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STUDY OF PROBLEMS IN WATER ALLOCATION IN THE PRAIRIE PROVINCES

Report No. 1

The Economic Significance of Water Requirements Relative to Human Activities and Needs in the Saskatchewan River Basin

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in co-operation with

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PREFACE

This report is the first in a series of three reports published by the Prairie Farm Rehabilitation Administration and the Economics Division of the Canada Department of Agriculture. These reports are part of a study begun in 1952, in conjunction with "A Survey of the Law of Water in Alberta, Saskatchewan and Manitoba" by Per Gisvold, to co-ordinate all known facts concerning the geographical location of interprovincial watersheds in relation to present and probable future activity and need, and to evaluate the legal and economic significance of various physical and engineering possibilities.

The three reports include:

Report No. 1, "Preliminary Investigation of the Economic Significance of Water Requirements in Relation to Human Activities and Needs in the Saskatchewan River Basin".

Report No. 2, "Physical Features of the Saskatchewan River Basin".

Report No. 3, "Annotated Bibliography of Selected Documents Pertaining to Water Allocation and Utilization in the Saskatchewan River Basin".

The present report is mainly concerned with the economic aspects of the water problems and the extent of the water shortage.

The report on "Physical Features of the Saskatchewan River Basin" discusses the physical features in relation to water supply and water use.

The "Annotated Bibliography of Selected Documents Pertaining to Water Allocation and Utilization in the Saskatchewan River Basin" deals only with Canadian literature on the subject.

The author gratefully acknowledges the encouragement, inspiration and help given by the late Dr. L.B. Thomson, Director of the Prairie Farm Rehabilitation Administration, Dr. C.C. Spence, Western Supervisor, Regional Offices of the Economics Division, and Mr. W.M. Berry of the Prairie Provinces Water Board. Thanks are due to Mr. R.H. Clarke for criticizing the first draft.

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CHAPTER 1. INTRODUCTION: THE FRAME OF REFERENCE

In 1952 the Economics Division of the Canada Department of Agriculture undertook a study of problems in water allocation in the Prairie Provinces for the Prairie Provinces Water Board.1/

The rules regulating the use of water in each of the provinces of Canada do not apply interprovincially. Within each of the Prairie Provinces the practice has been to issue licenses for all reasonably "good" projects with priorities being allotted in strict conformity to their respective dates of application (provision being made to allow a "higher" type of user to take over the priority of a "lower" type of user, providing that the need is demonstrated and damages are paid.2/

The Prairie Provinces Water Board was created in 1948, among other things, "to recommend the best use to be made of interprovincial waters in relation to associated resources in Manitoba, Saskatchewan and Alberta and to recommend the allocation of water as between each such province of streams flowing from one province into another province".3/

Many questions bearing on allocation are likely to be asked by anyone having to decide how to apportion the water. For example, he will want to know how much water is available. He already knows that he cannot rely on figures on the average annual flow, since the flow varies from a high flow in early summer to a low flow in the winter, and, unless the spring and early summer flow is stored, it is not available for use.

At Edmonton the discharge of the North Saskatchewan River has varied from a minimum of 220 cubic feet to a maximum of 204,500 cubic feet per second.4/ At Medicine Hat, the South Saskatchewan River has varied from a minimum of 214 cubic feet per second to a maximum of 145,000 cubic feet per second.5/

Water shortages will be felt whenever the load on the river exceeds the minimum flow. Storage, modifying the natural regimen of the river, tends to increase the load that can safely be placed on the river.

1/ Prairie Provinces Water Board, Minutes of 17 December 1952.

2/ See Appendix A; see also: Gisvold, P., A Survey of the Law of Water in Alberta, Saskatchewan and Manitoba, Edmonton, Canada Department of Agriculture, P.F.R.A. and the Economics Division, May 1956, pp. 28-32. The legislation varies slightly between provinces, but in general the priorities of use are: domestic, municipal, industrial, irrigation, water power and other purposes.

3/ Agreement between the Governments of Canada, Manitoba, Saskatchewan and Alberta, 28 July, 1948.

4/ January 1, 1950 and June 28, 1915, respectively. See Water Resources Paper No. 109, Department of Northern Affairs and National Resources, Canada, 1954, p.182.

5/ October 2, 1948 and June 3, 1923, respectively. Flow affected by storage and irrigation above this station. See Ibid., p.197.

On the demand side it is legitimate to ask what uses of water may be attempted in the foreseeable future. How much irrigation will be needed? How much power production will be desired? How much water will be needed for domestic, municipal and industrial uses, and to control pollution?

Water pollution becomes a matter for interprovincial consideration when river water used downstream is polluted upstream in another province. It may be controlled by action on two fronts: the quality of effuence may be improved, and the discharge in the river may be increased.

As a refinement of the question concerning irrigation, one might ask what economic priority attaches to the agricultural development of the presently uninhabited grey wooded soils, the soils of the Saskatchewan delta which can be reclaimed by flood control and drainage, and soils which can be reclaimed by irrigation.

<u>Purposes of the study</u>.- The present study was undertaken to assist the Water Board in making decisions about the allocation of water.

The Board was deeply conscious of the need for information on the economic significance of activities and needs related to water development. The information would be particularly useful in making recommendations concerning the allocation, among provinces, of the flow of water in interprovincial streams.

The Board's assignment referred to the allocation of water in the Prairie Provinces. Strictly speaking, however, the Saskatchewan is the only river system to raise many interprovincial problems. The scope of the study, at least in its initial stages, had therefore to be limited to water problems in the Saskatchewan river basin.

The more specific purpose was to collate and analyze data on water resources development and thus provide criteria for the allocation of water between provinces. The Board was guided by the concept of allocation according to the "most equitable use". The determination of what is most equitable may finally rest with the judicial power but, in any case, economic criteria should play an important role in arriving at a decision.

The economic significance of human needs and activities can only be expressed in terms of expected economic development. For the Saskatchewan river basin, for example, a comparative assessment must be made of the amount of water needed for irrigation and hydro-electric power purposes and of the potential and relative contributions of each to economic development.

A study of water allocation in a given river basin should begin with estimates of the volume of water that would be available for use if all usable engineering sites were available. These estimates would enable the economist to draw an economic supply curve depicting the water supply as a function of cost. This curve could then be confronted with various combinations of loads the river system might be expected to carry. A development plan that could be undertaken in the foreseeable future would then be elaborated and engineering works planned to ensure the maximum use of available water.

This approach entails many costly engineering studies. Their immediate usefulness might not be justified by any load the river system may be required to carry. As we have enough engineering data for a preliminary appraisal, the most realistic way to begin our work is to make a general examination of possible future needs and activities, before embarking on more refined engineering studies. This examination, however, depends on the analysis of projects now carried on; the economic worth of these projects will serve as a guide in determining if similar projects ought to be undertaken. An analysis of the relation between the water supply and its utilization is handicapped more by the lack of economic than of engineering data. The first step then should be to begin with studies of economic projects, already developed or being developed.

A study of water development in the Saskatchewan river basin is a many-angled project. Attention must be given to past experience and to the engineering, agronomic and economic aspects of proposed irrigation projects. But, as irrigation is not the only way to reclaim land or expand the agricultural land area, one must also consider what land area may be reclaimed through drainage and the clearing of forest lands.

The development of the hydro-electric power potential of the river may lead to economies in the use of other scarce resources such as coal and help many industries which depend on large power resources for their development. The regulation of the flow of water would help control flooding and increase recreational facilities and pollution control could be effected as a by-product of this regulation of the flow of water.

The fundamental problem, however, is to determine if the available water supply is sufficient for present and expected future needs.

CHAPTER 2. THE GEOGRAPHICAL SETTING

The Saskatchewan River basin stretches across the provinces of Alberta, Saskatchewan and Manitoba; a small area in the southwest of the basin lies in the northwestern corner of the State of Montana. The area covers about 149,500 square miles, or 95.5 million acres, of which 82,000, 66,600 and 900 square miles lie in the provinces of Alberta, Saskatchewan and Manitoba, respectively.

The basin is drained by the north and south branches and the main stem of the Saskatchewan River, and their tributaries. The two branches merge about 30 miles east of the city of Prince Alberta, from whence the main stream carries the water to Lake Winnipeg which discharges, via the Nelson River, into Hudson Bay.

To the north, drainage is effected by the Athabasca and Churchill rivers. South of the basin, the prairie provinces are drained by the tributaries of the Missouri and by the Assiniboine River and its tributaries.

The western part of the basin is bounded by the Rocky Mountains, which separate the Pacific drainage from the interior. The eastern slopes of the

Rockies drain into the Saskatchewan River and contribute a very large proportion of the total runoff of the basin.

Relief.- The three prairie "steppes", which cut across the basin, are the chief characteristics of the area. The highest of these elevations slopes northeastward from the mountains, falling from about 4,000 feet to 2,200 feet at the Missouri Coteau. The latter is an escarpment that can be easily identified from its shape: it consists of dirt hills that rise as much as 500 feet above the surrounding prairie and cut across the basin just west of a line drawn between Weyburn and Mosse Jaw and extending generally in a northwest-southeasterly direction. The relief on this "steppe" is far more broken than on the others, and erosion has gone further. In some areas the surface has been worn down into round hills, and in the vicinity of the rivers deep draws and coulees form a broken and picturesque topography.

The second level of the prairies comprises a rolling plateau with an average altitude of about 1,600 feet. It is bounded on the east by the Manitoba escarpment, a line of hills rising to 2,000 feet and separated from each other in places by many rivers flowing eastward.

The other prairie level stretches east of the Manitoba escarpment to the Canadian Shield and is a flat featureless plain, corresponding closely to the bed of glacial Lake Agassiz.1/

Climate, soils and vegetation.- The Saskatchewan River basin lies in the cool temperate zone. Temperature and precipitation vary greatly from one end of the basin to the other, owing to the large area covered by the basin itself.2/ It lies south of the 32 degree Fahrenheit isotherm marking the average annual temperature and has 120 frost-free days. The coldest months, December, January and February, have an average temperature of 10 degrees F. The warmest months, June, July and August, have an average temperature of 65 degrees F. These averages fail to show, however, that winter temperatures can be as low as 60 degrees F. below zero, and summer day temperatures as high as 105 degrees F.3/

Little rainfall reaches inland from the Pacific, because of the mountains, but the rainfall deficiency is not uniform. Medicine Hat is one of the driest districts in Canada, the average annual precipitation amounting to only 12.81 inches; toward the north, near Red Deer, the average annual precipitation is

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1/ For a more detailed account of the physical characteristics of the Saskatchewan River basin see interim report on "Physical Features of the Saskatchewan River Basin".

2/ The basin stretches across the Prairies through 18 degrees of longitude, from 117 degrees west to 99 degrees west, a distance of about 650 miles. At its point of maximum width, excluding the portion lying in Montana, the basin extends from 49 degrees north, to 54 degrees north, a distance of about 300 miles.

3/ For a more detailed examination of climate from the hydrological point of view, see Interim Report "Physical Features of the Saskatchewan River Basin".

20.63 inches.1/ Fortunately for agriculture, the largest part of the precipitation occurs during the growing season during June in the south, and gradually later as one proceeds north where the rainy season is in July. The paucity of moisture makes imperative the use of drought-resistant varieties of crops, and of moisture conserving cultural methods.

Data on precipitation and temperature conceal the fundamental issue as far as agriculture is concerned. Evaporation and transpiration are more important than the absolute amount of rainfall. Evapo-transpiration , which varies with temperature, wind direction, amount of sunshine and vegetation, etc., largely determines the efficiency of moisture for agricultural purposes.

Some idea of the aridity of the Saskatchewan River basin may be inferred from the following. A study of the evaporation from large lakes and reservoirs, equivalent in size to the Lake of the Woods, shows that evaporation is considerable, even during the winter months.2/ According to this study, which deals with potential open water evaporation, mean evaporation in the Calgary-Lethbridge area, in January, is equal to 0.6" whereas the region running from the Calgary-Lethbridge area east to Swift Current has an evaporation potential of 0.5" in January. In the remainder of the basin evaporation would be less severe. In July, the mean evaporation in the Manyberries-Leader (Sask.) area would amount to 7.5". For much of the basin, for instance, from the international boundary at about longitude 113 degrees, north to about Strathmore, and east to Scott and Saskatoon, and to the international boundary at about 100 degrees longitude, the mean July evaporation would be equal to or exceed six inches. The area just depicted describes fairly closely the Palliser Triangle which is disucssed in some detail in the following chapter.

Mean <u>annual</u> evaporation would vary from very little in the upper reaches of the Rockies to 37.5 inches in the Manyberries-Leader (Sask.) region. The area described above has an evaporation potential exceeding six inches in July and a mean annual evaporation of 30 inches.

In the foregoing, no consideration has been given to transpiration, and indeed no thorough study of the evapo-transpirtation characteristics of the basin exists.3/ The figures cited above refer to large, open bodies of water; how these figures would compare with evaporation from the land is not known. Nevertheless, when the potential evaporation is equal to 30 inches, and precipitation is in the neighborhood of 15 inches, a semi-arid condition is bound to be the outcome. This is the situation in the area previously described. In the Manyberries-Leader (Sask.) region, evaporation exceeds precipitation by 25 inches on the average. Nowhere in the basin with the exception

1/ <u>Climatic Summaries for Selected Meteorological Stations in the Dominion of Canada</u>, Vol. 1, Meteorological Div., Dept. of Transport, Toronto, p.42.

2/ Evaporation from Lakes and Reservoirs on the Canadian Prairies, Canada Department of Agric., P.F.R.A., <u>Prairie Provinces Water Board Report</u>, No. 5, Regina, 1952.

3/ A study, sponsored by the Prairie Provinces Water Board, dealing with evapo-transpiration characteristics on the Prairies, is nearing completion.

of the back ranges of the Rockies does precipitation equal or exceed evaporation.

The relative aridity, already great because potential evaporation exceeds precipitation, is made more intense by the fact that a good deal of precipitation is lost to agricultural purposes because of runoff. One of the main reasons why most of the Saskatchewan River basin can be used for a type of agriculture which relies on natural precipitation is that precipitation occurs mainly in the early summer during the growing season.

It is generally understood that a fairly large area of the Canadian Prairies lies in a region of low moisture efficiency but there are no data to depict the exact boundaries of that region. Soil types and vegetation are indicators, however, and the region of lowest moisture efficiency on the prairies can be delineated approximately by these characteristics.

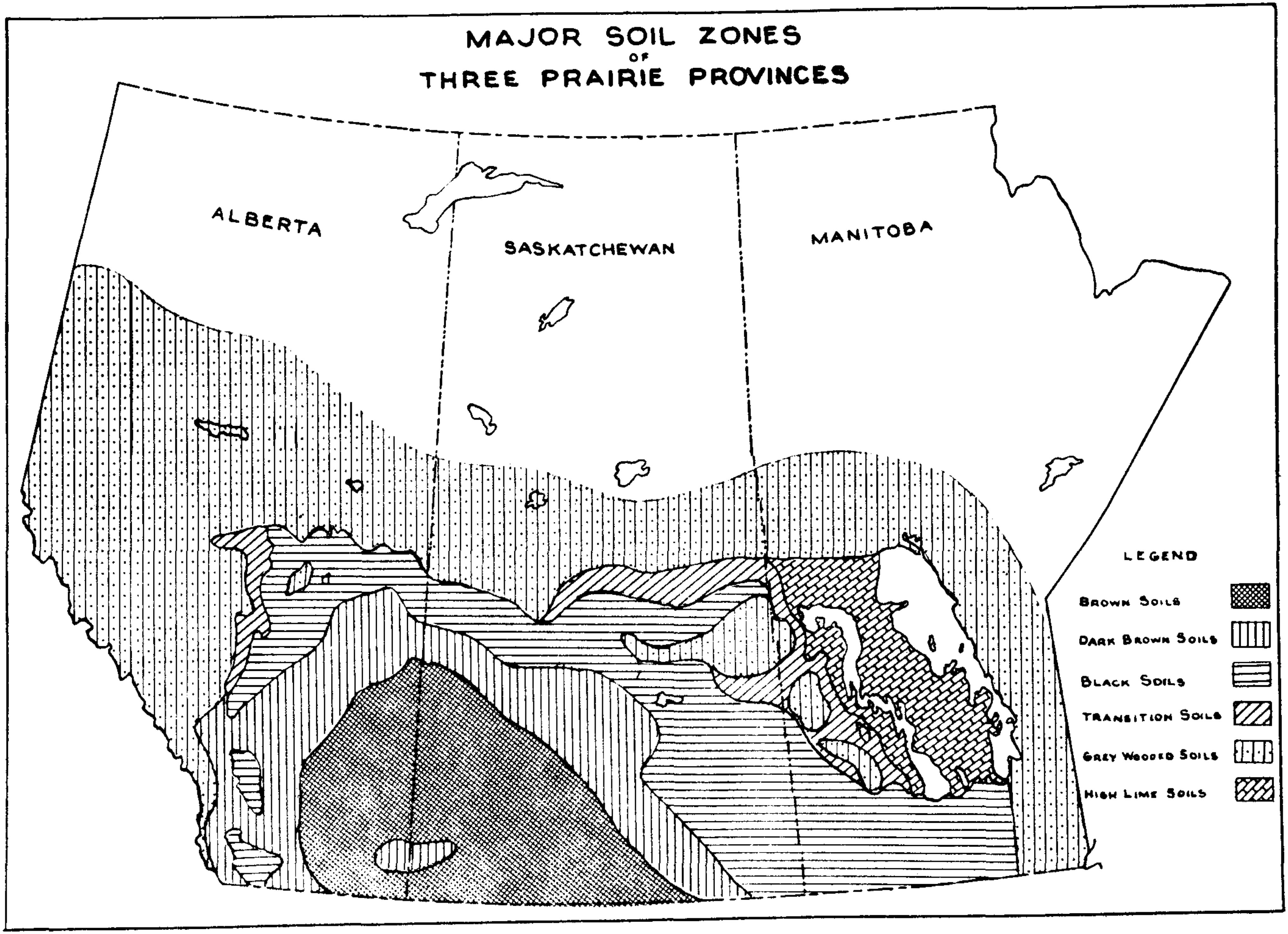
The northward extension of the Great Plains region of the United States, commonly known as the short-grass area, comprises the southern part of the basin. This is the region of brown soils. Its vegetation is sparse, with a cattle carrying capacity which may be as low as 40 acres per animal. Common grasses are blue grama, june and spear grass. The brown soil region is seen in the accompanying chart as the darkly shaded area with its base on the 49th parallel.

This area can be identified in a rough way by reference to certain census divisions. In Saskatchewan these are Divisions 2, 3, 4, 7, 8, 12 and 13; in Alberta, Divisions 1, 3, 5 and 7.

The brown soils with their characteristic short grasses merge into the dark brown soils; these soils have somewhat longer and more luxuriant grasses. The brown soil region is bounded by a black soil zone characterized by tall grasses and scattered trees - a park belt. Surrounding the park belt is a region of transitional soils and grey podsols typical of timbered country. The type of vegetation and the soil types indicate that moisture efficiency improves as one proceeds outward from the "inner triangle" of brown soils and short grasses. The type of agriculture becomes more intensive as moisture efficiency increases. Thus, a good deal of the brown soil zone is given over to grazing; the dark brown soil zone is used mainly for wheat production; and the black soil zone supports a "mixed farming" type of agriculture in which livestock enterprises are a common characteristic. The transitional soil zone is an exception to the general trend; climate and markets are more serious limiting factors for agriculture than moisture efficiency *per se*.

The Saskatchewan River and its salient characteristics.-1/ The Saskatchewan River rises in the Rocky Mountains east of the Great Divide. The South Saskatchewan proper begins at the confluence of two of its most important tributaries, the Bow River and the Oldman River west of Medicine Hat, Alberta.

1/ See Interim Report "Physical Features of the Saskatchewan River Basin", for a more detailed account. See also Denis, L.G., and J.B. Challies, *Water Powers of Manitoba, Saskatchewan and Alberta*, Commission of Conservation, Canada, Toronto, Warwick Bros. and Rutler, Ltd., 1916 chs. 6-11 inclusive.


MAJOR SOIL ZONES
OF
THREE PRAIRIE PROVINCES
ALBERTA
SASKATCHEWAN
MANITOBA
LEGEND
BROWN SOILS
DARK BROWN SOILS
BLACK SOILS
TRANSITION SOILS
GREY WOODED SOILS
HIGH LIME SOILS

The Red Deer River, the third important tributary, joins the South Saskatchewan at a point just east of the Alberta-Saskatchewan boundary. The North Saskatchewan itself rises as a result of melt from the Saskatchewan glacier of the Colombia Icefields.1/ It has several tributaries, of which the Clearwater River is the most important from the standpoint of discharge. Both branches of the Saskatchewan River meet at a point about 30 miles below Prince Albert , Saskatchewan. Below the confluence the Saskatchewan River receives several more tributaries, of which the most important are the Carrot River and the Torch River. Below Nipawin, Saskatchewan, the gradient of the river flattens and the last stretch of the river displays a great variety in the relief of its banks, so that lakes and marshes are characteristic of the region. Shortly before emptying into Lake Winnipeg, the gradient of the river changes rapidly, the water falling 120 feet in about five miles.

The first important feature is the variation in river gradient. In the mountain and foothills area slopes range from 5 to 100 feet per mile and the banks are shallow. Farther eastward, in what may be called the Western Prairie Region 2/ , the river gradients are more moderate, river banks are deeper, running as much as 100 feet or more, and irrigation by gravity is possible because of the rather shallow banks and fairly steep slopes. Most of the irrigated land is in that part of this region which lies in the southern area of Alberta. Farther east, e.g., at Medicine Hat on the South Saskatchewan, and at Edmonton, on the North Branch, the banks are deeper, and the gradients flatter. In this region, depending on the existence of suitable foundations for dams, the deep valleys have great storage potentials, since the banks may be as much as 500 feet above the surface of the water. As already mentioned, the river banks become shallow again somewhat east of Nipawin.

Secondly, the great importance of the eastern slopes of the Rockies for stream flow should not be overlooked. On the average 58 per cent of the discharge of the North Saskatchewan at The Forks is at Rocky Mountain House, some 100 miles southwest of Edmonton. It is difficult to get comparable figures for the South Branch, since it involves consideration of three tributaries, the Oldman, the Bow, and the Red Deer. The flow of the South Saskatchewan River at Medicine Hat is about 76 per cent of its total flow, although the drainage area at this point is only about one-third of the total area. At the confluence of the South Saskatchewan and the Red Deer rivers, 95.4 per cent of the total flow is present, and 67.7 per cent of the drainage basin has been utilized.

The third important feature is the variation, both seasonal and annual. With respect to the former, flood stage occurs in the early summer, and minimum flow in January and February. Table 1 depicts the extremes of stage recorded for each of the north and south branches and for the main stream of the river but does not distinguish between seasonal and annual variability.

Both types of variability are present in the figures given in the table but seasonal variability is the most important cause of the great disparity between maximum and minimum discharges.

1/ The Columbia Icefield is a remnant of the Cordilleran Icesheet, estimated to hold about 17 million acre-feet of water.

2/ Canada, Department of Agriculture, P.F.R.A., Hydrology Division, Full Development Possibilities in the Saskatchewan River Basin, Regina, Sask., 1952.

Table 1.- Average Annual Runoff and Maximum and Minimum Extreme Records for the North and South Branches and the Saskatchewan River, at Selected Points, 1913 to 1951

River and recording station	Average annual runoff a/ (acre-feet)	Extremes of stage recorded b/ Maximum (c.f.s.)	Minimum (c.f.s.)
North Saskatchewan river at Prince Albert	6,234,000	200,000 c/	395 d/
South Saskatchewan river at Saskatoon	7,176,000	131,000 e/	502 f/
Saskatchewan river at The Pas, Manitoba	18,000,000	105,500 g/	1,790 h/

a/ Alberta, Report on Surface Water Supplies and Water Power of Alberta, Water Resources Office, Edmonton, 1948.
b/ Canada, Water Resources Paper No. 109, Department of Northern Affairs and National Resources, Ottawa, 1954.
c/ July 2, 1915.
d/ January 23, 1935.
e/ June 6, 1923.
f/ December 12, 1936.
g/ June 11, 1948.
h/ February 3-4, 1930.

Source: As shown in footnotes a/ and b/.

Seasonal variability makes storage necessary to maximize hydro-electric production. It may be necessary also to ensure domestic and industrial supplies of water, and for pollution abatement. Such river regulation might come about by power storage on the headwaters, assuming it would be released during periods of peak power demand. Since the latter coincide very nearly with minimum natural discharge the low-flow would be augmented, bringing benefits to some downstream users.

Annual variation makes river control necessary only when the demand on the water is so great as to exceed the discharge on low-flow years. This might come about because of extensive irrigation or because of a combination of irrigation and other uses. Storage, to offset annual variability, might have to be quite large, and if so, the works necessary to contain it would be costly.

Water resources in relation to major sources of primary energy.- The hydro-electric power potential in the Saskatchewan River basin must be considered in relation to the magnitude and distribution of energy sources in the Prairies. Development of the power sites depicted in the key map following this chapter would result in an installed capacity of about 600,000 horse power. However, most of these sites are in Alberta, a province with large reserves of coal and oil. Canadian oil reserves in 1957, were estimated at 3.6 billion barrels (excluding the Athabasca oil sands) and natural gas reserves at 28 trillion cubic feet. About three-quarters of the Canadian oil and gas reserves are in Alberta, and most of the remainder in Saskatchewan. Recoverable reserves of coal have been estimated at 72 billion tons for Alberta 1/ and 12 billion for Saskatchewan. Manitoba, on the other hand, has very little indegenous coal and oil and depends heavily on hydro-electric power as a source of primary energy.

Summary.- The Saskatchewan River basin, with its continental type of climate, may be described as sub-humid to semi-arid. Therefore, water is a limiting factor in agriculture, especially in the brown soil zone. While the limits placed by water vary throughout the basin, except for the upper reaches of the mountains, potential evaporation exceeds precipitation to some extent, and in some cases this potential evaporation is as much as 25 inches greater than precipitation. Water for hydro-electric production, assumes important proportions in Manitoba, because of the paucity of other sources of primary energy.

1/ Britnell, G.E., "Perspective on Change in the Prairie Economy", The Canadian Journal of Economics and Political Science, Vol. 19, No. 4. (November 1953), pp. 437-454 c.f. Report of the Royal Commission on Coal, 1946, which places recoverable coal reserves in Alberta at 24 billion tons.

CHAPTER 3. THE HISTORICAL SETTING

According to the Census of Canada, in 1951, 1,060,547 people occupied the portions of Alberta and Saskatchewan laying within the Saskatchewan river basin. (Table 2)

Table 2.- Population of Alberta and Saskatchewain within the Saskatchewan River Basin, 1901-1951

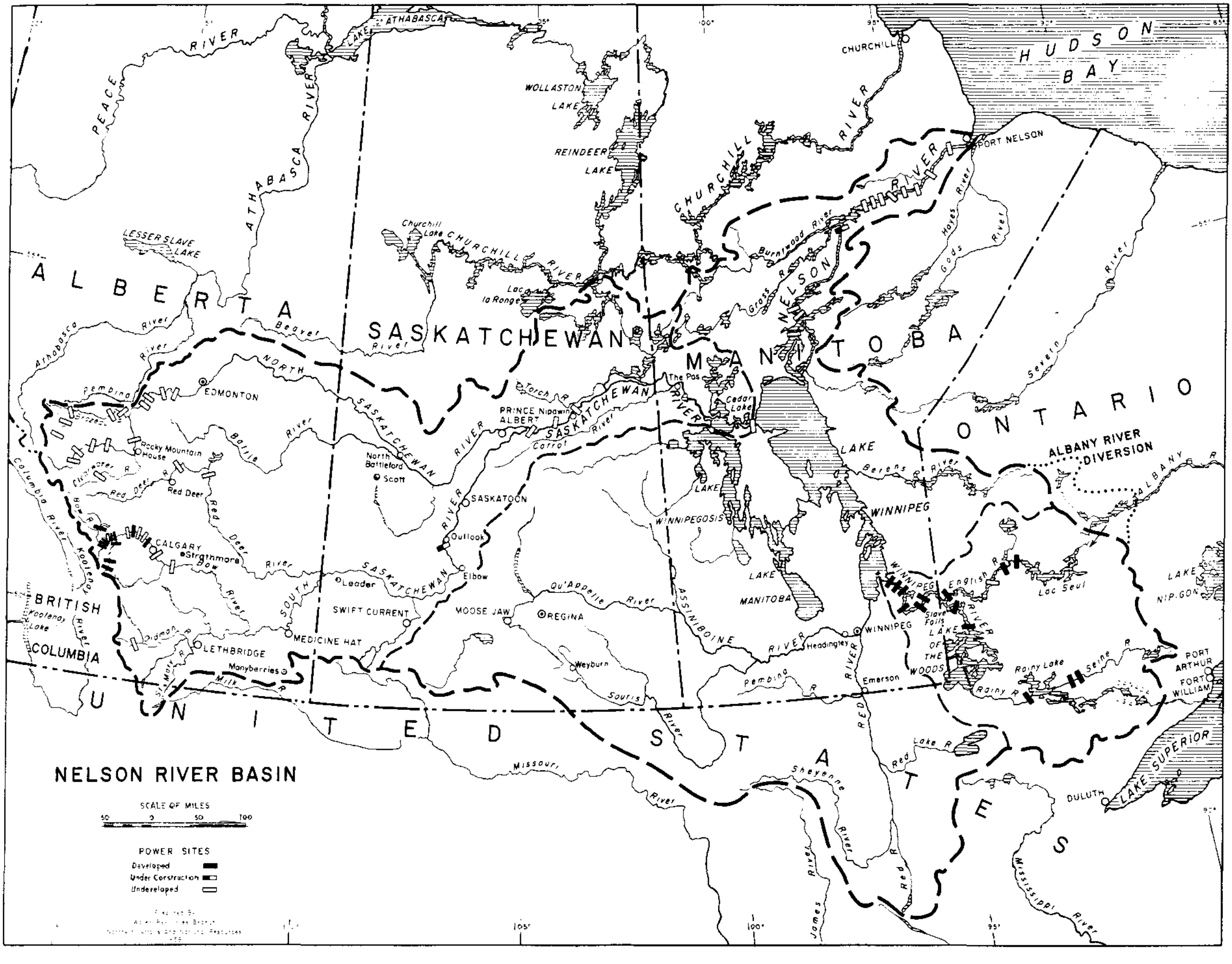
Province	Decennial census year					
	1901	1911	1921	1931	1941	1951
Alberta	66,831	350,785	532,670	631,027	668,222	802,356
Saskatchewan	14,782	142,031	256,175	316,639	288,683	258,191
Total	81,613	492,816	788,845	947,666	956,905	1,060,547

Source: Canada, Census Reports.

The history of settlement of the basin is essentially the general story of prairie settlement. Therefore, we shall not attempt to distinguish between prairie settlement and the economic development of the basin, the two being broadly synonymous. Our discussion will be almost wholly confined to development, as it affects land and water use.

Prairie settlement.- The history of prairie settlement has been written elsewhere and the problems created by the occupation of a sub-humid to semi-arid region have been explored.1/ However, as an aid to the understanding of the mid-twentieth century water problem, some of the more important aspects of settlement will be sketched.

1/ For a detailed account of settlement and problems arising out of the attempt to apply agricultural practices to the Prairie Provinces, the following should be consulted: Britnell, G.E., The Wheat Economy, Toronto, the University of Toronto Press, 1939; England, Robt., The Colonization of Western Canada, London, P.S. King and Son Ltd., 1936; Fowke, V.C., "The Historical Setting", Report of the Royal Commission on the South Saskatchewan Project, Ottawa, The Queen's Printer, 1952, pp.71-130; Fowke, V.C., Canadian Agricultural Policy: The Historical Pattern, Toronto, The University of Toronto Press, 1947; Hedges, J.B., Building the Canadian West, New York, The Macmillan Co., 1939; Innis, Mary Q., An Economic History of Canada, Toronto, The Ryerson Press, 1948, chs. 9 and 10; Mackintosh, W.A., Prairie Settlement: The Geographical Setting, Toronto, Macmillan Co. Ltd., 1934; Mackintosh, W.A., Economic Problems of the Prairie Provinces, Toronto, The Macmillan Co. Ltd., 1935; Mackintosh, W.A., The Economic Background of Dominion-Provincial Relations; A Study Prepared for the Royal Commission on Dominion-Provincial Relations, Appendix 3, Ottawa, King's Printer, 1939; Morton A.S. and Martin, Chester, History of Prairie Settlement and "Dominion Lands" Policy, Toronto. The Macmillan Co. Ltd., 1938; Murchie, R.W., Agricultural Progress on the Prairie Frontier, Toronto, The Macmillan Co. Ltd., 1936; Webb, W.P., The Great Plains, Boston, Ginn, 1931.


NELSON RIVER BASIN
SCALE OF MILES
50 0 50 100
POWER SITES
Developed
Under Construction
Undeveloped
HUDSON BAY
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
BRITISH COLUMBIA
UNITED STATES
ALBANY RIVER DIVERSION
PEACE RIVER
ATHABASCA RIVER
LAKE ATHABASCA
WOLLASTON LAKE
REINDEER LAKE
CHURCHILL RIVER
CHURCHILL
PORT NELSON
NELSON RIVER
LESSER SLAVE LAKE
Churchill Lake
Lac la Ronge
Burntwood River
Grass R
Hayes River
Gods River
Severn River
Beaver River
NORTH SASKATCHEWAN RIVER
SOUTH SASKATCHEWAN RIVER
SASKATCHEWAN RIVER
EDMONTON
PRINCE ALBERT
Nipawin
The Pas
Cedar Lake
Torch R
Carrot River
North Battleford
Scott
Battle River
Red Deer River
Red Deer
Rocky Mountain House
Clearwater R
Bow R
Bow River
CALGARY
Strathmore
SASKATOON
Outlook
Elbow
Leader
SWIFT CURRENT
MEDICINE HAT
LETHBRIDGE
Manyberries
Oldman R
Milk R
St. Mary R
Kootenay River
Kootenay Lake
Columbia River
Pembina River
Qu'Appelle River
MOOSE JAW
REGINA
Weyburn
Souris River
ASSINIBOINE RIVER
Headingley
WINNIPEG
LAKE WINNIPEG
LAKE WINNIPEGOSIS
LAKE MANITOBA
Berens River
WINNIPEG RIVER
English R
Lac Seul
Slave Falls
LAKE OF THE WOODS
Rainy Lake
Rainy R
Seine R
LAKE NIPIGON
PORT ARTHUR
FORT WILLIAM
LAKE SUPERIOR
DULUTH
Emerson
RED RIVER
Red Lake R
Sheyenne River
James River
Missouri River
Mississippi River
Red R
105°
100°
95°

Settlement of the Prairie provinces began in the mid-nineteenth century, but most of it was done during the first three decades of the present century. National policy in Canada, revolving around tariffs, railroads and western lands, had for its economic purpose essentially commercial ends, and promoted settlement as an instrument to accomplish its objectives.1/

In spite of Palliser's 2/ opinion that a great deal of the West was unfit for settlement, and in spite of Hind's 3/ corroboration concerning the "triangle", control of the area was taken over from the Hudson's Bay Company, by the Canadian Government, through an agreement reached in 1869 and plans were laid to effect settlement.4/

Palliser regarded only the drier part of the Prairies as unfit for settlement. This, he recognized as the northern part of the American desert which "extends, however, but a short way into the British territory, forming a triangle, having for its base the 49th parallel from longitude 100 degrees to 114 degrees W., with its apex reaching to the 52nd parallel of latitude."5/ The region he described is not a triangle, and the area involved is in excess of what is now recognized as the really dry belt. The latter corresponds fairly closely to the brown soil zone, described briefly in Chapter 2. His opinion of the triangle's fitness for agriculture, which can be seen from the following quotation, was not optimistic.

> "The true arid district, which occupies most of the country along the South Saskatchewan, and reaches as far north as latitude 52 degrees, has even early in the season a dry parched look... The grass is very short on these plains, and forms no turf, merely consisting of little wiry tufts. Much of the arid country is occupied by tracts of loose sand, which is constantly on the move before the prevailing winds. This district, although there are fertile spots throughout its extent, can never be of much advantage to us as a possession".6/

He was much more enthusiastic about the region that surrounds the arid area in an arc. The following remarks indicate his high opinion of the park belt for future agricultural settlement.

> "The richness of the natural pasture in many places on the Prairies of the second level along the North Saskatchewan and its tributary, Battle River, can hardly be exaggerated.

1/ Fowke, V.C., Canadian Agricultural Policy: The Historical Pattern, Toronto, The University of Toronto Press, 1947.

2/ Palliser, Capt. John, Journals, Detailed Reports, and Observations Relative to the Exploration of ... British North America .... 1857-1860, London, 1863.

3/ Hind, H.Y. Narrative of the Canadian Red River Exploring Expedition of 1857 and The Assiniboine and Saskatchewan Exploring Expedition of 1858, Vols. I and II, London, 1860.

4/ Fowke, V.C., "The Historical Setting", The Report of the Royal Commission on the South Saskatchewan River Project, Ottawa, 1952, pp.71-130.

5/ Palliser, op. cit., p.7.

6/ Ibid, p.246.

Its value does not consist in its being rank or in great quantity, but from its fine quality, comprising nutritious species of grasses and carices, along with natural vetches in great variety, which remain throughout the winter sound, juicy and fit for the nourishment of stock.

"Almost everywhere along the course of the North Saskatchewan are to be found eligible situations for agricultural settlement, a sufficiency of good soil is everywhere to be found, nor are these advantages merely confined to the neighborhood of the river; in several districts, such as northwest of Carlton,1/ we traversed fine land fit for all purposes, both of pasture and tillage, extending towards the thickwood hills, and also to be found in the region of the lakes between Fort Pitt 2/ and Edmonton.

"In almost every direction from Edmonton the land is fine, excepting only the hilly country at the higher level, such as the Beaver Hills".3/

The British Government had sent Palliser to explore the Canadian West in 1857. In the next year the Government of Canada sent H.Y. Hind, whose objective among other things was to determine the agricultural possibilities of the region, comprised of the Assiniboine River and Saskatchewan River valleys. Hind, like Palliser, concluded that the region of the Saskatchewan River valley, known as the short grass plains, was wholly unfit for settlement. This opinion along with his delineation of the region is indicated in his own words as follows:

"The true limit of the Plains in Rupert's Land, east of the South Branch [of the Saskatchewan River], is well shown by the Grand Coteau de Missouri. The country east of that natural boundary may be classed as Prairie country, over the greater portion of which forests of aspen would grow if annual fires did not arrest their progress. The plateau of the Grand Coteau [de Missouri] forms the true Plains of Rupert's Land, where both soil and climate unite in establishing a sterile region. The Grand Coteau de Missouri, distinctly visible from the Eyebrow Hill begins in latitude 45 degrees, about sixty miles southwest of the head of the Coteau des Prairies in latitude 45 degrees 55'; the intervening valley is occupied by James's River, an affluent of the Missouri.

"Its boundary pursues a course nearly due north, under the 99th meridian, and still preserving a northwesterly direction comes on the South Branch of the Saskatchewan, a few miles from the Elbow in longitude 108 degrees. The region east of the Grand Coteau

1/ Near Carlton, Sask., some 70 miles S.W. of Prince Albert.

2/ Fort Pitt does not exist at the present time. It was located on the north side of the river, northeast of Lloydminster. See MacGregor, J.G., Blankets and Beads, Edmonton, The Institute of Applied Arts, Ltd., 1949, pp.137-8.

3/ Palliser, op. cit., p.10.

belongs to the prairie region, the Grand Coteau itself and its prolongation towards Battle River, from its eastern boundary to the foot of the Rocky Mountains, constitutes the Plains properly so-called for the northwestern territories of the United States and of British America. From the character of its soil and the aridity of its climate, the Grant Coteau is permanently sterile and unfit for the abode of civilized man".1/

Despite the pessimistic reports of Palliser and Hind, the Canadian Government acquired the region of Rupert's Land, and provided arrangements for its settlement.

Plans for settlement, in the first quarter of a century after acquiring the Hudson's Bay Territories, consisted in three institutional arrangements. These were first, the retention of unalienated lands by the Dominion. This was a departure from usage since it was established by the B.N.A. Act 2/ that control of resources rested in the provinces. Thus the Manitoba Act (1870) provided that -

> "All ungranted or waste lands in the province shall be, from and after the date of the said transfer, vested in the Crown and administered by the Government of Canada for the purposes of the Dominion, subject to, and except and so far as the same may be affected by, the conditions and stipulations contained in the agreement for the surrender of Rupert's Land by the Hudson's Bay Company to Her Majesty." (33 Victoria, Section 30).

These provisions were extended to Alberta and Saskatchewan when the latter were created in 1905.3/

The second institution, really an adjunct of the first, was the Homestead regulations, incorporated in the Dominion Lands Act of 1872. Nothing like all the lands in the West were available for homesteading: The Hudson's Bay Company retained one-twentieth of the land, and one-eighteenth was allocated for educational purposes. The amount of land involved in these two instances accounted for about 14 million acres. In addition, 25 million acres were set aside to help finance the construction of a transcontinental railroad. The latter is the third institution to which reference was made above.

Settlement lagged at first. Even with the completion of the Canadian Pacific Railway in 1885, the number of homestead entries did not increase. Not until the early years of this century did settlement begin to occur rapidly. Thus, from 1874-1899 inclusive there were only 81,437 homestead entries, whereas in the five years from 1900 to 1904 there were 87,682 entries.4/ With the outbreak of war the flow of immigrants slowed down

1/ Hind, op.cit. pp.350-351.
2/ Section 92 (5).
3/ Section 21 in each Act.
4/ Mackintosh, W.A., Economic Problems of the Prairie Provinces, Toronto, The Macmillan Co. Ltd., 1935, p.282.

but by 1930, that is, in just over half a century, 672,268 entries had been recorded.

Settlement tended to take place in the fertile belt around the short grass plains, rather than on these plains. However, summerfallowing, a technical innovation, associated with the name of Angus Mackay, made settlement of the short grass region feasible. With summerfallowing moisture could be stored from one season to the next.1/ Armed with this technique and, after 1910, first Marquis wheat, settlement of the short grass region was accomplished during the 1906-1916 period. From 1909 to 1912, the area between Moose Jaw and Calgary was thrown open to homesteading and occupied.2/ After reaching a peak of 300,523, in 1936, the number of farms then declined steadily although the number of occupied acres, with the exception of a minor set-back during World War II, continued to expand. The decline in the number of farms can be attributed to three factors. First, the quarter and half-section farms, fostered by the settlement policy, proved to be too small to provide an economic unit. The extensive type of farming required in the dry-belt, owing both to paucity of moisture and extreme variability, made it economically imperative to have larger farms. Second the technical revolution in the farm equipment industry, mainly the substitution of power by the internal combustion engine for horse and mule power, made larger holdings possible. And, finally, thousands of acres of land were taken out of cultivation by governmental action and placed under the administration of the government concerned. Reference is made in particular to the special areas of Alberta and the community pastures and other devices used in Manitoba and Saskatchewan. Table 3 describes the changes in the number of farms, area occupied, area improved, and area in field crops, during the first half of our century.

While land abandonment, and increases in farm size drastically reduced the number of farms in the drier areas of the three provinces, settlement was taking place in the Peace River block and in the northern grey-wooded areas of all three provinces. Therefore, the figures showing the number of farms in Table 3, although indicating a decline, greatly under-estimate the reduction in farm numbers in the semi-arid region. Irrigation development to the extent that it occurred, with the small holdings that have been common, tends also to obscure the extent of land abandonment in the drought areas. Hence, a good deal of the region depicted by Palliser and Hind as unfit for settlement has been abandoned to grazing, or has been made arable through irrigation.

Of course, the pace of settlement may be discerned from indicators other than these shown. Prairie farm investment more than doubled in the

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1/ Because of susceptibility to wind erosion, the original practice of "black" summerfallowing gave way in the early 1930's to a "trash covered" type of summerfallow, made possible by a technical revolution in the farm equipment industry which introduced suitable machinery and which made practically absolete, on the plains proper, what had been considered standard equipment - namely, the mouldboard plow.

2/ Fowke, V.C., Royal Commission, op. cit., p.100.

Table 3.- Number of Farms and Area Occupied, Improved and Under Field Crops, by Census Years, Prairie Provinces of Canada, 1901-1951

Year	Number of farms	Occupied (acres)	Improved (acres)	Field crops (acres)	Field crops per farm (acres) a/
1901	55,176	15,412,411	5,592,601	3,608,000 b/	65.4
1906	c/	c/	c/	c/	c/
1911	199,203	57,642,844	22,969,774	17,677,091	89.0
1916	218,563	73,300,135	34,330,246	24,595,915	112.5
1921	255,657	87,931,804	44,863,266	32,203,206	126.0
1926	248,162	88,929,994	49,264,625	34,987,081	141.0
1931	288,079	109,782,602	59,819,436	40,006,091	138.9
1936	300,523	113,112,500	60,849,957	40,194,581	133.7
1941	296,469	120,129,544	65,531,714	38,300,618	129.4
1946	269,601	117,538,678	65,395,228	41,626,834	154.7
1951	248,716 d/	123,853,220	71,839,624	45,427,637	182.8 d/

a/ Simple arithmetic mean.

b/ Area under crops includes gardens, orchards and nurseries, in this instance.

c/ Not available.

d/ Not directly comparable because of a change in definition of a farm.

Source: Canada, Dominion Bureau of Statistics, Census Reports.

1900-1930 period (Table 4), while transport investment, including railways, increased more than sixfold. During the 1926-1930, five-year period, farm and transport investment accounted for over 28 per cent of total gross capital formation.1/

Table 4.- Prairie Farm and Transport Investment and Gross Capital Formation in Canada, by Five-year Periods, 1901-1930
Prairie Provinces

Period	Gross capital formation a/	Prairie farm investment	Transport investment	Per cent Prairie farm investment is of gross capital formation	Per cent transport investment is of gross capital formation
	- millions of dollars -				
1901-1905	1,284	221	201	17.2	15.7
1906-1910	2,241	319	539	14.2	24.1
1911-1915	3,230	463	848	14.3	26.3
1916-1920	4,138	370	661	8.9	16.0
1921-1925	3,702	245	753	6.6	20.3
1926-1930	5,898	454	1,225	7.7	20.8

a/ Figures are for Canada as a whole.
Source: Buckley, K.A.H., Professor of Economics, University of Saskatchewan, unpublished data.

In 1931 the administration of resources passed from the Crown in the right of Canada, to the Crown in the right of the respective provinces, and this legal change coincided with the close of a period when prairie settlement sparked capital formation in Canada. Thenceforth, the investment frontier was to be found in connection with the rocks of forests of the Canadian Shield.

Problems arising from aridity, and some ameliorative measures adopted.- The main cause of trouble in the semi-arid prairies turned out to be variability and paucity of precipitation. The result was that lands were settled which were unsuitable to continued cultivation, and there was a shortage of water for stock. Because of the annual variability in precipitation, the long-term suitability of a tract of land for agriculture was frequently appraised too optimistically. Hence, lands were settled under favorable climatic conditions; then when the dry years came severe hardships were experienced.

The drought of 1921-23 forced the abandonment of land in the eastern part of Alberta in parts of Census Divisions 1, 3 and 5, and resulted in the creation of the Special Areas, of which the Tilley East Area was the

1/ For a detailed account of the effect on national income which resulted from prairie settlement see Buckley, K.A.H., Capital Formation in Canada, 1896-1930, Toronto, University of Toronto Press, 1955.

first.1/

In Saskatchewan, both the Provincial and Federal Governments handled relief and rehabilitation problems brought about by drought in the early 1930's. The latter government, through the Prairie Farm Rehabilitation Administration 2/, removed settlers from large tracts of land and created community pastures; it experimented with and advised on cultural practices, and concerned itself with water husbandry.

The husbanding of water is made possible through financial and engineering assistance by P.F.R.A., for three sizes of projects.

Individual projects are small in size, consisting usually of "dugouts" 3/, or small reservoirs created by little dams. They are located on farm land not supplied by natural streams and depend on local runoff for the water supply. The water may be used for stock watering and, if plentiful, for limited irrigation. From the inception of the program in 1935, to March 31, 1957 inclusive, 53,579 individual projects had been completed. The latter consisted of 43,633 dugouts, 6,718 dams and 3,228 small irrigation schemes.4/

Community projects are built with P.F.R.A. assistance where Water Users' Associations have been created with the intention of storing and using water on a community basis. Nearly 300 of these projects had been completed by 1953.5/

The foregoing discussion of water husbandry measures pertains to the whole of the southern part of the Prairie provinces; something less than the above number is to be found in the Saskatchewan river basin.

Major irrigation projects, occur, in the main, within the boundaries of the basin, and "the artificial application of water to soil for the purpose of supplying the moisture essential to plant growth" 6/, is the most important aspect of water husbandry on the Prairies in terms of volume of water utilized. Tables 5 and 6 describe the comparative importance of the irrigated acreages in Alberta and Saskatchewan in 1950.7/

1/ Statutes of Alberta, 1927, c.45.
2/ Created by the Prairie Farm Rehabilitation Act, Statutes of Canada 25-26, Geo. V. c. 23 (1935).
3/ A dugout is a strategically located excavation of capacity usually of 1.5 acre-feet.
4/ Annual Reports, P.F.R.A., 1951-52 to 1956-57 inclusive.
5/ Loc. cit.
6/ Israelsen, O.W., Irrigation Principles and Practices, 2nd Edition, New York, John Wiley and Sons, Inc., New York, 1950. p. 1.
7/ As of March 31, 1957, the irrigable acreage developed in Alberta and Saskatchewan amounted to 930,000 acres. See Annual Report on Prairie Farm Rehabilitation and Related Activities, 1956-57, Regina, Sask., 1957, pp. 91-92.

Table 5.- Area Irrigated, Area Irrigable, Number of Farms Reporting Irrigation by Provinces, Alberta and Saskatchewan, 1950

	Irrigated	Irrigable	Number of farms reporting
	- acres -		
Alberta	447,032	564,453	4,044
Saskatchewan	37,498	43,113	722
Total	484,520	607,566	4,766

Source: Census of Canada, 1951, Vol. VI, Part 2.

Table 6 shows that while the total number of acres irrigated is impressive, the number of farms utilizing irrigation is quite a small percentage of the total number of farms in Alberta and Saskatchewan.

Table 6.- Number of Farms and Number of Farms Reporting Irrigation, Alberta and Saskatchewan, 1950

	(a) All farms	(b) Farms reporting irrigation	Per cent (b) is of (a)
Alberta	84,315	4,044	4.8
Saskatchewan	112,018	722	0.6
Total	196,333	4,766	2.4

Source: Census of Canada, 1951, Vol. VI, Part 2.

Within the Saskatchewan river basin, irrigation had been carried out for many years before the P.F.R.A. became involved. And today, with the exception of one irrigation project 1/, the P.F.R.A. lends assistance only to the extent of building the main capital works.

Irrigation development began more than 60 years ago as the ranchers' effort to grow winter feed by diverting water from small streams to flood native meadows.

By the early 1890's the possibilities of irrigation had been demonstrated and in 1894 the North-West Irrigation Act was passed. Following prolonged drought during the 1880's and 1890's, interest in irrigation rose and by 1895 some 112 individual projects had been constructed to serve more than 79,000 acres of land.

The construction of large-scale projects began in 1901 when water from the St. Mary River, near the international boundary, was carried to Lethbridge

1/ The present Bow River Irrigation Project, purchased by Canada from the Canada Land and Irrigation Company, in 1950.

through canals provided by the Alberta Irrigation Company.1/ During the period from 1904 to the outbreak of World War I, the Canadian Pacific Railway Company projects at Strathmore and Brooks, and the Canada Land and Irrigation Company project at Vauxhall were established. After World War I, some community projects were constructed by local irrigation districts financed by bonds guaranteed by the Alberta Government. Projects in this group are the Taber, Lethbridge Northern, New West, Magrath, Raymond, United, Little Bow and Mountain View irrigation districts. During the 1930's the drought that prevailed heightened interest in irrigation, but depressed business conditions prevented the initiation of new works, and some of those that existed suffered financially. Following World War II, construction on the St. Mary-Milk Rivers Project went forward under an agreement between Alberta and Canada.2/ Work was carried out also on the Canada Land and Irrigation Project which was purchased from the owners by the Canadian Government in 1950; the name of the project was then changed to Bow River Irrigation Project.

The development of irrigation, under federal government assistance, had had for one of its purposes the rehabilitation and relocation of farmers who had settled on lands hard hit by drought. This was especially true in the case of the Bow River Project.

