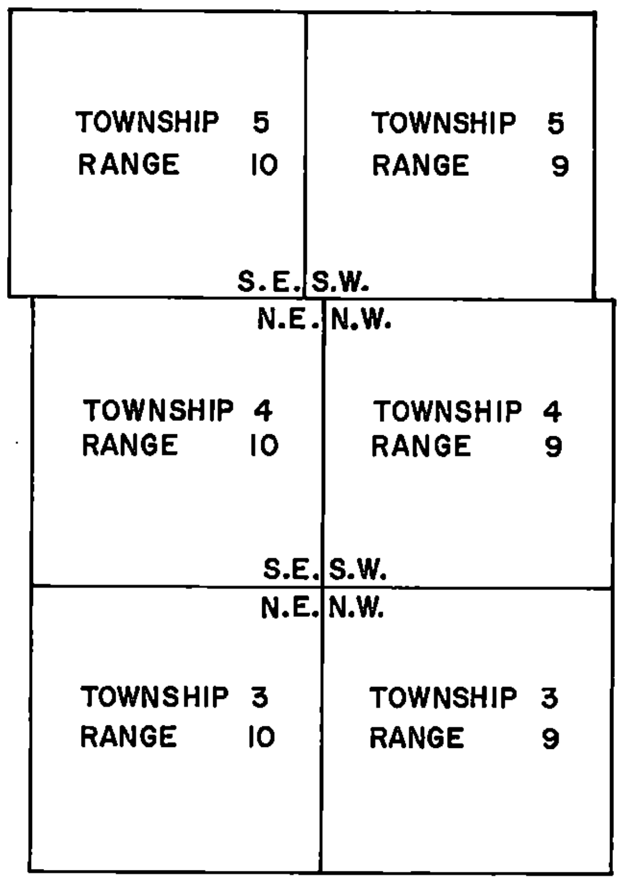


Figure 4.

LOCATION OF CENTROIDS OF A TOWNSHIP

	1	3	5	7	9	11
1	31	32	33	34	35	36
3	30	29	28	27	26	25
5	19	20	21	22	23	24
7	18	17	16	15	14	13
9	7	8	9	10	11	12
11	6	5	4	3	2	1