Summary.- The paucity and variability of precipitation over a great area of the prairies, especially throughout the region known as the brown soil zone, have been the cause of much hardship. Potential evaporation, in part of this regions, exceeds annual average precipitation by 25 inches; hence much of the region is fit only for ranching unless soil moisture from precipitation is supplemented by irrigation. In the foregoing, the ameliorative measures discussed were mainly those involving water husbandry. Others, perhaps as important as water husbandry have been omitted because they do not have a direct bearing on the problem of interprovincial water allocation. The implications of irrigation development on water allocation are discussed in the next chapter.

1/ In 1898 the Alberta Irrigation Company became the Northwest Irrigation Company and in 1904, as a result of an amalgamation with the Alberta Railway and Coal Company, (from which the lands were acquired in the first place), it became the Alberta Railway and Irrigation Company. In 1912 the Canadian Pacific Railway acquired the assets and in 1945 they passed to the Government of Alberta. See Report of the Royal Commission on the South Saskatchewan River Project, Ottawa, Queen's Printer, 1952, p.139.

2/ Pursuant to the regulations set out in P.C. 2298.

CHAPTER 4. WATER SUPPLY IN RELATION TO PRESENT AND PROSPECTIVE REQUIREMENTS

A. SURFACE SUPPLY

Surface water supply may be found on the earth's surface or held in suspension in the soil and in local catchments, but it usually finds its way through drainage and percolation to the river system. In either case the ultimate source is precipitation. That part of the precipitation which finds its way to the streams depends on such factors as basin configuration, vegetative cover, soil type, climate and land use. Some water finds its way to the streams by sub-surface channels; porosity and permeability of the underlying strata are the controlling factors.1/ Subsurface supplies to stream flow have an indirect bearing on allocation problems since the waters interrupted by wells upstream may not be available for use downstream. But, for the most part, surface water not entering the river system cannot be an allocative problem and hence require no consideration here. Attention will be concentrated on stream supply in what follows.

Supply available in rivers.- The supply available at various points along the river system depends on uses made of the water upstream. Late summer supply will be increased if stored water of the spring flood can be released. Winter supply will be increased by power storage upstream, released during the winter for power production. Summer supply will be decreased by irrigation activities upstream.

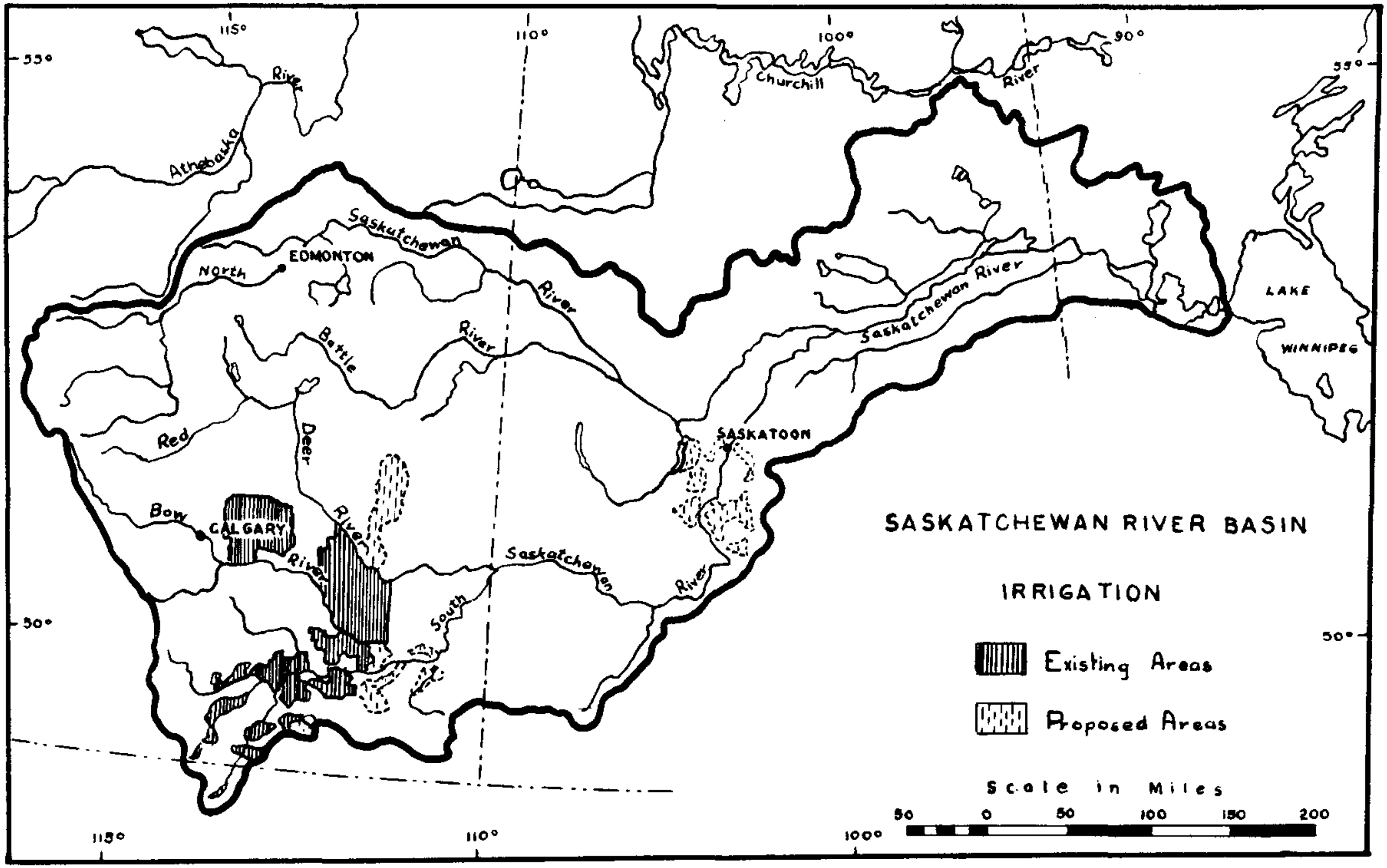
The water rights for present diversions for irrigation, and present storage for both irrigation and power, have been established and are recognized: the question of additional allocation remains. Therefore, in what follows, consideration is given to the supply available in the future, and the requirements to be met.

(a) Supply available in the North Saskatchewan river

The total supply in the North Saskatchewan river varies from year to year and, since a negligible quantity is diverted, the natural flow may be taken as the supply to be allocated. The recorded flow at the mouth exceeds six million acre-feet, on the average (1911-12 to 1947-48).2/ However, the flow has varied over this period from 3.5 million to 9.9 million acre-feet. Inasmuch as a water shortage is most likely to occur in a year of low flow, the figure of 3.5 million acre-feet is the critical one.

1/ Strata of low permeability but high porosity tend to store water and to give it up slowly to the streams. Where the strata are highly permeable, the transfer will be rapid.

2/ Canada, Department of Agriculture, Summary Report of Recorded and Natural Monthly Flows at Certain Points on the Saskatchewan River System, Prairie Provinces Water Board Report No. 1, Regina, Sask., 1950, Table 8. As most of the figures for river flows will be taken from the series of reports of which the above is the first, reference from here on will be to P.P.W.B., Report No. 1, or 2, etc.


SASKATCHEWAN RIVER BASIN
IRRIGATION
Existing Areas
Proposed Areas
Scale in Miles
50 0 50 100 150 200
Saskatchewan River
North
EDMONTON
Battle
River
Red
Deer
River
Bow
CALGARY
River
South
Saskatchewan
River
SASKATOON
Saskatchewan River
Churchill
River
Athabaska
River
LAKE
WINNIPEG
115°
110°
100°
90°
55°
50°

(b) Supply available in South Saskatchewan River

In March 1949, the Government of Alberta requested that 2,237,000 acre-feet a year be allocated by the Prairie Provinces Water Board from the South Saskatchewan river basin for use on existing irrigation projects. The following table depicts both the acreages involved and the water requested for the various projects.

Table 7. - Irrigation Projects, Acreage, and Water Requested in Alberta's 1949 Request

Irrigation project	Number of acres	Acre-feet of water requested
St. Mary and Milk River Development	465,000	796,000
Western Irrigation District	50,000	85,700
Eastern Irrigation District	281,000	562,000
Bow River Irrigation Development	240,000	478,534
United Irrigation Development	34,000	51,000
Lethbridge Northern District	96,135	150,000
Mountain View Irrigation District	3,600	6,000
Leavitt Irrigation District	4,400	7,000
Aetna Irrigation District	7,300	13,000
Macleod Irrigation District	5,000	8,000
Private Projects	70,000	80,000
Total	1,256,435	2,237,234

Source: P.P.W.B. Report No. 2, P.1.

The effect of this irrigation commitment will be felt downstream in terms of reduced flows. The average annual "natural" flow 1/ at Saskatoon is estimated for the water years 1911-12 to 1947-48 at 7,610,000 acre-feet.2/ Alberta's request for 2,237,234 acre-feet reduces the "natural" flow to 5,185,000 3/, or 32 per cent. However, the low flow years are the critical ones, and these should be examined in the light of Alberta's 1949 request. The year of lowest "natural" flow at Saskatoon was 1930-31 4/, with a discharge of 4,254,000 acre-feet.5/ Allowing for Alberta's request reduces this flow to 2,988,000 acre-feet 6/, which is a reduction of 30 per cent.7/

1/ "Natural" flow is the flow that would exist if there were no upstream works. It is an estimate. See P.P.W.B. Report No. 1, for a description of the method used.
2/ P.P.W.B. Report No. 1, Table 4
3/ P.P.W.B. Report No. 2, (Average figure for 1923-24 to 1947-48).
4/ This is the least flow year from 1911-12 to 1947-48.
5/ P.P.W.B. Report No. 1, Table 4.
6/ P.P.W.B. Report No. 2.
7/ The apparent anomaly of a smaller percentage being taken during a year of low flow may be explained by the activity of Calgary Power Ltd., on the headwaters of the Bow storing water for power, and by the water received by the South Saskatchewan from tributaries and ground water below the Alberta-Saskatchewan boundary.

The above analysis is on an annual basis. It is still open to question how Alberta's 1949 request affects the lowest monthly flow. In February 1936, the lowest "natural" flow was experienced (for the years 1911-12 to 1947-48); it amounted at Saskatoon to an average discharge of 288 second-feet.1/ With allowance for Alberta's irrigation request, and assuming river regulation as existing in 1949, the discharge would be for a future month equivalent to February 1936, not less but more; in fact it would be 2,027 second-feet.2/ These data seem to warrant the conclusion that upstream water use on the South Saskatchewan and tributaries at the present time leaves untouched over two-thirds of the water at Saskatoon and, because of hydro-electric storage on the Bow River, improves the regimen in winter.

It remains to examine the effect of Alberta's 1949 request on water flow at The Pas.3/ The annual average "natural" flow at The Pas (1911-12 to 1947-48) is estimated to be 17,719,000 acre-feet.4/ This would be reduced to 14,318,000 acre-feet 5/, or 19 per cent. During the year 1940-41, the lowest "natural" flow was experienced, the discharge amounting to only 9,035,000. This would be reduced, assuming Alberta's 1949 request to 7,555,000 acre-feet, or 16 per cent. Hence, as in the case of the flow at Saskatoon, because of regulation upstream and other factors, the diminution in flow, assuming Alberta's 1949 request, is less serious in terms of proportions in the lowest flow year than it is on the average. The minimum monthly flow is of greater significance, especially for power development, than is the annual flow. The lowest "natural" flow, for the years 1911-12 to 1947-48, occurred in February 1937 with a monthly average rate of discharge of only 1,342 second-feet (compared with an extreme maximum flow in June 1948 of 99,870 second-feet).6/ With Alberta's 1949 request, the flow for a month like February 1937 would be 2,744 second-feet.7/ On the basis of these figures it seems fair to say that as of the present time, four-fifths of the water of the Saskatchewan river is available for use in Manitoba, assuming average flow conditions; that there would be 7,555,000 acre-feet available in a low flow year; and that regimens are improved as a result of upstream power development, extremely low discharges under "natural" conditions being improved.

<u>Supply available in rivers in relation to requirements</u>.- The analysis, in Section 2 above, showed that at the present time no serious shortage of water can be said to exist. It remains to consider the supply in relation to possible future needs. Since it is not known what future requirements may be, certain assumptions respecting probable needs will be made. The realism of the assumptions can be tested only as history unfolds; one must therefore proceed with caution; modifications will have to be made wherever the

1/ P.P.W.B. Report No. 1, Table 4.
2/ P.P.W.B. Report No. 2.
3/ The Pas is chosen as a base point because records of flow for a considerable period of time are available, and the flow at this point is almost equal to the discharge available to Manitoba and Grand Rapids power site.
4/ P.P.W.B. Report No. 1, Table 12.
5/ P.P.W.B. Report No. 2. (Average figure is for the water years 1923-24 to 1947-48).
6/ P.P.W.B. Report No. 1, Table 12.
7/ P.P.W.B. Report No. 2.

assumptions prove to be inadequate. In the case of irrigation requirements, it will be assumed that certain presently known projects alone might be developed.1/ For other uses, fairly broad estimates will be used.

North Saskatchewan River

Since no irrigation is contemplated with the use of water from this river, the flow to be allocated remains as in Section 2 above. However, a tributary, the Clearwater River, might be diverted to the Red Deer River basin to provide additional water for developing the Red Deer River Diversion Project. This would reduce the annual flow at Edmonton, and subsequently downstream, but would leave unaffected the winter flow, since only the summer flood waters would be appropriated, the winter flow and at least an equivalent amount of summer flow would drain normally to the North Saskatchewan river.2/

Edmonton.- Water consumption, in the City of Edmonton, was about 15.4 million imperial gallons a day, or about 80 gallons per person, in 1954.3/ In the same year industry used about nine million imperial gallons per day.4/ Total use in the Edmonton area was thus about 24.5 million I.G.D. By 1960, presently existing industries expected to be using 3.1 million I.G.D. more than in 1954.5/ Assuming that population grows at the rate of ten per cent per year, which is a rather high rate of growth, and assuming that the city continues to use about 80 gallons per capita per day, urban requirements in 1960 would be 17.2 million I.G.D. more than in 1954. On the above basis the total supply needed by 1960 would be 44.8 million I.G.D. The annual requirement at the above rates of use would be as follows: present needs - 32,941 acre-feet; future needs - 60,235 acre-feet. The average annual runoff at Edmonton is 5,611,000 acre-feet 6/, and the urban and industrial requirements are thus a small proportion of total runoff. (0.59 per cent and 1.07 per cent respectively).

However, it is during the periods of low flow that water shortages may occur. The lowest flow recorded was 220 c.f.s. 7/ The present requirements would use 20.7 per cent of such a low flow, and the estimated needs by 1960 would take 37.8 per cent of this low flow.8/

. . . .

1/ The Red Deer River Diversion Project will be taken as of the P.F.R.A. Report by S.H. Hawkins, April 30, 1947. This report may already be outdated (Conversation with Mr. Hawkins, August 1954), and the water requirements for this project may turn out to be greater or smaller than what is used in this analysis.

2/ This diversion is considered again under the heading South Saskatchewan River, below.

3/ Data from City Waterworks Department, August 19, 1955.

4/ Questionnaire distributed to major water-using industries, March 1955.

5/ If more large water-using industries located in the Edmonton area by 1960, the additional water needed would increase proportionally.

6/ Report on Surface Water Supplies and Water Power of Alberta, Their Present and Ultimate Uses, Edmonton, Alberta, 1948, p.28.

7/ Water Resources Paper 109, op.cit., p.182.

8/ The low flow is given as a rate in cubic feet per second. Such a low rate might not last as long as a day, hence the proportion used would be reduced accordingly.

The foregoing population estimate assumed a population of just over 400,000 by 1960. What if the city grows eventually to over a million people and industry develops accordingly? It is a fair guess that the city would require all of the water in the river, if it fell to 220 c.f.s. again, but would use only two or three per cent of the average annual flow.1/

Battleford.- The municipality of Battleford used 15,000 imperial gallons a day, as of 1954, from the North Saskatchewan river.2/ Granting that the town grew from its present 1,500 (approximate) people to 15,000, and assuming that water requirements per capita increase from 10/I.G.D. to about 80 I.G.D., the needs would be 1,200,000 I.G.D., or 1,613.4 acre-feet a year. The total runoff for the year 1949-50 was 4,541,000 acre-feet; 3/ hence the proportion required by a population of 15,000 using 80 I.G.D., would be very small (0.03 per cent). However, it is the low flow that is critical, and the minimum flow recorded was 400 c.f.s. on December 28, 1949. The present withdrawal of 15,000 I.G.D. represents a small part of 400 c.f.s. flowing for a whole day (0.007 per cent). A possible future need of 1,200,000 I.G.D. would use 5.6 per cent of the low flow (maintained for 24 hours). Hence, the quantity of water is sufficient. The quality is another question.

Industrial use of water in the Edmonton area already has given trouble downstream in terms of imparting an undesirable taste to the water in the winter time. Further industrial development presumably would intensify the problem. Since the pollution appears to be related to low flows, the quality of water downstream from Edmonton could be improved by storage upstream operated to increase the low winter flows.

North Battleford is supplied with water from wells; consumption is 400,000 I.G.D.,4/ and the population in 1951 was 7,473. If the population should increase by 100,000 and water use per capita became about 80 I.G.D., it is possible that the river might become the source of a large part of the additional water needed. Adding 8,000,000 I.G.D. to what Battleford might need in the future (1,200,000) makes a total of about 9,000,000 I.G.D. How would a demand such as this be met during a period of low flow? If a flow of 400 c.f.s. were maintained for 24 hours, the above demand would be 4.2 per cent of the water available. Hence, the quantity of water appears to be satisfactory; it is a question of quality only, as explained above.

1/ A population approaching one million, based on expansion of industry, could probably find the funds with which to erect some works to regulate the river to keep flows from falling as low as 220 c.f.s.

2/ Correspondence with Mr. J.G. Schaeffer, Director, Division of Sanitation, Dept. of Public Health, Regina, Sask., November 22, 1954. North Battleford gets its water from wells and uses 400,000 I.G.D. It uses the North Saskatchewan River as a destination for sewage. The town of Battleford uses the Battle River to dispose of sewage. Hence, it might be said that the North Saskatchewan River receives the sewage from both of these municipalites.

3/ This figure is for the gauging station near Frenchman Butte, a few miles below the Alberta-Saskatchewan boundary. See Water Resources Paper 109, op. cit., p.184.

4/ Correspondence with Mr. J.G. Shaeffer, op.cit.

Table 8. Water Withdrawal for Urban Use in Principal Municipalities, North Saskatchewan River Basin, 1953

Town	Population	Source of supply	Amount of Withdrawal g.p.d.	Amount of withdrawal Ac-ft. per day	Annual amount of withdrawal Ac-ft.	Date of installation of water system	Destination of sewage
Bonnyville	1,600	Moose Lake	60,000S	.221	33.6	1951	Jessie Lake
			50,000W	.184	39.1		
Castor	798	Battle River	31,920 e	.118	43.1	1953	Castor creek
Devon	1,509	N. Sask. River	180,000S	.662	100.7	1950	N. Sask. river
			110,000W	.405	86.2		
Edmonton	183,417	N. Sask. River	14,500,000S	53.36	8,116.1	Before	N. Sask. river
			13,900,000W	51.15	10,889.8	1940	
Lac La Biche	1,004	Lac La Biche	36,000	.133	48.6	1952	Pond
Nordegg	1,014	N. Sask. River	40,560 e	.149	54.4	--	--
Red Water	1,308	N. Sask. River	42,343S	.16	24.3	1949	Redwater river
			38,820W	.14	29.8		
St. Albert	625	N. Sask. River	25,000 e	.092	33.6	1953	--
St. Paul	2,000	Lake St. Cyr	452,800S	1.67	254.0	1951	Upper Therian lake
			344,000W	1.27	270.4		
Sedgewick	560	Battle River	22,400 e	.082	29.9	--	Pond
Stony Plain	875	Surface Supply	24,000S	.088	13.4	1952	Creek
			20,000W	.074	15.8		
Battleford	1,350	N. Sask. River	15,000	.055	20.1	1913	Battle river
Prince Albert	17,149	N. Sask. River	1,800,000	6.624	2,417.8		

NOTE: S = Summer (152 days)
W = Winter (213 days)
e = Estimate at 40 gallons per person per day.

Source: Mr. H.L. Hogge, Provincial Sanitary Engineer, Edmonton, Alberta, from a questionnaire circulated by Mr. Hogge in 1953; and Mr. J.G. Schaeffer, Director, Division of Sanitation, Dept. of Public Health, Regina, Saskatchewan, correspondence November 22, 1954.

Prince Albert.- This city was using about 2,000,000 I.G.D. in 1954 1/ supplied by the North Saskatchewan River, and the population in 1951 was 17,149.2/ Minimum recorded discharge at Prince Albert was 395 c.f.s., 3/ or 212,617,440 I.G.D. if flow at 395 c.f.s. were maintained for 24 hours.4/ At 80 I.G.D. per capita, it would require a population of 2,657,718 to exhaust the minimum flow. Quantity may be sufficient, but the quality of the water depends on the upstream uses to which the river is put.5/ Data on water use in some of the principal municipalities in the North Saskatchewan River basin are given in Table 8.

Summary.- Water supply for the municipalities of Edmonton, Battleford and Prince Albert is adequate for many years at present rates of growth, as far as quantity is concerned; below Edmonton the quality of the water may not be good during periods of low flow; however, the quality could be greatly improved by river regulation upstream, which would increase the flow in the stream during winter, or by improving the effluent that is discharged into the river in the Edmonton area.

South Saskatchewan River

From its beginning, at the confluence of the Bow and Oldman rivers west of Medicine Hat, the South Saskatchewan river flows through the latter city, picks up another tributary,, the Red Deer river, just east of the Alberta-Saskatchewan boundary, and flows on, through Saskatoon, and joins the North branch east of Prince Albert .6/ For analytical purposes it is convenient to examine the water supply and water requirements associated with the three principal tributaries and then consider the South Saskatchewan itself. These tributaries will be dealt with as follows: the Bow river, the Oldman river and the Red Deer river.

The Bow river.- Hydrology studies indicate that water requirements are reaching the stage when the water supply in the Bow river will be insufficient to meet the needs.7/ However, the only serious shortage, assuming full irrigation development, would occur once every 15 years, on the average, in the Bow River Irrigation Project. Water shortages will be more severe if more hydro storage is permitted, if irrigation is expanded beyond what

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1/ Ibid.

2/ Since June 1956 there has been talk of building a pulp and paper mill in the vicinity of Prince Albert. If this mill uses North Saskatchewan River water, or it puts its effluent in the river, a considerable change in demand for water, and a change in the quality downstream will occur, not accounted for in the above discussion.

3/ Water Resources Paper 109, op. cit., p.186.

4/ The quantity used, of this flow for 24 hours, would be about 0.94 per cent.

5/ See above remarks on. quality of water at Battleford.

6/ The South Saskatchewan River begins in Township 11, Range 13, West of the 4th Meridian, at Grand Forks. It joins the North Branch in Township 49, Range 21, West of the 2nd Meridian.

7/ Canada, Department of Agriculture, P.F.R.A., Water Supply and Utilization in the Bow River Watershed, Hydrology Report No. 9, Regina, Saskatchewan, September 1955, p.20.

is presently authorized, and if the river is not carefully controlled.1/

It will be observed that water shortages on the Bow River system are a local, not an interprovincial problem. Even with full development of existing irrigation projects, downstream shortages cannot occur at present and winter flows are improved because of upstream uses.2/

So far as domestic, municipal and industrial requirements are concerned, the load on the Bow River is small.3/ Calgary, the only urban center of any size, gets its water supply from the Elbow River, a tributary of the Bow River.

There is no pollution problem of any great concern.

The Oldman River.- In contrast to the Bow River system where some 600,000 acre-feet of water are stored for power purposes,4/ no Hydro storage exists on the Oldman River system, and the principal use of the water, in terms of quantity, is for irrigation. (Table 9).

Table 9.- Existing Irrigation Districts Depending on Water in the Oldman River System, Year Started, and Irrigable Acreages, 1952

Project	Year started	Irrigable acreage: Present	Irrigable acreage: Ultimate
United Irrigation District	1921	21,000	34,000
Mountain View Irrigation District	1925	3,600	3,600
Leavitt Irrigation District	1943	2,500	4,400
Aetna Irrigation District	1945	50	7,300
MacLeod Irrigation District	1948	500	10,000
St. Mary-Milk River Project	1901	150,000	510,000
Lethbridge Northern Irrigation District	1922	75,900	96,000

Source: Canada, Department of Agriculture, P.F.R.A., Full Development Possibilities in the Saskatchewan River Basin, Hydrology Report No. 1, Regina, Sask. 1952.

The St. Mary, Waterton and Belly rivers, which are tributaries of the Oldman river, arise in the United States, On October 4, 1921, the International

1/ Ibid. See especially Figure 1, for a chart showing Hydroplants of Calgary Power Limited, existing and proposed, and the irrigation districts dependent on Bow River water.

2/ Water Supply and Utilization in the Bow River Watershed, op.cit., Canada. Dept. of Agric., P.F.R.A., Full Development Possibilities in the Saskatchewan River System, Hydrology Report No. 1, Regina, Sask., June 1952; Russell, B., Report on Surface Water Supplies and Water Power of Alberta, their Present and Ultimate Uses, Edmonton, Government of Alberta, Dec. 1948, pp.23-25 and 37-42.

3/ Table 10, shows urban withdrawal for principl centers in the South Saskatchewan River Basin.

4/ Full Development Possibilities ...., op.cit.

Joint Commission 1/agreed on the apportionment of the St. Mary and Milk rivers, allotting to Canada half the water.2/ The water remaining in the St. Mary river is insufficient to irrigate all the land visualized in the St. Mary-Milk River Development, and assumed in Alberta's 1949 request, and it will have to be supplemented by water of the Belly and Waterton rivers.3/

As with the Bow River, the Oldman river and its uses are a local, not an interprovincial, problem (although it has been of international concern); the amount of water necessary for full development of the St. Mary-Milk River Project has been allocated: it is a question of interprovincial interest to allocate only what remains. Before considering further the remainder of the water, brief attention will be given to the domestic, municipal and industrial requirements to be served by the Oldman river.

The municipalities of McLeod and Lethbridge are the principal communities depending on the Oldman river for urban purposes. These cities used about five million I.G.D. in 1953.4/ The lowest recorded flow in the Oldman river, at a point between MacLeod and Lethbridge, occurred on October 10, 1950 and it amounted to 51 c.f.s.5/ Such a flow, if maintained for 24 hours would be 27,451,872 I.G.D., and the urban requirements of Lethbridge and MacLeod would be about 18.2 per cent of such a flow. That is, water needs would have to increase five times before all the water, at minimum flow, would be utilized for urban purposes. With the construction of facilities for further storage upstream on the Belly and Waterton rivers, flows quite possibly could be held above 51 c.f.s.

The Red Deer River.- Present use of the Red Deer river is for urban purposes at Red Deer and Innisfail.4/ Both town require such a small

1/ Treaty between the United States and Great Britain relating to Boundary Waters, and questions arising between the United States and Canada, signed at Washington, January 11, 1909.

2/ The text of the Order is as follows:
"1. (a) During the irrigation season when the natural flow of the St. Mary River at the point where it crosses the international boundary is six hundred and sixty-six (666) cubic feet per second or less Canada shall be entitled to three-fourths and the United States to one-fourth of such flow.
(b) During the irrigation season when the natural flow of the St. Mary River at the point where it crosses the international boundary is more than six hundred and sixty-six (666) cubic feet per second Canada shall be entitled to a prior appropriation of five hundred (500) cubic feet per second, and the excess over six hundred and sixty-six (666) cubic feet per second shall be divided equally between the two countries.
(c) During the non-irrigation season the natural flow of the St. Mary River at the point where it cross the international boundary shall be divided equally between the two countries". The agrement called for reciprocal treatment of the water of the Milk River, with the United States getting the larger proportion at certain seasons. Since both rivers are treated, for purposes of apportionment, as one river, it means that Canada is entitled to roughly one half of the flow of both rivers, the United States, the other half.

3/ Canada, Department of Agriculture, Prairie Provinces Water Board Report No. 2. Regina, Saskatchewan, 1950, p.3.

4/ See Table 10.

5/ Water Resources Paper 109, op. cit., p. 205.

proportion of the flow even under the minimum flow conditions (64 c.f.s.)1/ that a water shortage could not occur except under greatly expanded urban and industrial development.

However, if the proposed Red Deer River Diversion Project 2/ were developed in the future there would be insufficient water in the Red Deer river to develop it completely. (This would leave undiminshed the water supply at Red Deer). To fully develop this project requires a diversion from the Clearwater, a tributary of the North Saskatchewan river.3/ This is a local problem that does not affect interprovincial allocation unless the water supply is diminished downstream.

South Saskatchewan River proper.- This river provides water for urban purposes to Medicine Hat, Saskatoon, Regina and Moose Jaw, as well as several smaller centers.4/ At Saskatoon, the urban water requirements were 6,000,000 I.G.D. in 1953.5/ The lowest recorded flow at that city occurred on December 12, 1936, and was 502 c.f.s.,6/ or 270,212,544 I.G.D. if flow at that rate lasted for 24 hours. Regina's water requirements were about 5,500,000 on the average, in 1952,7/ and were provided by wells. However, the latter source is fully developed, and further water supplies will be coming from the South Saskatchewan River.8/ Moose Jaw gets most of its water from Sandy Creek at Caron, some 20 miles west of the city.9/ The city depends on future supplies from the South Saskatchewan river. Since both Regina and Moose Jaw require supplementary water only from the South Saskatchewan river it may be safe to assume that for the immediate future requirements will not exceed 10,000,000 I.G.D. on the average. Therefore, Saskatoon, Regina and Moose Jaw together may require 20,000,000 I.G.D. This is about 7.4 per cent of the lowest flow at Saskatoon.10/ Thus, the

1/ Occurred on December 7, 1922. It amounts to 34,449,408 I.G.D. if this low flow lasted for 24 hours. Present consumption of 600,000 I.G.D. is about two per cent of the low flow.

2/ Hawkins, S.H., General Report Proposed Red Deer River Diversion Project, P.F.R.A., Calgary, Alberta, 1947.

3/ Canada Department of Agriculture, Preliminary Report on Effects of Certain Major Projects in the Saskatchewan River Drainage Basin, Prairie Provinces Water Board, Report No. 3, Regina, Saskatchewan, 1951, pp.3-4.

4/ See Table 10. Regina and Moose Jaw are not included in the table as they lie outside the basin. However, they will be using water, from the S. Sask. River, pumped into the Qu'Appelle Valley at a point near Elbow, Sask., and carried to Buffalo Pound Lake for storage, purification and piping to the two cities.

5/ See Table 10.

6/ Water Resources Paper 109, op. cit., p.201.

7/ Record of Proceedings at Public Sessions of the Commission the Province of Saskatchewan, September 10 and 11, 1952, Royal Commission on the South Saskatchewan River Development, p.115.

8/ Ibid., p.116.

9/ Reports of Surveys of Moose Jaw's Water Supply, Consolidated, 1951. In addition to Sandy Creek there are two or three other sources of minor importance.

10/ Presumably, the low flow at Elbow will approximate the low flow at Saskatchewan.

domestic, municipal and industrial demand for water for these three cities could increase about 15 times before all the water at such a low flow would be used.1/ (See Table 10, for details as to consumptive use of water for urban purposes, South Saskatchewan River Basin).

Little water is taken from the South Saskatchewan river for irrigation, and no hydro-electric power is developed. Swift Current Creek provides water for the Swift Current Irrigation District, which has 21,000 irrigable acres.2/ Some water is taken directly from the South Saskatchewan river for irrigation just south of Saskatoon at French Flats-Valley Park, some 6,500 acres being irrigable.3/ Future irrigation development involves the South Saskatchewan River Project.4/ The effect that providing this project with water will have on water supplies downstream has been examined elsewhere.5/

At Saskatoon, assuming that water for Alberta's 1949 request and for the South Saskatchewan River Project is provided for, the average (1923-24 to 1947-48) 6/ flow will be 4,192,000 acre-feet, and regimen would be greatly improved because of existing hydro-electric power developments, the minimum monthly flow being 2,248 c.f.s., as compared with 288 c.f.s. under the "natural" flow conditions.

At The Pas, the average annual flow for years such as 1923-24 to 1947-48 would be 13,302,000 as compared with 17,719,000 acre-feet under "natural" conditions.7/ Regimens would be improved from 1,342 c.f.s. (minimum) under "natural" conditions to 4,824 (minimum).8/

Assuming the above water demands plus the Red Deer River Project and some smaller developments in Alberta, the effects would be for water years

1/ It should be pointed out that the situation with respect to providing Regina and Moose Jaw with water from the Saskatchewan Systems differs from that of providing water for cities in the basin. Water for urban purposes is almost all returned to the stream in most cases, but Regina and Moose Jaw dicharge sewage into the Red River Basin via Moose Jaw Creek and Wascana Creek, tributaries of the Qu'Appelle River, and hence water taken from the South Saskatchewan River for these cities is lost to the basin. However, the quantity taken relative to the total flow, will be so small in the foreseeable future, that it may be disregarded.

2/ Canada, Department of Agriculture, Full Development Possibilities ... op.cit., p.11.

3/ Loc. cit.

4/ Canada, Report of the Royal Commission on the South Saskatchewan River Project, Queen's Printer, Ottawa 1952. See also various Dept. of Agriculture, P.F.R.A., reports for details.

5/ Canada, Dept. of Agriculture, P.F.R.A., Preliminary Report on Effects of Certain Major Projects in the Saskatchewan River Basin, Prairie Provinces Water Board Report No. 3, Regina, Sask., 1951.

6/ P.P.W.B, Report No. 3, op. cit., Table 29. This comparea with an average "natural" flow of 7,610,000 acre-feet.

7/ P.P.W.B. Reports Nos. 1 and 3, Tables 12 and 35 respectively.

8/ Loc. cit.

Table 10.- Water Withdrawal for Urban Use in Principal Municipalities
South Saskatchewan River Basin, 1953

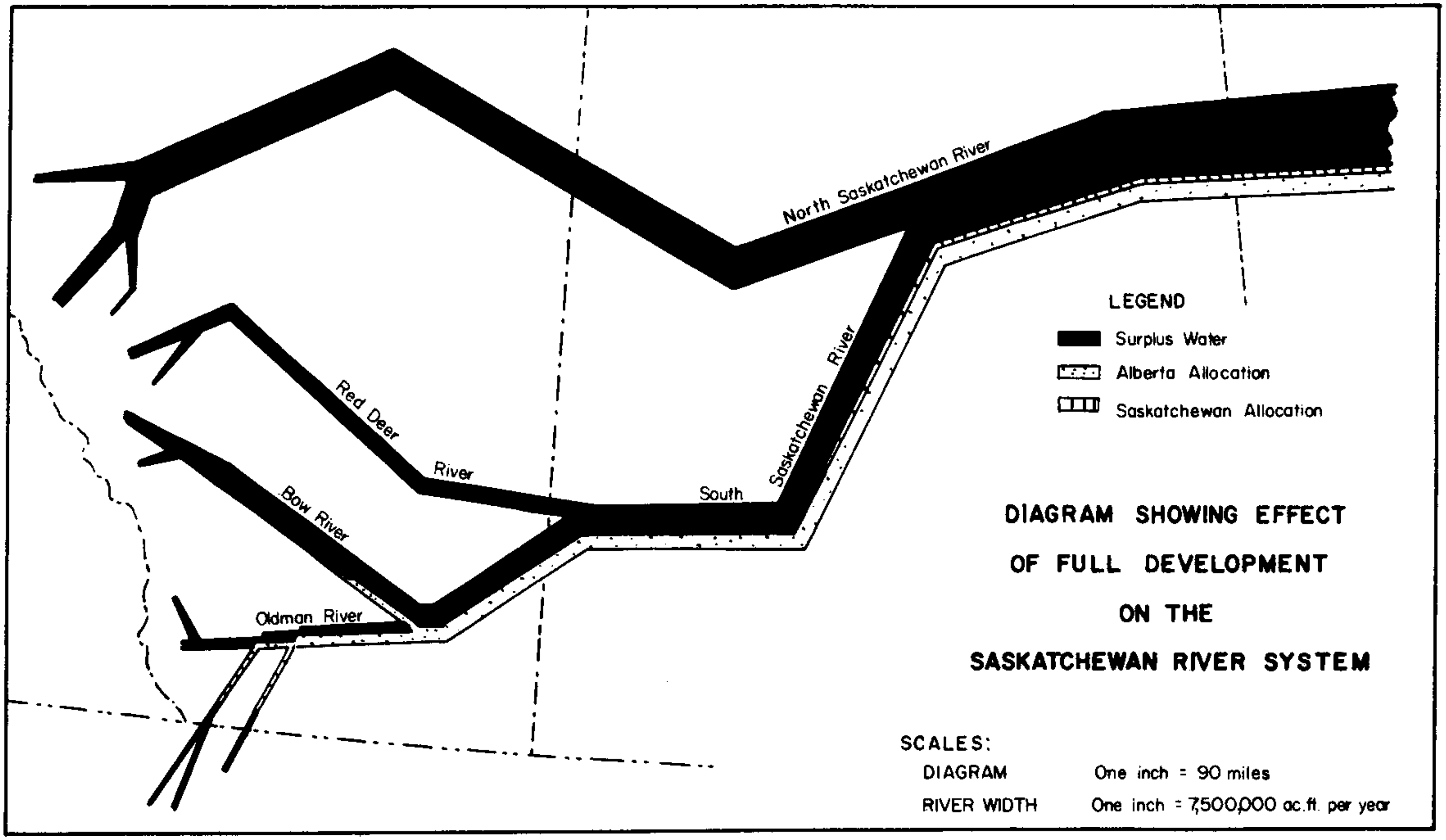
(1) Town	(2) Population	(3) Source of supply	(4) Amount of withdrawal g.p.d.	(5) Amount of withdrawal Ac-ft.per day	(6) Annual amount of withdrawal Ac-ft.	(7) Date of installation of water works	(8) Destination of sewage
Banff	10,000S 2,500W	Forty Mile Creek	40,000S 10,000W	.472 .368	302.2	Before 1940	--
Bassano	575	Bow River	23,000 e	.085	31.0	Before 1940	Pond
Bow Island	750	S. Sask. River	3,000 e	.011	4.0	1948	Through Coulee to S. Sask. river
Brooks	2,000	Bow River	80,000 e	.294	107.3	Before 1940	One Tree creek
Calgary	145,000	Elbow River	24,432,000S 22,466,000W	89.910 82.675	31,276.8	Before 1940	Bow river
Canmore	600	Mtn. Reservoir	2,400 e	..009	3.3	Before 1940	---
Champian	380	Spring Runoff	7,500W	.028	10.2	1952	---
Claresholm	2,525	Willow Creek	80,000W	.294	107.3	--	Disposal field
Cochrane	524	Bow River	20,000S 15,000W	.074 .055	11.3 11.7	1951	Bighill creek
Ft. MacLeod	2,567	Oldman River	1,300,000S 1,000,000W	4.784 3.680	727.6 783.5	Before 1940	Oldman river
Frank	300	Mtn. Stream	12,000 e	.044	16.1	Before 1940	---
Granum	400	Willow Creek	30,000S 15,000W	.110 .055	16.7 11.7	1949	Pond
Hanna	2,500	Storage Dam	110,000S 85,000W	.405 .313	61.6 66.6	1941	Bull Pond creek
Hillcrest	300	Mtn. Stream	12,000 e	.044	16.1	Before 1940	
Innisfail	1,509	Red Deer River	45,000	.166	60.6	1947	Lake

Table 10.- Water Withdrawal for Urban Use in Principal Municipalities, South Saskatchewan River Basin, 1953 (continued)

(1) Town	(2) Population	(3) Source of supply	(4) Amount of withdrawal g.p.d.	(5) Amount of withdrawal Ac-ft.per day	(6) Annual amount of withdrawal Ac-ft.	(7) Date of installation of water works	(8) Destination of sewage
Lethbridge	25,000	Oldman River	4,136,500S 2,267,000W	15.222 8.343	2,315.3 1,776.2	Before 1940	Oldman river
Redcliff	1,700	S. Sask. River	500,000S 126,000W	1.840 .464	279.9 98.8	Before 1940	Lagoon
Red Deer (e)	10,000	Red Deer River	600,000	2.208	805.9	Before 1940	Red Deer River
Taber	3,461	Belly River	239,036	.880	321.2	1948	---
Tilley	253	Creek	1,500S 1,000W	.006 .004	1.8	1952	---
Turner Valley	800	Sheep River	640,000S	2.355	859.9	Before 1940	---
Waterton Park	5,000S 142W	Cameron Creek	250,000S 7,000W	.920 .026	139.9 5.5	Before 1940	Waterton lake
Medicine Hat	16,364	S. Sask. River	(e) 654,560	24.088	8,792.1	Before 1940	---
Outlook		S. Sask. River	24,000	.088	32.1	1910	
Saskatoon	53,268	S. Sask. River	6,000,000	22.08	8,059.2	1906	S. Sask. River
Sutherland		From City of Saskatoon	(500,000)			1912	
Swift Current	7,458	Swift Current Creek	500,000	1.840	671.6	1911	Swift Current creek

NOTE: S = Summer (152 days)
W = Winter (213 days)
e = Estimate at 40 gallons per person per day.

Source: Mr. H.L. Hogge, Provincial Sanitary Engineer, Edmonton, Alberta, from a questionnaire circulated by Mr. Hogge in 1953; and Mr. J.G. Schaeffer, Director, Division of Sanitation, Dept. of Public Health, Regina, Sask., correspondence, November 22, 1954.


North Saskatchewan River
Red Deer River
Bow River
Oldman River
South Saskatchewan River
LEGEND
Surplus Water
Alberta Allocation
Saskatchewan Allocation
DIAGRAM SHOWING EFFECT
OF FULL DEVELOPMENT
ON THE
SASKATCHEWAN RIVER SYSTEM
SCALES:
DIAGRAM One inch = 90 miles
RIVER WIDTH One inch = 7,500,000 ac.ft. per year

such as 1923-24 to 1947-48 as follows:

At Saskatoon average annual flow would be 4,055,000 acre-feet (7,610,000 "natural"), at The Pas, average annual flow would be 12,632,500 acre-feet (17,719,000 "natural").1/ The following chart depicts the river flow under average conditions, and demonstrates that after the above mentioned irrigation allowances have been made, almost four-fifths of the runoff arrives at the mouth of the river.

For the seven years of lowest flow, assuming full irrigation development, discharge at The Pas would be around 9,727,000 acre-feet,2/ or 55 per cent of the "natural"discharge. This is a large reduction in flow but there would be some improvement in the regimen, similar to that which has been experienced as a result of the construction of hydro storage in the head-waters of the basin. This improvement in the regimen would benefit down-stream hydro plants with little natural storage. However, those hydro sites with very large natural storages, such as those on the Nelson river, will be adversely affected by the diminution in the total flows.3/

B. SUB-SURFACE WATER SUPPLY AND REQUIREMENTS

Surface and sub-surface waters are interrelated to some extent. Ground waters are re-charged from surface supply and are therefore, the indirect concern of interprovincial allocation. Intensive pumping in the upper basin may use water that otherwise might find its way to the streams.

Ground water supply.- Very little is known about ground water supplies. There was a study made in 1936 of ground water in Saskatchewan as far north as Township 32 (just south of Saskatoon), using farm wells as basic data.4/ The Alberta Research Council is engaged in an intensive study of ground water in Alberta.5/ It is known that most of the urban municipalities in the

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1/ Ibid., Tables 4 and 12, and Tables 30 and 36.
2/ P.P.W.B. Report No. 3, p.7.
3/ The Report on Measures for the Control of the Waters of Lakes Winnipeg and Manitoba, June 1958, by the Lakes Winnipeg and Manitoba Board, presents the results of a study on the benefits of regulation of Lake Winnipeg for Nelson River Power with the inflows from the Saskatchewan River modified by various upstream developments. The Lakes Winnipeg and Manitoba Board was set up by an Agreement between the Governments of Canada and Manitoba, signed July 5, 1956. According to the terms of reference, the Board shall plan, supervise and carry out a survey of Lakes Winnipeg and Manitoba and the resources of waters within Manitoba flowing into and from those Lakes and shall determine and report what further developments and controls of these water resources, in its judgment, would appear to be physically practicable with particular reference to (a) flood control, and (b) hydro-electric power.
4/ Personal interview with Dr. R.T.D. Wickenden, Georgraphical Branch, Dept. of Mines and Technical Surveys, Calgary, Alberta, August 6, 1954.
5/ Personal interview with Dr. N.H. Grace, Director, Research Council, of Alberta and Dr. C.P. Gravenor, Acting Chief Geologist, Research Council, June 8, 1956. See Research Council of Alberta, Round-table Conference on Ground-water in Alberta, Preliminary Report 56-1, September 27, 1955, p.84.

Saskatchewan river basin depend on ground water for domestic, municipal and industrial purposes. The growth of many communities will be limited unless further ground water supplies can be found, or unless an alternative surface supply can be used.1/ Fortunately, the prospect of finding further supplies of ground water, at least in Alberta, is believed to be fairly good.2/ However, until more basic data become available, very little can be said about this important subject.

C. SUMMARY AND CONCLUSIONS

From the point of view of present economic development, and as far as interprovincial allocation goes, no water shortage is apparent. Further, even with full development of presently proposed irrigation projects, no serious water deficiency is obvious. The water supply at The Pas, under "full development" would be four-fifths of what it would be under "normal" conditions, assuming average flows, and it would be over half the "natural discharge,assuming conditions similar to those in the seven lowest flow years. In addition, regimens have been greatly improved and would be further improved, assuming "full development", providing a more reliable supply of water for urban and power purposes. According to the data used in this analysis, 3/ it is difficult to see where there is a water shortage that will force choosing among various projects to eliminate all but the most desirable. There appears to be ample water for all the uses that may be desired in the foreseeable future.

These preliminary conclusions are valid for the Saskatchewan river basin only: when the effects of "full development" are considered in relation to hydro-electric development in Manitoba, one further and very important relationship becomes relevant. Consumptive uses of water, like irrigation, will have a detrimental effect on the water power potential of the Manitoba lake system and the Nelson river. How serious the effect may be cannot be assessed without good engineering data and some fairly clear notion of the tempo of possible development.

Ground water supplies may be larger than was once thought. Yet at the present time these supplies place a limit on the growth of many communities. In Alberta, work is going forward to gather more basic data on ground water supplies.

CHAPTER 5. METHODOLOGY FOR ECONOMIC ANALYSIS OF RIVER BASIN WATER DEVELOPMENT

Water problems arise because of deficiencies or surpluses of water. In either case, water is the limiting factor in the more intensive use

1/ Round-table Conference, op.cit.
2/ Loc. cit.
3/ Some data are from preliminary reports; when further work has been done in estimating stream flow under various conditions, some modifications of the above conclusions may be necessary.

of other resources. To modify this limitation, capital works are required; therefore, the relevant analysis must rely heavily on capital theory. For projects whose scope does not appreciably affect the national economy, marginal analysis is appropriate, the initiation and scope of the project being determined by the excess of benefits over costs at the margin. For large-scale projects, whose implementation will effect a more intensive development of an entire region, as is the case with many river basin projects, a structural, not a marginal change is involved, and the appropriate tools are input-output analysis and linear programing. In what follows no attempt will be made to provide the final work on methodology. Instead, reliance will be placed on summarizing and then commenting on the procedures recommended in the United States and the current United States practices used in evaluating water development projects.

A. PROCEDURES RECOMMENDED IN THE UNITED STATES AND CURRENT PRACTICES FOR EVALUATING RIVER BASIN PROJECTS IN THE UNITED STATES

Scope.- The discussion below concerns only two documents, the report to the Federal Inter-Agency Committee, by the Subcommittee on Benefits and Costs, 1/ and Circular No. A-47, of the Bureau of Budget. 2/ Since no final definitive approach to evaluation has been written, it does not seem relevant to include here a discussion of all the literature, much of it controversial, 3/ that has become available during the past few years. The procedures recommended in the above-mentioned documents give, in the case of the former, what is considered to be the best thinking on the subject by those closest to this field; and in the case of the latter, what is recommended by the Federal Government. The procedures in use will be considered in the section below, "Current Practices".

Subcommittee on benefits and costs

(a) Viewpoint.- Inasmuch as evaluation is concerned with public expenditures, a narrow, financial justification approach is spurned in favor of a

1/ United States, Proposed Practices for Economic Analysis of River Basin Projects, Report to the Federal Inter-Agency River Basin Committee, by the Subcommittee on Benefits and Costs, Washington, D.C., U.S. Government Printing Office, May 1950 (hereafter referred to as "Subcommittee").

2/ United States, Circular No. A-47, Executive office of the President, Bureau of the Budget, Washington 25, D.C., December 31, 1952.

3/ See the following sources on water and water development. Picton, Walter, L., Water Use in the United States, 1900-1975, United States Department of Commerce, Business and Defense Services Administration (BSB-136), January 1956. Golton, Patricia L., Economics of Water Resources Development, in the Eleven Western States, an Inventory of Research, Giannini Foundation of Agricultural Economics, University of California, Berkeley, California, (for the Western Agricultural Economics Research Council), December 1951. There is a Supplement I, June 1954, to this study, and another Supplement is expected. For an earlier period, and dealing more with land than specifically with water, see United States Department of Agriculture, Bibliography on Land Utilization, 1918-1936 (annotated), by Berceau, Louise O., and Annie H. Hannay, under the direction of Lacy, Mary G., Miscellaneous Publication No. 284, Washington, D.C., January 1938. Also, Land Utilization A Bibliography, compiled by Culver, Dorothy C., Bureau of Public Administration, University of California, Berkeley, May 15, 1935.

"comprehensive public viewpoint ... which would include consideration of all effects, beneficial or adverse, short-range or long-range, that can be expected to be felt by all persons and groups in the entire zone of influence of the project." 1/ In addition to market values, which would be considered if "allowance could be made in the summation for all transferences, cancellations, and offsets," 2/ the Subcommittee recommends that intangible effects receive consideration.

"The ultimate aim of river basin development, in common with all productive activity, is to satisfy human needs and desires." 3/ The value of the means with which these needs and desires are satisfied indicates the value of the development. However, this is not the whole story from the public viewpoint because "various influences such as subsidies, tariffs, price supports, and imperfect markets ..." 4/ "Despite limitations of the market price system in reflecting values from a public viewpoint, it is concluded that there is no other suitable framework for evaluating the effects of public works projects in common terms. Accordingly, a market price system has been selected as the starting point for formulation of [the] ... evaluation." 5/

(b) Principles for evaluation of costs.- When factors of production are used for any given purpose their use is precluded from other purposes. The economic cost of using them, therefore, is the value of foregone services and goods. If the factors are unemployed, the economic cost of using them is nil. The Subcommittee assumes that there would be other uses for the factors, and, therefore, the market prices of the factors give an indication of the benefits foregone. "Market prices may, therefore, be used to evaluate costs of using goods and services for project purposes in the usual case." 6/

(c) Primary and secondary benefits.- Primary benefits are the value of the immediate products or services resulting from the project, such as the value of wheat produced by a farmer engaged in irrigation made possible by the project. 7/ (These benefits must be net of farmers' costs, except water charges), to get the value attributable to the project. 8/

Secondary benefits "are the values added over and above the value of the immediate products or services of the project as a result of activities stemming from or induced by the project." 9/ There are two kinds: first, where economic activity is increased over what it would have been without the project, and, second, where goods and services are provided to the consumer at a price that is less than it would have been in the absence of the project (due to the

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1/ Subcommittee, op.cit., p. 6
2/ Loc.cit.
3/ Loc.cit.
4/ Ibid., p. 7.
5/ Subcommittee, op.cit., p. 7
6/ Subcommittee, op.cit., p. 9.
7/ Ibid., p.8
8/ Ibid., p.10
9/ Ibid., p. 9

otherwise increased costs of supplying additional quantities under free market conditions.)

The Subcommittee recognized that the evaluation of such secondary benefits is complicated and difficult, and recommended that, since they are likely to be of minor importance relative to the primary benefits, main reliance be placed on the evaluation of these benefits. 1/

(d) Economic limitations on scale of project development. The size of development that will be the most economic is such that the total benefits exceed total costs by a maximum amount. At this point the cost of adding the last increment to scale of development is just equal to the added benefits given by that increment. 2/

(e) Analysis of justification. A project is economically justified when four criteria have been met. Benefits must exceed costs; each separate segment of the project must have benefits at least equal to costs; the scale is such as to provide the maximum excess of benefits over costs; and there must be no more economic method of accomplishing the same results. 3/ Analysis would need go no further if it were not for the intangibles; but since the latter might be important either as benefits or costs, they must be considered and included as part of the economic analysis.

(f) Comparison of justified projects. The excess of benefits over costs could be compared, but this would give no indication of the magnitude of the benefits or costs. The rate of return on investment could be compared for various projects, but since this method abstracts from operation and maintenance costs it would give a distorted figure in many instances where there are significant differences in these costs. Finally, in the words of the Subcommittee,

> The procedures recommended herein are based on the assumption that, in general, the economic resources involved in the project development over and above those accounted for in project benefits and project costs would be used with equal effectiveness with or without the project. Therefore, a ratio of project benefits to project costs constitutes the proper measure of the effectiveness of use of the Nation's resources insofar as the use of such resources for project purposes is concerned. In the usual case, the relative desirability of a number of projects can be satisfactorily determined by comparing their ratio of project benefits to project costs. 4/

(g) Measurement of benefits and costs. To standardize evaluation procedure it is necessary to utilize the same price level, interest rate, risk allowances, and the time period of analysis. In addition the treatment of

1/ Subcommittee, op.cit., p. 11
2/ Ibid., p. 13.,
3/ Ibid., p. 37.
4/ Subcommittee, op.cit., p.14.
5/ Ibid., p. 20.
6/ Ibid., p. 24.

tangibles and intangibles, adjustments for levels of economic activity, etc., must be comparable.

(1) Price Levels

In order to satisfy the various purposes to be served by benefit-cost analysis the use of prices reasonably expected to prevail at the time of benefit and cost accrual is recommended. For installation costs, prices expected during the construction period should be used. This may or may not mean the use of current prices prevailing at the time of the investigation, depending upon how soon construction will begin and the extent of price changes anticipated in the interval. In calculating most types of benefits and in calculating costs for operation, maintenance, and minor replacements, the prices used should be the average prices estimated to prevail over the life of the project. 1/

(2) Interest and discount rates

It is recommended that estimates of benefits and costs accruing at varying times be made comparable by adjustment to a uniform time basis through the use of interest rates. The interest rate for Federal, non-Federal public, and private investment should in general be the long-term borrowing rate applicable. 2/

(3) Time period of analysis

It is recommended that the maximum period of analysis be the expected economic life of the project or 100 years, whichever is shorter. Even for projects involving basic structures of extended life, and, those having continuing replacement possibilities, it is recommended that a 100-year period of analysis be used as the upper limit on economic life, with allowance for salvage at the end based on nonproject uses. The amortization charge should be sufficient to cover the capital investment during the period of analysis, calculated on a sinking fund basis using the investment cost interest rates. Except in special cases, the basis for estimating benefits and costs should be under the assumption of maintaining the project at full operating capacity. 3/

(4) Intangibles

Tangible effects are defined as those measurable in monetary terms; intangibles are those that cannot be so measured by any satisfactory device. The measurement of some intangibles such as loss of life in floods could be evaluated in terms of compensation rates paid. This method would not necessarily place an adequate evaluation on human life but it would produce comparable results, if adopted by all agencies, and

1/ Ibid., p.20
2/ Ibid., p. 24
3/ Subcommittee, op.cit., p. 26.

would serve to help compare the relative merits of various proposed projects. Where no possible monetary value can be attached, even through estimation by means of anology, intangibles should be considered on a qualitative basis. 1/

(5) Adjustments for the level of economic activity

Since labor is, in general, the only factor that is lost if not used currently in production, it is the only factor for which adjustments are to be made. The amount by which labor costs should be reduced can be estimated from the expected reduction in relief payments that would be necessary in the absence of the project.

In times of relatively low economic activity, a project may result in employment of labor in nonproject activities that would otherwise be unemployed and may result in use of otherwise idle plant capacity. The project can be credited only with the difference between such secondary effects resulting from the project and similar effects of any comparable increase in economic activity which might be undertaken in the absence of the project. The net effect creditable to the project would be difficult to measure and should usually be regarded as intangible. 2/

(h) Cost allocation for multiple-purpose projects. Cost allocation is the process of attributing costs of the project to the various purposes served. This is not the same thing as determining repayment schedules, although it may be used as a basis for the latter. The method of paying for the project has no necessary relationship to the cost allocation among functions. It may be that all charges attributable to flood control, navigation, etc., might be defrayed out of general taxation, while other charges, for irrigation, power, etc., would be placed on the beneficiaries. This is a problem for policy.

The recommended method is the "separable costs-remaining benefits" method of allocation. It consists of determining the separable cost of including each of the functions in the project and establishing an equitable distribution of common or joint costs.

(1) Separable costs

The separable cost for each project purpose is the difference between the cost of the multiple-purpose project and the cost of the project with the purpose omitted. Separable costs include more than the direct or spe-

1/ Ibid., pp. 26-28

2/ Subcommittee, op.cit., p. 28. The text considers also such things as Costs of Affected Public Facilities, Acquisition of Land and Improvements, Treatment of Taxes, Displaced Facilities, Extension of Useful Life, and Consequential Damage. These items are technical in character, and, since their bearing on evaluation is more in the nature of additional detail than fundamental, it will serve no useful purpose to examine them in the present discussion. (See Ibid., pp. 29-33.)

cific costs of physically identifiable facilites serving only one purpose. ... They also include all added costs of increased size of structures and changes in design for a particular purpose over that required for all other purposes ... 1/

(2) Distribution of joint costs

Joint costs are ... the difference between the cost of the multiple-purpose project as a whole and the total of the separable costs for all project purposes... The distribution of joint costs in proportion to the excess of benefits over separable cost assigns to each purpose an equitable share of project savings. The amount of project benefits used as a basis for allocation of costs to any purpose should not exceed the cost of providing equivalent services for the same area from the most likely economically feasible alternative source available in the area to be served. From such benefits for each purpose, separable costs are deducted to give remaining benefits. Then, joint costs are distributed in proportion to the remaining benefits for each purpose.2/

(3) Total allocation

The sum of the separable costs and assigned joint cost for each purpose constitutes the total allocation to that purpose ... The total cost allocated to each purpose should not be less than the cost of including that purpose ... and should not be more than the benefits of that purpose or the cost of the most economical single-purpose alternative.3/

(i) The foregoing has set out in summary form the salient features of the methodology proposed by the Subcommittee. The method is general-i.e., it is to be applied to all river basin evaluation problems. It is designed to give comparable results from which the most economic projects may be selected for development.

3. Budget Circular No. A-47 4/

(a) Purpose.

The purpose of the Circular is "to draw together certain ... policies for water resources programs and projects and to provide the agencies in advance with a better understanding of the consideration which will be used in ...5/ evaluating reports submitted, in order that uniformity may be obtained

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1/ Ibid., p.54.
2/ Subcommittee, op. cit., pp.54-55.
3/ Ibid., p.55. The total cost allocated to each purpose could be less than the cost of including that purpose in the project if the total of the separable costs for all purposes exceeded the total cost of the multiple-purpose project, for in this case there would be no joint costs to allocate but a joint saving. This saving would then be distributed to each of the purposes thereby reducing separable costs.
4/ Circular No. A-47, Executive Office of the President, Bureau of the Budget, Washington 25, D.C., December 31, 1952.
5/ Circular No. A-47, op. cit., p.1.

for the object of establishing priority for projects and securing affective resource development at minimum cost. It refers to Federal programs for the conservation and development of water and related land resources. It does not tell the agencies how evaluation is to be conducted but gives some of the criteria that should be standardized.

(b) Information required. A description of the need for the proposed production of goods and/or services is the first requirement. A complete estimate of benefits and costs is to be included. The report must have a statment on cost allocation, proportion of costs reimbursable, and the reason why some of the expenses should be paid out of general taxation.

Benefits to be discussed include those from flood control, reclamation, navigation, hydro-electric power, domestic, municipal and industrial water supply, recreation, fish and wildlife and pollution control. Secondary benefits must be considered but until standard procedures are developed for measuring them, the emphasis must be on primary benefits.

All costs incurred must be considered. Those arising out of displacement of people, decreases in land values effected, damanges to highways, etc., business losses if any, losses in tax revenues, damage to recreation, fish and wildlife, and abandonment of economically useful structures must receive attention, as well as the costs of the structures. Detriments to the general welfare, whether or not they can be estimated in monetary terms, are to be stated.

The interest rate for converting benefits and costs to an annual basis (which is required) is to be based on interest-bearing United States marketable securities of comparable length of time of maturity.

Where the cost allocated to irrigation is too great to be paid out by the irrigation beneficiaries, an irrigation subsidy may be recommended.

Recreation, fish and wildlife and domestic, municipal and industrial water supply are to be considered a local or State responsibility, unless the benefits have such far-reaching effects as to be in the general welfare and, in the latter instance, the Federal Government will assume some of the costs.

The foregoing is a very brief summary of the Circular. It will be noted that the Circular has very little to say about the economics of evaluation. Its purpose is administrative. And it is concerned with the financial aspect of project evaluation; it leaves to the agencies any economic analysis deemed proper.

B. CURRENT UNITED STATES PRACTICES FOR EVALUATING WATER DEVELOPMENT PROJECTS

Usually a distinction is made between direct and indirect benefits and costs. Direct benefits result directly from the project and include such benefits as the additional values resulting from irrigation. Indirect benefits result from activities induced by the project, such as the increased retail business done by firms serving the area. Since these direct and indirect benefits are considered to be measurable in monetary terms they are considered tangible, and their sum is confronted with tangible costs to compute the benefit-cost ratio. Intangibles are usually considered qualitatively. In what follows most of the emphasis will be on benefits, since the evaluation of costs presents less difficulty.

1. Direct Benefits

(a) Power. The method for evaluating benefits from power developed in a multiple-purpose project is as follows:

> The Bureau of Reclamation defines direct power benefits as the expected gross revenues from the sale of power produced by the plant. If the transmission lines are included in the cost of the project, the revenues are those realized at the load center where the power is marketed; otherwise, the value of the power is measured at the project site. An additional power benefit may result from increases in usable energy at downstream power plants due to the regulation of stream flow by the project. Sometimes the construction of a project will result in the decrease in power production at an existing plant. This may be caused by the diversion of water for other purposes or by the flooding of an existing plant by the project. The value of the decrease in power production is subtracted from the benefits. All the costs of power are project costs.
>
> The Corps of Engineers uses the measurement methods of the Federal Power Commission. The direct benefit from power is based on the cost of producing an equivalent amount of power by the most economical alternative method available, usually a steam-electric plant. Adjustments are made for the differences in transmission costs, transmission losses, system efficiency, and similar factors. The project is credited with increases at downstream plants as well as at the project site.
>
> The difference between the two methods of computing the direct benefits of power lies in the manner in which the agencies handle the saving from cheaper power. The Bureau restricts the direct benefit of power to the gross revenues received for power. The saving is counted as an indirect benefit. The other two agencies, who define the direct power benefit as the cost of the cheapest available alternative, are actually combining the receipts to the Government with the saving from cheaper power. 1/

(b) Irrigation. The Bureau of Reclamation and the Corps of Engineers both evaluate irrigation benefits and costs, but the Bureau has primary responsibility and the Corps either gets estimates from the Bureau or uses the same procedure.

The Bureau "defines the direct benefits of irrigation as the value of the increase in agricultural production or of the decrease in agricultural operating costs resulting from the project." 2/ "In calculating the expected changes in farm income and costs, the Bureau first estimates the types and sizes of farms with the project and without the project. Representative farms then are analyzed in order to determine what the changes would be for their group." 3/ The associated increased costs to utilize the water for irrigation at the farm level

1/ "Economic Evaluation of Federal Water Resource Development Projects," House Committee, Print No. 24, 82nd Congress, 2nd Session, December 5, 1952, p. 13, (hereafter, reference to this document, will be "Economic Evaluation.")
2/ Economic Evaluation, op. cit., p. 9
3/ Ibid., p. 10

are taken into consideration in arriving at the benefits. These costs consist of charges for leveling, ditching, etc., and the increased costs for soil preparation, cultivation, harvesting, etc. (One charge which most likely would appear is not considered. This cost is the added incentive necessary to motivate the farmer to take on the added management problems that irrigation farming would entail over dry-land farming. 1/ From the farmer's point of view, the benefit is the added income accruing through irrigation over his alternative, dry-land farming. In calculating repayment rates or water charges, there might be some tendency to use the gross figure resulting from the above method. If this were the case it would mean that the farmer is expected to take on the extra work of management that irrigation entails, with no compensation. To arrive at a net benefit from irrigation, the farmer's added incentive should be subtracted from the gross benefit as calculated by the above method. Although the amount necessary as added incentive would be somewhat hypothetical beforehand, some reasonable attempt would have to be made to calculate it before water charges were assessed.)

(c) Watershed management. Through the Soil Conservation Service and the Forest Service, the United States Department of Agriculture engages in watershed management programs. Two types of effects are recognized; on-site benefits and costs and off-site benefits and costs. On-site benefits are subdivided into those relating to public and non-public effects, respectively, based on land ownership. "The public benefits are the increase in income from Government-owned land or the decreased costs of maintenance on roads and highways as a result of the control of erosion and of runoff rates. The costs necessary to realize these benefits are project costs. Non-public benefits are a result of runoff and waterflow retardation and of soil-erosion prevention on privately owned land. Decreases in operating costs or increases in productivity are counted as benefits; increases in operating costs or decreases in productivity as associated costs." 2/ The procedure is to select a sample of farms, estimate the effects a certain program would have, and generalize the findings to the region to be affected by the watershed program.

Off-site benefits and costs are associated principally with flood control and can be more easily dealt with under that heading.

(d) Flood control. The direct benefits of a flood-control program, 3/ stem from the reduction of physical damages caused by the direct action of floodwaters and from the increased utilization of land formerly inadequately protected against floods. 4/

To compute the benefits from reducing physical damages caused by floods, the Corps uses the criterion of costs for repairs, rehabilitation, or replacement.

1/ Joss, Alexander, "Benefits from Irrigation under Sub-Humid Conditions," Journal of Farm Economics, Vol. 28, No. 2 (May 1946), pp. 543-559.

2/ Economic Evaluation, op.cit., p. 10.

3/ "The Corps of Engineers has primary responsibility for flood control. The other agencies, however, deal with flood-control benefits: The Bureau of Reclamation and the TVA as part of their multiple-purpose projects, the Department of Agriculture as part of its watershed programms , and the Federal Power Commission as part of its analysis of projects involving hydro-electric power. All of these agencies obtain estimates for flood-control benefits either from the Corps of Engineers or else by using similar methods." Ibid., p. 10.

4/ Ibid., p. 10.

For crops, if replanting is impossible, the loss is estimated at the market value less unincurred costs (further cultivation, harvesting, etc.); if replanting can be done, it is the difference between the market value of the two crops, plus the extra costs necessitated by the second planting. Average annual flood damages are computed by means of the data recorded on flood frequency and levels. The Corps estimates the likely damage if each flood should re-occur. The damage at each flood stage is multiplied by the number of floods attaining that stage, giving the frequency-stage damages. When this sum is divided by the number of years concerned, it gives the annual average damage. If there is quite a likelihood that the highest stage in the recorded floods will be exceeded at some time, a design flood is considered, and the relevant damages averaged with the others.

The second type of benefit - arising out of increased utilization of land made possible by flood control - is arrived at by applying the current rate of return on long-term private investment to the estimated increase in land value. When additional capital investment is needed to make a higher use of the land protected from flooding, this cost is deducted from the increase in land value, and the interest rate is applied to the remainder. In estimating the expected increase in value the Corps compares probable future values with and without the flood protection works, taking care not to count values that might result regardless of flood control. 1/

(e) Navigation. The Corps of Engineers had primary responsibility for estimating benefits and costs associated with navigation. The Bureau of Reclamation and the Federal Power Commission are concerned with the matter but they "either obtain estimates from the Corps of Engineers or else, when necessary, make their own estimates using the same method." 2/

The method is, briefly, to calculate the reduction in costs made possible by the works. This is the benefit. There is no attempt to establish the real costs, but only the monetary costs; it is assumed that the savings are passed on to the consumer.

(f) Other multiple-purpose functions.

(1) Recreation. The Department of Agriculture does not measure tangible recreational benefits; the Bureau of Reclamation obtains estimates from the National Park Service; and the Corps of Engineers makes its own estimates.of "The net income from recreational facilities such as hotels, camps, and concessions." 3/ The net incomes are the benefits.

(2) Fish and Wildlife. The United States Fish and Wildlife Service provides all the agencies engaged in multiple-purpose water development projects with estimates of benefits. 4/

(3) Pollution Control. The benefits are estimated by all the agencies in terms of the cost of the most practical alternative method that would be used to decrease pollution in the absence of the project. 5/

1/ Economic Evaluation, op.cit., pp. 10-11
2/ Ibid., pp.11-12.
3/ Economic Evaluation, op.cit., pp.13-14
4/ Ibid., p. 14
5/ Loc.cit.

(4) Domestic and Industrial Water Supply. Sometimes the benefit is based on what the beneficiaries are willing to pay for water, but usually it is based on the cost of the cheapest alternative way of providing the water. 1/

(5) Sedimentation Control. The various agencies base this benefit on the damage prevented by the control. 2/

(6) Salinity Control. This benefit is estimated on the basis of the damage prevented, the method being similar to that in measuring flood control benefits. 3/

2. Indirect Benefits

Indirect benefits are the values resulting from activities induced by the project, such as increased freight loadings, made necessary by the greater economic activity. It is an attempt to measure the net effect that the project has on national income, recognizing that since the project may have favorable repercussions on the national economy, these effects are a benefit and should be credited to the project. Because it is impossible to isolate the effects of a water project from the effects of other Government expenditures (on highways, airports, etc.) on national income, the various agencies estimate these effects locally, assuming that local indirect benefits are national income benefits. Indirect benefits are measured for irrigation by the Bureau of Reclamation, for hydro-electric power, by the Bureau, and for flood control by the Corps of Engineers, the Bureau, the Federal Power Commission, and the Department of Agriculture.

(a) Irrigation. The indirect benefits arise because of the increased sale of farm products and from the increased demand for goods and services brought about by the economic activity connected with instituting the project. The Bureau calculates indirect benefit factors to apply to the primary production, derived from the contribution that each type of activity makes to the national income, e.g., in the processing and distributing industries, the indirect benefits creditable to the project arise out of the increased production of farm commodities. The indirect benefit factor is 10 per cent for the wholesaling of grains produced, and the total factor for grains is 83 per cent, so that, if there were an increase of $20,000 in the production of grains, the indirect benefit accruing to the project would be $2,000 in the former case, and $16,000 in the latter case. 4/ Similarly, factors are worked out to apply to the increase in local business activity to determine the benefit creditable to the project. It is assumed that there is a benefit felt by the suppliers of goods and services which arises out of the development of the project, e.g., in the case of motion-picture theatres, it is maintained that there is a 39 per cent increase in the value of admissions paid. Since the increase in business activity results partly from the project investment, and partly by virtue

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1/ Loc cit.
2/ Loc.cit.
3/ Loc.cit.
4/ Economic Evaluation, op.cit., p. 15.

of farmers' increased costs, a "Federal cost-adjustment factor" is applied to determine the net amount of the benefit that is creditable to the project. 1/ This factor will deflate the total benefits from processing, etc., and supplying goods and services by a considerable amount, perhaps 80 per cent, so that one-fifth of the value found for indirect benefits originally would be credited to the project. 2/

(b) Hydro-electric power. The indirect benefits are assumed to arise out of the saving to the consumer through using Bureau developed power over what it would have cost to develop an equivalent amount of power using the cheapest alternative means, plus the benefit resulting from the use of the power in the final production of goods and services. Where the power is distributed by an outside utility, the effects on the latter are taken into consideration.

(c) Flood Control. Indirect benefits from this function arise out of losses avoided by the project. These losses are the net loss of goods and services due to the flood, plus the costs of flood fighting. In the first instance, business and commercial activities are curtailed and the value of goods and services that would have been produced are permanently lost. In the second instance are costs of evacuation and care of flood victims, emergency protective works, and increased costs of carrying on essential services during a flood. 3/

C. COMMENT

Circular No. A-47 requires no comment; its purpose is administrative rather than analytical. It merely sets out the policy of the United States Government with respect to water development projects. 4/

The Subcommittee's report is a commendable attempt to bring to comparability, through a standardized procedure, the many diverse water development projects proposed from time to time for consideration by the government. These projects often vary a great deal in their purpose: some provide mainly for flood control; others are designed mainly for power; and still others have for their major function reclamation through irrigation. Regardless of the major function, these projects usually provide also for the other functions just mentioned, and frequently for many minor functions as well. To bring these projects together, so that they can be compared objectively, requires a great deal of ingenuity, but with the help of one or two simplifying assumptions, the Subcommittee has achieved its purpose amazingly well. The assumption adopted

1/ Ibid., p. 16

2/ The foregoing statement on the determination of indirect irrigation benefits does not quite do justice to the Bureau's method. For full details, the relevant texts should be consulted.

3/ Economic Evaluation, op.cit., p. 17.

4/ While no decision to revise the circular had been made as of April 15, 1955, it was under review by the Executive Branch of the Government. Information courtesy of Carl H. Schwartz, Chief, Resources and Civil Works Division, in correspondence dated April 15, 1955. A revision may be expected in the future, however.

are, first, that the economy is fully employed, so that the market price of factors used in the river project can be assumed to represent the sacrifice or real economic cost to the community; second, that the effects of business cycles and unemployment may be largely disregarded; 1/ and third, that the market price expresses the public values attached to the benefits and costs attributable to the projects. 2/ The resulting analytical framework is logically conceived and must result in comparable evaluations. Therefore, where the object is to consider two or more competing projects as to their relative merits, the Subcommittee's recommendations form the best guide developed so far.

Yet, the assumption of full employment vitiates the method outlined by the Subcommittee when economic rather than financial feasibility is to be considered. Full employment, for the most part, is a special case; there is almost always some unemployment, varying from the unquestioned unemployment of a general depression to unemployment or underemployment which may exist only in certain sectors of the economy.

Therefore, the question of the possible effect of the project on general welfare - its significance for providing economic opportunities and regional development - is left begging. This omission is understandable. Techniques for analyzing these effects have not been perfected. Hence it is no discredit to the Subcommittee that this facet of the problem is not dealt with. Yet, the simple truth is that if a capital asset is created which has profound effects flowing from it for the region in which it is located, the economic benefits are very important, both regionally and nationally. This has been shown qualitatively in a recent study of the Tennessee Valley Authority. 3/ The author of this paper concluded that benefit-cost analysis provides an investment criterion rather than one which is useful for evaluating the effects regionally and nationally. He continues as follows:

> "Perhaps more useful for this latter purpose is an analysis of the process of development and how regional development programmes may influence the process. This requires an examination of the effects such programmes have on the parameters of the region's production and consumption functions over time and the trend in the structure of markets. Although precise quantitative criteria may be more difficult to formulate in this case, an approach along these lines is likely to be more relevant, more informative, and more suited for analysis of the dynamic aspects inherent in problems of economic development." 4/

1/ If construction is to take place during periods of low economic activity, the reduction in relief costs may be credited to the project as a benefit. Op.cit., p. 29.

2/ White it is recognized that the market may not always reflect all the values, because of the influence of subsidies, tariffs, price supports, and imperfections in the markets, this creterion is chosen because it represents the only suitable framework for evaluating projects in common terms. See op.cit., p. 7

3/ Krutilla, J.V., "Criteria for Evaluating Regional Development Programmes", American Economic Review, Vol. 45, No.2, (May 1955), pp. 120-132.

4/ Ibid., pp. 131-132.

Another recent contribution to the literature on regional economic problems compares development in Idaho and California. 1/ The writer of this contribution uses the technique of linear programming and, although the paper does not pretend to put forth a perfected technique, it is a valuable addition to the literature on the problem of economic analysis of regional development. 2/

While work is rapidly going forward and progress being made in development of techniques for regional analysis, much more work is required before the proper tools are finished.

In summary, the Subcommittee's report is a valuable guide where the problem is one of economic comparison of two or more projects competing for public funds. But it leaves unanswered the question as to the effects of the development on the economy of the region and nation generally.

The main criticism, with respect to current practices, concerns the handling of indirect benefits. The Bureau of Reclamation's attempt to measure national income benefits at the project site commands respect , for it is an extremely difficult task to accomplish. It requires painstaking inquiries about the indirect benefits in existing project areas to determine the magnitude of the indirect benefits that have been realized in the past. However, generalizing from such studies to projects proposed for development assumes that future undertakings would produce identical results. Such an assumption may not be warranted.

Rather than attempt to isolate all the various indirect benefits, (effect on theatre attendance, etc.), it might be more realistic to limit the inquiry to a study of the changes in rent, and of the rewards to other factors associated with the development. Such an inquiry might give a conservative measure of the net change in national income as a result of a river basin project, but it would not involve any double-counting.

1/ Moore, F.T., "Regional Economic Reaction Paths," American Economic Review, Vol. 45, No. 2 (May 1955), pp. 133-148.

2/ On the question of the advantages of the tool of linear programming over partial economic analysis, one writer states emphatically that there is no issue as to which tool is best for "determining the allocation of investment which will maximize the increase in national income". It is linear programming. The latter "can deal with the composition of output, price relationships, foreign exchange relationships, and alternative production methods far better than can partial analysis. These advantages result from the nature of economic development; namely, that the economy is changing, not marginally, but in all parts at once and in some parts by large increments or large structural changes. Change in each part of the economy affects other parts, and none can be analyzed without simultaneously analyzing all." See Hagen, E.E., "Discussion", on Development Policy in Underdeveloped Countries, American Economic Review, Vol. 45, No. 2, (May 1955), p. 74.

D. CONCLUSION

In the absence of satisfactory techniques for evaluating indirect or secondary benefits, major reliance should be placed on the evaluation of direct benefits, while indirect benefits would be discussed qualitatively. If a benefit-cost ratio must be shown, indirect benefits must be given a monetary value; however, it would be preferable as regards sound economic analysis, to handle indirect benefits in qualitative terms.

The product of such analysis would be as follows. On the one hand there would be the estimated monetary costs. On the other hand there would be the estimated monetary returns. If these balanced there would be no real necessity to discuss indirect benefits, if any, but inclusion of these would make the analysis complete. If monetary costs exceeded monetary returns (both estimated), the contribution of indirect benefits to national income would have to be considered. However, these would be stated qualitatively and there would be no possibility of comparing their value directly with the difference between monetary returns and costs, Whether or not such qualitative benefits were felt to compensate for the monetary deficiency would be a matter of judgment at the policy level.

CHAPTER 6. SUMMARY AND CONCLUSIONS

1. Summary

This study, undertaken by the Economics Division and P.F.R.A. of the Department of Agriculture (Canada), had for its purpose the collection and analysis of basic data relating to the economic significance of human activities and needs with respect to water development in the Saskatchewan river basin, to provide the Prairie Provinces Water Board with basic information useful in making decisions about allocating water among the provinces through which it flows. Although the study as a whole has not as yet been completed, the data collected thus far have been made available in interim reports. The present report brings into focus the problems associated with interprovincial water allocation and examines available data to determine the extent of water shortage in the Saskatchewan river basin.

The Saskatchewan river basin lies athwart the three prairie provinces and has an area of about 149,500 square miles of which 8,2000 lie in Alberta, 66,600 in Saskatchewan and 900 in Manitoba. Climatically, it is sub-humid in the north and semi-arid in the south; but variability of precipitation gives rise to more agricultural problems than any absolute deficiency of moisture. It is, however, a moisture deficient area in the sense that potential evaporation exceeds precipitation, and in a large part of the basin, over an area roughly approximating the Palliser's "Inner" Triangle, or the brown soil zone, potential evaporation exceeds precipitation by 25 inches or more. Although variability and, to some extent, deficiency of precipitation limits agricultural production over part of the basin, in Manitoba water for hydro-electric production assumes important proportions because of the paucity of other indigenous sources of primary energy. These two facts point up the incipient conflict of uses for the water: irrigation in the upper reaches, and power production in Manitoba.

In 1951 just over one million people occupied the portions of Alberta and Saskatchewan lying within the Saskatchewan river basin.

Settlement of the prairie provinces lagged until the turn of the present century, after which the major part of the agricultural lands were occupied in the space of 30 years. Attempts to farm the short-grass region gave rise to great hardships, especially throughout the region depicted by the brown soil zone. Ameliorative measures were begun in Alberta in 1927 with the creation of the Special Areas, and in the 1930's in Saskatchewan through the Prairie Farm Rehabilitation Act and provincial legislation.

The husbanding of water, made possible through financial and engineering assistance by P.F.R.A., has occurred at three levels of size of project, "dug-outs", community projects, and major irrigation projects.

When the supply of water in the Saskatchewan river basin is confronted with present and foreseeable future uses, (domestic, industrial, irrigation and power), no absolute shortage appears to exist. Temporary shortages may manifest themselves from time to time at urban centers, in particular as regards pollution, but additional storage, improving the river's regimen, would relieve these shortages. Even with full development of presently authorized irrigation projects, including the South Saskatchewan River Project, the average flow at The Pas for water-years similar to those of 1923-24 to 1947-48, would be 13,302,000 acre-feet as compared with 17,719,000 acre-feet under "natural" conditions. In addition, regimens would be improved, because of present and prospective power development upstream, so that the minimum monthly flow would be 4,824 c.f.s. as compared with 1,342 c.f.s. under "natural" flow conditions. However, although such improvements in regimen would benefit downstream hydro plants with little natural storage and provide more water for urban and industrial uses and for pollution control, hydro sites with very large natural storages, such as those on the Nelson River, would be adversely affected by the diminution in the total flow.

2. <u>Conclusions</u>

(a) The water available in the Saskatchewan River System would seem to be adequate for present uses in the basin itself, but full development of presently authorized irrigation projects and of proposed projects would adversely affect the power potential of the Nelson river.

(b) Basic data are required for an extended economic analysis of water allocation problems. In particular, data have to be gathered to assess the economic value of presently operating irrigation projects and to test methods which could be used to evaluate proposed projects; the power potentials and requirements of Manitoba need to be studied, so that values may be attached to diminution of power potential resulting from future irrigation development; studies must be undertaken to compare the relative value for agricultural development of delta soils through drainage; grey-wooded soils through clearing, and prairie soils through irrigation; and finally, data are needed for evaluating various methods of controlling pollution.

APPENDIX A

OUTLINE OF THE PROBLEM INVOLVED IN PROPOSED STUDY BY ECONOMICS SERVICE "STUDY OF PROBLEMS IN WATER ALLOCATION IN THE PRAIRIE PROVINCES"

The waters of the Saskatchewan river basin, in the main, rise in the eastern slopes of the Rocky Mountains, with several tributaries in the State of Montana and the Province of Alberta and flow eastward to join four main tributaries in eastern Alberta and two in western Saskatchewan, and eventually form one stream with additional tributaries in northeastern Saskatchewan and northwestern Manitoba to merge into a chain of lakes of the Manitoba Lake System.

In addition to the Saskatchewan River System, several other river basins of less importance, in western Canada need to be considered. Claims for use of these waters have already arisen, or will arise in the future and they must be considered in any discussion of an equitable allocation of water in the Prairie Provinces. The Saskatchewan River basin covers half of the settled part of the Prairie Provinces and directly affects the life and economy of about half of the people who reside there. The importance of this to the people affected is made many times greater by the fact that water is a comparatively scarce resource.

No one principle has been followed in determining rights to water carried by a stream across boundaries of more than one jurisdiction. In international disputes equal division is usually recognized for common boundary waters, whereas for streams crossing the boundary an equitable division is made (or attempted). Interprovincially, the Prairie Provinces Water Board has the responsibility of recommending allocations; and their functions are defined as -

> "to recommend the best use to be made of interprovincial waters in relation to associated resources...and to recommend the allocation of water as between each such province of streams flowing from one province into another province."

In local provincial water-right administration, the practice has been to issue licenses for all reasonably 'good' projects with priorities being allotted in strict conformity to their respective dates of application (provision being made to allow a higher type of user, say 'domestic', to take over the priority of a lower type of user, say 'irrigation', providing the need is demonstrated and all damages are paid): very recently some of the provinces have taken the right to reserve any unappropriated water so allocations may be reserved among the applicants in any manner deemed "best in the public interest".

In recommending allocations of interprovincial waters, the Prairie Provinces Water Board has frequently been aware of the lack of basic information dealing with the economic significance of human activities and needs in relation to water development.

There is need for a broad study of interprovincial watersheds which will co-ordinate

(a) All facts known concerning their geographical location in relation to present and probable future human activity and needs;

(b) the economic significance of various physical and engineering possibilities related to these activities;

(c) present and required legal framework regulating human activity in relation to water; and

(d) other relevant aspects.

WATER ALLOCATION AND UTILIZATION IN THE SASKATCHEWAN RIVER BASIN

Report No. 2

Physical Features of the Saskatchewan River Basin

John Boan and Craig Duncan

Economics Division

in co-operation with

Prairie Farm Rehabilitation Administration

Canada Department of Agriculture

61/14 (2) Ottawa, July 1961.

PREFACE

This is the second in a series of three reports on the Saskatchewan River Basin. In conjunction with "A Survey of the Law of Water in Alberta, Saskatchewan and Manitoba", a report written by Mr. P. Gisvold, these three reports are designed to co-ordinate all known facts concerning the geographical location of interprovincial watersheds in relation to present and probable future activity and need, and to evaluate the legal and economic significance of various physical and engineering possibilities.

The three reports include:

Report No. 1, "The Economic Significance of Water Requirements in Relation to Human Activities and Needs in the Saskatchewan River Basin."

Report No. 2, "Physical Features of the Saskatchewan River Basin."

Report No. 3, "Annotated Bibliography of Selected Documents Pertaining to Water Allocation and Utilization in the Saskatchewan River Basin."

Acknowledgments are due to the late Dr. L.B. Thomson, Director of Prairie Farm Rehabilitation Administration, Dr. C.C. Spence, Western Supervisor, Regional Offices of the Economics Division and Mr. W.M. Berry, for their encouragement, constructive criticism and assistance and to many others, too numerous to mention, who through conversation or correspondence assisted in various ways.

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CHAPTER 1. PHYSICAL CHARACTERISTICS OF THE SASKATCHEWAN RIVER BASIN

A. Introduction

The continued replenishment of streams is ultimately due to precipitation in some part of the watershed.

Some of the precipitation is intercepted by the vegetation of the basin, the amount varying with the type of precipitation. Hydrologists have estimated that about 20 per cent of the rain falling in the open is intercepted by deciduous trees (beech, oak and maple), and about 60 per cent may be intercepted by spruce although, in this latter case, the method of measuring has been criticized.1/ Interception of wet snow and freezing rain may amount to a considerable proportion of total precipitation. Interception of precipitation may lead to sublimation or evaporation even while the snow or rain is still falling. Wind, by increasing the processes of sublimation and evaporation, adds to this loss. A lag between the time or precipitation and stream replenishment is encouraged where any form of vegetation is present, a factor conducive to a more favorable regimen. Forests protect the surface water, particularly if water is in the form of snow, by acting as a heat screen; but generally, through their interception, forests are wasters of water. The loss of water due to these causes is critical in areas of low precipitation. Loss of water due to interception must, however, be balanced against the beneficial effects of forest cover in giving a greater control of runoff and in decreasing erosion. In the Rocky Mountain Forest Reserve, where restricted cutting of the timber is allowed, experiments are being conducted which have as their purpose to obtain an optimum runoff in terms of forestry practices. Patch cutting would appear to offer the best solution.2/

Regarding the precipitation that reaches the ground, some will evaporate from the surface, some will percolate into the soil, and the remainder will flow to the rivers. The structure of the soil is the chief determinant of the rate of infiltration. A dry, finely pulverized soil prevents rapid infiltration whereas a moist soil, but one that is not saturated, quickly absorbs additional moisture. A small pore space of the fine soil particles decreases the infiltration rate, so that surface runoff is more rapid. Sandy soil thus has a much higher infiltration rate than has a clay soil. Clay soil particles swell when water is added, decreasing the pore spaces. Infiltration is completely reduced if the ground is frozen. Runoff is then considerably increased.

Water may be held as soil moisture. Some of this will reach the stream channel through interflow,3/ or as groundwater moving laterally

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1/ Linsley, Ray K., Max A. Kohler, Joseph, L.R. Paulus. Applied Hydrology. McGraw-Hill (Civil Engineering Series). New York 1949, 260 p.

2/ Personal interview with D.K., Crossley, Forestry Branch, Department of Northern Affairs and National Resources, Calgary, Alta., Aug. 20, 1954.

3/ Interflow is the portion of the water that seeps into the soil, moves laterally in the upper soil until its course is intercepted by a stream channel or until it returns to the surface at some point downslope from its point of infiltration.

below the level of the water table. Subsurface flow is significant in the replenishment of the prairie streams. Water is stored in the soil and then released slowly. From midsummer to the end of autumn, subsurface water is often the only source of water for many prairie streams and it helps maintain their flows. The amount of water obtained will vary with the soil type and the underlying geoglogical structure.

The bulk of precipitation falling to the earth spreads as a thin sheet over the surface. From this sheet there is loss through sublimation and evaporation. Some water collects in hollows, becomes depression storage and is of no further use. Overland flow begins when the thin sheet of water which has built up over the basin surface, is no longer able to remain in a position of equilibrium. It flows to lower levels and, eventually, to the stream. When precipitation is in the form of snow, overland flow must await the warmer temperatures that will bring about a thaw. Volume and the rate of overland flow depend primarily on the amount of discharge and the configuration of the surface. For example, on the undulating surface of the prairies, the movement of water to the major stream channels is much slower than is a comparable volume in mountainous areas.

Stream regimen is the end product of an aggregation of physical factors. Of these, climatic influences are the most important in determining the particular pattern the flow will take. But within thebroad pattern dictated by climate there are many local variations in the natural flow. These directly reflect the relief over larger areas; and the surface configuration, vegetation and soils over smaller areas. Agricultural activities, insofar as they modify the land surface, also play a part in modifying stream flow. A detailed examination of physical inter-relationship is beyond the scope of this study. General physical patterns must first be outlined for an understanding of the analysis of regimen.

B. The Physiography of the Saskatchewan River Basin

The site of the Saskatchewan River basin was originally a vast lowland region, the Alberta Shelf, which extended from the Great Slave Lake in northern Canada to the Gulf of Mexico. From pre-Cambrian times the shelf existed as a western extension of the central North American craton of which the Canadian Shield was the core. It suffered alternating periods of broad subsidence, marine and fresh water sedimentation, emergence and erosion. To the west of the Shelf, along the present western boundary of the province of Alberta, lay a deep trough, the Rocky Mountain geosyncline. Sedimentation within this trough was more or less a continuous process. The sediments originated from an orogenic belt further west bordering the present Pacific coast and, later, from a high mountain landmass which J.B. Webb named the Cordilleran geanticline 1/ and F.J. Fraser, et alia, named Zephyria.2/ Whatever the name, it occupied the present site of the Purcell,

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1/ Webb, J.B., "Geological History of the Plains of Western Canada," Bulletin of the American Association of Petroleum Geologists, Volume 35, 1961, p.2294.

2/ Fraser, F.J., F.H. McLearn, L.S. Russell, P.S. Warren and R.T.D. Wickenden., "Geology of Southern Saskatchewan", Memoir Number 176, Geological Survey, 1935, p.114.

Selkirk and other ranges. From this landmass came the bulk of the Cretaceous materials which form the bedrock over most of the basin. The Cretaceous seas were mostly mud or silt bottomed. They were invaded by marginal alluvial plains, delta plains and swamps. During the same period, clastic sediments were building up a marginal alluvial plain from the Canadian Shield in the east.

The rise of the Cordilleran geanticline had broken up the geosyncline immediately to the east but this was able to persist as a trough and sedimentation continued. As the Mesozoic era drew to a close, uplift, initiated by tremendous crustal forces from the west, was directed against the geosyncline. Rocks were compressed and uplifted, and the site of the former sea was converted into a mountainous region. This, the Laramide, or main Rocky Mountain orogeny, resulted in the Rocky Mountain geanticline. The region of uplift was bounded in thewest by the Rocky Mountain Trench and to the east, by the foothills and these in turn by the shallow dip of the Alberta Shelf. Folding within the boundaries of this region continued, developing folded thrust faults in the foothills of the Rockies. These have been studied in the northwestern portion of the basin 1/ and in the southwest. It is in this latter area that the most spectacular relief forms have resulted from overthrusting. The famous Lewis overthrust 2/ has been traced 100 miles north into Canada. The overthrust led to a reversal of the normal stratigraphy so that the Lewis and Livingstone ranges are "perched" on Cretaceous materials. Along the foothills region the overthrust is at the contact between Palaeozoic and Mesozoic sediments and it often coincided with the trace of an overthrust fault plane. Within the bands of sedimentary rock, evidence of intrusive igneous activity has been exposed. A diorite sill is a prominent feature high up in the Lewis range.

In summary, the Rocky Mountains may be described as an anti-clinorium, modified by faulting, overturning and overthrusting with local areas of intrusive igneous activity.

Erosion followed the period of uplift and the young sediments were removed from the mountain mass so that today granite, forming the core of the Rockies, has been exposed. Other sediments are composed of a thick mass of folded and faulted materials ranging in age from pre-Cambrian to late Palaeozoic. Mesozoic formations often occur as inliers in the Paleozoics and the ridges of Paleozoic and pre-Cambrian formations occur outside the main front of the Rockies. For some time, antecedent rivers persisted across the rise of the Rockies, and, although eventually defeated, they did cut the lower passes. Erosion of the uplifted mass was particularly extensive in the southern part of the basin. Maturity in the cycle was reached during the Miocene and the Pliocene periods. Most of the eastern extension of the overthrust was removed until only outliers, the most striking of which is Chief Mountain, remained. The abrupt termination of the

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1/ Hake, B.F., Robin Willis, and C.C. Addison, "Folded Thrust Faults in the Foothills of Alberta," Bulletin of the Geological Society of America, Volume 53, 1942, pp.291-334.

2/ Dyson, James L., "The Geological Story of Glacier National Park," Special Bulletin Number 3, Glacier Natural History Association, Inc., West Glacier, Mont., 1949, pp.14-19.

Rockies is a characteristic in the south. Effective, but less complete erosion of the bedrock to the north, resulted in the sculpturing of the eastern ranges. The present topography of the northern foothills is related to the eastern dip of the Alberta geosyncline. Erosion of the fresh water clastics has resulted in "strike ridges of more resistant stones ... paralleled by broad valleys carved in softer shales ... The drainage system developed on a gravel plain formed during the early or middle Tertiary and has been superimposed on the Cretaceous rocks so that the present day streams are only partially adjusted to structure".1/

Sediments, particularly fresh water clastics, rapidly accumulated about the site of the present foothills. In the shallow geosyncline extending east to the Shield, and Oligocene gravel plain was built up. It consisted of "Saskatchewan gravels," coarse gravels, sand and quartzite pebbles which greatly differed from the earlier Cretaceous clastics of Zephyria. Paleocene warping of the geosyncline was associated with the formation of the Sweetgrass Arch which extended from the south into central Alberta. The smaller Alberta geosyncline was formed to the west of this. During the Miocene and the Pliocene periods erosion reduced most of the original Tertiary sediments until only remnants remained. Attempts have been made to correlate these levels with the old Flaxville and other peneplain surfaces of Wyoming and Montana. The height of these surfaces above the general prairie level varies. The western hills in the Cypress Hills area have a local relief of 600 feet. In the east the hills rise 1,600 feet above the plains. A most striking feature of these remnants is the nearly level summits found at their tops. They are often bounded by steep slopes whereas in the Cypress Hills, gorges "meet the upland surface at marked angles and form strong contrasts with the upland surface."2/ Other more prominent remnants include such topographic features as the Milk River Ridge, an elevated ridge of country, the Porcupine Hills, which are closely associated with the Rockies, the Hand Hills, and the base of the Missouri Coteau. The Hand Hills rise to 3,550 feet, about 1,200 feet above the surface of the plains. They form "an elevated tableland, the top of which, however, is not flat but composed of five ridges which radiate from a center lying to the southeast".3/

Gravel benches associated with these features indicate brief periods of aggradation. "In the valleys of Mill and Pincher creeks and those of the forks of the Oldman, east of the actual base of the mountains, wide terraces and terrace flats are found stretching out from the ridges of foothills and running up the valleys of various streams".4/ Similar terraces are found in the valleys of the Bow and Crowsnest rivers.

1/ Hake, B.F., Robin Willis and C.C. Addison, op. cit., p. 295.
2/ Williams, M.Y., "The Physiography of the Southwest Plains of Canada," Transactions of the Royal Society of Canada, Volume 23, 1929, p. 64.
3/ Tyrrell, J.B., Annual Report, Volume 2, Geological Survey Canada, 1887, p. 29.
4/ Williams, M.Y., op. cit., p. 66.

In general, the prairies are underlain by Cretaceous Rocks, the only exceptions being in the area of the lower Saskatchewan river where Silurian and Ordovician bedrock outcrops, and adjacent to the foothills where early Tertiary sediments have been preserved in the Alberta geo-syncline. Sufficient variety is found in the composition of formations to influence local drainage and topography. The Edmonton formation consists of very fine clastics combined with abundant clayey matter. They have tended to develop very flat or low-angle topography. The soft beds of white and pale-gray, argillaceous sands and grey and brown clay weather into typical badland forms. Water does not readily seep through the rocks but is either retained as shallow, intermittent lakes or cuts courses to drainage ways through steep-walled gullies. The paskapoo formation to the west consists of coarse clastics, loosely cemented, with alternating harder and softer bands.

> The coarse sands are not as readily moved by wind or rain action and can form relatively steep protective taluses. This feature in conjunction with the ribbed nature of the bedding has resulted in the Paskapoo surface assuming a sharply rolling character locally.1/

Paskapoo rocks, like the porous Belly River rocks to the east, absorb water readily; so that the surface is marked by fewer lakes and streams. Large lakes, where the Paskapoo formation is the surface bedrock, have bottoms at the level of the Edmonton formation.

The oustanding topographic features at the plains level are two east-facing escarpments of the Manitoba cuesta and the Missouri Coteau. These are hilly belts of outcropping Cretaceous rock, oriented about northwest to southeast across the basin, which mark a break between erosion levels. The Manitoba escarpment has been described as "a series of water worn cliffs overlooking a region of Silurian bedrock and alluvial sediments of the former lake."2/ In the north, the cliffs disappear and the cuesta becomes more a line of contact between Cretaceous rocks in the west and Silurian in the east. The Missouri Coteau is a long, narrow upland extending to the northwest. Glacial moraines perched on its top, accentuate the height.

During Pleistocene times, ice advanced over the plains from both the west and the northeast. The western movement was from the Cordilleran ice cap and was basically a piedmont extension of valley glaciers. Within the Rockies, it considerably modified the mountain scenery developed under normal erosion. Great U-shaped valleys, paralleling the mountain ranges were gouged out. Above the sheer rock sides, massive peaks persisted as nunataks. Jagged aretes, cirques at the heads of main and tributary valleys, cols and hanging valleys are today characteristic features of the Rockies resulting from this glaciation.

1/ Allan, J.A. and J.O.G. Sanderson, "Geology of the Red Deer and Rosebud Sheets, Alberta," Report 13, Research Council of Alberta, Edmonton, 1945, p.11.

2/ Thayer, W.M., "The Northern Extension of the Physiographic Divisions of the United States," Journal of Geology, Volume 26, 1918, p.24.

The valley floors are flat-bottomed, across which streams flow in braided channels. Masses of valley train material line the valley floors, while culluvial debris slopes in long talus comes to form the sides. Lakes occupy steps in the valley floors or are found retained behind the lips of cirques in the upper valleys. There are also evidences of former lakes, temporarily dammed behind glacial debris, in the sorted sediments of the valley floors. Moraines are not a conspicuous feature except in areas adjacent to present day glaciers.

Cordilleran ice several times advanced beyond the confines of the mountain valleys to make contact with the Laurentide ice from the east. Quartzite erratics, , dumped as the ice melted, marked the extent of advance. The Continental ice covering the Canadian Shield advanced during Laurentide times 1/ into the foothills until it reached elevations which it could not surmount. Barriers, like the Porcupine Hills, blocked advance, but great lobes of ice extended up the lower reaches of the valleys. In the southwest "the northern lobe, enveloping the northern end of the Porcupine Hills near Stimson Creek, extended down the valley now occupied by the Chain Lakes."2/ A central lobe extended into the Porcupine Hills and a southern extension left moranic material at 4,400 feet. The Laurentide drift contained pieces of granite, gabbro, gneiss, schist, and other types of rock derived from the Canadian Shield. Erratics mark the extent of this drift. In southern Alberta are found two layers of drift of eastern origin, and these are separated in places by lignite-bearing interglacial deposits. Where the earlier ice sheet went well into the foothills, cordilleran drift overlaps this and in turn is overlapped by later Laurentide drift. In southern Saskatchewan, borings show evidence that at least three till deposits were separated by two series of interglacial deposits.3/

Three types of unconsolidated materials are found over the basin. There are some gravels and sands, possibly of preglacial origin, the drift deposits of Laurentide times, and to a more limited extent, Cordilleran origin, and some post-glacial river and lake deposits.4/ Of these the drift deposits are the most extensive. They consist of both sorted and unsorted materials, till, boulder clay and semistratified silts and clays. The thickness of the drift varies over the basin, but it is generally between 25 and 50 feet thick and is seldom more than 100 feet deep in the interstream areas. The till deposit is somewhat thinner west of the Coteau than it is to the east. Where the till of ground moraine has been dumped on the land, a flat to undulating plain has resulted. Not all lowland features are aggradational. Flat areas to the east of Red Deer have been smoothed and planed by glacial action. "Rock Drumloids", small roches moutonnees north of the Hand Hills, have been formed by ice sculptoring of the bedrock. Post-glacial dissection of the morainic features varies with the length of <u>exposure of post-glacial erosion and</u> the proximity of actively eroding

1/ There appears to be some confusion in the use of terms "Laurentide" and "Keewatin" in naming the ice sheets advancing from the east. Some writers use the words synonomously, while others use the word "Laurentide" to distinguish the northesterly from the more easterly component. "Laurentide" is here used as the more modern name for the ice sheet advancing from the east.

2/ MacStalker, A., "Surficial Geology of Southwestern Alberta," <u>Third Annual Field Conference and Symposium</u>, Alberta Society of Petroleum Geologists, 1953, p.21.

3/ Johnston, W.A., and Wickendem, "Moraines and Glacial Lakes in Southern Saskatchewan and Southern Alberta, Canada". <u>Transactions of the Royal Society of Canada</u>, Volume 25, 1931, p.31.

4/ Allan, J.A. and Ralph L. Rutherford, "Geology of Central Alberta", Division <u>Report Number 30</u>, Research Council of Alberta, Edmonton, 1934, p.9.

streams. All features are topographically youthful, although those in the west show, in their greater complexity, a longer exposure to erosion. The hills are steep-sided and the lowlands often undrained. Many of the hollows have been filled with lacustrine sediments. It has been pointed out that the moraines of Alberta contain very little out-wash. "Kame topography is rare and is usually well localized. Eskers, valley trains, and glacial lake deltas are also rare."1/ A pitted outwash plain lies to the west of Edmonton. It appears as an accumulation of hills and hollows rising nearly 100 feet above the plain of the ground moraine. Three types of glacial deposits are found, (1) terminal or end moraines consisting of unsorted till and boulder clay, (2) partly sorted material and, (3) well sorted gravel, silt, sand and clay. The end moraines form marked surface irregularities over the basin. A prominent moraine, the Viking, lies east of Edmonton. Its hilly surfaces extend a considerable distance south. Moraines have been built up around structural features as, for example, at the western end of the Milk River Ridge. One, eight miles west of Cardston, stands 200 feet above the plain. The Missouri Coteau formed a barrier to the Westward movement of the ice and two prominent terminal moraines are located there, one along the crest and another a few miles to the west.