Figure 5

DLS-CROPP MATCH PROGRAM
FLOW CHART

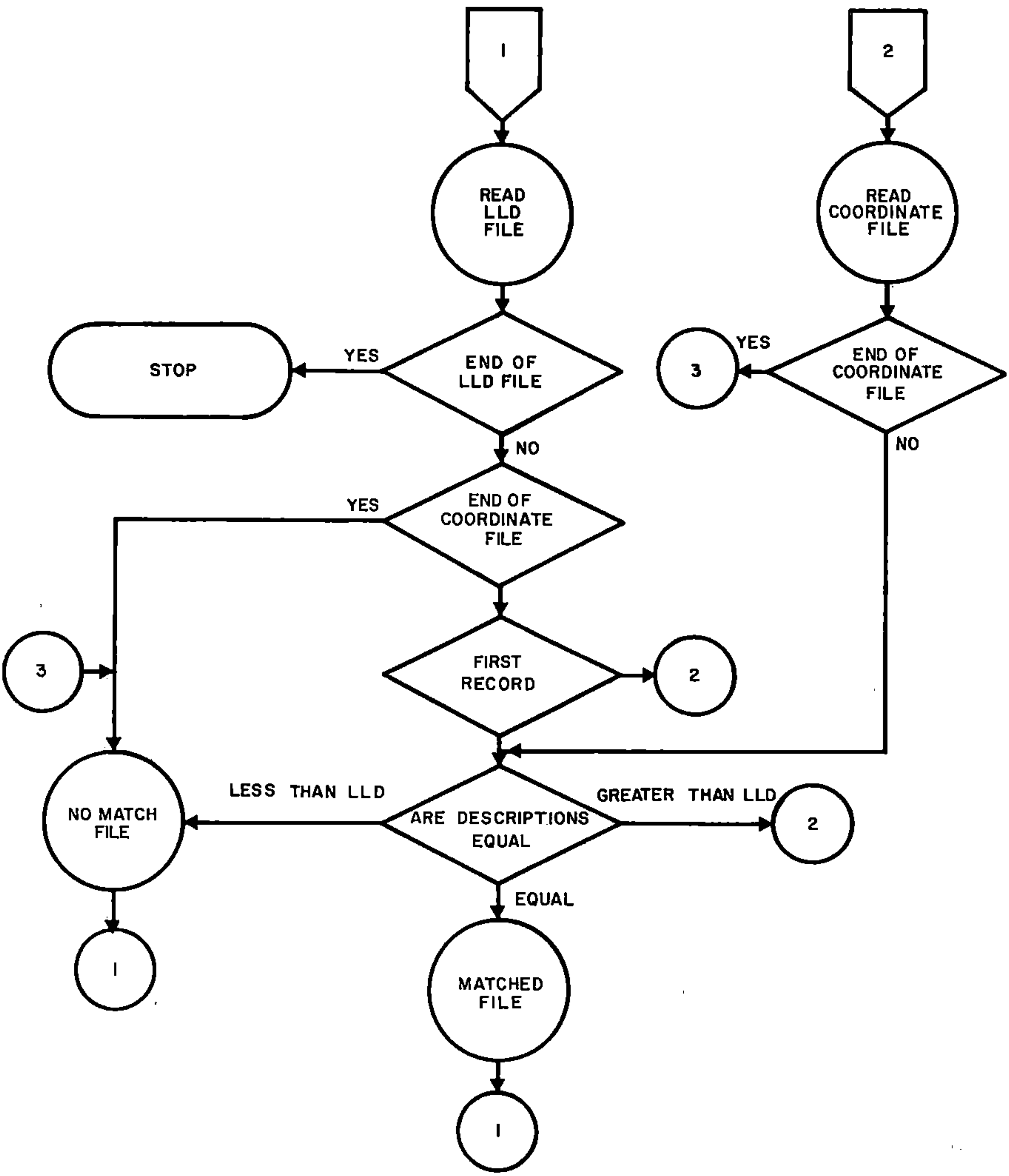