In some areas of eastern Alberta it is considered that moving ice caused intense deformation of surface features. Tit Hills and Mud Buttes show abnormal distortions of strata which are of surficial nature. "If the surficial nature of the distrubance is granted, the surficial nature of the force and its direction lead naturally to the assumption that the thrusting force was the great ice sheet, because it was the only competent force."2/

As the ice front retreated east across the plains, fluvial and lacustrine deposits were established beyond the retreating ice and in the ice itself. Lakes were formed where the ice blocked east-flowing streams; Lake Magrath, in the southwest, was the first of these. They increased in size toward the east, the largest being Lakes Regina and Agassiz. Sediments were deposited in these. In englacial lakes fine materials were gradually lowered on to the surface as the ice melted. A covering of lacustrine sediments, varying in depth from a few inches to several feet, was formed over part of the morainic material. West of Edmonton, six inches of lacustrine silt covers rolling morainic hills. In other areas, morainic hills alternate with flat lacustrine basins. This is typical topography of the area between the North and the South Saskatchewan rivers. In some areas, particularly to the south, ridges of sand dunes mark successive lake shores formed during pauses in the shrinkage of the post-glacial lakes. Today sand dune areas are found scattered over the basin. They provide some relief especially in the Great Sandhills, the most extensive of these dune regions. Beach ridges

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1/ Bretz, J. Harlen., "Keewatin End Moraines in Alberta, Canada," Bulletin of the Geological Society of America, Volume 54, 1943, p.35.

2/ Hopkins, Oliver B., "Some structural Features of the Plains Area of Alberta Caused by Pleistocane Glaciation," Bulletin of the Geological Society of America, Volume 34, 1923, p.428.

rise across the course of the lower Saskatchewan River in Manitoba. They were formed by the retreating Lake Agassiz. Smaller sand deposits and lenses in the till material resulted from some fluvial sorting during deposition.

The lakes have all but disappeared, drained by an extensive system of rivers which carried meltwater to the south. Lake remnants remain as shallow, saline sloughs. Lake Pakowki and Manito Lake are good examples. Some have shrunken to the size of their deeper depressions as in the case of Lake Winnipeg, a remnant of the former Lake Agassiz. Other lakes occupy portions of the old, abandoned channels of ancient streams. Many of the present day lakes occupy depressions in the drift and have become the receptacle for the drainage of adjoining high land. Some are spring fed. Grassy Island Lake and Lake Newell are examples of these although the latter now receives most of its supply from irrigation canals.

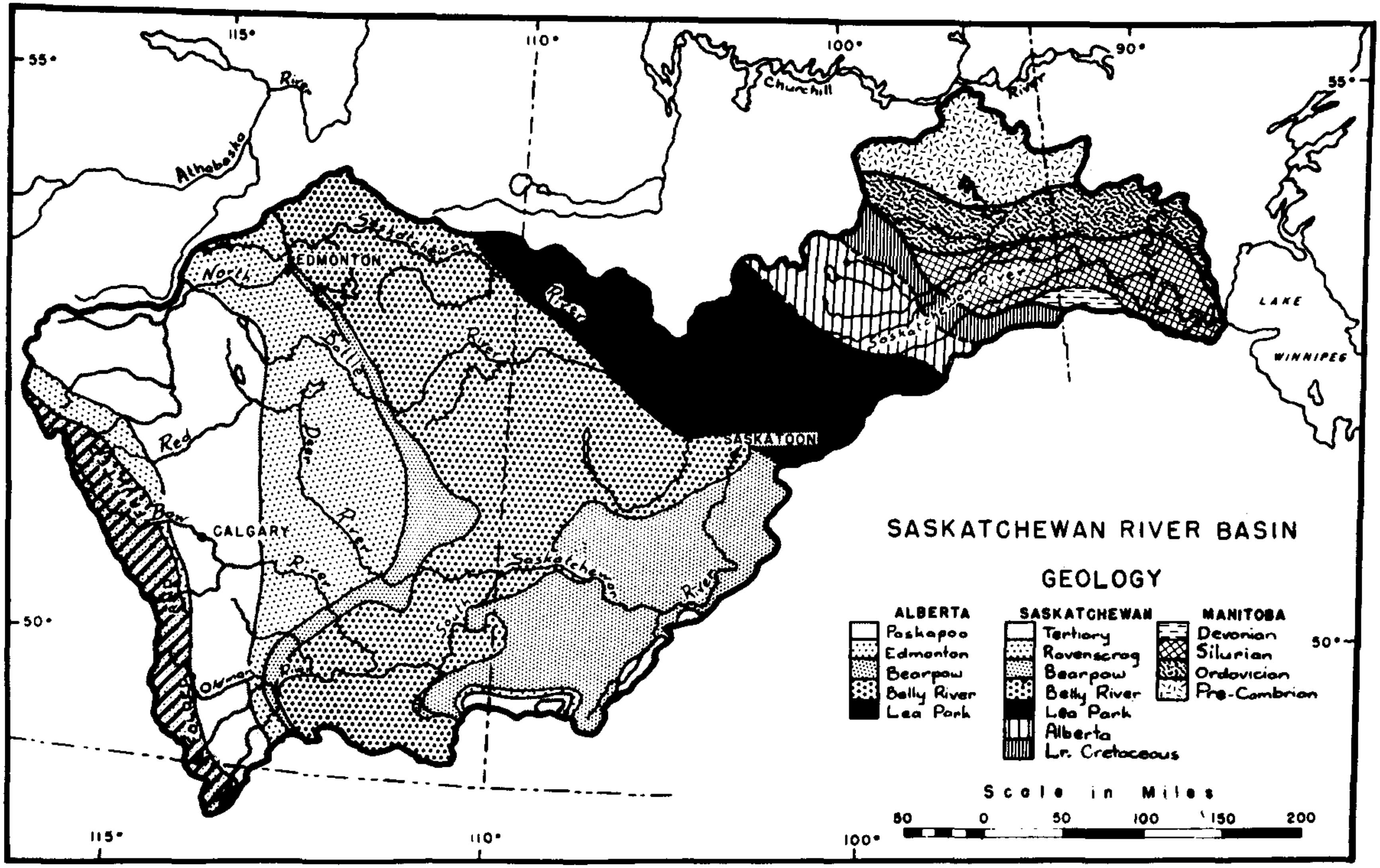
Evidence of an inter and post-glacial drainage system is to be found in the coulees which traverse portions of the basin in intricate patterns. They provide a unique topographic feature with their broad, flat-bottomed valleys, steep sides and truncated spurs. The valleys have all the features of late maturity but the interfluves still retain the convexity of youth. The valleys are shallow. Downcutting through the older tills to bedrock had not advanced very far before the source of water supply was reduced. Today they remain as dry valleys or valleys which carry, for part of their lengths, the small flow of the prairie streams. Fortymile Coulee in southern Alberta is one of these. It

> leaves the valley of the South Saskatchewan River north of Burdett as a depression between three and four miles wide. Three miles south of Burdett it contracts to one mile in width and one and one-half miles further south it is joined by a narrow valley from the west, with a marshybottom ... Chin and Fortymile Coulees curve eastward below this junction and finally bend northward forming Seven-persons Coulee. This is a valley more than one-half mile in width becoming shallower to where it widens out 12 miles southwest of Seven-persons town, continuing as a wide shallow valley to Medicine Hat.1/

The present drainage systems of the Saskatchewan river basin are still badly disorganized. They reflect the various geologic influences in the history of the basin. The main river flows in an easterly direction and is consequent upon the slope of the land towards Lake Winnipeg. Discrepancies, however, do arise. Where the North Saskatchewan River crosses the western limit of Laurentide moraines, it swings sharply northwest. Warren suggests that the northwest trending channel was probably produced by escaping meltwater from the large Clearwater glacial lake.2/ As the drainage re-established itself, the North Saskatchewan made use of this channel in forming its course. The river is later turned

1/ Williams, M.Y. and W.S. Dyer, "Geology of Southern Alberta and Southwestern Saskatchewan," Memoir 163, Department of Mines, Ottawa pp.107-108

2/ Warren, P.W., "The Drainage Pattern of Alberta," Transactions of the Royal Canadian Institute, Volume 25, 1944, p.10.



SASKATCHEWAN RIVER BASIN
GEOLOGY
ALBERTA
Paskapoo
Edmonton
Bearpaw
Belly River
Lea Park
SASKATCHEWAN
Tertiary
Ravenscrag
Bearpaw
Belly River
Lea Park
Alberta
Lr. Cretaceous
MANITOBA
Devonian
Silurian
Ordovician
Pre-Cambrian
Scale in Miles
50
0
50
100
150
200
EDMONTON
CALGARY
SASKATOON
LAKE
WINNIPEG
Churchill
River
Athabaska
North
Saskatchewan
River
Red
Deer
River
Battle
Oldman
Bow
115°
110°
100°
90°
55°
50°

from its northeast course by the Viking moraine. Moraines bordering the lower course would indicate a similar influence. Over the Third Prairie Plain the North Saskatchewan river flows in a narrow lower valley flanked by a broad and steep-sided upper valley. After cutting through the hills of the Coteau, the upper valley drops considerably until, near its junction with the South Saskatchewan, the valley sides become rolling, convex slopes. The course of the South Saskatchewan, generally consequent, was deflected by morainic barriers. This is seen where it turns north after traversing the Missouri Coteau. On the Alberta Plain, the South Saskatchewan is generally a youthful river. It flows in a steep-sided gorge which, at Medicine Hat, is 250 feet deep. Thirty-five miles east, the depth increases to 500 feet. This section is considered by Williams to be a re-exaavated preglacial channel.1/

Several influences control the direction of the tributaries of both the North and the South Saskatchewan. These have been discussed by Warren.2/ A physiographic control of stream pattern predominates in the mountains and in the vicinity of the residual hills. The main streams emerge from the foothills in wide valleys with well developed subsequent tributaries. These tributaries indicate a local structural control.

On the prairies, streams seldom expose the underlying rock so structure has little influence on stream patterns. In the Red Deer basin the smaller tributaries and a portion of the main stream between Drumheller and Yardley show the influence of a structural control. They align themselves along the longitudinal folds, flexures of the Rocky Mountain orogeny . Beyond Drumheller, the influence of structure ceases and consequent stream development is followed.

Glacial features exercise considerable control on stream patterns. Moraines turn tributaries from general consequent directions to flow north-south instead of in the usual east-west direction. Near the mountains and over limited sections of the plains, streams occupy pre-glacial channels. The course of the Bow River is largely preglacial. Like the upper course of the North Saskatchewan, the Red Deer, Oldman, and the Bow cut across the general line of uplift and are antecedent to that uplift. They became re-established in these courses in post-glacial times.

For sections of their valleys, many modern streams occupy parts of the old coulees. Battle River, for example, is a small stream occupying a very wide valley. Streams like the Dogpound, Sevenpersons Creek, and Fortymile Creek look grotesquely small where their courses follow through the wide coulees.

In the Saskatchewan section of the basin, similar features are seen. Steep-sided arroyos, separated by extensive interfluve areas, result in a coarse dissection pattern. Apart from the South Saskatchewan river, permanent streams are few. Interior drainage predominates.

1/ Williams, M.Y., op. cit., p.78.
2/ Warren, P.W., op. cit., pp.3-14.

Between the Saskatchewan boundary and Lake Winnipeg the delta area is located. "In only rare instances are there a promontory that rises more than a few feet above the level of the surrounding lands."1/ The pond areas of the delta is separated from the Saskatchewan Plain by the Tobin Rapids. The river channel through the delta is very unstable, and evidence of numerous former channels is prevalent over the plains. At present the main channel empties into Cumberland Lake which is rapidly silting up. The Bigstone cutoff and Tearing River, both containing rapids, are outlets from Cumberland Lake. From where these join the old channel of the Saskatchewan River to The Pas, the river is broad, deep, and meandering. The low, flat land is broken up by only a few ridges of boulder clay. Of these, the most prominent are located where the river cuts through at the Barriere below Tearing River and again at The Pas. In certain sections, the river is held to its course between levees. Generally it is sluggish and much of the water is temporarily lost to the numerous backwaters and lakes adjacent to the main stream.

C. The Vegetation and Soils of the Saskatchewan River Basin

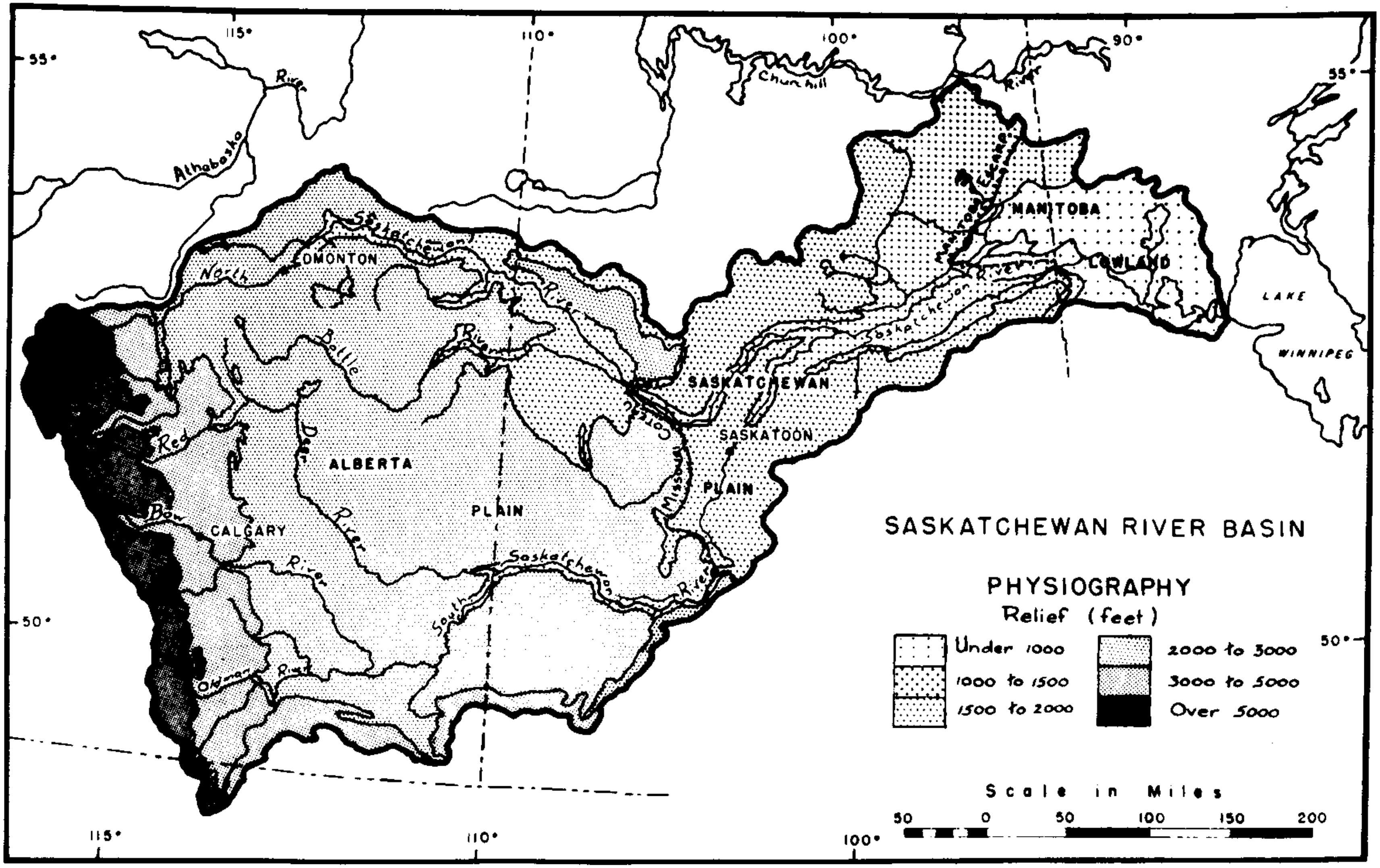
The vegetation.–2/ Major differences in natural vegetation throughout the basin are a reflection of climatic differences. Coniferous forests predominate in the mountain section where precipitation is higher and temperatures, because of altitude, are lower. Grove or bluffs of trees alternate with areas of grass in the Parkland Belt.3/ This occupies the northern portion of the basin and is roughly coincident with the North Saskatchewan tributary basin. Rainfall is between 15 and 20 inches, and temperatures are generally cooler than in the south. The southern portion of the basin is characterized by grassland vegetation. Precipitation decreases from about 15 inches around the grassland periphery to about ten inches in the heart of the Palliser Triangle. Grassland deteriorates from a luxuriant tall-grass prairie to an open stand of short-grass steppe. In the east, the Saskatchewan River flows through an area dotted with lakes and muskeg. Where these are not present, forest predominates. Temperatures in this eastern region are lower, and precipitation higher than in the west.

Within these broad groupings of plant formations, associations persist under favorable local conditions. Areas of grassland extend into the foothills and have resisted the encroachment of forest vegetation. Grassland is interspersed among the coniferous forest species of the northwest and appears to be a relic of more xeric conditions. In the parkland, bluffs which are usually dominated by poplar, may also contain spruces and tamarack in wetter sites. The conifers may be relics of a moister period and have persisted under favorable conditions. Although prairies are characteristic of the drier, southern portion of the basin, forest species are often a characteristic of the moister, north-facing slopes of the deeply incised rivers.

1/ Attwood, C.H., The Water Resources of Manitoba, Manitoba Economic Survey Board, Winnipeg, 1938, p.52.

2/ For further details regarding vegetation see the section below headed "Hydrologic Regions within the Saskatchewan River Basin."

3/ The term "bluff" appears to be local, referring to the small patches of woodland appearing in an otherwise grassland area and usually occupying the rough land or the depressions.



SASKATCHEWAN RIVER BASIN
PHYSIOGRAPHY
Relief (feet)
Under 1000
1000 to 1500
1500 to 2000
2000 to 3000
3000 to 5000
Over 5000
Scale in Miles
50 0 50 100 150 200
ALBERTA
PLAIN
SASKATCHEWAN
SASKATOON
PLAIN
MANITOBA
LOWLAND
CALGARY
EDMONTON
LAKE
WINNIPEG
Athabaska
River
Churchill
North
Saskatchewan
River
Battle
River
Red
Deer
River
Bow
River
Oldman
River
South
Saskatchewan
River
Saskatchewan
Missouri
Coteau
115°
110°
100°
90°
55°
50°

They are also found in the coulees, adjacent to the streams where the water table is much higher. In order that the distribution of species in the present plant communities may be more fully understood, some knowledge of the environmental history of the basin is required.

The outstanding events influencing the present forest composition were the advances and retreats of the Cordilleran and Laurentide ice sheets. As the Wisconsin, or final advance began, "there is reason to believe that the bulk of the tree vegetation was destroyed and was not forced south by the ice."1/ Continual re-establishment of species as the ice advanced south, would not be rapid enough and the winds of decreasing relative humidity from the anticyclones over the glaciers would still further discourage rapid plant retreat. In spite of these factors refugia were established, areas where the more fortunate species, after migrating, were able to persist along with those already established there. Within the basin, refugia may have been established either on the higher residual blocks or in the inter-lobate areas. Lodgepole pine (Pinus contorta var. latifolia), and associated species are characteristic of the north-facing slopes of the Cypress Hills. They form an ecological outlier from the main region within the Rockies, one that may have survived the various ice advances. Definite refugia were established to the northwest and south of the basin. The boreal refugia were located around the Bering Sea with an extension into the Yukon. Both would contain certain rigid species, permanent fixtures in these regions while other, more plastic species, would advance south and east with the advent of more favorable conditions. Spruces and tamarack (Larix laricina) would be characteristic species from the first center, trembling aspen (Populus tremuloides), white birch (Betula Papyrifera), lodgepole and pine and alpine fir (Abies lasiocarpa) from the second. Typical west coast species were associated with a southern extension from the present Bering Sea area.

What Halliday and Brown call the Western refugia was "situated beyond the former Cretaceous depression of the center of the continent and centered on the Cordilleran land mass."2/ As the ice melted, various plastic species advanced into the present Saskatchewan River Basin from this location. In migrating from both refugia, species encountered temporary, but significant barriers, in the form of the post-glacial lakes across the region. The migration of white spruce (Picea glauca), was channelled along certain lines by the intervening lakes. Bog pollens tell the story of advance of the boreal forest from the south. Such species as white spruce, black spruce (Picea mariana), balsam fir (abies balsamea), and jack pine (Pinus Bankisiana) were associated with the first advance. There is considerable evidence to support the observation that a xeric period followed this first advance, as species associated with warmer and drier conditions have left pollen grains above those of the first advance. Remnants of a more extensive grassland vegetation are found in the northwestern portion of the basin. There was a swing back to cooler and moister conditions later which resulted in a re-invasion of some of the northern bogs and associated with them, spruce and fir.

In the eastern portion of the basin some species, such as eastern white cedar (Thuja occidentalis), white elm (Ulmus americana), green ash

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1/ Halliday, W.E.D. and A.W.A. Brown, "The Distribution of Some Important Forest Trees in Canada," Ecology, Volume 24, 1943, p.355.

2/ Halliday, W.E.D. and A.W.A. Brown, op.cit., p.355.

(Fraximus pennsylvanica var. lanceolata), and mountain maple (acer spicatum), migrated from the Appalachian refugia to this region. Those which are able to withstand the colder winters of the northern portion of the basin are still migrating west and north while others, like the burr oak (Quercus macrocarpa), are limited to the eastern portion of the basin.

It is considered that the forest regions "are now possibly somewhat in the same positions as they were immediately preceding the oncoming of the Wisconsin."1/ Glaciation has considerably modified the composition of the vegetation. Many species have been eliminated so that today the vegetation of the basin is comparatively simple. It is composed of a limited number of species. In the climax forest association white spruce is considered as the dominant species. Trembling aspen is the dominant species in the parkland and is found associated with balsam poplar (Populus balsamifera). On the prairies, needlegrass (Stipa sp.) and grama grass (Bouteloua sp.) have the most extensive development.

The soils.- The soils of the Saskatchewan River Basin fall into three broad groups. Mountain soils, reflecting all the complexities of mountain regions, are characteristic of the western part of the basin. They have been studied in the Kananaskis River area.2/ Climate and the nature of the forest vegetation should result in the domination of podzolization but well developed profiles are difficult to find. Unconsolidated surface deposits are of recent origin and include glacial till, transported deposits of alluvial and lacustrine origin, and residual and sorted residual deposits. In the lowland or valley bottom soils, there is evidence of new lacustrine materials deposited over previously well developed soil profiles.

Most of the soil in the area studied was developed over limestone and this has a higher humus content than adjacent soils derived from grantie or sandstone, but podzolization has advanced further on the latter soils as they were less resistant to leaching. Soil textures are fine but the drainage is usually adequate. It is observed that there is little or no pan development to inhibit water movement through the profile, and the rocky, porous nature of the glacial till permits the maximum water infiltration. The soils are ideal for water storage. The following profile types have been identified within the area: (1) Alluvium, (2) Chernozem, (3) Rendzina, (4) Brown Forest, (5) Podzols brown grey.3/ There is no evidence of profile development in the alluvium.

A preliminary study of the soils of the upper Ghost and Red Deer rivers has been made. Classification into the following categories is based on the nature of the parent rock material:

1. Bare rock and rocky alpine soils.
2. Residual soils with some profile development. In these soils infiltration capacities are moderately high.

1/ Halliday, W.E.D., "Climate, Soils and Forests of Canada", Forestry Chronicle, Volume 26, 1950, p.292.

2/ Crossley, D.I., "The Soils of the Kananaskis Forest Experiment Station in the Sub-alpine Forest Region of Alberta," Silvicultural Research Note Number 100, Ottawa, 1951.

3/ Ibid., p.9.

(3) Coluvial soils. Detention storage in these is high.

(4) Glacial soils other than glacio-fluvial. The great depth, high water retention and storage capacities of these soils make them valuable for watershed management.

(5) Alluvial and glacio-fluvial soils. The infiltration and storage of these soils vary with the texture.

(6) Bog and marshland soils. These are of little use for retention and do not play any part in regimen improvement.

The mature prairie soils reflect a response to climate and vegetation and may be grouped broadly as soils developed under forest cover, occupying the northern and extreme eastern part of the basin, and soils developed under grassland and occupying the remaining part of the basin. The prairie soils include the brown soils (Chestnut) occupying the transition area are to the north and west of the Triangle. North of these lie the black soils (Chernozem), of the Parkland. The forest soils consist of degraded black, occupying a transition zone to the grey soils (Podzols) along the northern boundary of the basin and coincident with the increase of conifers to the west. Grey soils, interspersed with peat soils, are a characteristic of the western portion of the prairies and the northeastern portion of the basin. Wooded Calcareous soils dominate in the Delta region.

Local variations in climate and vegetation introduce regional variations in the prevailing profiles.

> The most arid section of the Brown soil Zone is represented by local areas of Grey-Brown soils; transition areas of mixed Brown-Dark Brown and Dark Brown-Black soils occur along the northern borders of the main Zones of Brown and Dark Brown soils respectively; climatic differences within the Black Soil belt have been recognized by the areas of Thin Black and Thick Black soils on the basis of the differences in the average thickness of the A horizons. Finally, local elevations in all zones produce a succession of soil profiles representing vertical zonation.1/

The soils of the plains are also modified in terms of the materials of their origin. Soils have developed on the three types of unconsolidated materials, residual, transported, and resorted or mixed. Residual soils, formed from the weathering and decay of underlying rocks, are common throughout the basin. In Alberta " they are formed from softer shale formations, often of marine origin, containing soluble mineral impurities like alkalies or alum".2/ Transported soils consist of rock debris

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1/ Mitchell, J. and H.C. Moss, "The Soils of the Canadian Section of the Great Plains," Proceedings, Soil Science Society of America, 1948, Volume 13, 1949. p.434.

2/ Allan, J.A., "Geology of Alberta Soils," Report Number 34, Research Council of Alberta, 1943, p.64.

transported mainly by ice. That from the pre-Cambrian Shield reached Alberta from the northeast and consists mainly of debris from pre-Cambrian rocks, many of them high in potash, magnesia and alumina. The debris left by the Cordilleran ice sheet consists largely of rock from the mountains where limestones and dolomites predominate. Hence the soils of Alberta differ particularly in mineral composition, according to the source of the debris. Rivers moved the finer rock materials down the surface slopes from west to east. Soils developed on alluvial materials are widespread, especially on flats adjacent to the rivers and in the lower Saskatchewan section. Loessal cappings to various types of soil profile are of local occurrence. Resorted or mixed soils are widely distributed but are often difficult to distinguish from the older glacial or alluvial soils.

Brown, dark brown and black soils are best developed on medium-textured glacial till, and lacustrine-alluvial deposits on well-drained, gently-sloping, upland sites. The structure is generally prismatic. In lower and flatter localities solonetz profiles occur. In an extreme form these develop into sterile "slick spots" or "blow outs". Soils of the glacial lake beds in Saskatchewan are developed in uniform heavy clay deposits and have a cloddy, granular structure. Their recent origin may be a factor accounting for the poor profile and structure development.

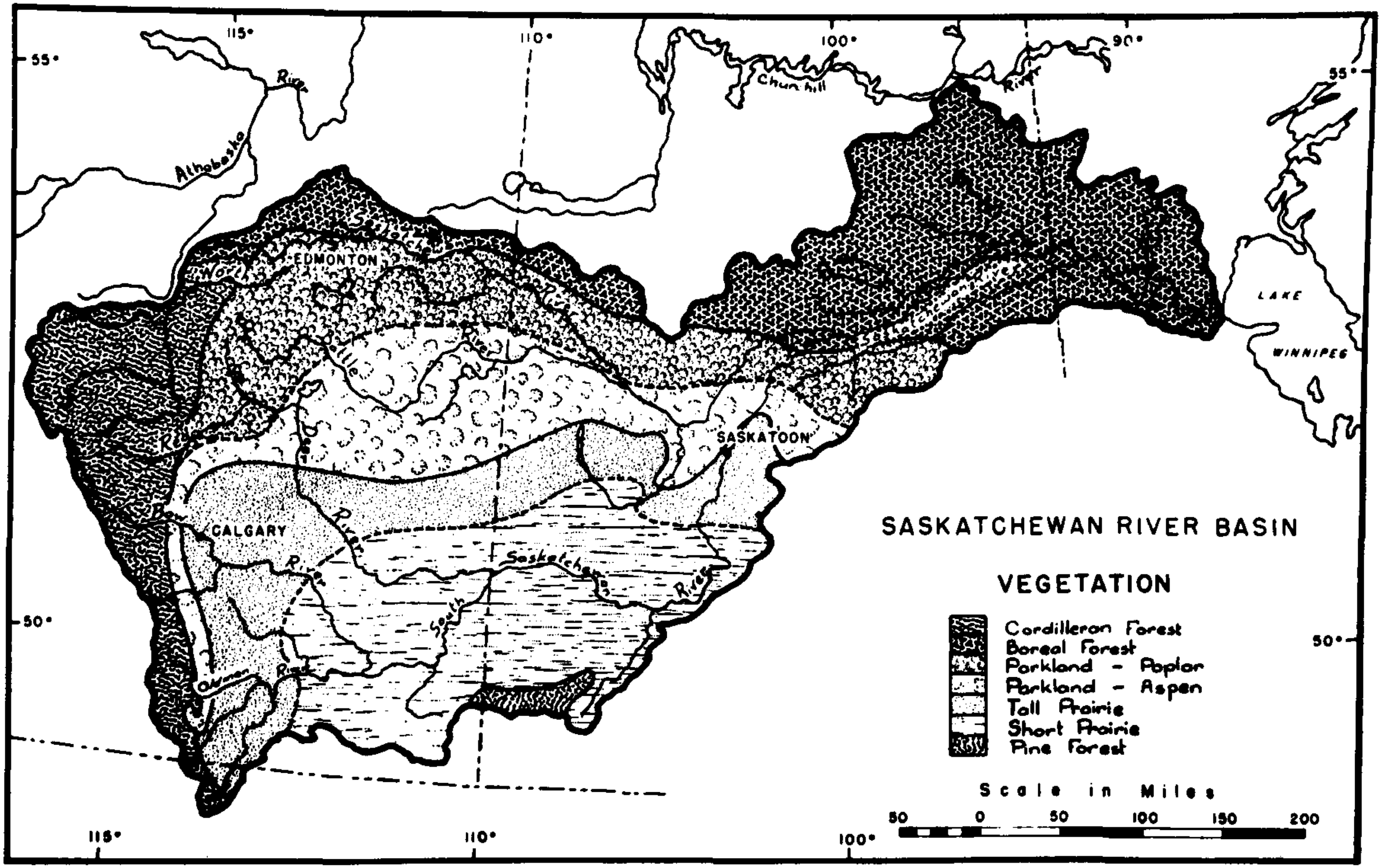
Degraded black soils appear to represent former black soil profiles of grasslands that have been under woodland for a sufficient period to show some stages of podzolic development. The grey wooded soils are characterized by leached, ashy grey A_2 horizons and heavy textured illuviated B horizons. Associated with flat to depressional topograhy, poor drainage and usually wet soil conditions are some intrazonal soils like the peat podzol, the meadow, and the peat soils.

D. Hydrologic Regions within the Saskatchewan River Basin

General.- The Saskatchewan River basin is subdivided into a number of hydrologic regions based on major groupings of the various tributary basins.1/ Some smaller and inland drainage basins have also been delineated. Describing some of these river catchment areas as "basins" is a misnomer. Few of the tributary areas could be visualized as basins from a physiographic point of view. Instead, they represent great undulating areas rising imperceptibly to indistinct water partings. Catchment boundaries are transition areas from one drainage system to another, and the direction of runoff is often adventitious. The term "basin", however, is a convenient one and is used with a realization of its limitations.

The North Saskatchewan river basin.- The basin extends from the continental divide of the Rocky Mountains to the confluence of the North and South Saskatchewan rivers at The Forks. The major phsiographic regions are included within its boundaries. The mountains, noted for their diversity of glaciated scenery, form the upper catchment of the basin. The foothills

1/ The subdivision is a standard one, obtained from the Hydrology Division, Prairie Farm Rehabilitation Administration, Regina, Saskatchewan.


SASKATCHEWAN RIVER BASIN
VEGETATION
Cordilleran Forest
Boreal Forest
Parkland - Poplar
Parkland - Aspen
Tall Prairie
Short Prairie
Pine Forest
Scale in Miles
50
0
50
100
150
200
EDMONTON
CALGARY
SASKATOON
LAKE
WINNIPEG
Athabaska
River
Churchill
Saskatchewan
River
South
115°
110°
100°
90°
55°
50°

have a maximum relief of 2,000 feet and a local relief that ranges from 500 feet to 1,300 feet. Long strike ridges, formed on resistant sandstones of the Cardium and Brazeau formations, are broken by transverse valleys. The North Saskatchewan river follows an antecedent course across these. Subsequent tributaries, developed along the strike of softer shale, enter the main rivers at right angles. "In many localities, where the geology is complicated by low dipping fault planes, the topographic expression is likewise more complex. Single ridges give way to multiple ridges, and straight ridges to arcuate ridges."1/ The major portion of the catchment is on the Alberta and Saskatchewan plains, those of the Third and Second Prairie levels, respectively. Surface features are associated with the aggradational forms of glaciation. Recessional moraines, rising 200 or 300 feet above the plain surface, form the only noticeable relief feature. In western Saskatchewan the Missouri Coteau, at right angles to the general basin trend, is a prominent relief feature. The Coteau, in the north, is not as high as it is to the south, nor do the long, low ridges rise abruptly from the plains. Nevertheless, it still represents a significant break in the plains' topography.

On the Alberta Plain, the major streams occupy well defined valleys, which usually consist of two parts. The lower valley is comparatively recent, and rises 100 to 200 feet above the stream bed. The upper part slopes gently back towards the water divide of the interstream area. The course of the North Saskatchewan river immediately to the west of Edmonton has been described as follows:

> From Berrymoor ferry east, the lower part of the Saskatchewan valley is, on the average, wider than it is to the southwest. There are numerous large islands in the stream course and the broad river terraces are common along the bottom of the valley. The stream channel frequently changes its course through these broad, low terraces. The meanders of the stream channel are more abrupt than those in the valley, which averages one to two miles in width.2/

On the Saskatchewan Plain the river flows between low banks from which the land shelves back to the divide. There is no longer a steep-sided inner valley. The Battle river occupies a large tributary basin to the south. For much of its course it flows through a series of coulees. The valley sides are steep and the valley floor flat and wide.

The vegetation of the North Saskatchewan Basin is predominantly that of parkland. Boreal forest is found in the western prairies and mountains. At higher levels, Engelmann spruce (Picea Engelmanni), grows in pure or mixed stands. Its best growth is made on deep, rich, loamy soils with a high moisture content. Lodgepole pine and alpine fir

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1/ Scott, J.C., "Folded Faults in the Rocky Mountain Foothills of Alberta, Canada,", Bulletin of the American Association of Petroleum Geologists, Volume 35, 1951, p.2319.

2/ Rutherford, R.L., "Geology of the Area Between the North Saskatchewan and McLeod Rivers, Alberta," Geological Survey Division, Report Number 19 Scientific and Industrial Research, 1928, p.67.

(Abies Losiocarpa), are often associated with the spruce or themselves form pure and mixed stands. Alpine fir grows as a stunted shrub at very high altitudes.

In the foothills and on the western plains, conifers occupy the more favorable locations. White spruce replaces Engelmann on the better drained land. Black spruce and tamarack take possession of the poorly drained sites.

Beyond the forest lies the parkland. Some would regard this as a climax assocation while others consider it as a transition from prairie to boreal forest. Two characteristic northern trees are present, white spruce and black spruce, the former being well established along ravines, the latter on muskeg. It is reasonable to regard the parkland as a transition belt "where slight differences in soil, climate and topography have allowed grassland to become invaded by northern vegetation, these special conditions giving preference to trembling aspen and members of the willow family, and where conditions offer a suitable habitat, by two characteristic trees of the northern forest."1/

Three associations are characteristic of the parkland. The "normal poplar" stand consists of dense clumps of aspen with which may be associated other light demanding species such as white birch, pin cherry (Prunus pennsylvanica), and balsam poplar. The "open poplar" association is common on sandy or gravelly soils. The poplars are widely spaced, short, and branching. Willows (Salix Bebbiana), are often a secondary species. The third type is the "poplar-spruce" association which may be regarded as a climax and is developed where the spruce has sufficient protection from fire. The poplar association has five well defined layers.

1. Tall trees with a continuous canopy.
2. Smaller trees and larger shrubs - an intermittent layer that shows poorer development in the aspen consociation.
3. A lower shrub which is usually inconspicuous except in the late summer as it is somewhat obscured by members of the next layer.
4. Taller herbs form a continuous stratum, and are prominent in the latter part of the growing season.
5. Lower herbs which consist mainly of mosses and lichens.2/

Ecotone areas lie about the northern and southern boundaries of the North Saskatchewan basin. In the south, aspen tends to invade and succeed

1/ Lewis, Francis J., Eleanor S. Dowding, and E.H. Moss, "The Vegetation of Alberta, II The Swamp, Moor and Bog Forest Vegetation of Central Alberta", Journal of Ecology, Volume 61, 1928, p.23.

2/ Moss, E.H., "The Poplar Association and Related Vegetation of Central Alberta", Journal of Ecology, Volume 20, 1932, p.398.

prairie. White spruce is more prominent in the north. Grasses occupy the area between the bluffs and form a closely knit mat. The most common of these are awned wheat grass (Agropyron subsecundum), slender wheat grass (Agropyron pauciflorum), fringed bromegrass (Bromus Ciliatus), and marsh reedgrass (Calamagrostis canadensis). Special vegetation types are associated with abnormal habitats. Muskeg fringes numerous small lakes. Moss and some conifers grow on some peat areas and are so similar to muskeg that peat-bog and muskeg are almost synonomous terms.1/ The areas are very noticeable as the contrast between parkland trees and those of the muskeg are very great. The transition zone is often only a few feet. The reed swamp and the low moors of the parkland are other special types. Reed swamps occur next to the water and are surrounded by low moor, the two types frequently merging.

All the soil zones except in the brown prairie soil zone are represented in the North Saskatchewan basin. The grey wooded soil is a characteristic of the coniferous forest of the mountains and the western plains. The surface horizon consists of a semi-decomposed leaf mould layer, a thin A_1 horizon and a severely leached and platy A_2 which has a depth of six to eight inches. The B horizons are heavier textured, compact and darker in color than the A horizon. A transition zone across the northern part of the basin corresponds to the vegetation ecotone where spruce is much more prevalent. Black prairie soils are located in the heart of the basin. These soils characterize the true parkland region. The normal profile has a black to a very dark brown A horizon that averages 12 to about 14 inches in depth. The more compact B horizon is brown to dark brown. A shallow black soil zone lies across the southern part of the basin and is succeeded by a dark brown zone. Although this area is called the short grass region, the growth is dense and taller grasses are found. The A horizon is about seven inches in depth and is dark brown in color. The B horizon is heavier and is more compact than the A. Farm practices and lumbering have modified the vegetation and soil patterns. Grain growing predominates but usually as part of a mixed farming economy. Lumbering has made inroads in the western coniferous forests of the plains.

The South Saskatchewan river basin.- This tributary basin includes the headwater basins of the Red Deer, Bow, Oldman and St. Mary rivers. It stretches from the main divide of the Rockies to The Forks. For some distance toward the east, the northern boundary of the basin coincides with that of the North Saskatchewan river. In eastern Alberta and western Saskatchewan a series of inland drainage basins later separates the two. The largest of these inland areas from west to east are the basins of Sullivan Lake, and Manito Lake. Physiographically there is little to distinguish the inland drainage areas from the basins to the north and south. The land surface is undulating, the moraines alternating with drift or glacio-fluvial lowlands. An area within the Manito basin has been described as follows:

The general effect of glaciation has been to

1/ Lewis, F.J. and E.A. Dowding, "The Vegetation and Retrogressive Changes of Peat Areas ("Muskegs") in Central Alberta", Journal of Ecology, Volume 14, 1926, p.317.

level the lowest areas and leave a wide plain. This plain is by no means uniformly level however, as it varies considerably in elevation, and it is cut up by many drainage channels consisting of coulees... a good deal of the plain is rolling in nature and in some parts it is quite hilly ... formed by glacial deposits and post glacial erosion...1/

Prairie vegetation predominates in the inland drainage region. It is a short grass vegetation which is almost devoid of trees except for those which fringe some of the rivers and lakes.

Soils consist of both dark brown and brown soils. Grain growing is the most important farming activity in the western part, but as precipitation decreases toward the east, it is replaced by ranching.

The basins of the Red Deer, the Bow, Oldman and the St. Mary head high in the Rockies. Mountain, foothill, and plain are crossed before the rivers flow into the South Saskatchewan. This traverses the hillier country of the Coteau then flows north on the Saskatchewan plain. The alpine portion of the basin is similar to that of the North Saskatchewan river. Features of glacial erosion predominate , valley sides are steep, valley floors are littered with much glacial debris. Stratified deposits of valley train material are common on the valley floors, whereas lenses of finer sands are varved clays suggest further fluvial and lacustrine action. The main divide is much lower about the head of the Crowsnest River, a tributary of the Oldman.

Foothills, consisting of alternating hard and soft bands of Cretaceous sediments, are much more porminent in the northern part of the basin than in the south. The Red Deer traverses a large trough before entering the ridge and valley section of the foothills.2/ Glacial materials floor the trough and the valleys which run through the foothills. Into these the Red Deer has cut terraces.

Where the Bow river traverses the foothills between the Kananaskis river junction and Cochrane, three elements in the relief may be observed. The higher areas are broken into several ridges which frequently extend for a considerable distance northwest or southeast from the respective sides of the Bow valley. Broad river or river-lake terraces occupy the lower parts of the valley. These terraces were probably formed when the Bow River was dammed at various times during glacial retreat. Morainal material, 25 to 50 feet high stand as islands in the terraces. Several small streams disappear on reaching these terraces because of the porous nature of the material. The Third Level is that cut into the terraces by the present Bow river. The Bow valley itself is probably preglacial.

From the St. Mary to the Oldman river there is an absence of foothills owing to the effective erosion of the Lewis overthrust. This

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1/ Wyatt, F.A. and J.D. Newton, Soil Survey of the Sounding Creek Sheet, The College of Agriculture, University of Alberta, Edmonton, Alberta, p.2, 1927.

2/ The trough has the appearance of a great graben and a tectonic origin has been suggested. Faulting in the region has been observed.

erosion in the eastern part of the overthrust block, in addition to producing its cremulated edge, has left several isolated remnants east of the main mass of the mountains. Chief Mountain is perhaps the best known of these. From the main mountain ranges, streams flow to the plains with but few interruptions.

The Red Deer, the Bow, and the Oldman rivers cross a portion of the Alberta Plain to join the South Saskatchewan River. The Red Deer enters the drift region with but little change in direction. The valley is wide and the banks are low until the town of Red Deer is reached. The valley is preglacial and is little, if at all, entrenched in the oldland. Just north of Red Deer the river swings to the southeast and enters a much more confined valley with high banks and continuous exposures. For the most of its lower course, the Red Deer flows in a gorge the sides of which get higher as the river traverses first, the residual area of the Wintering and then the Hand Hills. Badland topography is a characteristic of the sides. Valleys of tributaries descend 250 to 300 feet to the Red Deer. The steep walls of the inner valley rise from a broad floor of outwash debris which, in many areas, is half a mile wide. The Red Deer has entrenched itself 15 or 20 feet in an older flodplain and outwash deposits of clay, sand and gravel are a common occurrence. The upland is of rolling moraines and till and is capped by yellowish, silt clays which reach a maximum thickness of 75 feet. Residual hills rise above the glacial depositions.

The Bow river enters the high plains to the west of Calgary. The physiographic history of the lower Bow is complex. Advances and retreats of both Cordilleran and Laurentide ice, and prolonged inter-glacial periods all tend to complicate the picture. Its lower course is similar to that of the Red Deer river although topographical differences between upland and river level are not as great.

The Oldman River from the west and the St. Mary from the southwest join near Lethbridge to flow east into the South Saskatchewan river. Postglacial dissection is limited to the major streams in their cutting of major trenches. The steep-walled valleys are clearly developed on a mature land surface. Generally speaking the upland consists of a rolling plateau sloping northeastwards from the foothills of the Rocky Mountains and dissected by rather intricate stream systems. The glacial topography, although modified by lacustrine deposition, is recognizable in both end moraine and ground moraine areas.

> Moraine knolls are sharply defined in all the areas of end moraines and can be found at elevations up to 400 feet in the Porcupine Hills. Southwest of the area, moraine forms, unmodified by lacustrine deposition, are characterized by steepsided knobs, ridges and basins with hundreds of lakes and ponds. The initial glacial forms are essentially unmodified over wide area ...1/

The South Saskatchewan river flows east through the hilly country as it approaches the Coteau. Irregularities are probably due to erosion,

1/ Horberg, Leland, "Pleistocene Drift Sheets in the Lethbridge Region, Alberta, Canada", Journal of Geology, Volume 60, 1952, p.313.

following the uplift of the Sweetgrass Arch. Moraines in the vicinity of the Coteau tend to accentuate the relief. At Medicine Hat the South Saskatchewan river is 250 feet below the upland surface. Thrity-five miles below the city, the depth increases to 500 feet. The river is inset about ten feet in the floor of this great gorge. The valley sides consist of Bearpaw shales and are often characterized by badlands surfaces.

South of the river in Alberta, is an area of residual swells and a great number of coulees. Shallow alkaline lakes and dry coulees mark the drainage systems of the period at the end of the Pleistocene. Southern Saskatchewan is mainly flat or undulating, sloping towards the northeast. The area consists of a series of morainic ridges deposited along the edge of the till sheets. Intermorainic tracts of rolling till plain and level lacustrine areas separate these. The Great Sandhills Lake must have occupied the area between the Cypress Hills and the river. This now consists of an extensive area of sand dunes.

After the river crosses the Coteau, if flows north. The banks gradually become lower and, beyond Saskatoon, they are little more than low, sandy ridges. Moraines account for irregularities in a flat land surface and are particularly prominent south of Prince Albert.

Coniferous forest, parkland and prairie are all found in the basin of the South Saskatchewan river. Confierous forest is limited to the mountain area. Species increase in variety from north to south. Spruce and lodgepole pine still dominate the forest types. Several zones of vegetation have been recognized in the forests of Glacier National Park, Montana.1/ The lowest zone is a transition one represented in the lower foothills of the eastern slopes. Trembling aspen predominates but often the band is narrow, grasses extend to the mountain edge, and aspen form a galeria vegetation along the waterways. Fingers of broadleaf trees extend up the valleys of the coniferous forest areas. The next highest and largest is the Canadian Zone which includes most of the forested area of the park except the narrow belt just below the barren, rocky peaks. There is considerable overlapping but spruce, lodgepole pine and alpine larch (Larix lyalli) are the dominant species. Just below the timberline is a very narrow belt, the Hudsonian Zone, usually recognized by the strictly alpine types of vegetation. Alpine larch, alpine fir (Abies lasiocarpa), and whitebark pine (Pinus albicaulis) are characteristic. It is the region of gnarled trees, the whitebark pine being described as a stunted, much branched tree, often reduced to a sprawling shrub growing close to the ground. Alpine meadows are interspersed with trees and serve as a transition to the next zone, the Arctic-Alpine Zone which extends from timberline to the tops of the highest peaks. Vegetation is dwarfed and stunted and must resist the prolonged periods of cold and the high wind. There are no trees in the zone, but there are several dwarfed shrubs like the willow and the birch.

The vegetation of the plains section of the South Saskatchewan basin has been described as a mixed prairie.2/ It extends from the base of the

1/ Robinson, Donald H., "Trees and Forest of Glacier National Park," Special Bulletin Number 4, Glacier Natural History Association, Inc., West Glacier, Mont., 1950, pp.4-5.

2/ Coupland, Robert T., "The Ecology of the Mixed Prairie in Canada," Ecological Monographs, Volume 20, 1950, p.273.

foothills beyond the eastern extension of the basin. Three main types are found within the mixed prairie.1/ (1) The submontane mixed prairie dominates the vegetation in regions below the lodgepole pine forests and in certain areas near the outer margin of the mixed prairies. Rough fescue (Festuca scabrella) is the dominant grass in a fescue-oatgrass (Danthonia) association. Aspen, rose (Rosa acicularis) and willow are common along coulees and north-facing slopes. Pines form an ecotone between the grassland and the forest. The Submontane Mixed Prairie is at an elevation where summers are too short to permit grain growing, hence ranching predominates as the main land use.

(2) The Mixed Prairie consists of both short and medium tall grasses of the needlegrass - wheatgrass - grama grass association. Trees become increasingly important in areas adjacent to forest formations. Among the widest distribution are roses, western snowberry (symphoricarpos occidentalis), Willow, wild licorice (Glycyrrhiza lepidota), and trembling aspen. Several modifications of the dominant community exist within the confines of the mixed prairie.

(3) The Shortgrass Prairie occupies the driest areas of the basin. It contains some of the species found in the Mixed Prairie area but the dominants are needlegrass and grama grass. Blue grama grass (Bouteloua gracilis) accounts for a quarter to two-thirds of the basal grass coverage. It grows in association with variable amounts of other grass species which may or may not be relatively sparse. There are several subdominant species, both grasses and sedges, their occurrence varying with slope, exposure, and degree of salinity of soils. A number of herbs and shrubs, many of them xerophytic, are found associated with the shortgrass region. These include some succulents like prickly pear cactus (Opuntia polyacantha), and various sages (Artemisia sp.).

Grassland is a vegetational response to drier habitat conditions. Within the grasslands of the basin there are differences in the associations reflecting irregularities in the habitat. There is a marked change in grassland composition across the soil color zones. A topographic relationship is seen in the increase in blue grama grass and speargrass (Stipa Comata) and other needlegrass species on the steeper and drier south-facing slopes. The north-facing slopes in the Dark Brown soil zone have a considerable coverage of fescue grasses. Fescue is characteristic of the benchlands of the Cypress Hills and in the aspen groves of the northern part of the basin. In the Cypress Hills, it is considered as a subclimax to lodgepole pine which occupies the high tableland. In the parkland it is a postclimax to the aspen community.2/

The vegetation of the large areas of sand dune show certain differences within the grassland and parkland formations. A shortage of water coupled with a different soil type are the dominating factors. Any slight

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1/ Clarke, S.E. and J.A. Campbell, "An Ecological and Grazing Capacity Study of the Native Grass Pastures in Southern Alberta, Saskatchewan and Manitoba," Publication Number 738, Division of Forage Crops, Swift Current, Sask., 1942, pp.9-15.

2/ Coupland, R.T. and T. Brayshaw, "Fescue Grasses of Saskatchewan," Ecology, Volume 34, 1953, pp.386-405.

change in elevation or in amount of exposure may result in striking contrasts in vegetation. The vegetation of the sand dunes south of Edmonton have been described as follows: "The summits of the surrounding hills are practically barren, with a few old pines badly infected with Arceuthobium, a carpet of lichens and mosses under their shade, and a scattering of xerophytic grasses and flowering plants on the open ground."1/ The sand dunes of the grassland region have a vegetation cover that varies with the depth of the water table. On the exposed slopes, speargrass predominates. The undulating to gently rolling areas between the stabilized dunes are often dominated by shrubs, and grasses are common in a lower layer of vegetation. On bare sand, sand dock, (Rumex venosus) is the pioneer. On the lee slopes, shrubs and occasionally trees, dominate, balsam poplar being adapted to the habitat since it can withstand considerable burial by the sand.

Brown Prairie soil is the predominating type in the South Saskatchewan Basin. Narrow bands of dark brown, shallow black and grey wooded soils are found in the west. The brown soil develops under the mixed prairie vegetation. In the normal profile the surface horizon is about five inches deep and brown in color. The B horizon is light brown and makes up about 20 to 24 inches of the profile below which lies the parent material, usually glacial till.

Within this broad soil zone there are many variations. These are mainly determined by the nature of the underlying materials. Land use varies throughout the region and only the heavier-textured lacustrine soils are suitable for arable farming. Generally, where precipitation is insufficient for the latter, ranching is the common form of land use.

The Lower Saskatchewan river basin.- The lower basin, between The Forks and Lake Winnipeg, occupies a much smaller area than does either of its two major tributaries. For a short distance the Saskatchewan river flows east over the Saskatchewan plain. The banks are low and the land slopes back gradually to the water divides. A short distance downstream from Nipawin, the Manitoba Escarpment is reached. This prominent relief feature is structural in origin and separates the Saskatchewan plain from the Manitoba plain. Viewed from the west, there is little relief but from the east, slopes are steep, descending to the First Prairie Level. Down this step the river descends in a series of rapids called the Tobin Rapids. To the south, overlooking the Carrot river, lie the Pasquia hills, with rugged relief resulting from the deposition of much moraine during the waning of the ice front. To the north of the river lies the Canadian Shield.

The Saskatchewan river, after descending the rapids, flows over the Manitoba lowland. Many lakes occupy this area and these may be regarded as modern remnants of the glacial Lake Agassiz which occupied all of the lowland and adjacent portions of the Shield. As the ice retreated, the lake was formed. It extended from the ice barrier in the east almost to Prince Albert and, at first, the Saskatchewan River drained via the Qu'Appelle River. As the lake decreased in size it left ridges of sand and gravel which today are prominent relief features. The Saskatchewan river scoured an outlet

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1/ Dowding, Eleanor S., "The Vegetation of Alberta, III Sandhill Areas of Central Alberta ...", Journal of Ecology, Volume 17, 1929, p.88.

to Lake Agassiz through these ridges. As the lake receded, smaller remnants remained and into these the river flowed, building out deltas so that delta sediments are a characteristic of the area along the lower course of this river.

Numerous moraines were crossed. These often formed temporary blocks and one now forms the eastern boundary to Cumberland Lake. It has an uneven summit and morainic deposits of varying thickness are heaped upon the comparatively even floor of limestone material. The Saskatchewan River flows through the lowest gap.

Below The Pas the river has the character of a great estuary which it has gradually filled. Low, flat land is broken by a few ridges of boulder clay. For much of its course, the river is above the level of the land. It is confined between natural levees, but it periodically overflows and floods the adjoining land. Between Cedar Lake and Lake Winnipeg, the Flying Post Rapids are located.

The vegetation of the lower Saskatchewan is included in what has been called the Mixed Wood Belt, distinct from the coniferous forest region to the north.1/ It is an ecotone between the parkland and the coniferous forest. Both coniferous forest and broadleaf forest species predominate. The poplar-spruce is the most common on the Manitoba low-lands and is associated with Jack pine (<u>Pinus Banksiana</u>) on the limestone outcrops and bur oak (<u>Quercus macrocarpa</u>) on the southern beaches of the basin. On poorly drained areas tamarack and black spruce are common trees. Grasses, particularly the more hygrophytic sedges (Carex sp.) occupy large areas that are periodically inundated.

Soils in the region are intrazonal, developed on a high lime base. Grey wooded soils, the normal type for such a region are the exception here. The soil profile is very shallow and is characterized by much leaching and a dark colored surface horizon which is finely granular and friable, developed over a marly lime accumulation of rather crumbly consistency.

CHAPTER 2. THE CLIMATE OF THE SASKATCHEWAN RIVER BASIN

A. INTRODUCTION

Climatic elements play an important role in determining the supply and availability of water in the Saskatchewan river basin. Of these, the nature of the precipitation in its amount, frequency, form and distribution, is perhaps the most significant. In winter, precipitation is principally in the form of snow. Both this form and its release as runoff are a function of temperature. The delay in release is an important hydrological fact. In the winter, potential runoff may be considerably reduced by sublimation from the snow surface; in the summer by evaporation from the meltwater. . . . . . .

1/ Putnam, Donald F., ed., op. cit., p.352.

Most of the Saskatchewan river basin lies within one broad climatic region, which has been loosely called the Southern Prairies.1/ The region extends beyond the basin in all directions except on the west, where it is bounded by the Southern Interior Valleys region. Köppen, more specifically, includes the basin within three separate climatic regions, (1) the Humid Microthermal, Dfc, with cool, short summers, (2) the Semiarid, BSk'w, with cool summers and a summer rain period, and (3) the Humid Microthermal, Dfb, with cool but longer summers than in the Dfc region.2/

Three basic factors are of major importance in considering the climate of the basin, the latitude, the interior location and the topographic relationships. The latitudinal extent of the basin is from 48 degrees 30'N to 54 degrees N. In these latitudes, the intensity of direct sunlight is never great, the zenithal altitude of the sun ranging from 18 degrees in December to 66 degrees in June.3/ The hours of sunlight, however, are greatly extended during the high sun period, being twice as great in June as they are in December when only 7.92 hours of sunshine are possible on the 21st day of the month.4/ The great range in solar radiation dominates the course of the seasons.

The main tributaries of the Saskatchewan river have their sources along the western border of Alberta, 450 to 500 miles from the Pacific coast. They flow east, deeper into the heart of the continent. Continentality characterizes the climate. Seasonal temperature ranges, already great as a result of the latitudinal control of insolation, are accentuated. In the southwest, where the mountains are the lowest, the mean annual range is about 55 degrees F. In the eastern portion of the basin, the mean annual range is 74 degrees F.5/ Another characteristic of the interior location is the relative decrease in precipitation. Absolute humidity decreases as air masses lose their moisture in moving towards the interior of the continent. The precipitation potential is correspondingly reduced.

The third important control of the climate is topographic. Immediately to the west of the basin, and athwart the direction of westerly air movement, lie the cordilleras of the Rocky Mountain system. Within these ranges many peaks are over 10,000 feet high. Passes, like the Crowsnest and the Kicking Horse, 4,450 feet and 5,339 feet in elevation respectively, are ineffective as routeways for Pacific air. The Rocky Mountains form an effective barrier, shutting out the marine influences that might have an ameliorating effect

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1/ Connor, A.J., The Canada Yearbook, Dominion Bureau of Statistics, Ottawa, 1948-1949, p.42.

2/ Köppen, W., Die Klimate Der Erde, Berlin, 1923, Tafel. 1.

3/ Thomas, Morley K., The Climatological Atlas of Canada, Meteorological Division, Department of Transport, Ottawa, 1953, pp.185-186.

4/ Koeppe, Clarence E., The Canadian Climate, Bloomington, Illinois, 1931, p.3.

5/ Climatelogical statistics, unless otherwise stated, are taken either from The Climatic Summaries of Selected Meteorological Stations in Canada, Newfoundland, and Labrador, Volume I or The Climatological Atlas of Canada, prepared by Morley K. Thomas. Both were published by the Meteorological Division, Department of Transport, Ottawa, 1948 and 1953, respectively.

on the climate of the basin. To this circumstance, more than to any other, is attributable the low precipitation of the prairie area. Most of the Saskatchewan river basin is an area of rain shadow. Average precipitation totals are about 15 inches. Only in the headwater regions on the eastern slopes of the Rockies, is there an increase where clouds, trailing over the main divide, bring sufficient precipitation to raise the totals to 20 inches in the valleys and to higher amounts towards the crests.

Northwest of the Saskatchewan watershed, the Rockies are considerably lower. Peaks in the neighborhood of 5,000 feet are common, and maximum elevations are seldom over 8,000 feet. Pine Pass, which the newly constructed Hart Highway traverses in crossing the main divide, is but 2,850 feet above sea level. This low section of the Rockies does provide a somewhat circuitous routeway for Pacific air masses entering the prairie region.

Three types of air masses influence the climate of the basin. All have their distinctive source regions and all are considerably modified by the time they reach the area under consideration. Summer and winter airmass infuences differ in intensity and frequency. Those of summer are described in the following quotation:

> To the Canadian plains ... there is normally in summer an inflow of (a) dry, cool air which forms the western fringe of the polar-basin air on the Canadian Shield but which becomes warmer as it advances, (b) of Northern Pacific air which, getting across the mountain system, has carried with it little of the moisture originally present in the lower layers, (c) of air, heated on the continent and moving north.1/

The area of discontinuity between the modified polar and tropical air masses is that in which the belt of precipitation is likely to be found. In a normal year, the prairie section of the basin received rain in summer from this source after which the frontal area moves north and disappears as the tropical air is further modified. There are many variants to this movement. If the tropical air is less active, it will not push far enough north. The basin then has a cool but dry summer. If the air masses meet and a stationary front is developed over the basin, the area then has a relatively wet summer. Again, the frontal surface between the conflicting air masses may be carried rapidly north bringing but a brief period of rain to the basin. If the Pacific air becomes particularly vigorous in summer, it results in cool but dry conditions over the basin. Under these circumstances the droughts of summer are established. The character of the prairie summer is, therefore, extremely variable from year to year and is dependent upon the trends established by the dominating air masses.

It is usually not until the early autumn that the influences of Pacific air become a major factor in the region. Associated with the coastal storms, vigorous systems push over the mountains in the low area of the main divide, drive a wedge between the cold polar air in the Mackenzie basin and the retreating tropical air, and drift southward over

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1/ Connor, A.J., "The Climates of North America," Handbuch der Klimatologie, Berlin, 1938, p.347.

Alberta. Indian summer, associated with the warm dry air, persists as long, and as far east, as these influences are felt.

Cold spells in winter are caused by outbreaks of polar air. If these advance south from the Mackenzie basin, temperatures may drop to -45 degrees or lower. Sometimes the polar air moves southward by way of the North Pacific Ocean and enters the prairies after considerable warming. "There are cases where such a month has averaged more than 25 degrees F. warmer than a normal winter over a large area in Alberta, and 10 degrees F. or more warmer over the remainder of the Pacific."1/

In some winter months this polar air stretches from the Arctic to Hudson Bay. Then the Eastern prairies have cold winters, but Alberta is fed by warmed returning polar air from the southeast, or by Pacific polar air from the west and northwest. Considerable airmass variety is possible in one year and from year to year. The variety possible increases towards the western edge of the prairie portion of the basin. The Saskatchewan and Manitoba sections are more regularly under the polar influences. By April, polar air still dominates, but the effects of the tropical continental air are beginning to be felt as the Gulf air pushes north.2/

Over most of the basin, elevations are between 1,500 and 2,500 feet. Any climatic effects resulting from differences in altitude are of minor importance. On the high plains, the foothills and in the mountains, decreases in temperature are attributable to the higher elevations. Rocky Mountain House and Pincher Creek are about 3,500 feet above sea level. Nordegg and Banff are 4,500 feet above sea level, and Lake Louise 5,000 feet. Temperatures at these stations are lower than those of the adjacent plains.

The situation of the Saskatchewan river basin results in its being under the influence of the climatic controls outlined above. Pressure differences are also important in establishing gradients conducive to the movement of air masses but as their hydrologic effects are experienced indirectly through the air masses, they have not been analyzed here. Other influences on climate such as the cold air drainage to hollows, warmer and drier conditions on southfacing slopes, and the reduction of frost damage in areas of constant air movement, are all factors of local importance.

B. Precipitation and Temperature

A large portion of the Saskatchewan river basin is classified as either dry subhumid or semi-arid.3/ Average annual precipitation is

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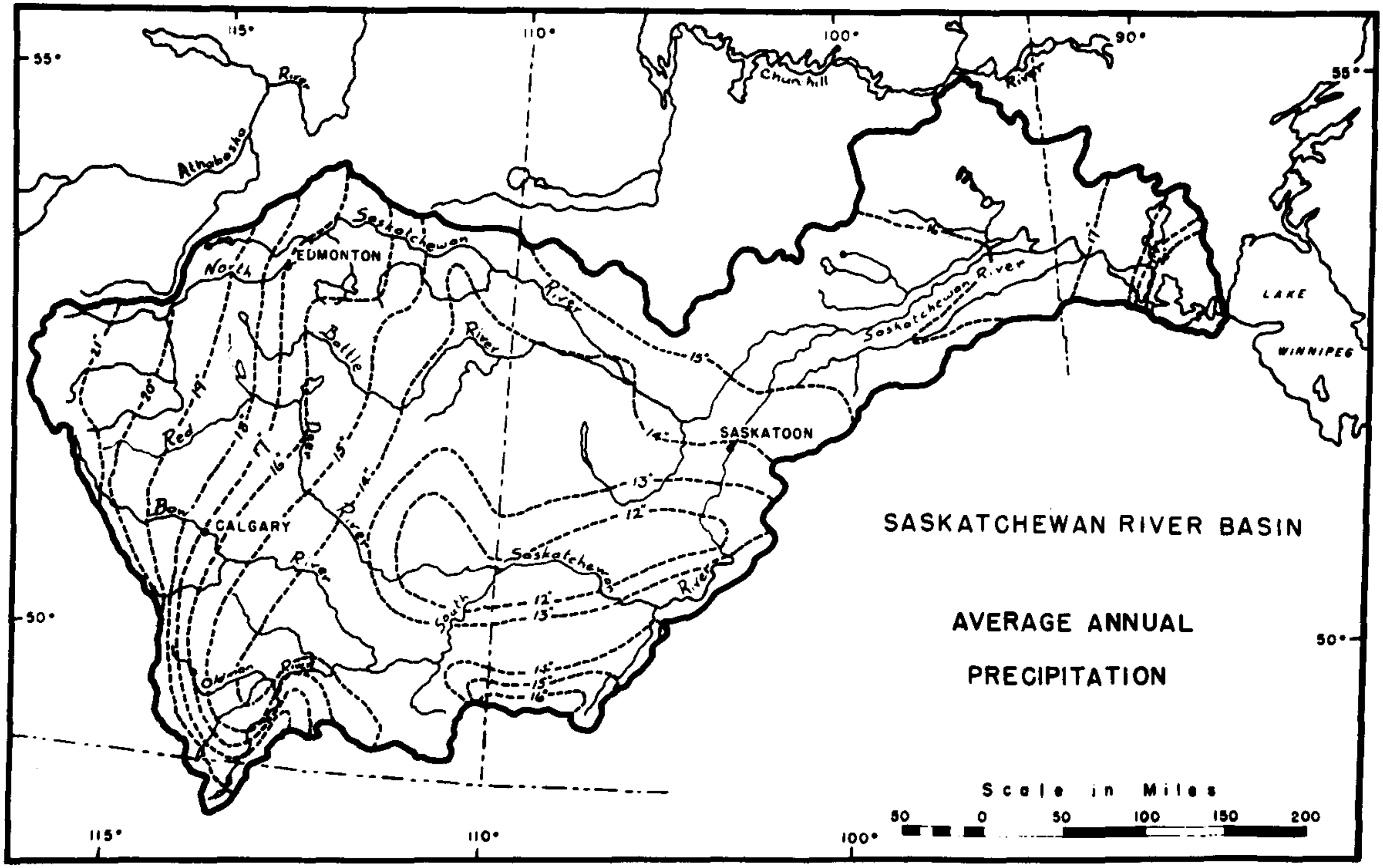
1/ The Canada Yearbook, 1948-1949. Ottawa, op. cit., p.50.

2/ Rheumer, G.H., Climate and Climatic Regions of Western Canada, Unpublished Ph.D. Dissertation, University of Illinois, Urbana, Illinois, 1953.

3/ Sanderson, Marie, "The Climates of Canada according to the New Thornthwaite Classification", Scientific Agriculture, Volume 28, 1948, Figure 6, facing p.514.


SASKATCHEWAN RIVER BASIN
AVERAGE ANNUAL PRECIPITATION
EDMONTON
CALGARY
SASKATOON
LAKE WINNIPEG
Athabaska River
Churchill River
North Saskatchewan River
Battle River
Red Deer River
Bow River
Oldman River
South Saskatchewan River
Saskatchewan River
Scale in Miles
50 0 50 100 150 200

generally between ten inches and 20 inches.

West of the driest region, which may be identified as the brown soil zone, average annual precipitation increases rapidly to about 20 inches. At Lake Louise, the average annual precipitation is 23.83 inches. Nordegg, in the northern portion of the mountains, has an average annual precipitation of 21 inches. Banff has 19.16 inches, and Babb, in Montana, has 19.43 inches.1/ Calgary, on the high plains, east of the mountains, has an average annual precipitation of 16.65 inches. East of this location, totals decrease to ten inches in parts of the brown soil zone.

Quite a proportion of the total precipitation is in the form of snow; the higher the elevation, the greater the proportion.2/ At Lake Louise, the snowfall is 59 per cent, at Banff, 41 per cent and at Nordegg, 38 per cent of the annual precipitation.

In the northern part of the Saskatchewan river basin, the average annual precipitation varies, increasing generally towards the south and west. At Rocky Mountain House, at about the same elevation as Calgary, average annual precipitation is 19.13 inches. At Edmonton it is 17.38 inches. Precipitation decreases towards the east so that at Battleford only 13.14 inches are recorded.

Average annual snowfall and its percentage of the total precipitation, decrease away from the mountains. At most stations 40 to 50 inches of snow are recorded, about 30 per cent of the total precipitation. At Battleford only 28 inches of actual snow are recorded, 21 per cent of the total precipitation. This lower figure for Battleford, may, in part, be due to the situation of the recording station in the more sheltered valley of the North Saskatchewan River. At Prince Albert, near The Forks, both total precipitation and snowfall increase again to 16.11 inches and 51.5 inches respectively.

1/ These data are long-term averages. Precipitation in excess of 60 inches has been measured in the mountains at the western extremity of the Basin. In fact, in the back range locations, 40 inches to 60 inches annually would be normal. In isolated spots precipitation may exceed 100 inches. Since there is very little evapo-transpiration at these altitudes, almost all the precipitation is net, and is therefore available to the drainage system. See Laycock, A.H., Precipitation and Stream Flow in the Mountain and Foothill Regions of the Saskatchewan River Basin, Prairie Farm Rehabilitation Admin., Regina, in process, to be puslished probably in 1956.

2/ Total precipitation is made up of the rainfall to which is added the water equivalent of the snowfall and all other forms of frozen precipitation. For this computation, ten inches of freshly fallen snow are considered as having an average water equivalent of one inch. Climatic Summaries for Selected Meteorological Stations in the Dominion of Canada, Volume 1, Toronto, Ontario, p.1.

The region of the South Saskatchewan river may be subdivided into three distinct sections. In the southwest, from Cowley to Cardston, average annual precipitation is about 20 inches. At Lethbridge the total has decreased to 15 inches annually; while in a line from Medicine Hat to Swift Current, the second subregion is distinguishable with an average annual precipitation near 12 inches.

South of this area, straddling the Alberta-Saskatchewan boundary, lie the Cypress Hills. Although they appear more as a gentle swell than as a distinctive landscape feature, their elevations, between 3,500 feet and 4,800 feet, are sufficient to induce orographic rain. Annual precipitation increases in this southern section to 17 inches. From The Forks to Lake Winnipeg, annual precipitation is about 15 inches. The percentage of this that is snowfall appears to increase from about 25 per cent at Melfort, to 29 per cent at The Pas.

A characteristic of precipitation in the prairies is the great variation possible from year to year. This is a natural result of the complexity of the climatic controls. " A nice balance between the momenta of the southern and northern air masses must exist if rain of a moderate to heavy quantity is to fall.1/ When this balance is upset variations from the average occur."

Generally speaking, mean annual temperature decreases from south to north. Because of the inconsistencies in climatic controls, variation from this simple pattern is to be expected. On the prairie section, the isotherms are oriented east-west, a pattern which may be considered as normal for the basin. Mean annual temperatures decrease from 42 degrees F. at Medicine Hat, in southern Alberta, to 33 degrees F. at Lloydminster, in the North Saskatchewan basin. Calgary, located near the western extremity of the prairies, has a mean annual temperature of 38 degrees F. Outlook, at about the same latitude in central Saskatchewan, has a mean annual temperature of 37 degrees F.

Along the western border of the basin, in the mountainous section, isotherms swing sharply southward. Negative temperature anomalies, resulting from the increasing altitude become apparent. Banff and Lake Louise have mean annual temperatures of 36 degrees F. and 31 degrees F respectively. In the northwest, centering on Edmonton, and in the extreme southwest, positive temperature anomalies are found. Edmonton has a mean annual temperature of 37 degrees F, four degrees higher than that of Lloydminster to the east. Less spectacular than the northern swing of isotherms in the northwest, is the swing from the southwest again indicating a positive anomaly. This warmer air may have drifted in from the Pacific over the lower section of the Rockies in northern Alberta, or it may be air that was forced to rise in order to cross the higher Rockies. The plus anomaly at the base of the Rocky Mountains is related to the warming of Pacific air by loss of moisture and descent to the plains.

In the east and northeastern portions of the basin, the isotherms are oriented towards the southeast, paralleling the path most frequently

1/ Hurd, W. Burton and T.W. Grindley, op. cit., p.4.

followd by Polar air masses. Saskatoon has a mean annual temperature of 34 degrees F., Melfört, on the Carrot River, 33 degrees F., and The Pas, in Manitoba, has 31 degrees F.

C. The Climatic Regions

General.- For purposes of further analysis of temperature and precipitation statistics, it is convenient to subdivide the basin into a number of regions.

The mountain and foothill region.- This is the region of heaviest precipitation within the basin. Annual and seasonal precipitation varies considerably, reflecting the great diversity of relief. Valley areas receive the least direct precipitation. Eastern slopes often receive heavier precipitation than the western slopes as these latter are usually sheltered by the higher ranges.1/ Orographic precipitation is the most type although precipitation may be frontal in nature, intensified by orographic uplift. In the late summer and autumn, Katabatic winds, rolling down the valleys from the cooler uplands, force the warmer air to rise, inducing convectional currents and resulting in convectional rain of high intensity. Frontal precipitation is more typical of winter than of summer and comes usually in the form of snow. Precipitation, generally, is lighter but is more prolonged in the mountains than on the prairies. Because of topographic modification, its distribution is patchy.

Precipitation regimes show certain broad characteristics. Lake Louise, located near a pass in the main divide, is more typical of the British Columbia type regimen. Maximum precipitation occurs in the months of November, December and January, and only 25 per cent falls in the three summer months. There is a secondary peak in the month of June. Farther east of the main divide regimes approach those of the prairies. Precipitation maxima are concentrated in the three summer months of June, July and August. At Nordegg, Banff and Babb percentage concentration of precipitation varies from 48 to 37 per cent. Throughout the rest of the year precipitation averages about an inch a month. In November, December and January the totals are the lowest for the year.

The variability of precipitation is less in this region than it is on the plains. At Banff it is about 48 per cent.2/ Within the region possible variations from the mean are greatest during the winter, the period of minimum precipitation, but at this time variations of precipitation will have little effect on stream flow.

From November to March 90 per cent of the average monthly precipitation is in the form of snow. From September on appreciable quantities of snow

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1/ Over 100 precipitation gauges (Sacramento Type "A"), have been installed in the Rocky Mountains National Forest. The observations are being used in a microclimatic study for watershed management.

2/ Mean, maximum and minimum precipitation figures are taken from Koeppe, Clarence E., op. cit. pp.256,257,261 and 263.

falls, the average amount decreasing from north to south. Again in April and May some snow is recorded. It is over 90 per cent of the total precipitation, November to March inclusive, at Nordegg, 79 per cent at Lake Louise, and 69 per cent at Banff.

Hence, unless there is some melting, streams in the mountain area will receive little surface replenishment during the winter months. Rainfall is low. Small diurnal fluctuations result from the melting, and minimum flow under the ice is maintained in the larger streams from ground-water. Summer months are those of maximum flow when both the winter snow melts and the summer rainfall is collected as runoff. The rainfall totals for June, July and August are the highest in the basin.

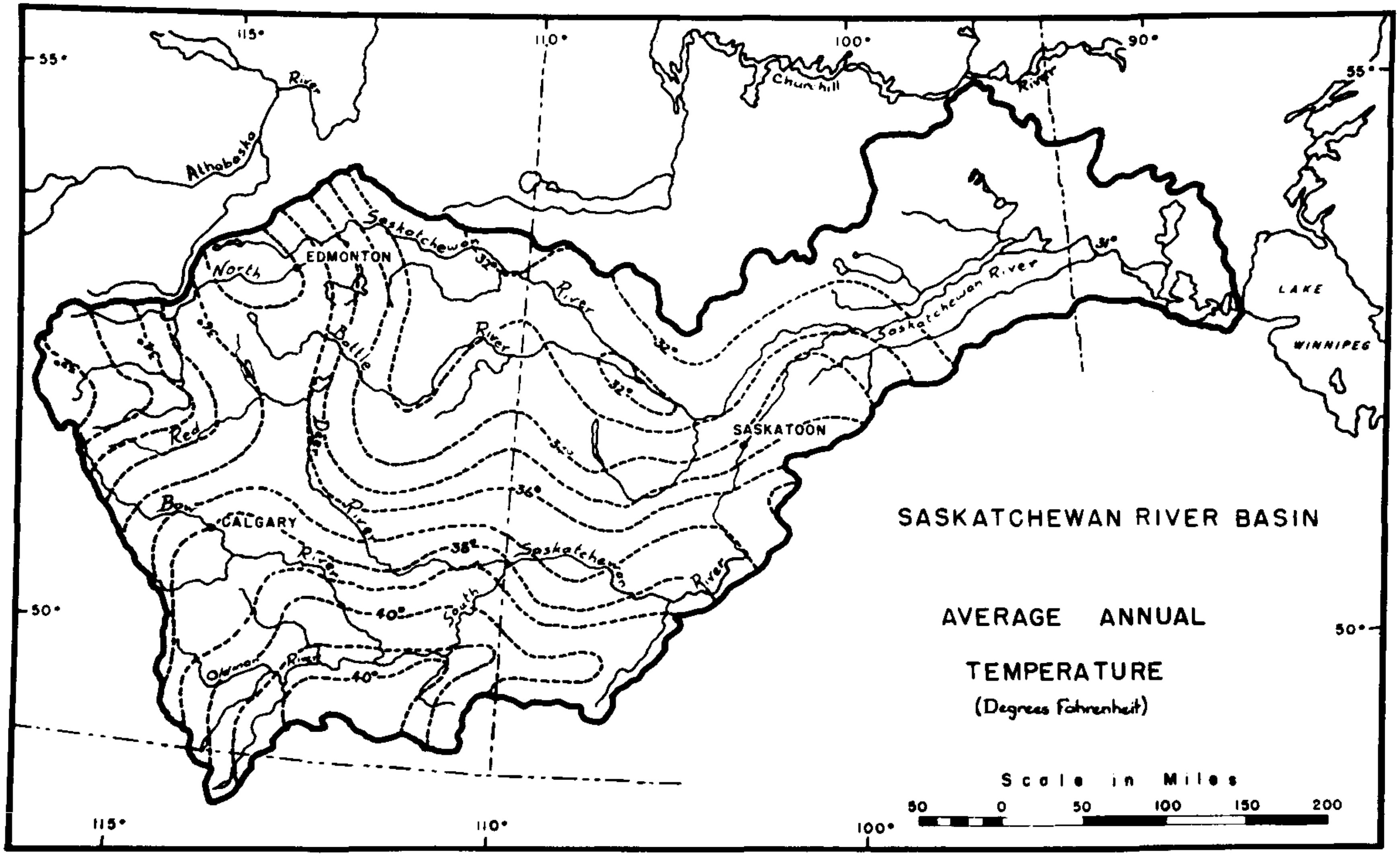
Average annual and monthly temperatures are lower than those on the prairies, a result of the higher altitude. A meteorological station is located near the main divide at Lake Louise, which has average monthly temperatures from 4 degrees F. in January to 54 degrees F. in July. These may be regarded as typical for most of the upper Bow valley. Peaks rising to 10,000 feet on either side of the valley have appreciably lower monthly temperatures. The annual range of temperature at Lake Louise is 50 degrees F. The average daily maximum temperatures in July and January are 71 and 36 degrees F., respectively. The average daily minimum for the same two month are 36 degrees F and -8 degrees F. Since extremes will be less conservative, it may be said that freezing temperatures are possible in any months at these altitudes.

Nordegg, Banff and Babb are recording stations at lower elevations but still in the mountains. They are all located at an elevation of about 4,500 feet in the northern, central and southern portions of the region respectively. Temperatures increase with the decrease of latitude. The monthly average temperatures for July are 55 degrees F at Nordegg, 58 degrees F at Banff, and 60 degrees F. at Babb.1/ For January, the minimum month, the average monthly temperatures are 12 degrees F. at Nordegg, 13 degrees F. at Banff, and 18 degrees F. at Babb. Annual temperatures are about the same but all are lower than that of Lake Louise. Below freezing temperatures are of no hydrologic significance in the three summer months of June, July and August.

Within the mountains, mid-October and April are the first and last months of appreciable snowfall. During each of these months the critical average temperatures are about 32 degrees F. Early or late freeze-ups and thaws will depend on the variations about this figure. The thaw period begins later in the mountains than on the prairies. Through November to March, the average daily maximum temperatures are below freezing and, although extreme temperatures may climb as high as 50 degrees F, there are few sustained periods of snow melt. Stream flow under ice is low.

Late spring is the period of thaw. Then snow and glacial ice melt on all but the highest and north-facing slopes and augment the prairie flow of streams already swollen with summer rain.

1/ The Climatological statistics for Babb were obtained from Climate and Man, The Yearbook of Agriculture, Washington, D.C., 1941, p.956.


SASKATCHEWAN RIVER BASIN
AVERAGE ANNUAL
TEMPERATURE
(Degrees Fahrenheit)
Scale in Miles
50 0 50 100 150 200
EDMONTON
CALGARY
SASKATOON
Saskatchewan
North
River
Battle
Red
Deer
Bow
South
Oldman
Athabaska
Churchill
LAKE
WINNIPEG
32°
36°
38°
40°
115°
110°
100°
90°
55°
50°

Variations in the contribution of glacial meltwater to stream flow is a function of the temperature. The importance of the contribution, particularly of the Columbia Icefield, is relative. In spring and early summer, snow melt and rainfall maintain a satisfactory level in streams. The contribution from the glaciers is of little consequence. In the wetter summers, when there is sufficient water in the major streams, the percentage of flow that is glacial meltwater is very small. The contribution does become of much greater importance in the latter part of a normal summer and in a dry year. Then two factors combine to increase significantly the importance of the glaciers' contributions. First, there is a relative increase in the meltwater as river flow from precipitation sources is so much less than normal. Secondly, there is an absolute increase in the volume of meltwater. Dry summers are usually hot summers so that melting is much greater. A considerable diurnal variation may be noted, especially from the south-facing slopes. This is a function of daily maximum and daily minimum temperatures.

The North Saskathcewan region.- The north is the more humid part of the prairies. Temperatures are lower and the precipitation higher and more effective. Frontal precipitation is typical. Rain, of moderate intensity, falls for longer periods than in other parts of the prairies. In winter snowfall replaces the rain. Convectional rain is associated with summer precipitation and, because this is much heavier than the frontal, its contribution to the annual totals is more important than the frequency would suggest.

Average annual precipitation decreases away from the mountains. Regimes are similar across the north. February is the month of minimum precipitation, June the month of maximum. The five stations selected have a typical prairie regime with the maximum concentration of precipitation in the summer months. From Rocky Mountain House in western Alberta to Prince Albert in central Saskatchewan the stations vary from 43 per cent to 51 per cent in their summer concentrations of average annual precipitation. This type of regime is of maximum benefit to farmers who are predominantly engaged in grain growing.

Precipitation on the prairies is much more variable than it is in the mountains. Monthly rainfall totals may be as high as three times the average in November and December at Edmonton, and twice as high as Prince Albert. Summer precipitation is more reliable than that of winter. The variation from the mean increases from west to east.

As in the mountains, snow forms the bulk of winter precipitation. In November it is about 90 per cent of average monthly precipitation in the northern part of the basin. It is not until April that the percentage of snow to total precipitation drops to about 50 per cent. In spite of these high percentages it must be remembered that the total precipitation is at a minimum so that actual inches of snow are generally about five inches for each of the winter months. Only at Rocky Mountain House is this figure exceeded. Except in more favorable years this snow accumulates and lies through the winter.

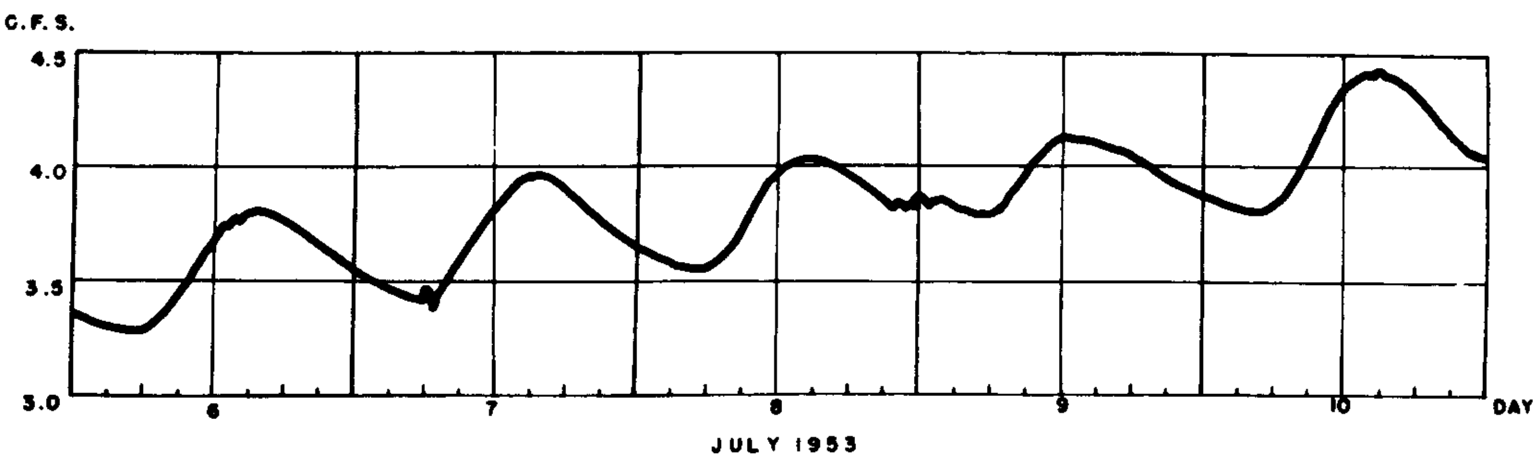
Precipitation over the northern portion of the basin adds to the flow of the North Saskatchewan river particularly in the early summer. Prairie tributaries are minor streams by comparison. Their major flows are in the early summer months when surface runoff, as well as groundwater flow, is available. Because of the greater variability of precipitation on the plains, the variation in the contributions of the tributaries to the North Saskatchewan's flow makes for considerable variations in the normal regimen. Both precipitation and stream flow are more reliable in the source region of the mountains and predictions of flow, once the river has crossed the prairies, are much more difficult.

In a study of the temperature characteristics of this northern section of the basin two sub-regions are distinguishable on the basis of annual temperatures. Average monthly temperatures add further emphasis to differences between the western and the eastern regions, The greater range of the eastern stations is the major differentiating factor . At Edmonton monthly average temperatures range from 6 degrees F. in January to 62 degrees F. in July, a mean annual range of 56 degrees F. At Lloydminster, about 145 miles east of Edmonton, the January temperature is -4 degrees F, that of July, 63 degrees F. The range has increased to 67 degrees F. Average monthly temperatures at Battleford and Prince Albert are similar to these.

In studying the average maximum, minimum and extreme temperatures the nature of the subregional differences becomes still further apparent. The Pacific air does reduce the temperature range for the western area as already mentioned, having less influence on the average maximum and minimum temperatures and still less on the extremes. It is the ameliorating factor in the west. Its influence, without considerable modification, is seldom felt beyond the boundaries of Alberta. In summer it may impede the northern advance of tropical air. In winter it may turn the polar air towards the east. The more extreme air mass types, polar and tropical continental, move over the eastern basin. Although occurring less frequently, these air masses do follow paths across Alberta and extremes in the temperature figures are related to this air movement more than to the Pacific air mass.

At Edmonton, the average daily maximum temperature is 74 degrees F. (July), the minimum -4 degrees F. (January). The averages of extreme temperatures are from 87 degrees F to -36 degrees F. for the same months. At Battleford the corresponding figures for average daily maximum and minimum are from 78 degrees F. to -10 degrees F., average extreme maximum and minimum are from 92 degrees F. to -39 degrees F. Prince Albert has still more extreme conditions. The differences between the eastern and the western sections of the region depend on the frequency of occurrence of the temperature controls.

Snowfall is not as heavy on the plains, nor does it lie as readily as in the mountains. April is the month of thaw but average temperatures are higher than those in the mountains. The thaw sets in earlier. Late spring rains and the spring thaw combine to increase the runoff during this period. It is a problem period. Flow ice often jams at certain locations and forms temporary dams. Frazil ice, freezing to the floe, accentuates the problem. The increased stream flows will build up behind the dams, overflow, and flood the surrounding lowlands. This type of flooding is associated with the early peak flow of the streams. In terms of the volume of water, this peak is secondary to the main peak which comes when the alpine thaw runoff, combined with the early summer rainfall over the basin, considerably augments the supply.



DAILY FLOW: SUNWAPTA RIVER AT ATHABASKA GLACIER

Adapted from official trace
Water Resources Div., Calgary

<u>The central region lying between the north and south Saskatchewan river.</u>- This, as has already been pointed out, is the driest region of the basin. Minimum precipitation is reflected in the increase in intermittent and interior drainage which centers on small lakes and brackish sloughs. The western boundary coincides fairly closely with the western boundary of the dark brown soil zone. The eastern climatic boundary extends beyond the basin. But, to the north and south, boundaries of this semi-arid center are not as distinct. There is a decrease in precipitation from the north to a central area between about Brooks and Outlook. Then precipitation totals gradually increase again to the south.

Precipitation is generally frontal in character, associated with the meeting and mixing of the summer masses of polar and tropical air. Violent thunderstorms bring heavy, although localized, rain to the central prairies. In western Alberta 25 days with thunderstorms is the annual average.

Rainfall regimes are similar to those of the northern region. There is about a 45 per cent concentration in the summer months of June, July and August, but the total precipitation for these months is lower. At Leader, a station typical of the drier core of the region, there is a 44 per cent concentration of precipitation in the three summer months. During that period an average of 5.21 inches falls. During the same period 6.81 inches is the average for Battleford, 8.73 inches for Edmonton. Winter precipitation is about half an inch per month from October through March.

J.W. Hopkins has sought to establish secular trends in prairie precipitation. He observes that most of the precipitation falls between April 1 and October 31 and that there is a greater variability in those months.

> The 31 year average was found progressively to increase from the low value of one inch or less in April to a maximum of three inches or more in June, after which there was again a diminution in July and August, such a progression being typical of the 'northern plains' type of precipitation. 1/

There is considerable variation possible in the annual precipitation. It is generally greater than that for the northern region but considerable differences are possible. At Medicine Hat the extreme figure is three times the mean precipitation figure.

From November through March over 90 per cent of the precipitation is again in the form of snow but the total snowfall is much lighter than in either the mountain region to the west or the prairie region to the north. The percentage which falls as snow decreases to the south.

1/ Hopkins, J.W., "Agricultural Meteorology: Some Characteristics of precipitation in Saskatchewan and Alberta," <u>Canadian Journal of Research</u>, Volume 14, 1936, pp.319-346.

Daniel and Harper have commented on the efficiency of different types of precipitation in increasing soil moisture.1/ Showers of .30 inches or less are of little benefit. Most moisture is evaporated or transpires. In April from 42 per cent to 66 per cent of total precipitation was in the form of showers (17 year period). In subsequent months the average amount falling on each rainy day was greater. Twenty-seven to 33 per cent of precipitation in June, and 28 to 31 per cent in July was under 0.30 inches. During this period about 23 per cent of precipitation was in amounts of over 1.50 inches a day. From the heavier downpours there was little gain in soil moisture. Most of the precipitation was lost as runoff. The optimum precipitation for replenishing the soil moisture lies between these figures. The relation to surface runoff is obvious. Light rainfall provides little surface runoff in summer. Heavy downpours result in too much runoff and flash floods which, if not confined within the stream banks, may cause considerable damage.

This region is subjected periodically to droughts. Conditions for droughts are accentuated by hot southwest winds in summer, while in winter mild dry southwesterly or chinook winds frequently cross the region (Table 1).

Table 1.- Number of Summers with Midsummer Drought, Selected Stations, Saskatchewan River Basin

Station	Period of record (years)	Number of droughts	Percentage of years with drought
Edmonton	52	6	12
Calgary	50	18	36
Medicine Hat	51	27	53
Swift Current	50	15	30
Prince Albert	50	17	34

Source: Connor, A.J., "The Climates of North America," Handbuch der Klimatologie, Berlin, 1938, p.363.

In terms of temperature, the central region is one of transition. Average monthly temperatures at Calgary range from 62 degrees F. in July to 13 degrees F. in January. Red Deer, approximately 100 miles to the north, has slightly lower monthly figures. Macklin, centrally located with the region, has an annual range from 64 degrees F. to -1 degree F. Outlook, to the southeast, has an annual range from 67 degrees F. to 3 degrees F. As in the northern region, mean annual range increases towards the east. Extremes also increase towards the east, but the differences between east and west are not so great as in the average figures.

This is the region where blizzards are an unwelcome, too frequent occurrence, particularly in the spring. Winds of over 50 miles per hour

1/ Daniel, H.A. and M.J. Harper, "The Relation between Effective Rainfall and Total Calcium and Phosphorus in Alfalfa and Prairie Hay," The Journal of the American Society of Agronomy, Volume 27, 1935, pp.644-652.

whip the fine, dry snow from the ground, simulating the effects of a snowstorm. Temperatures drop rapidly.

General temperature relations are similar to those in the north, March and November being the critical months for thaw and freeze respectively. Because there is much less snow lying on the prairies, the thaw period does not have the noticeable effects on local stream flow that it has in the west.

The South Saskatchewan region.- This region, the most southerly in the basin, is characterized by higher temperature figures. These allow a greater variety of crops to be grown. Precipitation within the region is insufficient for the needs of agriculture, and irrigation has been established as a practice aiding the development of the area. The region stretches from about Cowley in the west to Swift Current in the east. Within the area there is considerable diversity of climates. Nearer the mountains, precipitation is higher than on the eastern prairies and summer concentration, although still characteristic, is lower. Pincher Creek and Cardston have summer concentrations of about 38 per cent. Medicine Hat and Swift Current have average summer concentrations of 43 per cent and 47 per cent, respectively. Precipitation variability increases considerably towards the east.

Snowfall figures are similar to those in other prairie stations, the amount being greater nearer the mountains. From November to March, all stations record over 90 per cent of precipitation in the form of snow. In April, the amount of precipitation that falls as snow is still over 60 per cent in the western stations but there is a marked reduction towards the east.

The Oldman River and its tributaries collect the runoff from the southwestern area. The late spring and early summer maxima are characteristic when the rains of that period combine, first with the prairie, and later with alpine snow thaw. In the east the prairies are often bare of snow, the thin covering having been melted during the warmer winter periods.

In analyzing the temperature figures, a distinction between the western and eastern portions of this region is discernible. The average annual temperatures are about the same over the region varying only 2 degrees F. from 40 degrees F., but the mean annual range varies from west to east. The maximum monthly temperatures at Pincher Creek, Cardston and Lethbridge are about 5 degrees F. lower than those of three representative eastern stations, Medicine Hat, Maple Creek, and Swift Current. In winter the opposite is the case. Average January temperatures are about 5 degrees F higher at the western stations. The lower annual temperature ranges of western locations are a characteristic of piedmont areas within the basin (Table 2).

Table 2.- Average Monthly Range of Temperatures, Selected Stations, January and July, and Average Annual Range of Temperatures Saskatchewan River Basin

Meteorological station	Average January temperature	Average July temperature	Average annual range of temperature
Pincher Creek	18°F	61°F	43°F
Cardston	17°F	65°F	48°F
Lethbridge	16°F	64°F	48°F
Medicine Hat	12°F	69°F	57°F
Maple Creek	12°F	68°F	56°F
Swift Current	8°F	66°F	58°F

Source: The Climatic Summaries ..., "op. cit., pp.22-23

As in other prairie regions, there are not the great differences in extreme temperatures that might be expected from an examination of the averages. Monthly averages of daily maximum temperatures for the highest month are about 80 degrees F. over the whole of the region. Monthly averages of daily minimum temperatures for the lowest month are about 7 degrees F. in the west, 0 degrees F. in the east. In this region Pacific air is responsible for the less extreme temperatures of the west.

Of major importance in modifying the winter temperatures, is the occurrence of the chinook. Although the effects of this wind may be felt as far north as Edmonton, and as far east as Saskatoon, it is in the southwest area that they reach their best development. The Chinook has been described as a spectacular change from bitter cold to comparative warmth.

> The greatest contrast occurs when a severe prairie cold wave has occupied western Alberta and eastern Saskatchewan for one to three days with the temperatures well below zero and the whole mass of very cold air accelerates suddenly towards the southeast. In this case, air from the Pacific Ocean, which has been lying over the coast and filling the intermontane valleys of British Columbia moves east, crossing the Rocky Mountains. While the denser low levels of the Pacific air can reach the plains of Alberta only with great difficulty, usually moving northward through the intermontane valleys, yet the dry upper levels of the Pacific air cross readily enough, descending into eastern Alberta.1/

The temperature characteristics depend on the particular body of air. There may be a sudden gain of 50 degrees F. and, since the air is usually very dry, the sun shines brightly, the temperatures rise in the afternoon, while the snow lying on the ground is rapidly lost to the warmer, drier air by sublimation. When the air comes from the southwest, temperatures have been known to rise to 65 degrees F. at Lethbridge.

1/ Connor, A.J., The Canada Yearbook, op. cit. p.51.

"Farther east the chinook properties diminish or disappear and the mass may continue eastward with merely a warm front at the surface marking its progress.1/

With a wind shift, the advent of polar continental air terminates the conditions of the chinook. Unsettled weather follows with cloudy skies, chilly winds, snow storms, and generally foggy conditions in the foothills.

During milder winters thin coverings of fine snow are rapidly dissipated. Under the influence of the chinook, snow cover may completely disappear.

The lower Saskatchewan region.- In this, the most eastern of the climatic regions, the great range of temperature is the distinguishing feature. Precipitation totals are similar to those over most of the North Saskatchewan basin. The bulk of the precipitation falls in the summer when there is a concentration of about 45 per cent. From November to March inclusive, precipitation is mainly in the form of snow. Five inches of snow falls each month, which is not a very great deal in total. There is, however, considerable variation from year to year, but this has little effect on the flow of the main Saskatchewan River. If high water in the main river coincides with the summer period of maximum runoff in the tributaries, there will be flooding in the lower reaches. The main river acts as a dam backing up the tributary water.

At Melfort, a town located in the basin of the Carrot River, the average monthly temperature ranges from -3 degrees F. in January to 63 degrees F. in July. The Pas, nearer the eastern end of the basin, has a much greater range, from -9 degrees F to 65 degrees F. Average daily minimum temperatures for the coldest month is -13 degrees F. at Melfort and -18 degrees F. at The Pas. Both have an average daily maximum temperature of 75 degrees F. in July.

From November to March, the average monthly temperatures are below 32 degrees F. In October and April they are near that figure so freezing conditions may be expected. High water on the Saskatchewan river below Nipawin occurs twice a year. The first time in March or April, depending on temperature conditions. The ice breaks up and flow is supplemented by runoff from the winter snow. The second peak is caused by runoff from snows of the Rocky Mountains.

Winds in the Saskatchewan river basin.- Wind direction and velocity are of little direct importance in a hydrologic study. All points of the compass are represented at the stations where the records are kept. There is some regional differentiation. In the western part of the basin, winds from the south and the southwest predominate. In the lower Saskatchewan basin the prevailing winds are from the northwest and the northeast. The mean wind velocity is about ten miles per hour. Gusts up to 110 miles per hour have been recorded. The percentage of calms is greater in the winter than in the summer.

1/ Osmond, H.L., "The Chinook Wind East of the Canadian Rockies," Canadian Journal of Research, Volume 19, 1941, p.63.

CHAPTER 3. HYDROLOGIC CHARACTERISTICS OF THE SASKATCHEWAN RIVER AND ITS TRIBUTARIES

A. Introduction

In what follows, discharge refers to the volume of water that flows past a cross-sectional area during a unit of time. It is measured by a current metre, or is calculated from observations of the stage (the height of the water surface above an arbitrary datum). The discharge is measured in cubic feet per second, sometimes referred to as second-feet. For monthly records, it is sometimes convenient to refer to cubic feet per month. Total flows are measured frequently in terms of the acre-foot, which is the volume of water required to cover an acre to a depth of one foot.

Since some streams have been diverted for purposes such as irrigation, the natural flow must be estimated from the actual flow. Such estimates have been made by the Prairie Provinces Water Board, and their data have been relied on for statistics of "natural" flow.

The drainage system of the Saskatchewan river basin will be examined using three subdivisions, namely, the North Saskatchewan river and its tributaries, the South Saskatchewan river and its tributaries, and the main stem of the river and its tributaries.

B. The North Saskatchewan River

This river's source is the meltwater of the Saskatchewan Glacier, one of the great tongues of ice extending from the Columbia Icefield, a remnant of the Cordilleran ice-sheet, which is estimated to hold 17,600,000 acre feet of water. Other tributaries join the North Saskatchewan river from this icefield carrying meltwater from the snouts of glaciers, or from falls below hanging glaciers. Some meltwater seeps to the main stream through colluvial material deposited against the valley sides.

Nigel Creek is the first tributary of the North Saskatchewan river. It has its origin in the marshy land of the Sunwapta divide. The Alexandra, Howse, and Mistaya rivers are tributaries carrying meltwater from glaciers such as the Castleguard, Alexandra, Lyell, Freshfield and the Barkette. Many small streams along the west-facing slope are intermittent in character.

In these alpine valleys the more direct effects of runoff on regimen are delayed. Much of this precipitation reaches the stream by lateral movement through the loose glaciofluvial and colluvial material of the valleys. In addition, there are many lakes along the river courses. Some are cirque-head lakes; others occupy steps in the valley floors. These tend to absorb crest flows and then release the water gradually to the downstream outlet. In the Mistaya River course are several lakes. Peyto

Lake is located below a glacier of the same name; Mistaya and the two Waterfowl lakes are located further downstream. Small lakes on tributaries such as the Caldron, Capricorn and Cirque occupy cirque basins at the heads of their valleys. Most receive glacial meltwater from the east-facing slopes.

In the foothills belt, many tributaries join the North Saskatchewan. Of these the two most important are the Brazeau and the Clearwater rivers. Both have their headwaters in the main ranges. The Clearwater river rises in the eastern section of the main divide several miles beyond Clearwater Lake. Roaring Creek and Martin Creek are two tributaries joining the main stream in the mountain area. Small intermittent streams, probably of insequent origin supplement the main river flow. The Clearwater traverses a poorly drained lowland area before flowing north to join the North Saskatchewan river near Rocky Mountain House. Its runoff is estimated to be about 698,000 acre-feet from a drainage area of 1214 square miles.1/ Prairie Creek, the largest tributary, drains 318 square miles.

Near Rocky Mountain House there is a gauging station on the North Saskatchewan river. Records are available from June, 1913 to July, 1931 and from March, 1944 to October, 1949. The average annual runoff over this period is 3,701,000 acre- feet. The annual runoff varies from a minimum of 2,770,000 acre-feet to 5,133,000 acre-feet. Maximum flow is in July and August. The drainage area is 4,162 square miles so that runoff is 889 acre-feet per square mile.2/

The Brazeau river joins the North Saskatchewan about 45 miles downstream from Rocky Mountain House. Like the Clearwater, it has its origins in the Rocky Mountains. The northern tributary of this river taps a large icefield beyond the head of Maligne Lake, whereas other tributaries drain small glaciers in the eastern ranges. From the main ranges the river flows in an easterly direction, traversing a poorly drained lowland area that borders the main range. The Cardinal river joins it in this area. Over the latter part of its course the Brazeau river parallels the Arctic divide. In the narrow intervening area between divide and stream, it has few tributaries from the north of any consequence. Blackstone and Nordegg rivers enter from the south. Twelve miles west of Alder Flat it joins the North Saskatchewan river.

On the prairies, tributaries of the North Saskatchewan river decrease in length and volume. Usually they drain undulating lowlands. Small lakes, sloughs and marshes are typical features along the courses of these slow-flowing streams. Conjuring Creek, draining the small Wizard Lake, is typical

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1/ Alberta, Water Resources Division, <u>Report on Surface Water Supplies and Water Power of Alberta their Present and Ultimate Uses</u>, (by Ben Russell), Edmonton, Alberta, 1948, p.26.

2/ Discharge figures in the main are from the Water Resources Division, Department of Northern Affairs and Natural Resources, supplied by Mr. E.P. Collier, District Engineer, Calgary, Alberta; some data are taken from Canada, Department of Northern Affairs and Natural Resources, <u>Water Resources Paper No. 105</u>, Ottawa, 1953.

of these. Its discharge was recorded from 1924 to 1931. It has a drainage area of 15 square miles at the ganging station near Wizard Lake. The average runoff from May to October was 1,292 acre-feet. In some years no flow was recorded; in others, flow was as high as 4,590 acre-feet. The many small streams do add appreciably to the flow of the North Saskatchewan river as it winds across the plains. In addition to their effect on volume, the cumulative effect of the prairie streams, reflecting a more variable precipitation regime than in the mountains, is to increase the range of the regimen.