Figure 6

MAPPING APPLICATIONS FLOWCHARTS

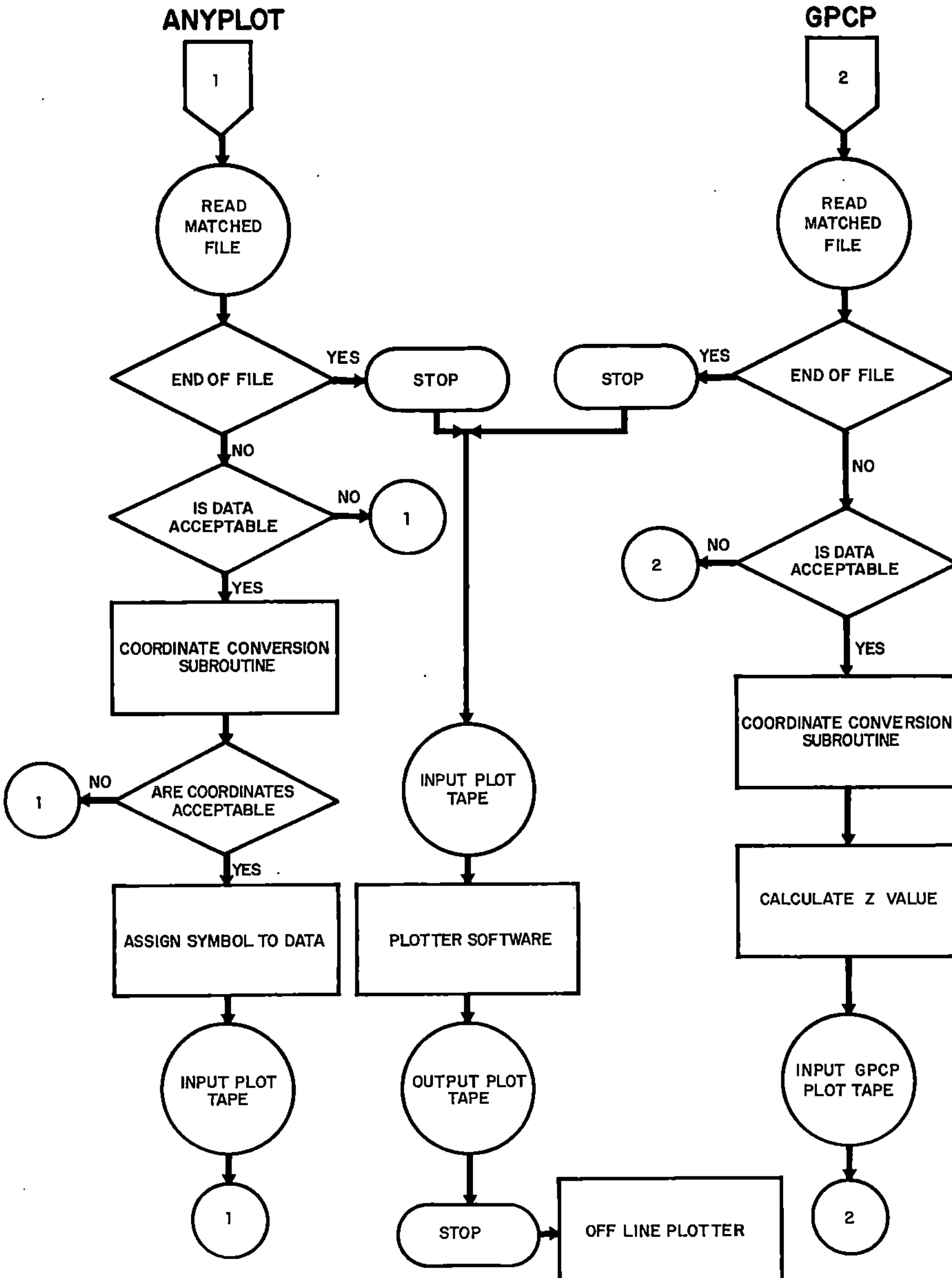
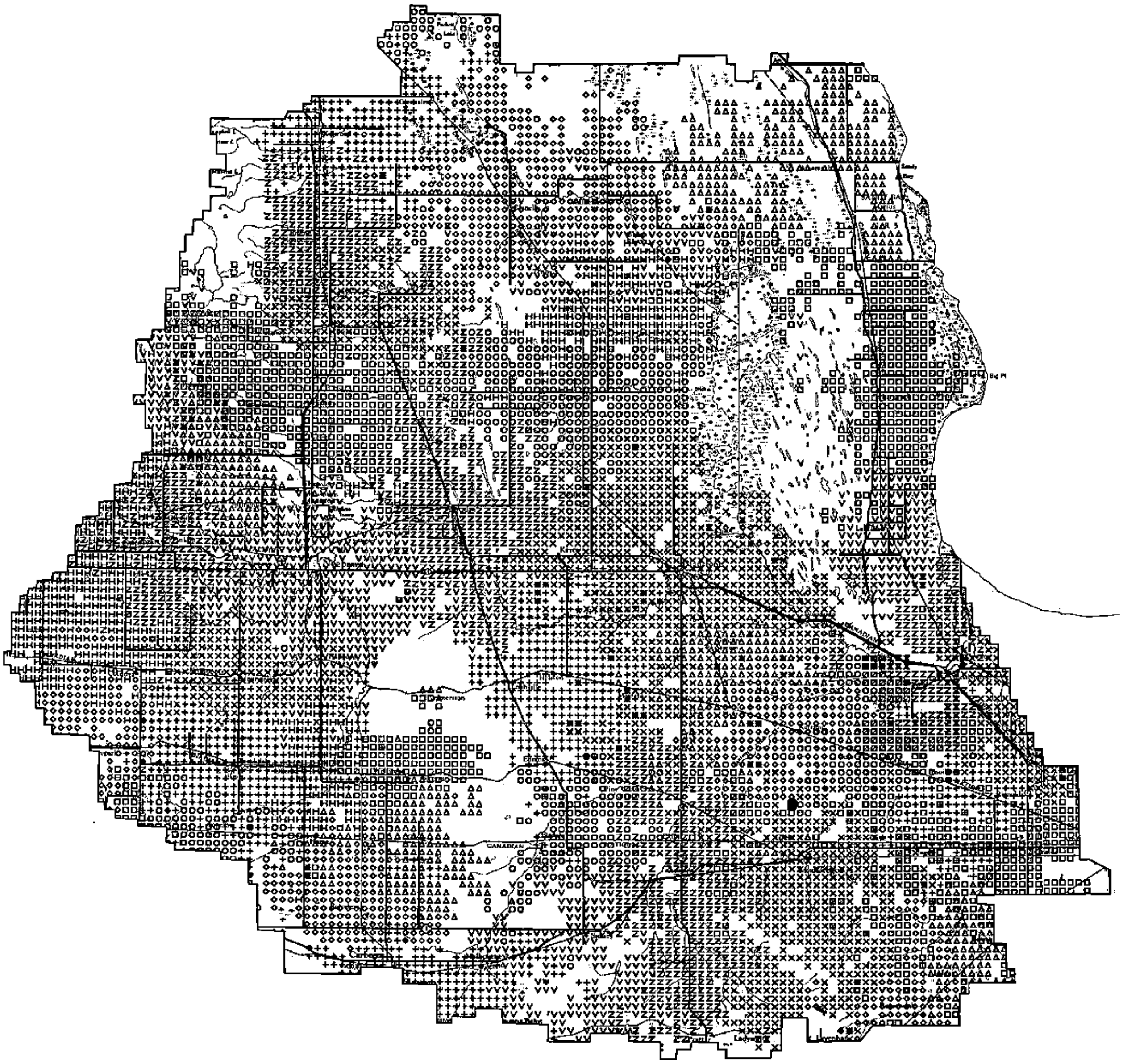