At Edmonton the average annual runoff of the North Saskatchewan river amounts to 5,611,000 acre-feet. Extremes range from a minimum of 3,679,000 to 8,467,000 acre-feet. As the area of the catchment increases to include more of the drier prairie, the runoff per square mile decreases, averaging 552 acre-feet persquare mile at Edmonton.

Between Edmonton and the Alberta-Saskatchewan border, the North Saskatchewan river flows in a northeasterly direction until, near Smoky Lake, a southeasterly trend is established. In this section the river parallels the height of land to the north varying in distance from it by about 20 to 30 miles. East of St. Paul it is but eight miles from the divide of the Beaver river. Streams flow generally from the northwest to join the North Saskatchewan. The Sturgeon river is one of the longest of these, and in its course it parallels for some distance the main river. It heads at Hoople Lake practically on the bank of the Pembina river but 200 feet above it. The stream drains several lakes, Isle Lake and Lake St. Ann being the two largest. These have the effect of regulating the flow on the 95 mile course which joins the North Saskatchewan river near Fort Saskatchewan. At a gauging station established near the mouth of the Sturgeon, records have been kept with some discontinuity, since 1914. Annual discharge records from 1914 to 1923, 1928 to 1931 show that, on an average monthly basis, there is some flow throughout the year. But winter flow is very low averaging 23 second feet in January (14-year record). The bulk of the runoff leaves the Sturgeon river in the April-July period.

About 12 miles downstream from the mouth of the Sturgeon river, Beaverhill Creek joins the North Saskatchewan from the south. It drains numerous lakes and sloughs in the morainic area, Cooking Lake and Beaverhill Lake being the two largest. The average annual runoff, April to September, was 85 acre-feet, the annual maximum, 618 acre-feet, the minimum zero. Flow is associated with heavy storms in the 830 square miles of catchment in summer.

Only small tributaries join Beaverhill Creek downstream from this point. Vermilion river, draining a large area of moraine and old lake bed, flows into the North Saskatchewan river in the neighborhood of Lea Park. It is a typical prairie stream with a gentle gradient and a sluggish flow. Although it occupies a broad valley, its volume is small.

The discharge of the North Saskatchewan river at the Alberta-Saskatchewan boundary, for the 37-year period 1911-12 to 1947-48, has been on the average six million acre-feet.1/

1/ "Summary Report of Recorded and Natural Monthly Flows at Certain Points on the Saskatchewan River System," Prairie Provinces Water Board Report No. 1, Regina Sask., 1950, Table 7.

A summary of the hydrologic record is given below in Table 3.

Table 3.- Flow of the North Saskatchewan River at the Alberta-Saskatchewan Border

(1) Monthly discharge (c.f.m.)

Average monthly discharge

O	N	D	J	F	M	A	M	J	J	A	S
5688;	2831;	1634;	1307;	1200;	1364;	6949;	11,164;	19,427;	20,918;	16,005;	10,603

Maximum monthly discharge

O	N	D	J	F	M	A	M	J	J	A	S
11,200;	5828;	2701;	2590;	2035;	2795;	14,050;	47,400;	38,280	51,443;	27,019;	26,550

Minimum monthly discharge

O	N	D	J	F	M	A	M	J	J	A	S
3402;	1725;	768;	644;	627;	862;	2339;	3170;	9140;	9653;	10,500;	5827

(2) Extremes of stage (at Frenchman's Butte)

Maximum, 10:00 p.m.	June 17, 1944	- 111,600 second-feet
Minimum	March 1, 1947	- 836 second-feet

(3) Annual runoff, March to October

Average annual - 5,971,000 acre-feet
Maximum annual - 9,409,000 acre-feet
Minimum annual - 3,605,000 acre-feet

(4) Drainage area: 21,700 square miles

(5) Discharge per square mile: 271 acre feet.

Source: "Summary Report of Recorded and Natural Monthly Flows at Certain Points on the Saskatchewan River System," Prairie Provinces Water Board Report No. 1, Regina, 1950, Table 7, and Water Resources Division, "Surface Water Supply of Canada, Arctic and Western Hudson Bay Drainage ...", Water Resources Paper Number 105, Ottawa, 1953, p.175.

In the Province of Saskatchewan there are few tributaries of any consequence which join the North Saskatchewan river. Turtlelake river drains a considerable area including many lakes and sloughs. A small stream flows from Rabbit, through Jackfish Lake to the North Saskatchewan. The Sturgeon river in Saskatchewan, joins the North Saskatchewan upstream from Prince Albert while the small Spruce river, flowing from the north, has its outlet at Prince Albert.

Two tributaries joining the North Saskatchewan river from the south are of some importance. Battle river has its origin to the west of Pigeon Lake in central Alberta. It joins the North Saskatchewan at Battleford. Although a long river of about 375 miles, it is not a large one. Hydrometric stations, established to measure lake elevations and stream discharge, have periodically been maintained along the course and on its tributaries, but no satisfactory records have been kept. Ribstone Creek, a tributary which has its source near Coronation, joins Battle river near the Alberta-Saskatchewan boundary. The stream drains a large area but average discharge is only ten acre-feet per square mile.

At Battleford, Saskatchewan, discharge records for the Battle river were kept from 1912 to 1921 and from March to August of 1922 to 1932. The average annual runoff was 306,600 acre-feet, the maximum annual runoff was about twice that figure. The drainage area is a little over 10,000 square miles, which means that average annual runoff is about 300 acre-feet per square mile. Figures from the minimum annual runoff are incomplete, Referring to the regimen, it is interesting to note that the months of maximum flow are April to May, not June and July as on the main river.

Eaglehill Creek is the only other southern tributary of any size. Recorded extremes of flow have varied from 977 c.f.s. to zero. The runoff is in the order of 700 acre feet per square mile.

The flow of the North Saskatchewan river at its confluence with the south branch (referred to hereafter as The Forks) has been estimated,1/ and it is purported to vary from a minimum annual discharge of 3.5 million acre-feet, to a maximum annual discharge of ten million acre-feet. The flow characteristics are depicted in Table 4.

...

1/ See "Summary ... System," Prairie Provinces Water Board Report, No. 1, op. cit.

Table 4.- Flow Characteristics of the North Saskatchewan River at The Forks

(1) Monthly discharge (C.F.M.)

Average monthly discharge

O	N	D	J	F	M	A	M	J	J	A	S
6441;	3161;	1784;	1353;	1255;	1349;	7689;	12,228;	18,680;	22,116;	16,679;	11,689

Maximum monthly discharge

O	N	D	J	F	M	A	M	J	J	A	S
12,290;	6415;	3186;	2709;	2034;	2165;	17,578;	52,922;	36,898;	59,476;	30,044;	25,597

Minimum monthly discharge

O	N	D	J	F	M	A	M	J	J	A	S
3768;	1838;	734;	703;	679;	705;	3361;	3038;	7030;	9650;	10,748;	7091

(2) Extremes of stage a/

Maximum, July 2, 1915 - 200,000 second-feet
Minimum, Jan. 23, 1935 - 395 second-feet

(3) Annual runoff

Average annual - 6,332,000 acre-feet
Maximum annual - 9,966,000 acre-feet
Minimum annual - 3,549,000 acre-feet

(4) Drainage area: 47,387 square miles

(5) Discharge: 134 acre feet per square mile.

a/ Figures are for Prince Albert.
Source: "Summary ... System," Prairie Provinces Water Board Report No. 1, Regina, 1950 and Water Resources Paper No. 105, Ottawa, 1953.

From a study of the flow and runoff statistics, certain charateristics become apparent. In Table 5 the relative importance of the various physiographic divisions through which the North Saskatchewan flows is illustrated. Although the mountain region occupies only eight per cent of the total area, it already has contributed 58 per cent to the total runoff. By the time the river reaches Edmonton 89 per cent of the runoff is carried in the river although only 22 per cent of the catchment has been crossed. No hydrometric station has been established on the Brazeau river. A station near Drayton Valley was established on the North Saskatchewan, but the length of record is insufficient to warrant its inclusion. If the record here could be used it would show the importance of that river to the headwaters system. The large drainage area of Battle river is a quarter of the total catchment, but it contributes very little to the volume of the North Saskatchewan.

Table 5.- Average Annual Runoff of the North Saskatchewan River at Selected Points, with Comparisons

	Average annual runoff (ac. feet)	Per cent of flow at The Forks	Area of catchment (sq. mil.)	Per cent of total catchment area
Rocky Mountain House	3,701,000	58	4,162	8
Edmonton	5,611,000	89	10,495	22
Alberta-Saskatchewan boundary	5,971,000	94 ...	21,700	46

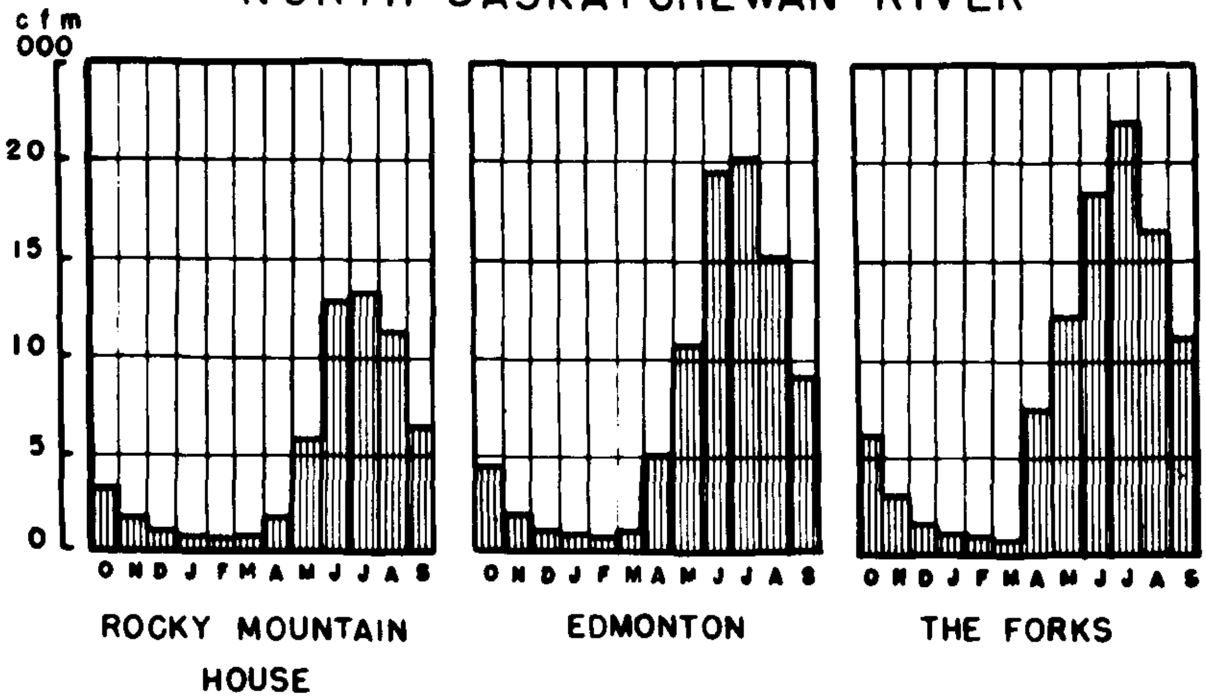
Source: Calculated from data in "Summary ...System," Prairie Province Water Board Report No. 1, Regina, 1950, and Water Resources Paper No.106, Water Resources Division, Department of Northern Affairs and National Resources, Ottawa, 1953.

The decrease in runoff per square mile on the North Saskatchewan river as it proceeds eastward is to be expected, because the river flows through a sub-humid area.

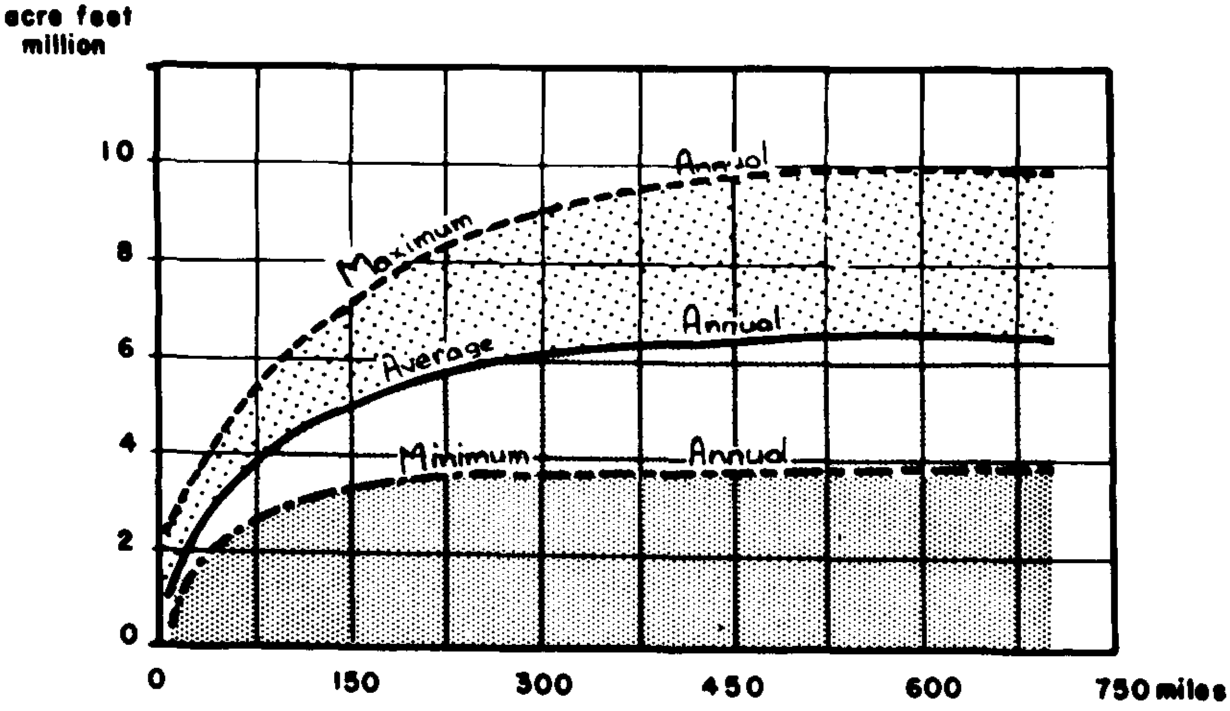
Turning now to a consideration of the regimen patterns throughout the drainage area, it may be said that all have in common the occurence of but one peak and that is associated with a concentration of flow in the summer months June, July and August. Even in May the flow has already doubled from the April average. Under average conditions February is the month of lowest flow on the North Saskatchewan river. April is the first month of increased flow. The thaw and spring rains have begun. The effect of these climatic conditions are felt first on the prairies where temperatures for the month of April are generally higher than in the mountainous region. As a result of this the increase in flow is much greater on the eastern than the western prairies. By May, however, the thaw has begun in the Rockies and the increase in flow is greatest in the western region, least at The Forks. June and July are the months of greatest runoff. A glance at Table 6 will be sufficient to show the concentration in these two months.

From August on there is a marked monthly decrease in flow. This is least in the western region, maintained still by meltwater and a higher groundwater reserve, whereas prairie streams are rapidly decreasing in flow to become but dry beds in some areas. The September flow becomes more rapid in the western region and relatively less in the east. The overall decrease in flow continues in October and into the winter months. The December figures indicate characteristic winter flows which decrease to reach a minimum in February.

NORTH SASKATCHEWAN RIVER



HYDROGRAPHS FOR AVERAGE MONTHLY FLOW



ANNUAL RUNOFF FROM SOURCE TO MOUTH

Table 6.- Concentration of Runoff on the North Saskatchewan River

Hydrometric station	Per cent of annual runoff in June and July
Rocky Mountain House	44
Edmonton	43
Alberta-Saskatchewan boundary	41
The Forks	39

Source: Calculated from "Summary ...System," Prairie Province Water Board Report No. 1, Regina, 1950, and Water Resources Paper No. 105, Water Resources Division, Department of Northern Affairs and National Resources, Ottawa, 1953.

In these regimens are revealed the interaction of various factors—the time and rate of snow melt in various portions of the basin, the distribution of precipitation, the amount and rate of groundwater charge and the relationship between mountain, foothills, and prairies areas as sources of supply.

The variation from the average annual runoff is an important characteristic of the regimen. Annual variation from the mean may be almost 60 per cent. There appears to be a regional trend in variation, increasing as the river flows over the plains.

Turning to the more detailed analysis of monthly variations, greater irregularities become apparent. The maximum variation from the average is in terms of the maximum summer flow month. Minimum monthly flows are less far removed from the average. Regional differences in variation from the mean point appear to show a greater variation on the plains than in the mountains where precipitation is less erratic. June is the month when greatest variation may be expected in the mountains, July on the plains. Variation from the average decreases considerably for the month of minimum flow, and it may be inferred, for the winter months.

Before turning to a discussion of the South Saskatchewan river system mention should be made of the large areas of interior drainage within the confines of the basin. There is little doubt that some of this interior drainage water does find its way to tributaries of the main system as ground water, but the proportion involved may be relatively unimportant.

Because of the irregular terrain, small undrained sloughs are a common feature of the whole of the basin. These may be disconnected kettle-holes and should not be considered as interior drainage systems. Where several tributaries flow to a central lake, developed inland systems may be said to exist. In the northern part of the Saskatchewan River Basin the streams centering on Birch and Redberry lakes in Alberta and Saskatchewan, respectively, are interior drainage tributaries. A great area between the North and South Saskatchewan rivers may be similarly considered. Gough Lake, Sullivan Lake, and Kirkpatrick Lake are all foci for independent inland drainage system. Eastward, in the Province of Saskatchewan, streams and lakes are more ephemeral features because of the lower precipitation, but Manito Lake, south of the Battle river, is the terminal point for the best developed interior drainage system in this portion of the basin. Eyehill Creek and its main tributary, Sounding Creek, flow northeast to the lake. Flow records have been kept on Eyehill Creek just before it enters the Lake. These illustrate the flow characteristics of the basin. Between 1920 and 1931, the average annual runoff, March to October was 6,460 acre-feet. An annual maximum of 12,932 acre-feet was recorded; the minimum was 3,470 acre-feet. As an indication of the paucity of precipitation, discharge was two acre-feet per square mile.

South of the South Saskatchewan river several areas of interior drainage are located which terminate at the Missouri-Saskatchewan water divide. Etzikom Coulee, which flows into Pakowki Lake, is one of these. Manyberries, Ketchum, and Canal creeks are tributaries from the east. Manyberries Creek at Brodin's farm has a drainage area of 137 square miles. The average annual discharge over the period from 1911 has been 6,440 acre-feet. The months of maximum flow are March and April; a zero flow for several months of some years is not uncommon.

North of the Cypress Hills, a number of streams flow towards the South Saskatchewan river but terminate in lakes and sloughs. Of these Britter Lake, Bigstick, Crane, and Antelope lakes are the most important. Many temporary lakes like Hay Lake and Whitegull Lake collect water from freshets in the Cypress Hills. Maple Creek, the largest of these streams, has had its flow recorded above Tenaille Lake reservoir. Runoff in the period from March to October, 1944 to 1949, varied considerably, being 620 acre-feet in 1949 and 10,150 acre-feet in 1948.

C. The South Saskatchewan River

General.- The South Saskatchewan river is formed by the confluence of the Bow and the Oldman rivers. In its course east and north, it has few tributaries, the Red Deer, joining it near the Alberta-Saskatchewan boundary being the only one of any size. In the western portion of the basin, streams are more numerous, the pattern more complex. Rivers, tapping plentiful mountain resources, furnish the bulk of the South Saskatchewan's flow. Because of their importance as sources of supply for both hydroelectric power and irrigation, many hydrometric stations have been located along their courses. Some of the tributaries in the extreme southwest have their headwaters in the United States. Detailed records of these streams have been kept in order to obtain a satisfactory record for purposes of international allocation. Hydrologic analysis of flow pattern is facilitated by the great number of stations, but, because discharge patterns are modified by reservoir retention and withdrawal, actual flow statistics may not be as conveniently used for analysis as in the North Saskatchewan river system. Natural flow averages have been estimated 1/ for several points on the rivers in the South Saskatchewan basin, and these will be used for comparative purposes.

1/ "Summary ... System," Prairie Provinces Water Board Report No. 1, Regina, 1950.

The Bow river.- The Bow river has its source about four and one half miles east of the Rocky Mountain divide. From Bow Pass, at an elevation of 6,878 feet, the river flows southeastward into the Bow Lake. Tributaries, many intermittent, drain the slopes to the east and west of the main stream. Some receive their flow from melting snow which has collected in high alpine basins during the winter months; others flow from the terminal faces of glaciers located high upon the main divide. Glaciers, such as the Bow, the Crowsfoot, the Balfour, Waputik and the Bath, all discharge their meltwater to the Bow river.

Near Lake Louise, Pipestone Creek, the first large alpine tributary, joins the Bow. Many other tributaries, all draining the mountain mass, flow into the Bow as it parallels the main ranges of the Rockies. At Banff, hydrometric records have been kept since 1909. Average annual runoff is about 1,000,000 acre-feet with an annual maximum of 1,370,000 acre-feet. Maximum monthly discharge occurs during June and July. A significant figure is that for discharge per square mile. At Banff it is 1,207 acre-feet, indicating the tremendous importance of the mountain catchment to the flow of the major rivers.

The Spray River joins the Bow from the south, downstream from Banff. It is typical of the alpine tributaries. Its headwaters are located near Palliser Pass on the main divide. Several of its tributaries have their origins under small glaciers while lakes and tarns are dotted along the headwater valleys. The Spray flows in a northwesterly direction to join the Bow. A gauging point is located just above the confluence of the Bow river and records have been kept since 1910. As in the case of the Bow, discharge in terms of catchment area is high, in this case being 1,249 acre-feet per square mile. The average annual runoff is 361,000 acre-feet.

Records have also been kept on the Forty Mile, the Cascade, and the Kananaskis rivers. The latter is an important tributary which, since 1932, has been controlled for power purposes. Like the Spray, it has several small lakes near its headwaters. From these it flows north to join the Bow River at Seebe. Its average annual dishcarge is 400,600 acre-feet. Of the rivers joining the Bow from the north, the Ghost, with its main tributary Waiparous Creek, is the most important. Flow characteristics are similar to those already described.

Near the Ghost River confluence, the Bow leaves the mountains and flows on to the high plains of the Third Prairie Level. Records of flow of the Bow river at Calgary have been kept since May, 1908.

The natural flow at Calgary, as it would be if unmodified by upstream power storage, varies from a maximum of 53,600 c.f.s., to a minimum of 105 c.f.s. The annual runoff has the following characteristics: average annual, 2,362,000 acre-feet; maximum annual, 3,652,286 acre-feet; minimum annual, 1,557,012 acre-feet. The drainage area is estimated at 3,136 square miles, and the average discharge annually is approximately 750 acre-feet per square mile.

With increasing distance from the mountains, the volume of water carried by tributaries decreases, variations in flow increase and some become intermittent streams. Only those which reach back into the mountains are of importance. The Elbow, joining the Bow River about one-half mile below the hydrometric station, is one of these. Its head-waters are in a swampy valley close to the main divide and from there it flows in a northeasterly direction. Hydrometric stations on the Elbow have been maintained at Bragg Creek and above and below the Glenmore Dam. Although the record above the dam has been kept from 1933 only, it is more indicative of the natural flow than that below the dam. Average annual runoff is 215,500 acre-feet. An annual maximum of 375,740 acre-feet has been recorded and a minimum of 113,500 acre-feet. June is the month of maximum flow, and the flow in May is slightly higher than that of July. Instantaneous peaks, coinciding with summer thunderstorms, have been as high as 25,200 c.f.s. The average discharge is 469 acre-feet per square mile, a contrast to the upper tributaries of the Bow.

The Highwood river, with its many tributaries, is the only other river of any size to join the Bow. Like the Elbow, its headwaters are but a short few miles from the main divide and but a short distance from the headwaters of that river. It is formed by the confluence of the Storm and Mist creeks and flows eastwards on to the prairies.

From the Highwood to the mouth of the Bow, the river has no tributaries of any importance. An area of 9,770 square miles is included within the catchment of the Bow River and about 2,700,000 acre-feet annually flow into the South Saskatchewan river.

<u>The Oldman river</u>.- The drainage area of the Oldman river occupies all of southwest Alberta and a portion of the adjoining State of Montana. The tributaries flow from the mountain region to be collected in the waters of the Oldman, which flows southeastward through mountain chains to be joined in turn by the Livingstone, Dutch Creek, and Racecourse Creek, the two latter flowing from the south. At the Gap the river drains 454 square miles and between 1944 and 1949 had an average annual runoff, from March to October, of 253,700 acre-feet. Near Cowley records have been kept from 1907 to 1949. Although some of these are incomplete and others only partial records, an indication of stream flow may be obtained from them. There is some control upstream from this point; so they are not completely indicative of natural flow. At this location, the Oldman has an average annual runoff of 403,100 acre-feet. Runoff has reached an annual Maximum of 653,725 acre-feet and a minimum of 266,174 acre-feet. May and June are the months of maximum monthly flow. Discharge is 552 acre-feet per square mile on the average.

About a mile downstream from this hydrometric station, a major tributary joins the Oldman from the west. This is the Crowsnest flowing from a pass of the same name. Castle river and Pincher Creek join the Oldman from the southwest. These and other smaller tributarires more than double the flow of the Oldman by the time it reaches Fort Macleod. At the latter point it has an annual average discharge of 1,022,000 acre-feet.

Willow Creek, to the east of Fort MacLeod, is predominantly a prairie stream. Its headwaters are in the foothills. Total annual runoff averages 112,700 acre-feet or 112 acre-feet per square mile.

Between Fort Macleod and Lethbridge two important tributaries join the Oldman from the south. These are the Belly and St. Mary rivers. The Belly river has its origin in the United States and flows about 15 miles northward before entering Canada. Along with its main tributary, the Waterton river, it has its source in the mountains of Glacier National Park, Montana. Remnants of old glaciers like the Ahern, the Old Sun, Chaney, Whitecrow and Miche Wabun stand at the head of the Belly river and its main tributaries. Lakes in the valley floors are characteristic of the upper courses of these rivers; lakes Helen and Elizabeth are in the main valley, with Ipasha, Margaret, Mokowanis, Glenns, Crossley and Miche Wabun in the tributaries. The glaciers are small and do not greatly affect discharge. The lakes influence the regimen of streams in temporarily storing precipitation in upstream portions of the catchment.

Near Mountain View, complete hydrometric records have been kept for the Belly river. To obtain the natural flow, the diversion into the Mountain View Irrigation Canal was added. The average annual runoff is 222,487 acre-feet, the annual maximum 363,000 acre-feet, and the annual minimum 133,137 acre-feet. As this runoff is obtained from only 121 square miles, the discharge is high, typical of the mountain region. June is the month of maximum stream flow.

About 35 miles downstream from this gauging station an important tributary, the Waterton river, joins the Belly. It also has its origins in Glacier National Park, Montana. Waterton Lake occupies part of its upper valley. Near the exit from the lake a record was kept between 1908 and 1933. The average annual runoff was 483,220 acre-feet, with a maximum of 710,000 acre feet, and a minimum of 290,000 acre-feet. The catchment area is 238 square miles, hence the runoff per square mile is 2,040 acre-feet. The Belly river joins the Oldman near Monarch.

The St. Mary is the largest of those rivers within the Saskatchewan river basin to have its origin in the United States. Meltwater from small glaciers like the Blackfoot and Red Eagle in Glacier National Park is a feature of the headwaters. The water flows into small cirque head lakes. Larger lakes, occupying about 15 miles of the valley, are the St. Mary and Lower St. Mary lakes. Swiftcurrent Creek, flowing from Lake Sherborne, is an important tributary. Between May to October, inclusive, it has a total runoff of 124,300 acre-feet. At the International Boundary a hydrometric station has been recording flow since 1901. This has been corrected to give the natural flow of the St. Mary at this point. The figures are similar to those for other mountain areas. Average annual runoff is 658,700 acre-feet; the discharge per square mile is high; and the month of maximum flow is June.

The actual flow of the St. Mary is reduced by diversions for irrigation. Two streams join the St. Mary below the hydrometric station. Lee Creek, at Cardston, has a mean annual runoff of 38,530 acre-feet. Pothole Creek at Magrath has a mean runoff, March to October inclusive, of 27,460 acre-feet. It joins the St. Mary near Lethbridge.

At Lethbridge all the major tributaries of the Oldman except the Little Bow have been accounted for. The mean annual runoff, as recorded at the Lethbridge hydrometric station, is 2,414,000 acre feet. The maximum variation from this average has been 50 per cent (1910-1949). The drainage area is 6,710 square miles, hence runoff per square mile is about 360 acre-feet.

The Little Bow river has its source in a spring which is practically on the banks of the Highwood river. For the first few miles, its flow is dependent on a number of springs until it is joined by Mosquito Creek, which drains the foothills country in the southwest portion of its basin. Diversions from the Highwood make an estimate of flow difficult. The area of the drainage basin is 1,745 square miles and the average annual runoff at the mouth is approximately 22,976 acre-feet or 13 acre-feet per square mile.1/ About 55 miles downstream from this junction, the Oldman joins the Bow to form the South Saskatchewan river.

The South Saskatchewan river.- The South Saskatchewan river has few tributaries. The Bow and the Oldman rivers, on the average, contribute 70 per cent to the total runoff of the South Saskatchewan or 5,484,115 acre-feet. This runoff is almost evenly divided between the two rivers. At Medicine Hat, 50 miles to the east of the confluence, the South Saskatchewan river has an average annual runoff of 5,906,558 acre-feet. The annual maximum runoff is 10,259,804 acre-feet and the minimum 3,150,124 acre-feet. June is the month of maximum flow, but July and not May is the second highest month. Flow in June, over the period of record from 1911, has varied from a minimum of 10,652 c.f.m. to 55,817 c.f.m. The extreme stage occurred also in June when 145,000 c.f.s. were recorded.

Downstream from the gauging station at Medicine Hat the Seven Persons river joins the South Saskatchewan. Its headwaters are in the western section of the Cypress Hills, from which it flows northeastward. Records have been kept spasmodically from 1912; average runoff is in the neighborhood of 12,000 acre-feet. The river has a catchment of 744 square miles, giving 17 acre-feet of runoff per square mile.

Bull's Head and Ross Creeks join just east of Medicine Hat to flow into the South Saskatchewan river. A hydrometric station has been maintained on the latter near Irvine since 1910 with a fairly continuous record. An average annual runoff of 10,350 acre-feet has been obtained. About 80 per cent of the flow is in the spring. The drainage basin is 233 square miles so that annual runoff is 44 acre-feet per square mile. Other stream systems flow northward from the catchment in the Cypress Hills. Many are ephemeral; most fail to reach the South Saskatchewan, terminating in lakes and sloughs.

Near Empress, the Red Deer, a large tributary of the South Saskatchewan, joins it from the north. It has its origin in the Sawtooth Range, east of the main divide of the Rocky Mountains and has a length of about 400 miles. The headwater tributaries have their origins in the meltwater of numerous glaciers on the slopes of Mount McConnell, Mount Drummond, and Mount St. Bride . The largest headwater tributary is in the south flowing from the Bonne Glacier into Douglas Lake. Small lakes are a feature of the upper course. Panther River and Burnt Timber Creek reach well back into the mountains for their supply of water, but they join the Red Deer

1/ Russell, Ben, Report on Surface Water Supplies and Water Power of Alberta-their Present and Ultimate Uses, Edmonton, Alta., 1948, p.23.

well downstream. A hydrometric station has only recently been established in the headwater region. Tributaries continue to tap foothill sources of water. The last to join the Red Deer and longest of these is the Little Red Deer River. From the north the Medicine river flows into the Red Deer. At the town of Red Deer hydrometric records have been kept since 1911. The average annual runoff is 1,326,000 acre-feet, the maximum 2,133,000 acre-feet and the minimum 566,000 acre-feet. June and July are the months of maximum flow. Runoff per square mile, from the 4,480 square miles of catchment area, is about 296 acre-feet.

Downstream from the town of Red Deer, many tributaries join the river. All are prairie streams and individual contributions to the main flow are small. Rosebud river has an average runoff, February to October, of 63,300 acre-feet; Berry Creek, farther downstream, about 25,000 acre-feet. Collectively, however, these and other smaller tributaries do affect the regimen of the Red Deer river. At Empress, near the mouth of the Red Deer river, complete hydrometric records have been kept. Some interesting comparisons with those at the town of Red Deer may be made. There is, as would be expected, an increase in total runoff at the downstream station, but the discharge per square mile shows a spectacular decrease. Although the size of the catchment area more than triples, the discharge per square mile drops from 331 acre-feet to 89 acre-feet, an indication of the climate over the lower course. Prairie streams, starting their flow earlier than those in the mountains, augment the spring and early summer flow of the Red Deer at Empress. Flow in January and February is higher at Red Deer than it is at Empress. Chinooks are not a characteristic at Red Deer, but modified temperatures resulting from chinook effects may account for this anomaly.

Downstream from Empress the Red Deer joins the South Saskatchewan river. The natural Canadian flow below the junction has been estimated.1/ By adding the United States' share of the St. Mary river, the total natural flow is obtained. This is given in summary form in Table 7.

Swift Current Creek is the only tributary of any size to join the South Saskatchewan river downstream from the Saskatchewan border. It has its source in the eastern end of the Cypress Hills and flows northward. An annual record of flow was kept at Swift Current from 1910 to 1931. After a break of two years, records from March to October, to the present day have been kept. Runoff for the period averaged 53,050 acre-feet.

At Saskatoon there is little appreciable difference from flow patterns at the border. The average annual runoff has increased 200,000 acre-feet, supplied mainly from groundwater and from small streams like Swift Current Creek. The discharge has decreased from 178 acre-feet per square mile to 150.

1/ "Summary ...System," Prairie Province Water Board Report No. 1, op.cit.

Table 7.- The Flow of the South Saskatchewan River Near the Alberta-Saskatchewan Border

(1) Monthly discharge (c.f.m.)

Average monthly discharge

O	N	D	J	F	M	A	M
6449;	3982;	2416;	2118;	2212;	4498;	10,326;	18,944;
J	J	A	S				
32,341;	20,948;	11,508;	8,717				

Maximum monthly discharge

O	N	D	J	F	M	A	M
15,710;	7482;	4402;	7530;	6022;	13,641;	28,082;	56,276;
J	J	A	S				
66,453;	55,364;	27,139;	24,690				

Minimum monthly discharge

O	N	D	J	F	M	A	M	J
2245;	1550,	478;	424;	945;	1663;	3222;	8412;	13,280;
J	A	S						
8166;	5744;	4257						

(2) Annual runoff

Average annual - 7,530,285 acre-feet
Maximum annual - 13,455,112 acre-feet
Minimum annual - 4,295,012 acre-feet

(3) Drainage area: 42,287 square miles.

(4) Discharge: 178 acre-feet per square mile.

Source "Summary ... Sytem," Prairie Province Water Board Report No. 1, Regina, 1950.

At The Forks a similar regimen is found. No large streams have joined the river. Inflow supplementing the exotic flow is in the form of spring runoff from streams, dry for most of the year, and from groundwater. The natural flow of the South Saskatchewan river at The Forks is given in Table 8.

Table 8.- Flow Characteristics of the South Saskatchewan River at The Forks

(1) Momthly discharge (c.f.m.)

Average monthly discharge

O	N	D	J	F	M	A	M
7240;	4187;	2488;	1994;	1922;	3584;	12,940;	17,040;

J	J	A	S
30,902;	24,830;	13,263;	10,044

Maximum monthly discharge

O	N	D	J	F	M	A	M
18,076;	9620;	5188;	8795;	4260;	14,217;	26,072;	52,080;

J	J	A	S
63,317;	58,137;	35,415;	30,555

Minimum monthly discharge

O	N	D	J	F	M	A	M	J
2916;	1060;	464;	353;	344;	808;	4809;	8091;	10,161;

J	A	S
9920;	6012;	5524

(2) Annual Runoff

Average annual - 7,894,285 acre-feet
Maximum annual - 14,658,000 acre-feet
Minimum annual - 4,476,012 acre-feet

(3) Drainage Area: 62,500 square miles.

(4) Discharge: 126 acre-feet per square mile.

Source: "Summary ... System," Prairie Province Water Board Report No. 1, Regina, 1950.

The characteristics associated with South Saskatchewan river are recapitulated as follows: Average annual runoff figures emphasize the importance of the mountain region as a source area. The Bow River has an average annual runoff of 2,687,769 acre-feet. At Banff, 1,028,000 or 38 per cent has been collected from about nine per cent of the total area. The Spray River, a typical mountain tributary, has an area of three per cent of the total catchment, yet it contributes 361,000 acre-feet or 13 per cent of the Bow's discharge. Other mountain tributaries also make substantial contributions to the flow of the main stream.

The Red Deer and the Oldman have similar characteristics. The first reliable measuring point on the Red Deer is beyond the mountains at a town of the same name. The runoff of 27 per cent of the catchment is measured and the annual average is 1,326,000 acre-feet or 83 per cent of the total runoff. The Oldman at Fort Macleod, again on the plains but collecting mainly mountain runoff, has an annual average of 1,022,000 acre-feet. The Belly and the St. Mary rivers add another 681,187 acre-feet. In all 61 per cent of the runoff is collected in but 2,848 square miles or 29 per cent of the Oldman catchment. The St. Mary river near the International Boundary, where it leaves the uplands, has an annual runoff of 658,700 acre-feet. This is about 24 per cent of the total runoff of the Oldman river, although it is collected from only 497 square miles of five per cent of the Oldman catchment.

Relationships between the Oldman, Bow and South Saskatchewan rivers emphasize again the importance of the mountains. The Bow river contributes 2,687,789 acre-feet or 34 per cent to the average annual volume of the South Saskatchewan. The catchment area is 9,705 square miles or 16 per cent of the total. Hence, as already pointed out, the average contribution of these two rivers is about 70 per cent of the total volume of the South Saskatchewan river.

At Medicine Hat the South Saskatchewan river has flowed through only about 33 per cent of its drainage area, yet it has collected as runoff, 5,906,558 acre-feet, or 75 per cent of the total volume. The addition of runoff from the Red Deer tributary adds a considerable volume to the flow of the South Saskatchewan. At Empress the runoff is 20 per cent of the total. The drainage area is about 30 per cent of the catchment of the South Saskatchewan river.

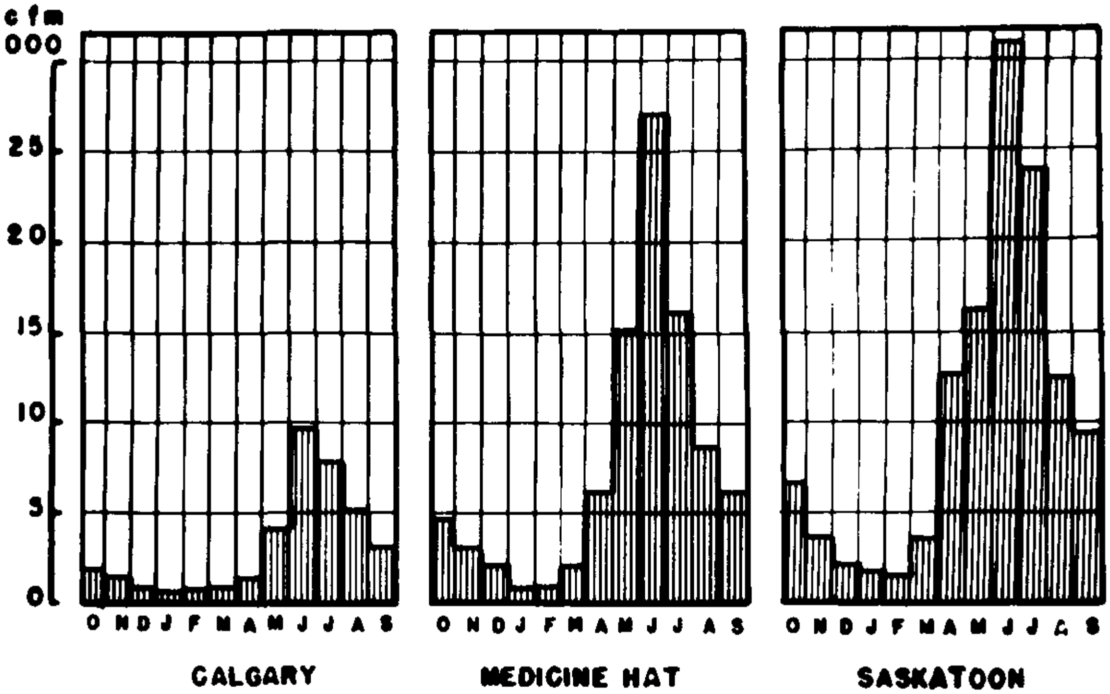
The combined runoff of the Red Deer and the South Saskatchewan rivers brings the total volume to 7,530,285 acre-feet or 95 per cent, although over 30 per cent of the drainage area has still to be covered. At Saskatoon the runoff of the South Saskatchewan river is 98 per cent of the total.

This analysis tends to emphasize the importance of the mountain region to the total catchment. In the long journey eastward over the plains, the rivers, to a large extent, function as canals conveying the surface water from the mountains to its destination in Lake Winnipeg. The runoff supplied by the prairie streams is of little significance in terms of total volume when compared with the quantity in the mountains.

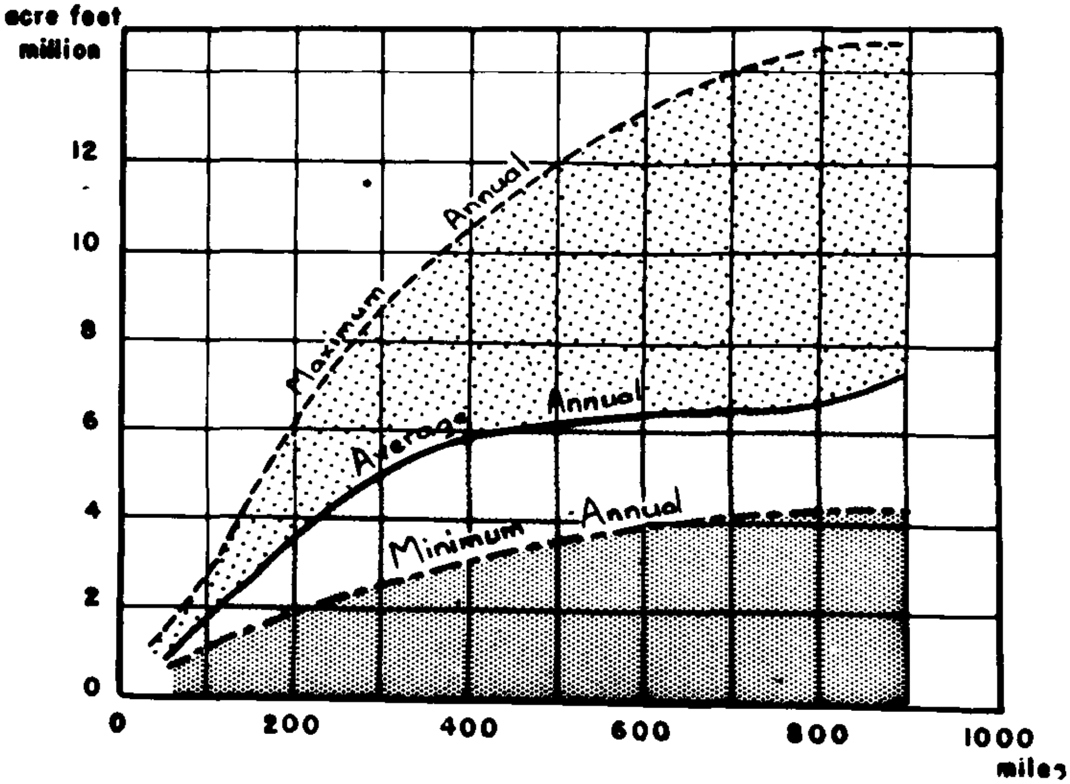
D. The Saskatchewan River

After the North and South Saskatchewan rivers join at The Forks to form the Saskatchewan river, the flow patterns reflect the combined characteristics of these two major tributaries. The water year 1926-27 may be taken as an example. In that year volume of the South Saskatchewan river at The Forks was 5,435,000 acre feet above the average, an increase of 70 per cent. In the North Saskatchewan river the increase over the same period was 2,527,000 acre-feet or 40 per cent of the average figure. At The Forks the combined volume was 22,085,000 acre-feet, an increase of 7,960,000 acre-feet or 56 per cent of the average figure. At The Pas the increase was 9,266,000 acre-feet or 52 per cent above the average. (Table 9).

SOUTH SASKATCHEWAN RIVER



HYDROGRAPHS FOR AVERAGE MONTHLY FLOW



ANNUAL RUNOFF FROM SOURCE TO MOUTH

Table 9.- "Natural" Discharge of the Saskatchewan River for 1926-27 and the Average for 1911-48, with Comparisons a/

River	Year 1926-27	Average for years 1911-48	Deviation of 1926-27 flow from average	Per cent of deviation
	- acre-feet in thousands -			- per cent -
North Saskatchewan at Forks	8,859	6,332	2,527	40
South Saskatchewan at Forks	13,226	7,791	5,435	70
Saskatchewan at Forks	22,085	14,125	7,960	56
Saskatchewan at The Pas	26,985	17,719	9,266	52

a/ The "Natural" discharge is the reconstructed natural flow estimated by the Prairie Provinces Water Board.
Source: "Summary ...System," Prairie Provinces Water Board Report No. 1, Regina, 1950.

The average volume of the North Saskatchewan at The Forks is 6,332,000 acre-feet; the average volume of the South Saskatchewan is 7,791,000 acre-feet. Hence, under average conditions the contribution of the South Saskatchewan is the larger, being 56 per cent of the total volume.

The North Saskatchewan river is, however, a more reliable source of water. Annual variation in runoff is lower by about 30 per cent than that of the South Saskatchewan, Although the absolute monthly maximum is higher on the South Saskatchewan than on the North, the minimum is about half that of the North Saskatchewan. The possible range on the South Saskatchewan is 62,973 c.f.m. On the North Saskatchewan it is 58,797 c.f.m. The latter river also has a higher runoff per square mile. Hence, it may be said that, although the South Saskatchewan contributes a greater volume of water to the Saskatchewan river, its flow is less reliable.

Between The Forks and Lake Winnipeg several streams join the Saskatchewan. These include the Torch river from the north, the Carrot and the Pasquia rivers from the south.

At The Pas, records have been kept since 1911. Extremes of stage occurred on June 11, 1948 (105,500 c.f.s.) and February 3-4, 1930 (1,790 c.f.s.). Annual runoff in acre-feet varies as follows:

Average annual	- 17,822,285
Maximum (1915-1916)	- 28,245,000
Minimum (1940-1941)	- 9,035,000

These figures are for reconstructured natural flows of the river. Actual flows are somewhat different.1/

1/ See "Summary ...System," Prairie Provinces Water Board Report No. 1, Regina, 1950.

The Pas is about 200 miles east of The Forks. In that distance the average annual runoff has increased by about 3,600,000 acre-feet. The catchment of the lower Saskatchewan river contributes more per unit area. The decrease noted over the semiarid plains is no longer a characteristic in this more humid region. A major difference, when comparing these figures with those for stations to the west, is to be seen in the river's regimen. There appears now a definite retardation of the summer maximum. At The Forks June is still the month of maximum flow, but by the time the river reaches The Pas, July has become the month of maximum flow and high flow remains through August. Several factors combine to account for this later summer maximum. Of these, the distance from the major source of water supply and the temporary ponding of water in the maze of waterways east of The Forks are the two most important.

Between 1912 and 1918 a hydrometric station was located at Grand Rapids near the mouth of the Saskatchewan river. The record for most of those years is incomplete, but in 1915, 1916 and 1917 the runoff was between 21,000,000 and 27,688,000 acre-feet.1/ The station was re-established in 1951. The regimen is similar to that of The Pas except that the July maximum becomes more definite. In 1951, August was the month of maximum flow.

Immediately to the east of Grand Rapids, the Saskatchewan river empties into Lake Winnipeg, and its identity is lost. Drainage from the lake is by way of the Nelson river to Hudson Bay.

E. Summary

The high proportion of the runoff that originates in the Rocky Mountains is an outstanding characteristic of the Saskatchewan River System. On the plains, the flow in prairie streams depends on summer precipitation which as a rule is less reliable than what falls in the mountains and the evapotranspiration is greater. A major feature regarding the regimen of the river system is the prevalence of a summer maximum. This maximum varies in time somewhat depending on the time of the snow thaw, the duration of the frontal rain period and the frequency of convectional rain. In general the characteristics of the Saskatchewan river are similar to other great rivers having their origin in the Rocky Mountains and flowing eastward. Differences in detail are due to the northern location of the Saskatchewan and consequently the increased importance of the freezing period as a modifier.

1/ Figures supplied by the Water Resources Branch, Winnipeg, Man., from old Department of the Interior Records. The flow for January and February was estimated.

WATER ALLOCATION AND UTILIZATION IN THE SASKATCHEWAN RIVER BASIN

Report No. 3

Annotated Bibliography of Selected Documents Pertaining to Water Allocation and Utilization in the Saskatchewan River Basin

John Boan

Economics Division

in co-operation with

Prairie Farm Rehabilitation Administration

Canada Department of Agriculture

61/14(3) Ottawa, July 1961.

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PREFACE

This report is one of a series of three reports, which, in conjunction with the report entitled, "A Survey of the Law of Water in Alberta, Saskatchewan and Manitoba," by Mr. P. Gisvold (Edmonton, 1956) makes a beginning at answering some of the questions raised in the terms of reference that outlined the work. The latter called for "... a broad study of interprovincial watersheds which will co-ordinate (a) all facts known concerning their geographical location in relation to present and probable future human activity and needs; (b) the economic significance of various physical and engineering possibilities related to these activites; (c) present and required legal framework regulating human activity in relation to water; and (d) other relevant aspects.

In addition to the law study just mentioned, these reports are as follows:

Report No. 1, "Preliminary Investigation of the Economic Significance of Water Requirements Relative to Human Activities and Needs in the Saskatchewan River Basin."

Report No. 2, "Physical Features of the Saskatchewan River Basin."

Report No. 3, "Annotated Bibliography of Selected Documents Pertaining to Water Allocation and Utilization in the Saskatchewan River Basin."

The documents used in the present report are Canadian or refer to Canada, and the selection emphasized data concerning Western Canada. No attempt was made to list all data referring to water the world over; and in fact, no claim is made that all of the distinctly Canadian data have been listed.

Acknowledgment is due to Miss Jean M. Rylance for help in assembling the material. Special thanks are due to the late Dr. L.B. Thomson and to Dr. C.C. Spence for encouragement and help.

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CHAPTER 1. BOOKS

1. Land

Bracken, John, Dry Farming in Western Canada, Winnipeg, Man., Grain Growers' Guide Ltd., 1921, 368 pp.

See Ch. 2, "The Climate of Western Canada in its relation to Crop Production," Ch. 4, "The Moisture Problem," and Ch. 13, "Irrigation Farming in Western Canada."

Mackintosh, W.A., Prairie Settlement: The Geographical Setting, Toronto, The Macmillan Co. Ltd., 1934.

This book examines the physical basis of settlement, the possibilities of further settlement, the actual extent and pattern of settlement and the prospects of future development.

Morton, A.S. and Chester Martin, The History of Land Settlement and Dominion Lands policy, The Macmillan Co. of Canada Ltd., 1938, 545pp.

Part I - History of Prairie Settlement - The themes of this volume are experiment and evolution, the development of the circumstances and the tools by which prairie settlement was effected. The author discloses some of the extended and detailed researches in the history of the prairie region. He advances and supports a thesis as to the prerequisites of successful settlement in this region and tells of the adaption of transport, productive techniques and agricultural produce which courage and ingenuity made.

Part II - Dominion Lands policy - This study is focussed on the free-homestead system as a land policy. Its case is that of a grassland region where the free homestead had its greatest chance of success. The author analyses the development and working of the type of land policy from its inception in Canada to its disappearance. As history, his study is one of Dominion policy on a front that was of dominating importance for half a century.

2. Water

Denis, L.G. and J.B. Challies, Water powers of Manitoba, Saskatchewan and Alberta. Commission of Conservation Canada, Toronto, Warwick Bros., and Ruther Ltd. Printers, 1916.

This book covers the three prairie provinces; Chapters VI-XI inclusive deal with streams pertinent to the Saskatchewan River Basin. For purposes of grasping some of the more essential characteristics of the river system, this is an excellent source. The data concerning discharge, precipitation etc. need to be supplemented by more recent material.

Denis, L.G. and A.V. White, Water Powers of Canada, Commission of Conservation, Canada, 328pp. plus appendices, bibliography and index, Ottawa, The Mortimer Co. Ltd., 1911.

Deals with power and power potentialities throughout the Dominion by provinces. Chapter 8 deals with Western Canada but it refers only briefly to the more immediately accessible powers, leaving to a later study in the series a more exhaustive analysis.

The appendices quote the International Treaty of 1909 concerning boundary waters of the U.S. and Canada and acts pertaining to water development.

The biliography (pp. 347-376) consists of books, reports and pamphlets containing data relating to the water-powers of Canada. However, the data is mainly for Ontario and Eastern Manitoba and not for the prairie region.

3. Population

England, Robert, Colonization of Western Canada, 308pp. plus appendices, London, P.S. King and Son Ltd., 1936.

A study of contemporary land settlement. (1896-1934)

The book is an effort to cover the story and the resulting structure of the colonization of Western Canada - Manitoba, Saskatchewan, and Alberta.

It is a study of the growth of ethnic group communities and their adaption to their environment. The story of drought conditions, the back to the land movement, the wheat situation, the variety of conditions in Western Canada have been touched upon as part of the whole picture. An estimate of the contribution of the early settlers is included and much attention given to the relation of immigration to colonization.

Most of the material in this book was written in 1933.

Hedges, James B., Building the Canadian West, 410 pp. bibliographical note, New York, The Macmillan Co., 1939.

Deals with the land and colonization policies of the Canadian Pacific Railway.

The book is an outgrowth of the authors' earlier studies of the influence of the railway on the settlement of the northwestern states of the United States. Those investigations aroused his interest in the role played by the same agency to the north of the 49th parallel, where in the Prairie Provinces one-fifth of the land area alienated by the Dominion Government was granted to the Canadian Pacific Railway and its subsidiaries.

The term Canadian West refers to Manitoba, Saskatchewan and Alberta. The work has been projected against the background of the American frontier and American experience. Parallel and contrasting development on the two sides of the imaginary boundary line have been kept constantly in mind.

Chapter VII deals with the launching of the Canadian Pacific Irrigation Co. Project.

4. Resources

Ashley, C.A. ed., Reconstruction in Canada, 145 pp. and bibliography, Toronto, University of Toronto Press, 1943.

This series of lectures deals with the reconstruction period after the war. The authors discuss constitutional difficulties, future of wheat, importance of gold, necessity of planning in reconstruction, government control, immigration, education and peace treaties. There are lectures on soil and water, forest resources, water, its use and control, construction projects, social services. The concluding lecture seeks to set forth some of the ideals which a reconstruction policy should realize.

McConkey, O.M., Conservation in Canada, 209 pp. and bibliography, Toronto and Vancouver, J.M. Dent and Sons (Canada) Ltd., 1952.

In this book the author discusses the conservation of Canada's natural resources i.e. soil, water, forests, wild life and minerals. It is suggested that Canada should develop a co-ordinated planned conservation program. The author compares Canada's natural resources with those of other countries and describes the results in other countries of misuse and lack of conservation programs. He also discusses the conservation projects already in progress in Canada.

Moore, E.S. Elementary Geology for Canada, 2nd edition, 425 pp., Toronto, J.M. Dent and Sons (Canada) Ltd., 1944.

Part I deals with physical geology in general and Part II the historical geology portion deals chiefly with Canadian formations and the major geographical events that have shaped this country. This portion has been discussed in eras and periods.

Young, G.A., Geology and Economic Minerals of Canada, Canada Geological Survey, Department of Mines, 187 pp., Ottawa, 1926.

5. Economics

Britnell, G.E., The Wheat Economy, Toronto, University of Toronto Press, 1939, 241 pp. Appendix.

This work is part of an extended project carried out by the Canadian Institute of International Affairs in co-operation with the Institute of Pacific Affairs on standards of living in Canada. In this book the author presents the final conclusions of a study on standards of living in Saskatchewan.

Fowke, V.C., Canadian Agricultural Policy - the historical pattern, University of Toronto Press, 281 pp. and bibliography, Toronto, 1947.

Part I - Pre-confederation period - deals with the French regime, Maritimes before confederation, the St. Lawrence Region, the agricultural frontier and Confederation. Part II - Federal Agricultural Policy - deals with the division of powers at Confederation, the encouragement of immigration and settlement, livestock and dairy industries, production and marketing of wheat and Canadian tariff policy and the farmer.

Portrayed here is the role or roles of agriculture within territories which now form the Dominion of Canada and the relation these roles have to the formation of the agricultural policies of the respective governments.

Innis, Mary Q., An Economic History of Canada, Toronto, 1948, the Ryerson Press, 345 pp. plus bibliography.
Economic History from 16th Century to 1931.

Mackintosh, W.A. (etc.), Economic Problems of the Prairie Provinces, 280 pp., appendix, Toronto, the Macmillan Co. of Canada Ltd., 1935.

An attempt is made in this book to elucidate those economic problems which are common to the whole region of the Prairie Provinces. Although the particular economy studied is that of the prairie region of Canada, the problems are in the main common to all regions of recent and rapid settlement. The thesis of this book is that the characteristic and, therefore, fundamental problems are those which result from the conjuncture of a highly variable regional income and heavy overhead charges. It specifically discusses economic trends and fluctuations, problems of transportation and marketing, problems of finance (deals with Alberta which is comparable to the other provinces) problems of taxation (deals with Saskatchewan) and concludes with a chapter on farm credit. It does not offer solutions to these problems but rather shows the essential characteristics of the economic problems which are inherent in the type of settlement which has taken place in the prairie provinces of Canada.

Murchie, R.W., Agricultural Progress on the Prairie Frontier, 292 pp. plus appendix "A" and "B", Toronto, 1936, The Macmillan Co. of Canada Ltd.

This book gives the results of extensive and carefully planned investigations to discover how far the settler of the Canadian prairie has succeeded in devising a system of economic utilization of the land and types of farming adapted to natural conditions and the possibility of market. It is part of a series describing the progress made by agricultural pioneers of the Canadian prairies.

CHAPTER 2. ARTICLES

1. General

Connor, A.J. - "Drought in Western Canada" - Canada Year Book, 1933, pp. 47-59, Ottawa, 1933.

Precipitation in crop years and temperature in the growing season at certain western points together with quotients when precipitation is divided by temperature 1883.4 1932.

Weighted quotients where precipitation in crop years is divided by temperature in growing period, expressed as a percentage of average 1886-1932.

Value of quotients where precipitation is divided by temperature in growing period, related to sun spot maxima.

Curre, B.W. - "Weather Modification". Saskatchewan Farm Science. Department of Extension, University of Saskatchewan. Vol. 1, No. 3, Saskatoon, August 1954.

Briefly described in this article are the stages of the precipitation process and how man can control one stage which is the process of inducing the formation of rain drops. This is called "seeding" the clouds. It discusses briefly the methods and effects of "seeding" although evaluation of this project on the prairies may not be possible for four or five years.

Hooker, Arthur, editor - Official proceedings of the Twenty-first International Irrigation Congress, Calgary, Alberta, Oct. 5-9, 1914, Government Printing Bureau 1915.

Contains, among others, papers as follows:

Hendry, M.C. - "Power and storage possibilities of the Bow River west of Calgary". pp.278-287.

Peters, F.H. - "The Dominion Government Laws respecting irrigation in Western Canada." pp.113-122.

Hays, D.W. - "The relation of the farmers to the irrigation district", pp. 207-216.

Stockton, R.S. "Irrigation in Alberta and the settler on irrigated land", pp.218-229

Mantle, A.F. - "Irrigation and Saskatchewan agriculture", pp.199-204.

Muckleston, H.B. - "Irrigation enterprises of the Canadian Pacific Railway Company in Alberta", pp.261-274.

"Prairie Farm Rehabilitation" - C.S.T.A. Review, Canadian Society of Technical Agriculturists, No. 23, Ottawa, Dec. 1939.

This issue contains the following articles:

"A Land Utilization Plan for Prairie Agriculture" - Archibald, A.S.
"Soil Surveys and Soil Research" - Leahy, A.
"Economic Research in the Drought Area of Western Canada" - Coke, J.
"Land Utilization in Alberta" - Longman, O.S.
"Land Utilization in Saskatchewan" - Eisenhauer, E.E.
"Manitoba and Prairie Farm Rehabilitation" - Ellis, J.H.
"Water Conservation and Resettlement" - Spence, G. and J. Vallance.
"Agricultural Improvement Associations" - Sherriff, C.
"Organized Methods of Soil Drifting Control" - Palmer, A.E.
"Community Pastures and Resettlement" - Frier, O and M. Mann
"Grazing Surveys and Regrassing Program" - Mathews, G.D. and P.W. Peake.
"Water Resources for Irrigation in Western Canada" - Russell, B.
"Progress of Small Water Development Projects" - Jacobson, W.L.
"Irrigation Development for Resettlement" - Fairfield, W.H., and G.N. Denike
"Soil Erosion Control" - Gibson W. and P.J. Janzen.
"Conserving Run-off Water and Controlling Soil Erosion" - Parker, J.S., W. Dickson and E.S. Hopkins.
"Sub-Stations and their Relation to Rehabilitation" - Moynam J.C. and M.J. Tinline

Report on Prairie Farm Rehabilitation and Related Activities, Prairie Farm Rehabilitation Branch, Canada Department of Agriculture, Regina, Saskatchewan (annual)

Contents:

Organization and Administration
Community Pastures and Water Development
Rehabilitation and Resettlement, Construction,
Equipment and Supply Division, Engineering Services,
Major Irrigation and Reclamation Projects,
Other Special Projects
Appendix I - Cumulative Statement, Development and Operation of Community Pastures under P.F.R.A., 1938-1955
Appendix II - P.F.R.A. Community Pastures in Operation during the Fiscal Year

Appendix III - Number of projects and amount of financial assistance paid since inauguration
Appendix IV - Progress by years in the Construction of small projects
Appendix V - Water development - irrigation projects, storage, community projects
Appendix VI - Major projects - Irrigation reclamation
Appendix VII - P.F.R.A. - Expenditure by activities.
Appendix VIII - Summary of Statistics relating to P.F.R.A. Projects.

Roe, Frank Gilbert - "Early Agriculture in Western Canada in Relation to Climate Stability", Agricultural History, Vol. 26, No. 3, (July 1952), pp. 104-123.

This article describes early agriculture in Western Canada. From this information he finds no historical support to any supposition of climatic change within the last two centuries or so in any really relevant sense of the term.

Staple, W.J. and J.J. Lehane, - "Wheat Yield and use of Moisture on Sub-stations in Southern Saskatchewan", Canadian Journal of Agricultural Science (formerly Scientific Agriculture), Agricultural Institute of Canada, Vol, 34, No. 5, pp.460-468, Ottawa, Sept.-Oct. 1954.

This paper discusses the statistical relationship between moisture and yield of wheat.

2. Land

"The Use and Conservation of Canada's Farm Lands", Agricultural Institute Review, Agricultural Institute of Canada, Vol. 9, No. 2, Ottawa, March - April, 1954.

This issue contains articles on the following:

Conservation practices of Western Canada Farmers - Moore, C.M.
The Value of Conservation - Booth, J.F.
Better Land Use through Irrigation - Jacobson, W.L.
Drainage Problems in Land Use - Banting, A.
Agricultural Aspects of Canada's Water Resources - Thomson, L.B.
Conservation and Flood Control - Richardson, A.H.
Urban - Rural Relationships in Soil and Water Conservation - Pleva, E.G.
The Task of Research in Conservation of our Agricultural Resources - Newton, R.

Bowser, W. Earl and H.C. Moss, - "A Soil Rating and Classification for Irrigation Lands in Western Canada", Scientific Agriculture, Agricultural Institute of Canada, Vol. 30, pp. 165-171, Ottawa, April 1950.

This article deals with the main factors to be considered in classifying and rating soils for irrigation. Soil profile, type of geographical deposition, soil texture, salinity, degree of stoniness wind and water erosion and topography.

Hudson, J.P., "Land Utilization and Rate of Land Improvement on Lands in the Saskatchwarn River Delta," The Economic Annalist, Economics Division, Marketing Service, Canada Department of Agriculture, Vol. XXIV, No. 5, pp. 104-108, Ottawa, Oct. 1954.

This article deals with some of the results of a study conducted by the Economics Division in 1953 of 27 farms in the Pasquia area or the Carrot River Reclamation Project. The author discusses land use, the rate at which the settlers have brought their land into production, and a net worth statement to show the financial progress of the settlers.

Hurd, W. Burton, "Post-war Agricultural Settlement Possibilities in Canada," Journal of Farm Economics, Vol. XXVII, No. 2, (May 1945) pp. 388-404.

This article attempts to summarize and explain in the briefest possible compass the main conclusions emerging from a comprehensive survey of agricultural settlement possibilities across Canada carried out under a directive from the Dominion Advisory Committee on Reconstruction. Each region is discussed separately, i.e. Prairie Provinces, British Columbia, Ontario, Quebec, the Maritimes, Yukon and Northwest Territories and then Canada as a whole. Although no part of these findings may be considered final the author traces a broad outline in a picture of agricultural settlement possibilities across Canada, which in spite of its inadequacies may be of use in considering settlement potentials in post war years.

Leahey, A., "The Agricultural Soil Resources of Canada, "Agricultural Institute Review, Agricultural Institute of Canada, Vol. 1, No. 5, pp. 285-289, Ottawa, May, 1946.

This article deals primarily with the extent and location of the soils in Canada that are or can be used for agricultural purposes. More attention is given to those soils that are suitable for cultivation than to those fit only for grazing purposes.

Spence, George, "Soil and Water Conservation on the Prairies," Canadian Geographical Journal, Vol. XXXV, No. 5, (Nov., 1947), pp. 226-241.

Discusses the rehabilitation of prairie agriculture and the work of the P.F.R.A. in cultural land utilization, soil and water conservation programs. Briefly describes the large proposed irrigation projects, i.e. St. Mary, Bow, Red Deer and South Saskatchewan River Developments.

3. Water

(a) Irrigation

Ayers, H.D., "Soil Permeability as a factor in the Translocation of Salts on Irrigated Land," Scientific Agriculture, Agricultural Institute of Canada, Vol. 31, No. 9, (Sept., 1951). pp. 383-395.

This article gives the results of a study carried out to investigate the transportation and accumulation of alkali salts on irrigation lands.

Appleton, J.M. and F.L. Wynd, "A Preliminary Study of the Application of the Percentage Yield Concept to the Response of Forage Crops to Irrigation Water," Scientific Agriculture, Agricultural Institute of Canada, Vol. 31, No. 4, (April, 1951), pp.133-147.

This paper discusses the historical background and the application of the percentage yield concept of crop response to soil nutrients.

It gives the results of a preliminary investigation to determine to what extent the percentage yield concept is applicable to the effects of irrigation water on the yields of certain forage crops.

Burchill, C.S., "The Origins of Canadian Irrigation Laws," The Canadian Historical Review, Vol. 29, No. 4, (Dec., 1948), pp.353-362.

This article gives the origin of irrigation in Alberta, Italy and Australia, summarizes the first government legislation in Australia and in Canada and gives a comparison of the two. It also gives the stand taken by the newspapers with respect to irrigation and irrigation legislation and concludes with the authors own comments.

Cross, F.G., "The Need of Water Conservation in Southern Alberta," Engineering Journal, Engineering Institute of Canada, Vol. 23, (May 1940), pp. 213-215.

An article discussing water conservation in Southern Alberta especially the Milk and St. Mary Rivers development.

Dunsmore, L.K., "Historical Development of the Eastern Irrigation District," The Economic Annalist, Economics Division, Marketing Service, Canada Department of Agriculture, Vol. XX, No. 3, (June, 1950), pp. 55-60.

A very brief history of development of the Eastern Irrigation District including crop census data for 1939-1948. Also discussed briefly in this article is the type of farming in the area as compared to other irrigation districts, based on a survey in 1949.

Fleming, W.M., "Irrigation of Cantaloupes," Scientific Agriculture, Canadian Society of Technical Agriculturists, Vol. 16, No. 12, (Aug., 1936), pp. 634-643.

This paper describes cantaloupe irrigation experiments conducted over a three year period to show the effect of irrigation in the yield and quality of cantaloupes.

Hays, D.W., "Irrigation Development, its Possibilities and Limitations," Engineering Journal, Engineering Institute of Canada, Vol. 22, (Jan., 1939), pp.13-18.

In this paper, Mr. Hays deals with the subject largely from an economic and humanitarian point of view, and after discussing the costs and the benefits, direct and indirect, of irrigating dry areas, he reaches the conclusion that the cost of irrigation development is warranted as a national undertaking, but it is not a matter for private enterprise. The paper gives an historical sketch and a physical description of the drought area. It discusses problems which arise in dealing with the farmer, and the necessity for the adaptability of settlers.

Hill, K.W., "Effects of Forty Years of Cropping under Irrigation," Scientific Agriculture, Agricultural Institute of Canada, Vol. 31, No. 8, (Aug., 1951), pp. 349-357.
Summarized here are data on yields and trends of yields over a 40-year period in a ten year irrigation crop rotation on a typical Southern Alberta soil at the Dominion Experimental Station, Lethbridge, Alberta. An attempt has been made to interpret therefrom information having application to agricultural production under irrigation. Changes in chemical content and physical structure of the soil is discussed briefly.

Jacobson, W.L., "The Need and Benefit of Irrigation on the Canadian Prairies," The Agricultural Institute Review, Agricultural Institute of Canada, Vol. 1, No. 4, (Mar., 1946), pp.221,226.
In this article the author discusses the factors which determine the need for irrigation and the factors to be considered in determining the agricultural feasibility of any proposed development project, i.e. climate, topography, soil types, cultural methods, soil improvement and markets. He concludes that supplemental irrigation developments have definite possibilities and offer a principal means of fortifying agriculture against drought. Large irrigation projects should be confined to the "dry bowl."

Kitching, H.W., "Portable Sprinkler Irrigation Systems," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 6, No. 1, (Jan., 1951), pp. 19-22.
Briefly discusses the steps to be followed in planning the installation of supplemental sprinkler irrigation systems.

Korven, H.C., "The Effect of Wind on the Uniformity of Water Distribution by some Rotary Sprinklers," Scientific Agriculture, Agricultural Institute of Canada, Vol. 32, No. 4, (April, 1952), pp. 226-240.
This article presents the results of a one-year study undertaken to determine the effect of wind on the uniformity of water application by some rotary sprinklers at various pressures and spacings starting with those recommended by the sprinkler manufacturers as a result of their routine tests to check the value of modification in their sprinkler design.

Mackenzie, G.L., "The St. Mary-Milk River Irrigation Project," The Engineering Journal, Vol. 31, (Sept. 1948) pp. 485-496.
In this paper the author outlines the early history of the Alberta Railway and Irrigation Project at Lethbridge, Alberta, its subsequent planning which has led up to Canada's decision to make use of her full share of these boundary waters. A description is given of the design of component structures, how they are being built and also a description of tunnel design and the methods employed in building Canada's highest earth fill dam.

McKenzie, R.E., "The Effect of Harvesting Practices on Yield and Winter Survival of Alfalfa under Irrigation," Scientific Agriculture, Agricultural Institute of Canada, Vol. 31, No. 11, (Nov., 1951), pp. 457-462.

This paper is a report of a study undertaken to compare crude protein and hay yields of Grimm alfalfa grown under irrigation when harvesting was done at three stages of growth throughout the season, and also to find out how these cutting treatments affected winter survival and vigour.

McKenzie, R.E. and J.L. Bolton, "Crop Production on Irrigated Heavy Textured Saline soils with particular reference to the Val Marie Irrigation Project," Scientific Agriculture, Agricultural Institute of Canada, Vol. 27, No. 5, (May, 1947), pp. 193-219.

An account is given of investigations relating to crop production and cultural and irrigation practices, conducted on the heavy textured saline soils of the Val Marie Irrigation project in South Western Saskatchewan from 1938 to 1943. These investigations were carried out to obtain information as to whether or not this type of land could be brought under irrigation successfully.

Palmer, A.E. "Irrigation in Western Canada - Its Possible Effects on Industry and Population," The Engineering Journal, Vol. 31, (Sept. 1948), pp. 497-499.

This article deals with the potential development of food processing industries arising from further irrigation development in the prairie provinces. Briefly describing existing plants and their annual value of production, the author discusses the possibilities for beet sugar production and its chances of competing with cane sugar, as well as the market prospects for canneries, creameries and other processing industries. Possible growth in rural and urban population resulting from irrigation development is assessed.

Peters, F.H., "Mountain Waters for the Prairie Grassland," Engineering Journal, Vol. 22, (January 1939), pp. 8-12.

The author expresses the opinion that irrigation waters should be spread over as large an area as possible, providing the maximum number of grain farms with sufficient water to ensure each year a good kitchen garden, and a sufficiency of fodder instead of looking for the maximum number of irrigable acres in any concentrated block. The argument is developed following a description of the dry grasslands, rivers and water supply with reference to lack of rainfall and to the absence of an organized plan. In conclusion, the benefits to be derived from the suggested plan are presented.

Porter, S.G., "Irrigation Engineering," Engineering Journal, Vol. 20, (June, 1937), pp. 403-414.

A resume of 50 years of irrigation in Canada. It is largely historical rather than technical. It concludes with a brief discussion of the trend in irrigation policy.

Russell, Ben, "Water for Irrigation," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 1, No. 5, (May, 1946), pp. 291-294 and 309.

This article discusses water supplies in the Saskatchewan River Drainage Basin and of possible water supply for smaller areas in

Manitoba, Saskatchewan and Alberta that are outside this drainage basin. The problem of allocation of these waters to the provinces is mentioned briefly. In conclusion the writer makes some suggestions for future development.

Spence, C.C., "Irrigation in Alberta," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 7, No. 3, (May, 1952), pp. 11-14, 58-62.

The author attempts to examine the development of irrigation in Alberta from three points of view - (1) the developing agencies (2) the farmers as preliminary users of the facilities and (3) the state at large which will include as well as the users, other groups of society who are directly engaged in servicing the primary users and others who have contributed to and received benefits from irrigation development.

Spence, George, "Water for the Prairies," Canadian Geographical Journal, Vol. XLIV, No. 2, (1952), pp. 48-57.

This article describes very briefly the opening of the St. Mary River dam and discusses the two types of farming carried on in the drought area of the Palliser Triangle: (i) ranching, (ii) dry land farming. It also tells briefly of the projects carried on by P.F.R.A. for conservation and development of water resources in the area.

Wilcox, J.C., Sprinkler Irrigation Experience in British Columbia Orchards," Scientific Agriculture, Agricultural Institute of Canada, Vol. 30, No. 10, (Oct., 1950), pp. 418-427.

In this article the author discusses the history of sprinkler irrigation in British Columbia, favorable and unfavorable experiences with sprinkler irrigation, special problems due to sprinkler irrigation and comparative costs of sprinkler and furrow irrigation.

Wilcox, J.C., "Irrigation of Horticultural Crops - Practice and Problems in British Columbia," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 7, No. 3, (July, 1952), pp. 20-23.

The conditions discussed in this article are those encountered in the semi-arid parts of the southern interior of British Columbia. It deals with the climate of the Okanagan Valley, the effects of irrigation on hardiness of horticultural plants, on yield and quality and effects on the soil. The author compares the advantage and disadvantage of sprinkler irrigation and concludes by discussing the harmful effects of sprinkler irrigation on the different horticultural crops.

Wilcox, J.C. and G.E. Swailes, "Uniformity of Water Distribution by some Undertree Orchard Sprinklers," Scientific Agriculture, Agricultural Institute of Canada, Vol. 27, Ottawa, (Nov., 1947), pp. 565-583.

This article gives the results of tests made on five sprinkler systems which were in common use for the undertree sprinkling in 1946.

Wilcox, J.C., T.G. Willis, and W.L. Jacobson, "Irrigation of Grassland," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 10, No. 2, (Mar., April, 1955), pp. 21-23.

This paper deals with some of the major problems encountered in the irrigation of pasture and hay crops in Canada.

3. **Water**

(b) Power.

Prentice, J.S., "Canada's Attitude Toward the Exportation of Hydro-Electric Power," Journal of Political Economy, Vol. XXXVI, No. 5, (October, 1928), pp. 592-624.

This article deals with the political and sentimental attitudes towards export of power which are more or less prevalent in Canada. It also deals with the economic attitudes towards vested interests and power trusts. It discusses the different attitudes of Quebec, New Brunswick and British Columbia and Ontario towards export power.

Starley, T.D., "Hydro Power Development on the Eastern Slopes of the Canadian Rockies," The Engineering Journal, Vol. 31, No. 9, 1948, pp. 500-504.

Tracing the history of early hydro power development in Alberta, the author outlines early projects built by Calgary Power, as well as the more recent additions for storage and generation. The importance of storage on rivers arising on the Eastern Slopes of the Rockies is shown, as well as how Alberta rivers are naturally divided between storage andproduction sections. Various local problems in design and operation are discussed. Reasons are given why storage for power is advantageous to irrigation. In conclusion, Alberta's hydro power resources are described and suggestions given as to how they may be fully utilized.

Stephens, D.M., "The Saskatchewan River and Manitoba's Water Problem," The Engineering Journal, Vol. 31, (Sept., 1948), pp. 470-475.

This paper, primarily a statement of Manitoba's claims on Saskatchewan River water, also points out that the Prairie Provinces must decide between more kilowatt hours in Manitoba, with the industrial development they will bring and more irrigation in the two other prairie provinces with its resulting stimulus to farm production. The five regions of the prairie provinces are discussed in relation to their needs for water. The proposed diversion of the Saskatchewan for irrigation purposes is translated into hydro electric power lost to Manitoba, and economic effects are evaluated. Maintaining that a piecemeal approach to prairie water problems is not good enough, the author urges the early formation of a Western Water Board.

3. Water

(c) Other

Bolton, J.L. and R.E. McKenzie, "The Effect of Early Spring Flooding on Certain Forage Crops," Scientific Agriculture, Agricultural Institute of Canada, Vol. 26, No. 3, (Mar., 1946), pp. 99-105.

This paper presents the results of experiments carried out to determine the survival effect of spring flooding on certain commonly grown forage crops. It relates to individual spring flooding projects although the experiments were carried out at the Val Marie and Eastend irrigation projects.

Forsaith, T.S., "Development of a Formula for Estimating Surface Run-off", Scientific Agriculture, Agricultural Institute of Canada, Vol. 29, No. 10, (Oct., 1949) pp.465-481.

This article discusses some of the aspects of the run-off problems for small watersheds as commonly encountered in soil and water conservation work. An analysis of Dominion Water and Power Bureau records for streams of the Southern Prairies is presented in an effort to bring existing data into a more usable and applicable form. An empirical formula is proposed for the southern portion of the Prairie Provinces.

Griffiths, J.A., "The History and Organization of Surface Drainage in Manitoba," Paper Presented before the Winnipeg Branch, Engineering Institute of Canada, Winnipeg, Manitoba, 1952, (typewritten) 26pp.

In this paper the author describes the early history of organized drainage in Manitoba. He tells of the first "Land Drainage Act" and the procedures to be followed in forming "Drainage Districts" as set out by this act. He discusses the success and the failures of these districts and the general dissatisfaction with the services provided. He deals with the investigations and recommendations of four different commissions appointed to improve these conditions, and the setting up of Drainage Maintenance Boards their organization and authority.

Russell, Ben, "The Water Resources of Alberta," The Engineering Journal, Vol. 31, (Sept., 1948), pp. 476-484.

The author outlines the Alberta Water Resources Act and other Dominion and Provincial legislation affecting water resources of the province. Surface waters are classified and the various drainage basins delimited. A brief description of the several irrigation projects existing and projected is given. Development of power in the province is noted and the growth of energy production recorded. Also discussed are available water supplies as related to demand, factors limiting beneficial use, benefits accruing from interconnection of power from the Bow and Red Deer, international and interprovincial problems respecting the diversion of water etc. The paper concludes with a description of the administration of water areas and drainage districts, and an explanation of how the duty of water for irrigation has been determined.

Wilcox, J.C., J.L. Mason and J.M. McDougald, "Consumptive Use of Water in Orchard Soils. II. Effects of Evaporating power of Air and of Length of Irrigation Interval," Scientific Agriculture, Agricultural Institute of Canada, Vol. 33, No. 3, (May-June, 1953), pp. 231-245.

This paper deals chiefly with the effects of: (i) the evaporating power of the air and (ii) the length of the irrigation interval, on the rate of consumptive use. A brief report is also made of the variability in consumptive use across a panel from one row of trees to the next.

4. Population

Campbell, D.R., "Neo-Malthusianism, its Origin, Decline and Recent Renaissance," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 10, No. 1, (Jan.-Feb. 1955), pp. 13-17.

This article describes the origin of Malthusianism, traces its decline during the last century and tries to supply reasons for its rebirth in the last few years. Then it examines the evidence (applied to Canada alone), and finds it largely against Neo-Malthusianism. There follows a prediction of our domestic demand for food over the next 30 years and our ability to meet these requirements. Finally, it tries to put Neo-Malthusianism and its opposite number "Micawberism" in perspective to assess what is good and what is dangerous about them.

Keyfitz, Nathan, "The Growth of the Canadian Population," Population Studies, Vol. IV, No. 1, 63 pp.

An attempt to estimate how much the growth in population of Canada has been the result of immigration from abroad and how much the natural increase of residents.

5. Resources

Hanson, W.R., "Grazing Use of Forest Lands," Paper presented at the annual meeting of the Canadian Institute of Forestry, Bank, Alberta, Oct. 11-13, 1951.

Use of forest land by range livestock is considered in its relation to other simultaneous uses of the same land. Conflicts between grazing and other uses such as timber, wildlife, recreation and watersheds is discussed and it is the author's intention to show that in the final analysis, grazing is a legitimate and proper use of forested wild lands and that it fits into the multiple concept, even to a point of being a helpful tool in the management of such lands.

Kennedy, Howard, "The Eastern Slopes," Forestry Chronicle, Vol. XXIV, No. 1, March, 1948.

This article gives the location and a description of these slopes, and discusses the problem of forest conservation confronting the Dominion and Provincial Governments not only from the economic value standpoint, but because of its regulating effect on the flow of streams originating within the watershed. The history of dominion and provincial responsibility and the formation of the Eastern Rocky Conservation Board is discussed along with the Board's purpose, its status and scope and its program.

6. Economics.

Anderson, J.L., "Paying Off Indebtedness on Irrigated Land," The Economic Annalist, Economics Division, Marketing Service, Canada Department of Agriculture, Vol. XIV, No. 3, August, 1944.

This article deals with reduction of indebtedness in the Taber and Eastern irrigation districts and the association of type of farm to the rapidity in which indebtedness is reduced.

Britnell, G.E., "The Rehabilitation of the Prairie Wheat Economy," The Canadian Journal of Economics and Political Science, Vol. 3, No. 4, (Nov. 1937), pp. 508-529.

In this article the author discusses the climatic and economic problems of the prairie wheat economy and several measures that have been proposed to provide stability. Among these are proposals to take some land out of wheat production, crop insurance, and the work of P.F.R.A.

Fowke, V.C., "Economic Effect of the War on the Prairie Economy," The Canadian Journal of Economics and Political Science, Vol. XI, No. 3, (Aug. 1945), pp. 373-387.

The effects of the war on the prairie economy can best be considered against a background of three elements - one of them general and two more specific. These background elements are sketched in briefly. First and most general of these elements is the historical position of Canadian agricultural groups and agricultural communities in war-time situations. The second is the specific position of the prairie economy in relation to the First World War. The third is the familiar record of prairie agriculture throughout the depression of the nineteen thirties.

The purpose of this paper was to suggest the degree and manner in which the war modified the prairie economy.

Hill, K.W., "Specialty Crops in Canadian Irrigation Farming - Results on Western Canadian Farms," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 5, No. 5, (Sept. 1950), pp. 11-15.

The author discusses yields, costs and returns, and the advantage of producing specialty crops on irrigation farms.

Hudson, S.C. and L.R. Fortier, "The Economics of Grassland Farming," Agricultural Institute Review, Agricultural Institute of Canada, Vol. 10, No. 2, Ottawa, (Mar. - April, 1955), pp. 70-72.

The economic advantages of grassland farming are dealt with in this article in terms of changes in farm organization, investment, costs and returns resulting from the program on individual farms. The authors also discuss briefly the importance of grass in Canadian agriculture.

Kline, C.M., "Production and Marketing of Potatoes from the Irrigated Areas of Alberta," The Economic Annalist, Economics Division, Marketing Service, Canada Department of Agriculture, Vol. XIX, No. 4, (Aug. 1949), pp. 85-87

This gives the production and acreage of potatoes in the four western provinces from 1938 to 1948 and a comparison of production on

Stewart, A., "Economic Survey in the Drought Area," The Economic Annalist, Economics Division, Marketing Service, Canada Department of Agriculture, Vol. VII, No. 3, (June, 1937), pp. 39-43.
This paper outlines the nature of the material which has been collected in the survey of the Sounding Creek area of Alberta. It indicates how such studies may fit into the general attack on the problems which exist, and suggests what contribution they may be expected to make towards the solutions of these problems. The problems of the distressed area are: vacant, abandoned and idle land, disused and delapitated buildings, depleted inventories and of discouraged and defeated people.

Summaries of Farm Businesses by Types of Farming for the Crop Year 1948-49 in the Five Irrigation Districts of Southern Alberta, Economics Division, Marketing Service, Canada Department of Agriculture, Edmonton, Alberta (unpublished)
This booklet contains 13 summaries showing the average for the three farms with the highest, and the average for the three farms with the lowest "Net Return to Capital and Family Labour" as compared to the average for the district and type.

Stutt, R.A., "The Economic Aspects of Land Use in Saskatchewan," The Economic Annalist, Economics Division, Marketing Service, Canada Department of Agriculture, Vol. XIX, No. 5, (Oct. 1949), pp. 109-114.
This article deals with the characteristics of Saskatchewan agricultural resources, i.e. size of area under occupation, under cultivation, size of farm, types of crops etc; the agricultural capacity of Saskatchewan; technical changes contributing to agricultural capacity in recent years such as changes in cultural practices, improved varieties of grain, improved management practices, and advances in mechanization. Also discussed are other changes associated with production i.e. re-organization of school units and migration of families from farms to towns and cities. Following this the author deals with changes in land use and an economic classification of land. He concludes with a discussion of under and over use and inefficient use of land resources.

CHAPTER 3. GOVERNMENT DOCUMENTS

1. General

Champlin, M.J., E.G. Booth, R.O. Bibbey and C.G. Waywell, Rainfall Records for Saskatchewan, Department of Field Husbandry, University of Saskatchewan. Agricultural Extension Bulletin, No. 18, 30 pp.
This bulletin records the average annual precipitation from 1886-1949, 1896-1949, 1906-1949, 1916-1949, 1921-1949, 1926-1949, 1940-1949 and total annual, total seasonal and total crop precipitation at 36 stations in Saskatchewan.

Cronkite, F.C. (chairman) Report of the Saskatchewan Reconstruction Council, Department of Reconstruction, Labour and Public Welfare, Government of Saskatchewan, 269 pp. Regina, Saskatchewan, 1944.

This report presents suggestions and recommendations of the Council which in their opinion would give a fuller life to the people of the province of Saskatchewan. It gives an analysis of proposed reconstruction projects in agriculture, natural resources, communications, industries, power, social service, health and medical services, position of labor, education, rehabilitation of service personnel, housing etc.

Appendix 5 (printed separately) - This investigation is concerned with the economic possibilities of new manufacturing or processing industries based on farm products as new materials. It only considers other natural resources such as coal and wood in so far as they may compete with agricultural products.

Department of the Interior Annual Reports, Government of Canada, Ottawa, 1894 to 1912.
See Appendix to this bibliography for details.

Riesen, H.G. and E. Kuiper, Interim Reports on Saskatchewan River Reclamation Project, Prairie Farm Rehabilitation Branch, Canada Department of Agriculture, Regina, Saskatchewan, 1953-54.

These are reports of various studies carried out during the overall investigation of the Saskatchewan Reclamation Project.
Interim Report No. 1, deals with degree of protection of the land by dikes or other structures.
Interim Report No. 2 deals with dikes, Pasquia area.
Interim Report No. 3 deals with hydrometric surveys 1953.
It describes a trip on the Saskatchewan River and its tributaries for the purpose of attempting to predict the future behavior of the Saskatchewan River after eventual reclamation of its flood plains; and the conclusions to which it led.
Interim Report No. 4 deals with history and geology.
Interim Report No. 5 deals with drainage - Pasquia area. It discusses the removal of local runoff from the land.
Interim Report No. 6 deals with outline of investigations. This outlines the nature and scope of the hydrometric, topographic and other surveys that were to be carried out in connection with the investigations.
Interim Report No. 7 deals with the hydrologic studies. It deals with the origin and nature of flood flows on the Saskatchewan River, Carrot River and Pasquia River and the magnitude of the design flood in the Pond area.
Interim Report No. 8 deals with the hydrometric surveys of 1954.
Interim Report No. 9 - notes on river morphology. These notes were based on the hydrometric surveys, subsequent office studies, any available literature on the subject and notes of discussions.
Interim Report No. 10 - deals with the computation of the design flood levels for the Saskatchewan River Reclamation project.

2. Land

Horsey, G.F., Carrot River Reclamation Project. Dominion Water Power and Reclamation Service, Canada Department of the Interior, 17 pp., Ottawa, 1924.

Report of a survey carried out to investigate the reclaiming of the large area of flat swamp lands lying between the Saskatchewan and

Carrot Rivers immediately west of the Pas Manitoba which are subject to periodic flooding. This report discusses the area in general, its soil, vegetation, timber, present value etc. and describes the effect of floods on the area. It presents a general scheme for the reclamation of the district and deals with the five alternative schemes based on the general plan.

Mitchell, J., H.C. Moss, and J.S. Clayton, Soil Survey of Southern Saskatchewan from Township 1 to 48 inclusive, University of Saskatoon, College of Agriculture. Soil Survey Report No. 12, 249 pp., Saskatoon 1944. Appendix gives soil textural classes used in Saskatchewan. Maps.

Palmer, A.E., Preliminary Report of Inspection of Soils and Topography of the Proposed South Saskatchewan Irrigation Development, P.F.R.A., 5 pp. Regina, (mimeographed) n.d. (1949).

A report of the author's trip to evaluate the soils ratings for irrigation made by Dr. Mitchell, professor of soils, University of Saskatchewan and his comments on the soils, topography and climate of the area. He gives a preliminary (general) estimate of the project and makes some suggestions for additional investigation.

Riesen, H.G. and E. Kuiper, Saskatchewan River Reclamation Project, Pasquia Area near the Pas, Manitoba Progress Report, Canada Department of Agriculture, Prairie Farm Rehabilitation Branch, 8 pp., maps, Regina, Saskatchewan, 1951.

This report on the reclamation of the Pasquia Section of the Saskatchewan River Delta region summarizes the results of surveys and investigations which have been made to date. It is an engineering report on the possibility of reclaiming the Saskatchewan River Delta. It also gives a cost estimate for reclaiming the area.

Riesen, H.G. and E. Kuiper, Report of Saskatchewan River Reclamation Project, Prairie Farm Rehabilitation Branch, Canada Department of Agriculture, 35 pp., List of Interim Reports, bibliography, maps, Regina, Saskatchewan, 1956.

This report deals exclusively with engineering aspects of the over-all study of the feasibility of reclaiming land in the delta of the Saskatchewan River.

In Part I of this study, the engineering staff has aimed at attaining a degree of accuracy commensurate with the exploratory nature of the subject.

Part II concerns the actual development of the Pasquia area. (135,000 ac.).

Soil Moisture, Wind Erosion and Fertility of Some Canadian Prairie Soils, Division of Field Husbandry, Soils and Agricultural Engineering, Experimental Farms Service, Canada Department of Agriculture, Publication 819, Tech. Bulletin 71, 74 pp. Ottawa, 1949.

This bulletin deals with the problems of soil moisture, soil fertility and soil erosion. The subject matter deals in general with the brown and dark brown soil of the Prairie Provinces and particularly with the soils and climatic conditions of southwestern Saskatchewan. The main period covered in this bulletin is 1943-47.

Wyatt, F.A. and J.D. Newton, Soil Survey of Medicine Hat Sheet, Department of Extension, University of Alberta, Bulletin No. 14, 76 pp., maps, Edmonton 1926.

Wyatt, F.A. and J.D. Newton, Soil Survey of Sounding Creek Sheet, Department of Extension, University of Alberta, Bulletin No. 16, 66 pp., maps, Edmonton, 1927.

Wyatt, F.A., J.D. Newton, W.E. Bowser and W. Odynsky, Soil Survey of Rainy Hills Sheet, Department of Extension, University of Alberta, Bulletin No. 28, 56 pp., maps, Edmonton, 1937.

Wyatt, F.A., J.D. Newton, W.E. Bowser and W. Odynsky, Soil Survey of Sullivan Lake Sheet, Department of Extension, University of Alberta, Bulletin No. 31, 102 pp., maps, Edmonton, 1938.

Wyatt, F.A., J.D. Newton, W.E. Bowser and W. Odynsky, Soil Survey of Rosebud and Banff Sheets, Department of Extension, University of Alberta, Bulletin No. 40, 126 pp., maps, Edmonton, 1943.

3. Water

(a) Irrigation

Alberta Department of Agriculture, A Guide to Potato Production under Irrigation in Alberta, Field Crops Branch, Alberta Department of Agriculture, Bulletin No. 2, 10 pp., Edmonton, 1950.

This booklet contains basic first hand information on potato production under irrigation which will be useful to guide the beginner who ventures into the potato business as well as be of aid to the veteran grower.

Anderson, G.G., Report on the Lethbridge Northern Irrigation District, Government of Alberta, 38 pp., Edmonton, 1920.

The author has presented, in this bulletin, facts bearing on the engineering, financial and administrative problems involved in the planning and completion of the Lethbridge Northern Irrigation Project. These facts are presented not soley as applied to the particular undertaking but as related to the determination of general policies affecting the development of the agricultural resources of the Province of Alberta.

Burchill, C.S., The Development of Irrigation in Alberta - An Historical Survey, Economics Division, Marketing Service, Canada Department of Agriculture, 42 pp. plus appendix, Edmonton, 1950, (manuscript).

An historical report of the development of irrigation in Alberta. It deals with private, corporate and communal developments and problems of irrigation development i.e. engineering, colonization and financial problems. It discusses subsidies and speculation and concludes with a chapter on viability of irrigation districts. Appendix A deals with dissemenation of the benefits of irrigation.

Canada, Department of Agriculture, Full Development Possibilities in the Saskatchewan River Basin, P.F.R.A., Hydrology Report No. 1, Regina, Saskatchewan, 1952, 5 chapters, appendices, maps.

This report reviews the more important development possibilities in the Saskatchewan River Basin and the Nelson River. Discussed in this report are the various uses of water, factors effecting full development, existing uses and full development possibilities.

Appendix A - Bibliography
Appendix B - Status of Basic Data
Appendix C - Recapitulation of Existing and Proposed Projects.

Canada, Department of Agriculture, Water Supply and Irrigation in the Swift Current Creek Basin, P.F.R.A., Hydrology Report No. 7, Regina, Saskatchewan, 1955, 16 pp., Appendices, maps.

This study was undertaken to evaluate the supply of water in the Swift Current Creek Basin so as to determine its adequacy for future possible irrigation development. This report gives a description of the basin, an outline of P.F.R.A. development to date and a summary of data available in the basin. It sets forth the assumptions made concerning future demands for water and the methods used for reservoir operation and a summary of findings. The concluding chapter deals with water supply for P.F.R.A. and for other uses, adequacy of reservoir facilities and recommended rules for reservoir operation.

Appendix A - Irrigation Requirements
Appendix B - Domestic, Industrial and Riparian Requirements
Appendix C - Reservoir and Project Operation
Appendix D - Period of Study and Reconstruction of Records.

Canada, Department of Agriculture, Water Supply and Irrigation in the Bigstick Lake Basin, Canada, P.F.R.A., Hydrology Report No. 8, Regina, Saskatchewan, 1955, 11pp., appendices, maps and charts.

A report on a study made of the water supply of the Bigstick River Basin and the various demands which it must meet. It deals specifically with the natural flow of the basin, the adequacy of water supply for existing developments and availability of water supply for further development.

The appendices include sections on assumption for water supply study, summary of drainage division report, preparing for floods, land use surveys, soils and crops and water rights summary.

Canada, Department of Agriculture, Water Supply and Utilization in Bow River Watershed, P.F.R.A., Hydrology Report No. 9, Regina, Saskatchewan, 1955, 21 pp., appendices, maps.

This report records the results of an investigation to determine whether the water of the Bow River can adequately supply the planned expansion of hydro-electric and irrigation development of new irrigated lands which are dependent upon water from the Bow River. These investigations showed that continued increase in construction of hydro plants and irrigation extensions has approached the limit of efficient utilization of the Bow River water unless different control measures were instituted.

The appendices include discussions of the history of the development and of the individual projects concerned.

Canada, Department of Agriculture, Water Supply and Irrigation in the Deer and Miners' Creek Basin, P.F.R.A., Hydrology Report No. 13, Regina, Saskatchewan, 1955, 8 pp., maps.

Deer and Miners' Creeks form a portion of a watershed which rises in Sweetgrass Hills in Montana and drain into the Milk River in Alberta. Deer Creek has been developed so that water shortages occur frequently and Miners' Creek has sufficient water to meet present commitments. Future development, most of which would take place in Montana, would lead to frequent shortages and Canadian irrigation projects would suffer most in dry years because of their downstream location. This report gives a preliminary picture of the water supply and irrigation development in the area with particular reference to international features.

Canada, Department of Agriculture, Preliminary Report on Effects of Certain Major Projects in the Saskatchewan River Drainage Basin.

A preliminary study making estimates as to the effect on water flow and total discharge at various points of the Saskatchewan River. It takes Alberta's 1949 request of 2,237,234 acre-feet as given, and, using certain assumptions respecting proposed irrigation projects, makes the estimates, using hydrometric data 1923-24 to 1947-48.

An appendix to this report makes the same estimates using hydrometric data 1911-12 to 1947-48.

It should be emphasized that the findings are preliminary, and are subject to change, if the assumptions used must be modified in the future as more and better information becomes available.

Canada, Department of Agriculture, Central Saskatchewan Development (Southern Saskatchewan Development) Summary Report of Investigations, Economics Division, Marketing Service and Prairie Farm Rehabilitation Branch, Ottawa, 1950.

A summary report of Central Saskatchewan Development. It is based on investigations undertaken in exploring the feasibility of the development. It gives an appraisal of the area under present conditions, and prospective agriculture under irrigation. It discusses the costs and benefits of the irrigation development as well as other benefits such as power, municipal water supply, recreation and stream control.

Canada, Department of Agriculture, Comparison of Two Alternate Developments in Saskatchewan River Basin, Prairie Province Water Board, Report No. 4, 10 pp., maps, Regina, Saskatchewan, 1951.

This report compares the physical results of these alternatives as expressed in acres irrigated, kilowatt hours produced and cost of development.

Canada, Department of Agriculture, Summary of Findings in the Economic Survey of Two Irrigation Districts in Southern Alberta, 1949, Economics Division, Marketing Service, Canada Department of Agriculture, Edmonton, Alberta, 1949 (Preliminary - unpublished).

A farm business analysis of a farm survey taken in the Canada Land and Eastern Irrigation Districts in 1949.

Ewing, A.F. (Chairman), Report of the Commission on Irrigation Development in Alberta, Government of Alberta, 33 pp., Edmonton, 1937.
A report of the findings and recommendations of the commission. It deals with the enquiries made in the irrigation districts concerning the following matters, value of land, ability of farmers to pay, conditions imposed by agreements for sale, or water agreement and policy of collections, the effect and application of debt legislation with respect to water rentals and water service charges and rights of distress for non payment of charges. It also presents the recommendations of the commission for a general policy of procedure in the best interests of irrigation.

Fairfield, W.H., Irrigating a Prairie Farm Garden, Dominion Experimental Station, Lethbridge, Pub. No. 657, 4 pp., Ottawa, revised, 1943.
This pamphlet describes the type of irrigation to be used on a prairie farm garden, preparation of the land and how and when to irrigate.

Hawkins, D.W., Preliminary Report of Proposed Red Deer River Diversion Project, Prairie Farm Rehabilitation Act, 20 pp., Regina, 1947 (mimeographed).
This report which reviews earlier studies and explores in some detail a project which confines the irrigable area to 450,000 acres in the Youngstown-Cessford area of the Special Areas with the possibility of an additional 50,000 acres in the Acadia Valley.
In this project it is proposed to divert the Red Deer River at Ardley where a high dam would be installed at which power would be produced and the water carried by canal to the irrigable areas. Cost estimates are given.

Hays, D.W., Report on the South Macleod Irrigation District, Department of Public Works, Government of Alberta, 47 pp., Edmonton, 1922.
This report presents data on the general description of the area, climatic conditions, prospective crop yields, estimated returns that can be expected, estimated cost of construction of the projects, its operation and maintenance, suggested changes in plans already made and also discusses the ability of the farmer to meet irrigation charges.

Hill, K.W. and A.E. Palmer, Irrigation Farming in Southern Alberta, Lethbridge Experimental Station, Canada Department of Agriculture, Pub. 883, 63 pp., Ottawa, 1953.
This bulletin deals with the common agricultural practices in the area and presents information which may assist in the stabilization of agriculture in this and other regions. It deals specifically with the climate of the area, soil, methods of irrigation, crops grown under irrigation, crop rotation, the place of livestock on irrigated farms, commercial fertilizers, soil drifting, and weed control and planning for permanence and balance in the farming enterprise.

Israelsen, O.W. and O.A. Israelsen, Irrigation and Drainage Progress and Problems in the Province of Alberta and Saskatchewan, Canada, P.F.R.A., 36 pp., Regina, 1949. (mimeographed)
This report records progress in the study made in 1949 of irrigation and drainage problems in two arid regions of Western Canada. It describes canal lining activities on typical projects in Wyoming and reviews drainage and canal lining in eleven western states.

Kirk, D.W., The Bow River Irrigation Project , Part I, P.F.R.A., Canada Department of Agriculture, 62 pp., Regina, Saskatchewan, 1955.
This bulletin presents the history and development of the Bow River irrigation project up to and including its purchase by the government of Canada in 1950. It includes sections on the historical background, negotiations leading up to the purchase of Canada Land and Irrigation Co. by the Dominion Government, the policy of the Government in regard to the development and the consumation of the agreement.

Korven, H.C., Irrigating the Prairie Home Garden, Dominion Experimental Station, Swift Current, Saskatchewan, Pub. 851, 21pp., Ottawa, 1950.
Discussed in this bulletin are the factors to be considered when irrigating a prairie home garden, i.e. water supply, location, fertility, planning, seeding, thinning, weeding, land preparation and the two methods of irrigating, surface flooding and sprinkling.

Korven, H.C., Sample Design of a Sprinkler Irrigation Project, Agricultural Engineering Division, Dominion Experimental Station, Canada Department of Agriculture, Swift Current, Saskatchewan, Pub. No. 6, Swift Current, 1951.

Meek, Victor, (Chairman), Report of the St. Mary and Milk Rivers Water Development Committee on Further Storage and Irrigation Works Required to Utilize Fully Canada's Share of International Streams in Southern Alberta, Department of Mines and Resources, Government of Canada, 119pp., Ottawa, 1942.
This is a comprehensive report of all aspects of the proposals that further storage and irrigation works be built in Canada on the St. Mary and Milk Rivers. The report is divided into two parts. Part I is a summarization of the factual data. Part II comprises full details upon which the findings and recommendations are based.

Minutes of Meeting Held to Discuss Possible Co-operative Development on Irrigation Projects., P.F.R.A., Department of Agriculture and Co-operation, Regina, Feb. 4, 1949.(mimeographed)
These minutes include an outline of P.F.R.A.'s policy in connection with irrigation and a brief preliminary discussion of problems in co-operative organization on irrigation projects, i.e. research required, preliminary extension work, legislation, possible types of co-operatives and assistance for and supervision of co-operatives.

Palmer, A.E., Use of Irrigation Water on Farm Crops, Dominion Experimental Station, Canada Department of Agriculture, Lethbridge, Alberta, Pub. 509, Farmer's Bulletin 10, Ottawa, 1936.

In this bulletin are reported the results of experiments with the irrigation of wheat, alfalfa, potatoes, sugar beets and sunflowers. Information is given as to the stage of plant growth when water should be applied, the value of fall irrigation, the number of irrigations required in different years by various crops, the inter-relations of soils, soil moisture and plant growth. From the information the author attempted to formulate standards of irrigation practice that would serve as a guide to farmers in the development of irrigation projects in Alberta.