Figure 7

WHITEMUD RIVER WATERSHED



MANITOBA
GRAIN HINTERLANDS

Legend: Delivery Point Symbols

- Δ Amaranth, Edwin, Golden Stream, Gregg, Springhill
- ◻ Eden, Justice, Langruth, Portage-La-Prairie, Wellwood
- ◇ Fairview, Glenella, Kartrima, Moorepark, Rossendale
- O Beaver, Fridale, Ingelow, McCreary, Plumas
- \+ Brookdale, Carberry, Helston, Kelwood(c), Rignold
- X Birnie, Gladstone, MacDonald, MacGregor, Mentmore
- Z Arden, Austin, Franklin, Riding Mountain, Westbourne
- V Clanwilliam, Lakeland, Neepawa, Sidney, Tenby
- H Bethany, Colby, Howden, Minnedosa, Oberon

Scale: 1: 250,000

Definition: A symbol denotes a quarter section of land from which grain is being delivered to the corresponding delivery point.

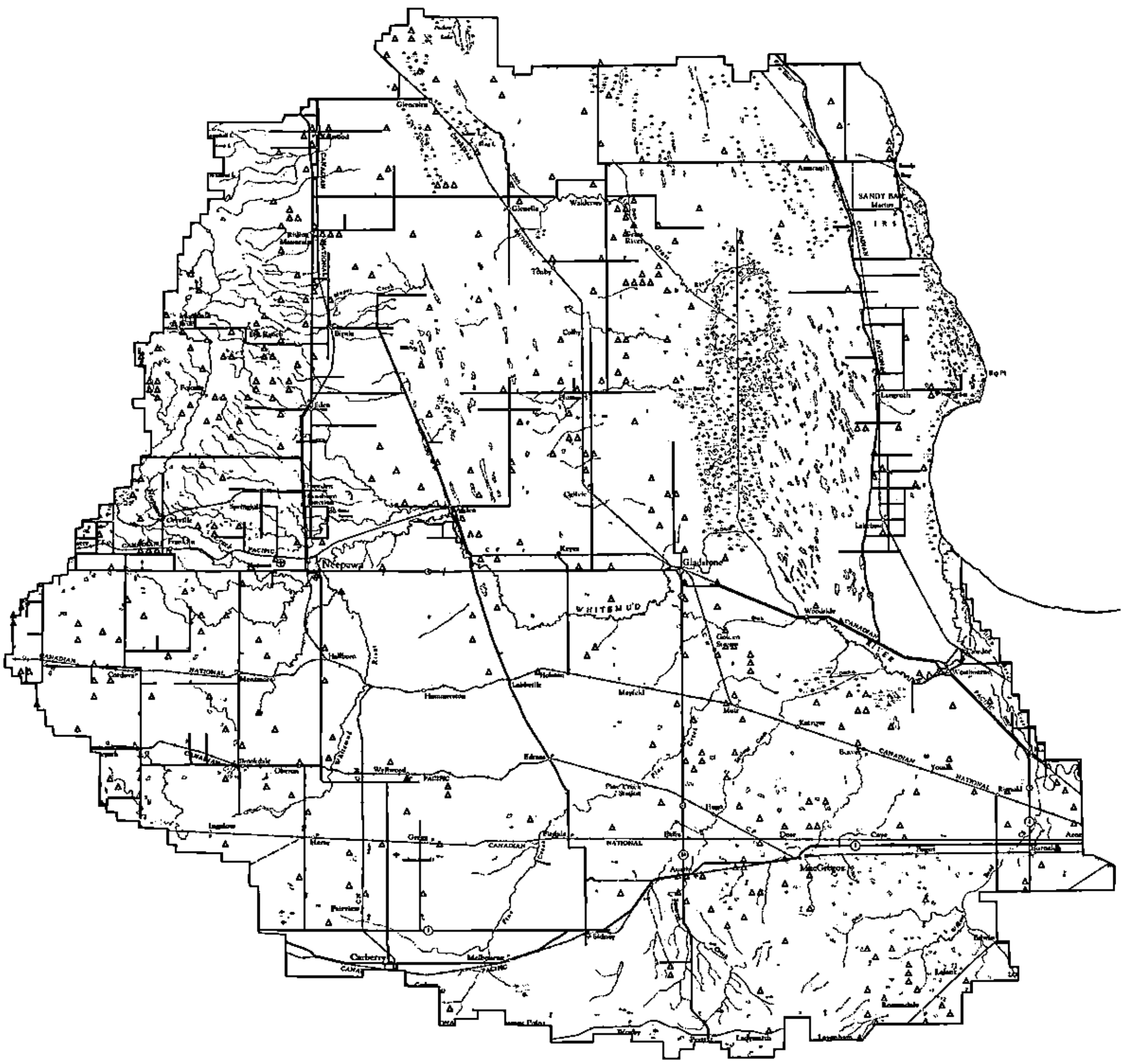
Source: Canadian Wheat Board 1970-71

Produced By:

Lands Directorate, Lands, Forests and Wildlife Service
Department Of The Environment
For
Whitemud River Watershed Resource Study
Manitoba Department of Mines, Resources and Environmental Management

Date: Dec. 1, 1971

WHITEMUD RIVER WATERSHED



MANITOBA

FARMS LESS THAN 160 ACRES IN SIZE

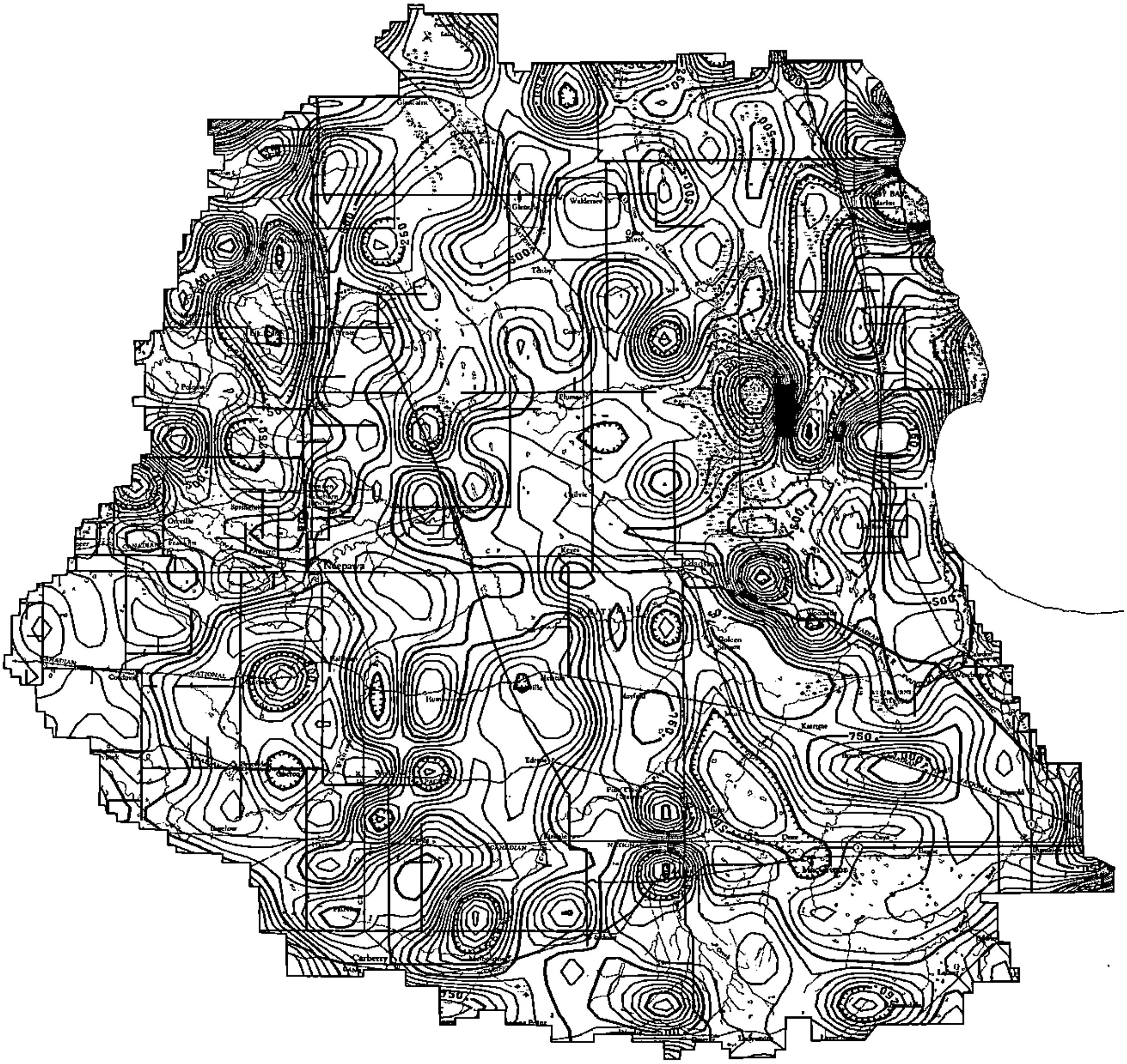
Each Symbol Represents A Farm Of Less Than 160 Acres

Scale 1:725,000

Produced By Lands Directorate, Lands, Forests And Wildlife Service
Department Of The Environment
For Whitemud River Watershed Resource Study,
Manitoba Department Of Mines, Resources And Environmental Management

October 1971

WHITEMUD RIVER WATERSHED



MANITOBA

CROPPING INDEX 1970

Scale: 1:250,000

Legend:

Contour Interval ...... 50 Units

Contours .... 750 / 700

Depression .... 500 / 450

Source: Canadian Wheat Board

Definition:

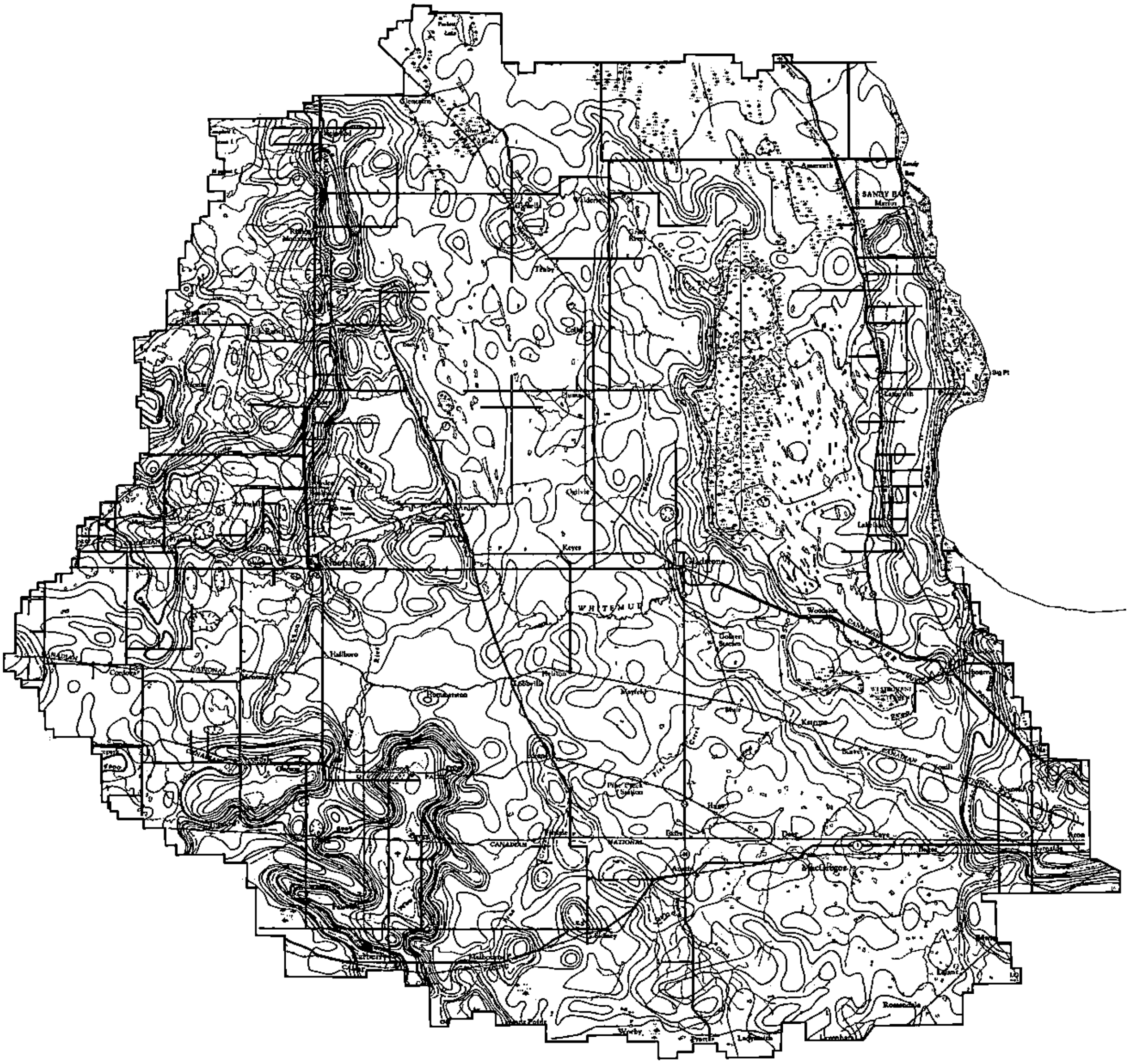
$$\text{Cropping Index} = \frac{\text{Acreage in Crops/Farm}}{\text{Total Farm Acreage}} \times 1000$$

Produced By:

Lands Directorate, Lands, Forests and Wildlife Service
Department Of The Environment
For
Whitemud River Watershed Resource Study
Manitoba Department of Mines, Resources and Environmental Management

Date: Dec. 1, 1971

WHITEMUD RIVER WATERSHED



MANITOBA

ASSESSED VALUE PER QUARTER SECTION

Scale: 1 : 250,000

Legend:
Contour Interval $500 Assessed Value/Per Quarter Section

Contours: 7500, 6000, 3500, 2500

Depression: ....

Source:
Manitoba Department Of Municipal Affairs,
Municipal Assessment Branch.

Produced By
Lands Directorate, Lands, Forests And Wildlife Service,
Department Of The Environment.
For
Whitemud River Watershed Resource Study,
Manitoba Department Of Mines, Resources
And Environmental Management.

Date: Dec. 1, 1971