Report and Recommendations of the Sprinkler Irrigation Committee for Western Canada, a report on Sprinkler Irrigation in Western Canada presented to a joint P.F.R.A. Experimental Farm Conference, held in Swift Current, Saskatchewan, Feb. 20 and 21, 1950.

This report discusses small sprinkler irrigation units for gardens etc., supplemental irrigation by sprinkler for dry and moist areas, the disadvantages of sprinkler irrigation as compared to surface and a comparison of the costs of the two methods.

Report of Committee on the Development of Irrigation in Alberta, Montana and North Dakota as it Relates to the Situation in Saskatchewan, The P.F.R.A., Department of Agriculture and Co-operation, Regina, 1949, (mimeographed).

This is a brief report of the committee after a trip to Alberta, Montana and North Dakota to study the organization and development of irrigation projects. It also summarizes the points that are considered relevant to the situation in Saskatchewan.

Saskatchewan Department of Resources and Industrial Development, Instructions for the Development of Dugouts, Domestic Dams and Irrigation Projects, Saskatchewan Department of Natural Resources and Industrial Development, Bulletin No. 1, 27 pp., Regina, 1948, (revised).

This bulletin outlines the procedure to be followed when constructing a dugout, dam or irrigation project. It deals with the possibilities to be investigated before construction, method of construction of dugouts and domestic dams, and factors to be investigated before constructing an irrigation project, different methods of irrigating, rate of application and time and amount of irrigating.

Snelson, W.H., Irrigation Practise and Water Requirements for Crops in Alberta, Dominion Water Power and Reclamation Service, Department of the Interior, Irrigation Series Bulletin No. 7, 88 pp., Ottawa, 1930.

This bulletin is a summary of the results of ten successive years of experimental work undertaken to determine the "duty of water" i.e. the quantity of water (irrigation plus rainfall) required to produce good crop yields in dry districts. Also included is some practical advice to beginners in irrigation regarding the preparations of the land and the most approved methods of applying water. See classified list of publications at back - re power, water resources papers and reclamation.

Submissions of the Province of Saskatchewan to the Royal Commission on the South Saskatchewan River Project, Government of Saskatchewan, 96 pp., Regina, 1952.

Part I: General brief - outlines briefly Saskatchewan's agricultural

problems and the effect of these problems on the provincial and national economies together with a summary of the impact of the development of these areas. Part II deals with the agricultural potential of the Central Saskatchewan development. Part III deals with industrial development. Part IV deals with integration and value of hydro electric power. Part V with economic use of water and Part VI is a statement of the counsel for Saskatchewan in reply to the submission of the province of Alberta.

Widstoe, John A., (Chairman), An Examination into the Conditions on the Lethbridge Northern Irrigation District, Government of Alberta, 26 pp., Edmonton, 1925.
This report gives a thorough examination of the Lethbridge Northern Irrigation District, its operation, financial difficulties, land value, marketing facilities and the financial condition of the farmers. It also gives recommendations for a general policy of procedure for future development.

Wilson, M.L., (Chairman), Report of the Commission Appointed to Report on the Lethbridge Northern and Other Irrigation Districts in Alberta, Government of Alberta, 42 pp., Edmonton, 1930.
A report on the production and cost of production and irrigation in all those irrigation districts in the province of Alberta whose debentures have been guaranteed by the provincial treasurer. The commission also presents its recommendations for procedure in future policy.

3. Water

(b) Power

Annual Reports of the Alberta Power Commission, Edmonton, Alberta.

Armstrong, D.E. and R.E. McClary, Analysis of Power Costs in the Province of Alberta, 1949, Research Council of Alberta, University of Alberta, 45 pp., Appendix 1 - 9, Graphs, Fig. 1-31, Edmonton, 1952.
This report gives a comparison of the costs of power generation by the following methods, hydro, coal steam, gas steam, oil steam, gas turbine, and gas diesel. The report deals only with the costs of generation and transmission of power from the source to the load center.
Appendix 1 - 7. Unpublished statistics and data
Appendix 8. Possiblities of Power Production at mine sites
Appendix 9. Waste fuel usage for power generation.

Barnett, H.E., Supplement to Report of 1931 on Power Development and Transmission 1946, Government of Saskatchewan, Department of Natural Resources, 38 pp., maps Regina, Saskatchewan, 1946. (typewritten)
This report deals with the feasibility and cost of developing hydro electric power at the Narrows site adjacent to Fort a la Corne on the Saskatchewan River and the transmission of such power to the main load centers of the province.

Hogg, T.H., Report of the Manitoba Water Power Commission 1948, Government of Manitoba, 49 pp., appendix, King's Printer, Winnipeg, 1948.

A report of the findings and recommendations of a commission appointed to investigate all matters pertaining to the supply of electrical energy in the province of Manitoba. The commission investigated such matters as requirements of various classes of hydro electric power up to 1953; water power developments required to be undertaken to meet anticipated needs; order in which these developments should take place; possible use of natural gas to govern choice between undertaking the further water power developments on the one hand and steam on the other; also to investigate the need or otherwise for co-ordination in operation of various hydro electric installations on the Winnipeg River and if such need is manifest to advise and make recommendations to the government as to various methods to achieve such co-ordination with respect to considerations which should govern choice of method.

Russell, Ben, Report on Surface Water Supplies and Water Power of Alberta - Their Present and Ultimate Uses, Alberta Department of Water Resources and Irrigation and Department of Industries and Labour, 65 pp., Edmonton, 1948.

This report briefly outlines some of the essential provisions of the Acts pertaining to the administration of the water resources of the province, and in quite some detail enumerates and classifies the water resources; reviews the surveys and investigations which have been made from time to time under provisions of the Acts and Regulations and then discusses some of the many problems incidental to the development of these water resources.

3. Water

(c) Other

Alberta, Annual Reports of the Water Resources Office, Government of Alberta, Edmonton, Alberta

Attwood, C.H., The Water Resources of Manitoba, Province of Manitoba, Economics Survey Board, 116 pp., Winnipeg, June 1938.

This report is an attempt to present a general view of the various problems relating to water, including its origin and distribution, its use and misuse, and its relationship to human activities and its effect on population. It contains chapters on hydrologic factors, Manitoba watersheds, use and control of water resources, and water power.

Canada, Department of Agriculture, "Evaporation from Lakes and Reservoirs on the Canadian Prairies," Prairie Provinces Water Board Report No. 5, 24 pp., appendices, bibliography, Regina, Saskatchewan, 1952.

A study based on thirty years of meteorological records 1921-1950. Lack of information on evaporation losses on the Canadian Prairies made this study necessary. A.F. Meyer's formula for evaporation was selected as a means of estimating evaporation losses from large lakes and reservoirs. Using this formula and the period 1921-1950 various calculations were made and conclusions drawn therefrom. With these results and using procedures outlined in this text, it is possible to estimate evaporation for any particular month for various sized lakes and reservoirs anywhere on the Canadian Prairies (except Cypress Hills).

Canada, Department of Agriculture, Recreation Report of the Southern Saskatchewan River Project, Canada Department of Agriculture, Prairie Farm Rehabilitation Administration, 83 pp., (typewritten) concluding section printed, Regina, 1949.

This report deals with the possible recreational benefits of the South Saskatchewan River project. The concluding section deals with an economic evaluation of these benefits.

Canada, Department of Agriculture, Report on Possible Recreational Benefits Connected with the Red Deer River Diversion Project, Canada Department of Agriculture Prairie Farm Rehabilitation Branch, 155 pp., Appendix, Bibliography, Regina, Saskatchewan, 1951, (typewritten).

Deals first with physical description, climate and population of the Red Deer River diversion project area. Secondly it discusses recreation in general, i.e. a definition, the trend in recreation, and recreation and the State. Then it deals with the project effects on recreational resources, and concludes with an economic evaluation of recreational benefits associated with the Red Deer River diversion project.

Canada, Various Departments, Water Resources Branch, Department of Northern Affairs and National Resources, Water Resources Papers, published annually (hydrometric), 1908-1954.

Clement, F.M., Report on Dyking, Drainage and Irrigation Part II, "Dyking and Drainage Districts," Government of British Columbia, pp. 113-150, Victoria, 1946.

This is the report of an inquiry into the ability of certain improvement districts to repay their indebtedness to the province.

Grindley, F.L. Possible Diversion from the Arctic Watershed to the Saskatchewan (Hudson's Bay) Drainage Basin, Water Resources Office, Government of Alberta, Edmonton, 1951.

This brief report is an examination of the possibility of diverting the McLeod and Pembina Rivers into the North Saskatchewan River above Edmonton.

Hogg, T.H. (Chairman), Report of the Royal Commission on the South Saskatchewan River Project, 274 pp., Appendix, Queen's Printer, Ottawa, 1952.

A report on the findings and recommendations of the Royal Commission appointed to investigate the feasibility of the South Saskatchewan River Development.

Part I deals with the recommendations and generalconsiderations of the commission.

Part II deals with the river basin and its development and contains chapters on the geographical setting, historical setting, irrigation in Western Canada, legal and constitutional aspects, the project itself and a cost estimate, long run economic and social benefits, and the immediate effect on the economy.

Part III - the appendix deals with the submissions of individuals and organizations in Manitoba, Saskatchewan and Alberta to the commission.

Hogg, T.H., Recommendations and General Considerations of the Royal Commission on the South Saskatchewan River Project. 40 pp., Queen's Printer, Ottawa, 1952.

This is a reprint of Chapter I of the report of the Royal Commission on the South Saskatchewan River Project. It contains the recommendations and general arguments relating thereto of the commission.

Lyons, M.A., Report and Recommendations on Foreign Water and Maintenance Problems in Drainage - Maintenance Districts Constituted under the Land Drainage Arrangement Act, 1935, Province of Manitoba, Government of Manitoba, Department of Public Works, 86 pp., map, Winnipeg, Manitoba.

Report of investigations of two main problems, (i) the foreign water problem, i.e. the claim by the taxpayers and municipalities that the higher lands in the watershed should bear a portion of maintenance costs in the Drainage District and (ii) the proportion of government assistance towards the cost of maintenance of drainage works.

Prairie Provinces Water Board Annual Reports, Regina, Saskatchewan.

Canada, Department of Agriculture, "Summary Report of Recorded and Natural Monthly Flows at Certain points on the Saskatchewan River System," Prairie Provinces Water Board, Report No. 1, 6 pp., plus statistical tables, Regina, Saskatchewan, 1950.

Gives the recorded flow and natural flow (the flow in the stream under natural conditions without upstream diversions) of the South Saskatchewan at the Alberta-Saskatchewan border, at Saskatoon and at The Forks, and the North Saskatchewan at the Alberta-Saskatchewan border and at The Forks, and the Saskatchewan River at The Forks and at Le Pas.

Canada, Department of Agriculture, "Stream Flow at Three Selected Points on South and Main Saskatchewan Rivers after Alberta's 1949 request," Prairie Provinces Water Board, Report No. 2, 6 pp., statistical tables, Regina, Saskatchewan, 1950.

This report indicates how the full development of projects in Alberta which would require 2,237,234 ac. ft. of water per year (Alberta's 1949 request) would affect the stream flow at the following points for the period 1923-1948.

1. South Saskatchewan River at the Alberta-Saskatchewan boundary.
2. South Saskatchewan River at Saskatoon
3. Saskatchewan River at Le Pas.

Proceedings of Round-table Conference on Groundwater in Alberta, Research Council of Alberta, Preliminary Report 56-1, 84 pp., Edmonton, Alberta, 1955.

Proceedings of a conference held to discuss the establishing of a program for better scientific information in matters of groundwater geology and hydrology. It served to point out the place which water supplies take in economic development, health and welfare in a growing country.

Discussed at the conference were such matters as the development of groundwater resources, their conservation and protection, their legal nature, their chemistry and their role in the economic and industrial future of the province.

4. Population

Keyfitz, Charles E. and N.H. Roseborough, The Future Population of Canada, Dominion Bureau of Statistics, Department of Trade and Commerce, Bulletin No. F-4, 61 pp., Ottawa, 1946.

This bulletin contains a projection of the size of Canada's future population to the period 1971 on certain definite assumptions. It is not a prediction of the actual population of the future. Its usefulness lies in the techniques used and the results obtained.

McNally, G.F., Report of the Royal Commission on the Metropolitan Development of Calgary and Edmonton, 17 chapters, Appendix A - "Reservations of Commissioners" Appendix B - "Decisions of Commission on Questions of Jurisdiction," Queen's Printer, Edmonton, Jan. 1956.

The Water Resources Paper No. 12 contains a reference to the evidence of Messrs. Purcell and Espenschied before the Committee on Agriculture and Colonization, Parliament of Canada, Session 1914.

5. Resources

Government of Saskatchewan, Saskatchewan - Its Resources and Industry, Industrial Development Office, Government Administration Building, 76 pp., Appendices, Regina, Saskatchewan.

The purpose of this booklet was to reveal the background of the new opportunities that are appearing in the province's growth. Information is presented on the major aspects of resources, industries markets and services. Under the heading "Saskatchewan and its resources" it deals with geology, climate, soils, vegetation and settlement. Under "Industry present and potential" it deals with primary and secondary aspects of industrial minerals, forest products and miscellaneous industries, and under "Facts for industry" it deals with the main advisory and financial services.

Appendix I - Index of Saskatchewan Industries.
Appendix II - Leading Industries
Appendix III - Cities of Saskatchewan

6. Economics

Brodrick, F.W. and S.E. Chernick, "Extracts from: Preliminary Report on the Carrot River Survey," Department of Mines and Natural Resources, Government of Manitoba, 83 pp. plus appendix, (manuscript) Winnipeg, 1946.

An economic survey of agriculture in the Carrot River district in Manitoba. This report deals with the agricultural possibilities of the Carrot River district, more specifically that portion of the Saskatchewan River Delta lying between the Carrot River in the north, the Pas River on the south and east and westward to the Manitoba-Saskatchewan boundary. Investigations were made of the wild-life, soils and agricultural methods. This is a preliminary report on the data gathered with an analysis of the materials and the conclusions and recommendations of the writers for future agricultural development.

The appendix contains a brief history of the Saskatchewan River Delta, its early exploration, development and trade.

Craig, G.H. and J. Coke, An Economic Study of Land Utilization in Southern Alberta, Economics Division, Marketing Service, Canada Department of Agriculture, Pub. 610, Technical Bulletin 16, pp. 79, Ottawa, 1938.

The focus of this study is a drought area in southern Alberta, a region of risk and uncertainty. A thorough scrutiny of the settlement process and various indexes of success were tested and evaluated as criteria upon which future land use and settlement policy may be based. This study gives a partial answer to the question whether the so called drought area is capable of producing a normal standard of living for its population and if so in what parts and by what method of land use.

Darcovich, William, An Appraisal of Market Possibilities for Specialty Crops in the Proposed Irrigation Area of Saskatchewan, Economics Committee appointed by the Director of P.F.R.A., 40 pp., Regina, 1949 (mimeographed).

This memorandum deals with probable acreage requirements in 1971 for the various specialty crops based on estimates of population, estimates of the level of per capita consumption and to some extent on the probable competitive advantage of the various crops in relation to other areas of production.

Edwards, Florence M., Farm Family living in the Prairie Provinces, Economics Division, Marketing Service, Canada Department of Agriculture, Pub. 787, Technical Bulletin 57, 28 pp., Ottawa, 1947.

A report on living conditions in the pioneer areas of northern Saskatchewan and in central Saskatchewan and central Alberta. It deals with the achievements of rural families in their short history of settlement, the kind of living provided by farms in various farming regions, the adequateness of housing facilities, community facilities and the amount of money farmers spend on living and what it is spent on.

Fowke, V.C., "The Historical Setting," Chapter 3 of Report of the Royal Commission on the South Saskatchewan River Project, pp. 71-130, Queen's Printer, Ottawa, 1952.

The historical setting is discussed here under the following headings, (i) national policy and western Canadian development (ii) preparation for settlement in the Canadian West, (iii) establishment of the Canadian wheat economy 1900-1930, (iv) the disastrous decade 1930-1939 and (v) effects of the second world war on the prairie economy.

Harries, Hu., The Economic Basis for Past Irrigation Expenditure in Alberta, Hu Harries and Associates, Edmonton, 1952, pp. 66.

A report on a study inquiring into the economic inducements which prompted private and government agencies to invest money on irrigation in Alberta. Agencies which invested money were the Dominion Government, Railways, Canada Land and Irrigation Co. and Government of Alberta. This study reveals instances in which these inducements were obvious and explicit; but it also reveals many cases where the economic basis for expenditure was ill defined and ambiguous even in the minds of the persons or organizations who were participating. There is a selected bibliography. A copy of the report is on file in the office of the Economics Division, Canada Department of Agriculture, University of Alberta, Edmonton.

Mackintosh, W.A., "The Economic Background of Dominion-Provincial Relations," A Study Prepared for the Royal Commission on Dominion-Provincial Relations, Appendix 3, King's Printer, Ottawa, 1939.

Manery, H.R., Sprinkler Irrigation in Alberta 1949, Economics Division, Marketing Service, Canada Department of Agriculture, 20 pp., processed publication, Ottawa, 1951.
A report on a survey to determine the cost of operating a sprinkler system under Alberta conditions, the causes of high cost operation, to collect data that would aid the design and operation of lower cost systems and to obtain a cross section of farmer's opinions after one season of operation.

Pyrch, A.J., Marketing of Specialty Crops from the Irrigated Areas of Alberta, Economics Division, Marketing Service, Canada Department of Agriculture, 52 pp., (manuscript), Edmonton, 1945.
Study of production, present markets and future potentialities for specialty crops in the irrigated areas of Alberta.

Spence, C.C., B.H. Kristjanson and J.L. Anderson, Farming in the Irrigation Districts of Alberta, Economics Division, Marketing Service, Canada Department of Agriculture in co-operation with the Department of Political Economy, University of Alberta, Pub. 793, Technical Bulletin 61, pp. 66, Ottawa, 1947.
This bulletin gives an analysis of factors in farm management which have the greatest influence on successful irrigation farming in Alberta. It shows what net revenue could reasonably be expected from irrigation land under varying conditions of farm organization for retiring debt or for savings. It evaluates the difference in productivity and unit income of the irrigated areas compared with dry land areas. It concludes with some future considerations in irrigation farming and with a suggested farm organization for an irrigation farm.

Stapleford, E.W., Report on Rural Relief Due to Drought Conditions and Crop Failures in Western Canada, 1930-37, Canada Department of Agriculture, 129 pp., Ottawa, 1939.
This report attempts to tell as briefly as possible the story of crop failures from which the west suffered from 1930-1937. Major portions of the report are devoted to Saskatchewan, where the full impact of the drought was felt. It sets forth the hardships which prairie farmers had to face and the effects these hardships had upon them. It deals with the response of the Federal Government to meet the emergency and the fine gesture of the people of Canada who sent voluntary relief of food and clothing to the drought stricken areas.
The report also endeavors to set forth the long term plans which are being worked in order to make it possible for the farmer to continue to produce on prairie soils in comparatively dry years and also to make it possible for him to support himself even in a period of protracted drought.

Stewart, A and W.D. Porter, Land Use Classification in the Special Areas of Alberta and in Rosenheim and Acadia Valley, Economics Division, Marketing Service, Canada Department of Agriculture in co-operation with the Department of Political Economy, University of Alberta, Pub. No. 31, Technical Bulletin No. 39, 68 pp., appendix, maps, Ottawa, 1942.

This bulletin is one of a series on land classification in Alberta and Saskatchewan. It describes in detail the methods employed in establishing the classification of land. In this publication considerable stress has been placed on the fundamental ideas upon which an economic classification of land may be based. An understanding of these principles is necessary for the proper interpretation and use of both the classification itself and supporting data contained in this report.

Appendix A contains a brief discussion on Alberta Special Municipal Areas.
Appendix B gives the Statistical basis of classification.

Van Vliet, H. Gordon Hasse and R.A. Stutt, An Economic Appraisal of the Irrigation Phase of the Proposed South Saskatchewan River Development, P.F.R.A., 148 pp., plus Appendix, Regina, 1951, (mimeographed).

This study examines three main aspects of the proposed South Saskatchewan irrigation project. First, there is a review of the present farming pattern in the area. Secondly, there is a projection of the type of farming that would likely develop in the area under irrigation practise, based mainly upon the experience of similar projects in Alberta. Thirdly, there are estimates of the increases in farm income and other benefits that irrigation would provide, both in respect to incomes that may be recovered to offset the capital costs of development, and to other indirect benefits that accrue to other segments of the economy.

Warren, D.M., A Study of Factors Associated with Land Values in the Proposed South Saskatchewan River Development, Economics Division, Marketing Service, Canada Department of Agriculture, Restricted Bulletin, 27 pp., Ottawa, 1954.

In this bulletin the author establishes a land value guide which helps to establish a fair basic price for lands within the proposed development area in Central Saskatchewan. Three series of land values were developed, the first based on historical data relating to land sales of the past, the second based on budget estimates and capitalization of probable net returns, and the third is based on the assessed value of land for each soil group and related to the price of the main product, wheat.

CHAPTER 4. OTHER

1. General

Brief of City of Medicine Hat and Medicine Hat Chamber of Commerce to the International Joint Commission - United States and Canada Waterton Belly Rivers reference, Medicine Hat, June 1950, 16pp.

This brief attempts to show the impact on the city of Medicine Hat and other urban centers in the lengthy series of agricultural reverses due to inadequate water supply and to show how the condition can at least be alleviated by the completion of the St. Mary's River Development scheme in this particular area.

Brief of Rural District of Medicine Hat to the International Joint Commission - United States and Canada - Waterton - Belly Rivers Reference, Medicine Hat, June 1950, 7pp.

An account of the attempt of the Medicine Hat area to make a living by farming the land. It also deals with the efforts made to obtain water for the growing of crops, both from the rivers and from the clouds.

Submissions of the Medicine Hat Chamber of Commerce respecting the Proposed Irrigation of the Redcliff-Ronalane district, Medicine Hat, Feb. 1938.

Fellows, E.S., Multiple Forest Use - Its Application on the Rocky Mountain Forest Reserve, Eastern Rockies Conservation Board, Calgary, 1951, (mimeographed).

In this paper the author discusses the multiple uses of the Rocky Mountain Forest Reserve that can provide the greatest contribution to the Canadian economy. The uses briefly discussed are, grazing, logging, mining, wild life, recreation, water supply and hydro.

Hanson, W.K., Mutual Watershed and Grazing Interests, Eastern Rockies Conservation Board, Calgary, 1952, (typewritten).

In this paper the author discusses the conflict between grazing and watersheds in the "multiple use" concept of forest reserves. He discusses the ways in which they conflict and how proper management of range resources can prevent damage to the watershed.

Laycock, A.H., Report of the Soil and Watershed Survey of 1953 of the Ghost and Red Deer District, Eastern Rockies Conservation Board, Calgary, Alberta, 1954.

This report is intended to serve as one of the bases of management planning for this and other regions of the Reserve. It has two major descriptive divisions. The first is a systematic review of the elements which have contributed to the development and which relate to the composition and use of the soils of this region. The second is a review of the soils of each of the major parts of the region with reference to the present and potential uses of these soils. The section following includes a discussion of particularly the use potential of the soils and a presentation of the author's conclusions and recommendations.

2. **Water**

(a) Irrigation

Annual Report and Financial Statement of the Lethbridge Northern Irrigation District, Lethbridge, Alberta.

Annual Report and Financial Statement of the Taber Irrigation District, Taber, Alberta.

Annual Report and Financial Statement of the Eastern Irrigation District, Brooks, Alberta.

Annual Report and Financial Statement of the Western Irrigation District, Strathmore, Alberta.

Annual Report of the Alberta Sugar Beet Growers, Lethbridge, Alberta.

Brownstone, M., Land Tenure on Irrigation Projects, Research Division, Economic Advisory and Planning Board, Government of Saskatchewan, 12 pp., Regina, 1949.

This bulletin gives a review and analysis of the effects of the three alternative forms of tenure on irrigation projects. These are private, co-operative and public ownership.

Canada Land and Irrigation Co. Ltd., Procedure in Organization of Irrigation Districts under the Irrigation Districts Act, 1920, of the Province of Alberta, Part I, "The Value of Irrigation," Part II, "Canada Land and Irrigation Co. Ltd.," 7pp., Medicine Hat, Alberta, 1921.

This pamphlet merely outlines the procedure to be followed in organizing an irrigation district and summarizes briefly the advantages of irrigation in an area where there is insufficient rainfall to produce a fair to good crop.

Canada Land and Irrigation Co. Ltd., Regulations Relating to Operation and Maintenance of Bow River Irrigation Project, Canada Land and Irrigation Co. Ltd., 12 pp., Medicine Hat, Alberta, 1922.

This pamphlet contains a statement of the general principles relating to the operation and maintenance of the Bow River Irrigation Project, for the convenience and guidance of the employees of the Canada Land and Irrigation Co. Ltd. and the water users taking water from its canal system. It covers regulations concerning ownership and control of works, delivery of water, damage to works, telephone system and duties of employees.

Canada Land and Irrigation Co. Ltd., Bow River Irrigation Project, Canada Land and Irrigation Co. Ltd., Medicine Hat, Alberta, 1923, (date determined from contents).

This bulletin describes the Bow River Irrigation Project with emphasis on points that would be of interest to new settlers, i.e. climate, soil, water supply, market and transportation facilities, and prices of land and terms of contract.

Lethbridge Board of Trade, Green Acres, Lethbridge Board of Trade, 39 pp., Lethbridge, Alberta, 1946.

This illustrated booklet presents in a highly favorable light, the story of irrigation in Southern Alberta, its beginning, its present day advantages and the opportunity that irrigation development provides for future settlers both on farms, and in industry. It deals with the possibilities for the further extension of irrigation and the need for industrialization to make the best use of the products produced.

McMullen, R.A., Tap the Water, Alberta Department of Economic Affairs, 31 pp., Edmonton, 1946.

This bulletin gives a brief summary of irrigation development in Alberta to 1946, acreage under irrigation, potential irrigable acreage, recommendations of the Alberta Post War Reconstruction Committee, also a discussion of the economic effect which the development of irrigation in southern Alberta would have on the province. The author concludes with his recommendations for future development as to government aid, rehabilitation of veterans, transfer of dry land farmers from semi-arid regions etc.

Pearce, Wm., Pearce Papers, Indexed by W.E. Sterling, Oct. 1930, Housed in the Rutherford Library, University of Alberta, Edmonton.

See appendix to this bibliography for further details re the Pearce papers.

Raley, C and S.G. Porter, A Brief History of the Development of Irrigation in the Lethbridge District, Lethbridge Historical Society, 44 pp., appendix, Lethbridge, Alberta, 1925, (typewritten).

This article gives first a brief, general outline of the beginnings of irrigation in western Canada and then a more or less detailed statement of the events associated with the development of irrigation in what is termed the Lethbridge district of southern Alberta.

APPENDIX - TABLES OF CONTENTS OF CERTAIN SOURCES

I. EXPLANATORY REMARKS

A. Expanded Table of Contents of Publications of the Department of the Interior

1. Scope

C. 1894, the Department of the Interior began to take a serious interest in irrigation and began to deal with the subject in its annual reports. For the years 1900 to 1907, however, the reports on irrigation were published in monograph form only, and for the years after 1912 reports on water were again printed separately. What has been entitled the "Expanded Table of Contents" covers the annual departmental reports for the years 1894 to 1899 and 1908 to 1912, the separate irrigation reports for 1900 to 1907, and a special pamphlet on natural resources in the Prairie Provinces.

2. Method

The above-mentioned sources are treated in this way: For each section relevant to the present study a heading and, in general, a detailed outline are given here. A section that is dealt with fully in this way is indicated thus, *. The reason is that when a section of a source is not dealt with fully, but a subsection thereof is, the heading of the former is listed in order to show the position of the latter in the source.

The outlines here given are in general more detailed than is the case in the tables of contents of the sources. Furthermore, to avoid confusion, it should be stated that sometimes the set of subsection headings in a given section of a source apparently did not follow closely and logically, and therefore did not give a clear indication of the actual organization of the section. In such cases the subsection headings here sometime depart from the system found in the source.

B. Contracted Table of Contents of Publications of the Department of the Interior

1. Scope

What has been entitled the "Contracted Table of Contents" covers the annual reports on reclamation (including irrigation) and water power for the years 1913-1929.

2. Method

The above-mentioned reports seem in general to have useful tables of contents. Therefore the method of treatment adopted was to copy certain headings and sub-headings that seemed relevant directly from the published tables of contents. The tendency in selection was to exclude the relatively technical data and information of topical interest. The resulting list is intended as a rough guide to, or a sample of, the sort of material which is available in the reports covered, and should be useful in that capacity.

To avoid confusion in examining the list, it should be emphasized that, in general, not all the main headings, nor all the sub-headings under a given heading, were included.

C. Indexes

1. General

The notation "I", "N", "R", "W", or "WR" preceding a reference means that the reference is, respectively, to a report on irrigation, to the pamphlet on natural resources, to a report on the Reclamation Service, to a report on the Water Power Branch, or to a report on the Water Power and Reclamation Service. The correspondence between such notation in the Index to the Contracted Table of Contents and the sections of the Table itself is: I—A.,B.; R—C.; W—D.; WR—E.

2. Index to the Expanded Table of Contents

As an example of the notation used, "1899, Pt. VII., w. pp. 14-22, pp. 29-30" means that the subject covered is found somewhere within pages 14 to 22 and also on pages 29-30 of Part VII of the report for the year 1899.

Since the material indexed deals almost exclusively with irrigation, the references under IRRIGATION are generally short general articles on the subject.

3. Index to the Contracted Table of Contents.

As an example of the notation used, "I, 1913, pp. 105-117" is a reference to an article in the 1913 report on irrigation.

D. Table of Contents of the Pearce Papers

A fragmentary table of contents of the personal files of the late Mr. Wm. Pearce is included. This is a list of those files which, by their titles, seemed relevant to the present study.

II. EXPANDED TABLE OF CONTENTS OF PUBLICATIONS OF THE DEPARTMENT OF THE INTERIOR

A. Annual Reports of the Department, 1894-1899, 1908-1912.

Annual report for the year 1894, Ottawa, 1895

"Report of the Deputy Minister of the Interior." p. ix ff.
* "Irrigation." pp. xvii-xx.
Activities of Mr. Wm. Pearce; North-west Irrigation Act; surveys in the arid district under Mr. J.S. Dennis, pp. xvii-xix.
"Progress of the Irrigation Movement." pp. xix-xx.
"International Irrigation Congress." p. xx.
Part I "Dominion Lands."
No. 1. "Report of the Commissioner of Dominion Lands." p. 1 ff.
* "Irrigation." pp. 3-4.
Miscellaneous comments.
* No. 3. "Report of the Superintendent of Mines on irrigation in the North-west Territories." pp. 29-35, Submitted by Wm. Pearce.
A brief history of irrigation in the area.
Irrigation companies chartered by act of parliament.
Some opinions and suggestions of Pearce on irrigation.
Pearce's trip to the U.S. in connection with the International Irrigation Convention.
Government aid to irrigation.
Part II. "Dominion Lands Surveys."
"Report of the Surveyor General." p. 3 ff.
* "Irrigation." p. 4,
Initiation of irrigation survey.
* No. 12. "Report of A.O.Wheller, D.L.S., Irrigation Surveys." pp. 43-47.
Details of organizing survey party.
Order of work.
Bench marks.
Summary of work done.
List of rivers and streams cross-sectioned for discharge.
Part V. "North-west Territories."
"Irrigation." p. 18.

Annual report for the year 1895, Ottawa, 1896.

"Report of the Deputy Minister of the Interior." p. ix ff.
* "Irrigation." pp. xvi-xx.
Progress of irrigation in the semi-arid portion of the North-west Territories in 1895. pp. xvi-xviii.
"Administration of the Irrigation Act." p. xviii.
"Irrigation Surveys." pp. xviii-xix.
"International Irrigation Congress." pp. xix-xx.
Part I. "Dominion Lands."
No. 2. "Report of the Superintendent of Mines."
* "Irrigation." p.20.

Part II. "Dominion Lands Surveys."
"Report of the Surveyor General."
* "Irrigation Surveys." p.4.
Brief summary of work.
* No. 1. "Report of the Chief Inspector of Surveys." pp. 8-11.
Largely concerned with the continuation of the administration of the irrigation surveys.
* Part III. "Irrigation," 155 pp. plus illustrations.
"General Report on Irrigation, and Canadian Irrigation Surveys during 1894." pp. 5-141. (Outline on p, 3)
Part I. "Irrigation in Canada". pp. 5-34.
History of Western Canada. pp. 5-6.
Geography of what was then called the semi-arid region of the North-west Territories, pp. 6-20
Boundaries and topograhy. pp. 6-7.
Soil p. 7.
Hydrography.
"Eastern District." pp. 7-8.
"Central District." pp. 8-9.
"Western District." p.9.
"Lakes and Lake Beds in the Arid Region." pp. 9-10.
Climate.
Precipitation.
General p. 10
"Eastern District," p. 11
"Central District." p. 11
"Western District," p. 11-12.
Temperature.
General pp. 12-14.
"Eastern District," p. 15.
"Central District." p. 15-16.
"Western District." p. 16.
"Meteorological Stations in the Arid Region." p. 16.
Tables.
Precipitation, pp. 17-18.
Mean temperatures. pp. 19-20.
"Irrigation Systems." pp. 21-27.
Brief history of irrigation in the region. p. 21.
"Schedule of Irrigation Canals and Ditches in operation, under construction, or projected ..." pp. 22-25.
"The Calgary Hydraulic Company." p. 26.
"The Calgary Irrigation Company." pp. 26-27.
"The Springbank Irrigation Canal." p. 27.
Five photographs of irrigation canals. Between pp. 26-27.
Irrigation legislation. pp. 27-34.
North-west Irrigation Act.
Irrigation District Ordinance.

"Branches of Highwood River." p. 86.
"General Remarks." pp. 86-87.
The region of the Belly River drainage basin.
"Highwood River to Little Bow River." pp. 87-88.
"Little Bow River to Oldman River." pp. 88-90.
"Between Oldman River and Belly River." pp.90-92.
"Between Belly River and St. Mary River." pp. 92-94.
"St. Mary River to the Township Outline between Ranges 22 and 23, West of [the] 4th Meridian." pp. 94-97.
"North of Milk River Ridge and East of Township Outline Between Ranges 22 and 23, West of 4th Meridian." pp. 97-98.
"General Remarks." p. 99.
"Hydrography". pp. 99-117.
Methodology of investigations.
To obtain some general knowledge of the entire water supply of Division B's territory. pp. 99-100.
To find the relative volume and value for irrigation of the waterways. pp. 100-102.
To find the location and capacity of bodies of still water and of basins suitable for irrigation sites. Includes a list of small reservoir sites. pp. 102-103.
To locate and measure the discharge of springs. pp. 103-104.
"Notes on Rivers and Streams of which the Discharge was measured." Includes some comment on irrigation possibilities, mainly for extensive areas.
"Pine Creek." p. 104.
"Mosquito Creek." pp. 104-105.
"Willow Creek.". pp. 105-106.
"Oldman River". pp. 107-108
"Pincer Creek." pp. 108-109.
"Waterton River." pp. 109-110.
"Belly River." pp. 110-113.
"Lee Creek." pp. 113-114.
"St. Mary River." pp. 114-116.
"North Branch of Milk River." p. 116.
"General Remarks." p. 117.
Part III. A manual of information, including statistics, relating to irrigation practice, largely composed of extracts from textbooks and reports. pp. 118-141.
"Report of Mr. J.S. Dennis, Chief Inspector of Surveys, on Irrigation Operations during the season of 1895." pp. 142-155.
Includes a section on Canadian irrigation law and its administration.
Part VI. "North-west Territories."
"Irrigation". p. 4 (6 ll.)

<u>Annual report for the year 1896</u>, Ottawa, 1897.

"Report of the Deputy Minister of the Interior." p. ix ff.
* "Irrigation." pp. xxvii-xxviii.
General remarks. p. xxvii.
"Administration of the Irrigation Act." pp. xxvii-xxviii.
"Irrigation Surveys." p. xxviii.

Part I. "Dominion Lands."
No. 2. "Report of the Superintendent of Mines." p. 25 ff.
* "Irrigation." pp. 25-26.
The outlook for irrigation.
* "Increase of the Grazing Area through Irrigation and Artesian Water Supply." p. 26.
* "Bulletin of Information from Irrigators." pp. 77-82.
Includes locations and numbers of acres irrigated.
Part II. "Dominion Lands Surveys."
"Report of the Surveyor General." p. 3 ff.
* "Irrigation Surveys." p. 5.
Brief summary of work.
* No. 10. "Report of J.S. Dennis, D.T.S., Chief Inspector of Surveys." pp. 56-60.
Summary of work done. Scope of the work as divided among the work parties.
* No. 11. "Report of Arthur O. Wheeler, D.L.S., for Season of 1895". pp. 61-67.
Summary of the operations of Division B of the Canadian Irrigation surveys in the 1895 season. Includes the following sections:
"Jumpingpound Creek." pp. 62-63.
"Elbow River." pp. 63-64.
"North Branch of Fish Creek" pp. 64-65.
"South Branch of Fish Creek." p. 65
"North Branch of Sheep River." pp. 65-66.
"South Branch of Sheep River." p. 66
* No. 12. "Report of Arthur O. Wheeler, D.L.S., for Season of 1896." pp. 68-70.
Summary of Division B's operations in the 1896 season.
* Part III. "Irrigation." pp. i-x, 1-112. (alphabetic index to contents, pp. iii-vi. Index to maps and Illustrations, p. vii. Letter of submission, p. ix, containing explanation of division of Part III into sections numbered Part I and Part II.)
Part I. General report on irrigation for 1895.
Explanation that the arid region is not to be regarded as barren. p.1.
Progress in irrigation development. pp. 2-10.
General remarks. pp. 2-8. Includes schedule of canals and ditches constructed and projected.
"Calgary Irrigation Company." p. 8.
"Calgary Hydraulic Company." p. 8.
General remarks. pp. 8-10.
"Springbank Irrigation Canals." p. 10.
"St. Mary and Bow River Canals." p. 10.
"Water Rights Granted, other than Those for Irrigation Purposes." pp. 10-11.
"Results from Irrigation during 1895." pp. 12-18.
Includes table of information from irrigators.
"Administration of Water Rights." pp. 18-23.
"Title to Water." pp. 23-24.
"The North-west Irrigation District Ordinance." pp. 24-25.
"Meterological Conditions in the Arid Regions." pp. 25-29.
"Water Supply in the Arid Region." pp. 29-37.
"Canal Surveys." pp. 37-40.

General. p. 37.
"The Red Deer River Canal." pp. 37-39.
"Saskatchewan River Canal." pp. 39-40.
"The Colonization of Arid Lands." pp. 40-44.
Part II. "Canadian Irrigation Surveys." pp. 45-112.
General. pp. 45-46.
Work of Division A of the survey. pp. 46-67.
Contains the following sections:
"St. Mary Irrigation Canal." pp. 47-54.
General. pp. 47-49.
"Dimensions of Canal." p. 49.
"Route of Canal and manner of Locating." pp. 50-52.
"Headgates, Dams and other proposed Structures." pp. 52-53.
"Lands Irrigable from main Canal and Branches." p. 53.
"Probable cost of proposed Works." pp. 53-54.
"The Bow River Irrigation Canal." pp. 54-62.
General.
"Dimensions of Canal." p. 56.
"Point of Intake." pp. 56-57.
"General Location." pp. 57-59.
"Headgates and Diverting Dam or Weir." p. 59.
"Estimated cost of Canal and Structures." pp. 59-60.
"Lands irrigable from main canal and principal laterals." pp. 60-61.
"Colonization of the reclaimed area." pp. 61-62.
"Hydraulic Investigations." pp. 65-66.
"Evaporation Investigations." p. 67.
Work of Division B of the survey. pp. 68-112.
Objectives of Division B's program. pp. 69-70.
"Methods and Instruments." pp. 70-76.
"Hydrography of Rivers and Streams." pp. 77-112.
"Jumpingpound Creek System." pp. 77-84.
"Storage Facilities." pp. 81-83.
"General Remarks." p. 83.
"Elbow River System." pp. 84-93.
"Storage Facilities." pp. 91-93.
"General Remarks." p. 93.
"Fish Creek System." pp. 94-98.
"North Branch." pp. 94-96.
"Diversion of Water from the Elbow River to North Branch of Fish Creek." p. 95.
"General Remarks." pp. 95-96.
"South Branch." pp. 96-98.
"Storage Facilities." pp. 97-98.
"General Remarks." p. 98.
"Sheep River System."
"North Branch of Sheep River." pp. 98-103.
"Water Storage." pp. 101-102.
"Ware Creek." pp. 102-103.
"South Branch of Sheep River." pp. 103-112.
"Water Storage." pp. 111-112.
Part V. "North-west Territories."
* "Irrigation." p. 5. Brief mention.

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"Report of the Deputy Minister of the Interior."
* "Irrigation." pp. 20-21.
Part I. "Dominion Lands."
No. 2. "Report of the Superintendent of Mines."
* "Irrigation." pp. 32-33.
* "Hamlet System Combined with Irrigation." pp. 33-35.
* "Irrigation Wells." pp. 36-37.
No. 5. "Report of the Clerk of Timber, Mineral, Grazing and Irrigation Lands."
* "Irrigation." pp. 53-54.
Part II. "Dominion Lands Surveys."
"Report of the Surveyor General."
* "Irrigation Surveys." pp. 6-8.
* No. 5. "Report of J.S. Dennis, D.L.S., General Irrigation Surveys." pp. 19-28.
Letter of J.S. Dennis, containing general remarks. pp. 19-20.
Report of Division A, Party No. 1. pp. 20-26.
"Waterton Lakes." pp. 20-21.
"Cypress Hills." pp. 21-22.
"Cypress Lake." pp. 22-23.
"Diversion of Battle Creek into Cypress Lake." p. 23.
"Dam Site East End of Cypress Lake." pp. 23-25.
"Frenchman Creek." pp. 25-26.
Report of Division A, Party No. 2. pp. 26-28.
* No. 6. "Report of A.O. Wheeler, D.L.S., Canadian Irrigation Surveys." pp. 29-39. Report on the operations of Division B.
* Part III. "Irrigation." pp. 1-74 + 12 photographs. (Alphabetical index to contents, pp. 71-74. Index to illustrations and maps, p. 74.) (pp. 72-74 have been mis-numbered 68-70.)
Section I. Irrigation. pp. 5-35.
Progress in irrigation development. pp. 5-12.
Includes schedule of canals and ditches constructed and projected, pp. 6-10.
Canals.
"St. Mary River Canal." p. 12.
"Bow River Canal." p. 12.
"Red Deer River Canal." p. 13.
"Springbank Irrigation Canals." p. 13.
"Water Rights for Domestic and Other Purposes." p. 13-15.
Results from irrigation. pp. 16-24.
General. p. 16.
"Wheat". p. 16.
"Barley." pp. 16-17.
"Oats". p. 17.
"Timothy". p. 17.
"Bromus Inermis." p. 17.
"Peas and Rye." p. 17.
"Native Grasses." pp. 17-18.
"Vegetables." p. 18.
"Number of Irrigations." p. 18.
"Planting Fodder Crops." p. 18.

"Statement of Acreage under Crop, and Yields from same, during Season 1896...". p. 19.
"Table of Prices Current at Calgary." p. 19.
"Statement of Temperature and Rainfall at certain points in Southern Alberta and Western Assiniboia, during the months of May to September, inclusive, during 1895 and 1896." p. 19.
"Information from Irrigators." pp. 20-24.
"Boundaries of the Arid Region and Meteorological Information regarding that Region." pp. 24-35.
Tables of mean temperatures at various stations. pp. 25-28.
Tables of precipitation at various stations. pp. 29-31.
Results of analyses of water from various streams. p. 32.
Statement of rainfall at Calgary. p. 33.
Observations of evaporation at two stations. pp. 34-35.
Diagrams of rise and fall of Bow and Elbow Rivers at Calgary. Between pp. 32,33.
Section II. "Canadian Irrigation Surveys." pp. 37-69.
Report of J.S. Dennis, including general remarks, and dealing particularly with the work of Division A of the survey. pp. 37-47.
"Schedule showing the Measured or Calculated [High Water or Flood] Discharge of Certain Streams during 1896..." p. 39.
"Schedule showing Low Water Gauging of certain streams during the year 1896..." p. 40.
"Proposed Canal to Divert Water from the South Saskatchewan River to the Regina and Moose Jaw Plains." pp. 41-43.
"The Red Deer Rosebud Canal." pp. 43-46.
"Source of Supply." p. 44.
Table of gaugings of Red Deer River. p. 45.
"Location of Canal." p. 45.
"Dimensions of Canal." p. 46.
Report of A.O. Wheeler, dealing with the work of Division B. pp. 48-69.
"Traverses." pp. 52-57.
"Elbow River." pp. 52-55. Includes a section, pp. 54-55, on a proposed reservoir site.
Sheep River, south branch. pp. 55-57.
Part V. "North-west Territories."
* "Irrigation." p. 3. Brief comment.

Annual report for the year 1898, Ottawa, 1899.

"Report of the Deputy Minister of the Interior." p. i ff.
* "Irrigation and Irrigation Surveys." pp. xxiv-xxv.
Part I. "Dominion Lands." p. 1 ff.
No. 2. "Report of the Superintendent of Mines." p. 26 ff.
* "Irrigation." p. 27.
* "Legislation in Aid of Irrigation." p. 28.
No. 4. "Report of the Chief Clerk, Timber, Mining, Grazing and Irrigation." p. 37 ff.
* "Irrigation." p. 55. Applications for authority to divert water for irrigation and other purposes, and regulations pertaining thereto.

Part VI. "Dominion Lands Surveys." p. 355 ff.
"Report of the Surveyor General." p. 357 ff.
* "Irrigation Surveys." pp. 364-365. Summary of work done, with some mention of findings.
* No. 23. "Report of J.S. Dennis, D.L.S., Irrigation Surveys." pp. 439-440. General report.
* No. 24. "Report of A.O. Wheeler, D.L.S., Irrigation Surveys." pp. 441-448. A more detailed report.
"Surveys."
"Party No. 1." pp. 441-442.
"Party No. 2." pp. 442-443.
"Party No. 3." p. 443.
"Hydrographic Records."
"Nilometers." p. 444. (Instruments to record a stream's rise and fall.)
"Gauge Rods." pp. 444-446.
"Evaporation." p. 446.
"Cross-Sections." p. 447.
"Rating Station." p. 447.
"Ditch Inspection." p. 447.
"Office Work." p. 448.
* No. 25. "Report of R.W. MacIntyre, C.E., Irrigation Surveys." pp. 449-450.
Operations of Party No. 2.
* No. 26. "Report of Jas. T. Child, C.E., Irrigation Surveys." pp. 451-452. Operations of Party No. 3, including examination of potential reservoir sites.
(Note: The "Fourth General Report on Irrigation and the Canadian Irrigation Surveys," which normally would have formed a Part of this annual report, was not included. It is found in the report for the year 1899, Part VII.)

<u>Annual report for the year 1899</u>, Ottawa, 1900

"Report of the Deputy Minister of the Interior." p. i ff.
* "Irrigation and Irrigation Surveys." pp. xxviii-xxix.
The unusually heavy rainfall of the past season.
Continuation of construction of irrigation works despite heavy rainfall.
Summary figures indicating the extent of irrigation.
Water rights for domestic purposes.
Irrigation surveys.
The special irrigation reports.
Part I. "Dominion Lands."
No. 2. "Report of the Superintendent of Mines." p. 25 ff.
* "Irrigation." pp. 27-28.
Some predictions about the future of irrigation in the semi-arid region.
The advantages of the hamlet system, related particularly to irrigation.
Possibilities of water power from the larger irrigation schemes.

* "Aid to Irrigation." p. 28.
* "Water Supply for Stock from Wells by the Aid of Windmills." p.28.

No. 4. "Report of the Chief Clerk, Timber, Mineral, Grazing and Irrigation." p. 36 ff.

* "Irrigation." pp. 60-61. Applications for authority to divert water for irrigation and other purposes, and regulations pertaining thereto.

Part VI. "Dominion Lands Surveys."

"Report of the Surveyor General." p. 3 ff.

* "Irrigation Surveys." pp. 9-10. Summary of the work done.
* Part VII. "Irrigation." pp. 1-78 + illustrations.

Irrigation surveys of 1897. pp. 1-35 + 8 diagrams + 4 plates.

"Report of J.S. Dennis, D.T.S., Surveys of 1897." pp. 1-5.

Summary of work of Division A, Party No. 1, and some of its findings regarding water storage and diversion possibilities. pp. 1-2.

Summary of work of Division A, Party No. 2, and some of its findings regarding water storage possibilities. p. 2.

Summary of work of Division B. pp. 2-3.

Climate, pp. 4-5.

Schedule of mean temperatures for 1897 at various stations. p. 4.

Schedule of precipitation for 1897 at various stations. p. 4.

Analyses of temperature and precipitation schedules. p. 5.

Report of R.W. Macintyre, C.E., on work of Division A, Party No. 1, pp. 6-12.

"St. Mary's Canal." p. 6.

"Waterton Lakes." p. 6.

"Cypress Hills." pp. 6-8.

"Cypress Lake." p. 8.

"Diversion of Battle Creek into Cypress Lake." p. 9.

The feasibility of the scheme.

"Dam Site East End of Crypress Lake." p. 9.

"Frenchman Creek." pp. 11-12.

Report of O. York, C.E., on the work of Division A, Party No. 2. pp. 12-14. Summary of work done, including inspection of some potential sites.

Report of Arthur O. Wheeler, D.L.S., on the work of Division B. pp. 14-22. Includes measurements of discharges of 8 streams.

Report of W.J. Mackenzie, on traverse of Highwood River. pp. 23-28.

"Traverse of the Upper Part of the Highwood River." pp. 23-26.

"Traverse of Pekisko Creek (Middle Fork of Highwood River)." pp. 26-27.

"Traverse of Stimson Creek." pp. 27-28.

"Methods of Traverse of Highwood River, Pekisko and Stimson Creeks and Cataract Branch". p. 28.

"Hydrographic Records," pp. 29-35.

"Discharge of Streams." pp. 29-30.

"Evaporation." pp. 30-31.

"Rating Station." pp. 31-33.

"Nilometers." pp. 33-34.

"Gauge Rods." pp. 34-35.

"Diagrams showing rise and fall and cross sections of various streams. Following p. 36.

Irrigation surveys of 1898. pp. 37-70 + 5 photographs + 15 diagrams, the illustrations following p. 78.

"Report of Arthur O. Wheeler, D.L.S., in Charge." pp. 37-49.

"General. pp. 37-38. Includes description of the functions of the three parties into which the surveys were divided, as follows: Party No. 1., to continue the photo-topography survey formerly conducted by Division B; Party No. 2, to obtain the detail needed to complete a contour map to show the irrigable areas and the routes by which water could be brought to those areas; Party No. 3., to continue the exploratory surveys to locate suitable water storage sites.

"Party No. 1," pp. 38-44.

"Party No. 2." p. 45.

"Party No. 3." pp. 45-46.

Miscellaneous, pp. 46-49.

Ditch inspection.

Inspection of a small lake.

Bench marks.

Temperature and precipitation data.

Report of R.W. Macintyre, C.E., on work of Party No. 2. pp. 50-53.

Report of James T. Child, C.E, on work of Party No. 3.pp. 54-58.

"Hydraulic and Hydrographic Records." pp. 59-70.

"Discharge of Streams." pp. 59-60.

"Rating Station," pp. 60-62.

"Evaporation." pp. 63-64.

"Nilometers."pp. 65-66.

"Gauge Rods." pp. 66-69.

"Office Work," pp. 69-70.

"Results from Irrigation, 1897-98." pp. 71-78.

"Bulletin No. 3. Information from Irrigators." pp. 72-74.

"Bulletin No. 4. Information from Irrigators." pp. 75-78.

<u>Annual report for the year 1908</u>, Ottawa, 1909.

"Report of the Deputy Minister of the Interior." p. ix ff.

* p. xxxiii, paragraph 6. Investigation of the "water powers of the northwest provinces."

Part III. "Surveys."

"Report of the Surveyor General." p. 3 ff.

* pp.6-7. Investigation of the water power on the Winnipeg River.

Part VII. "Forestry."

Report of the Superintendent of Forestry, R.H. Campbell, p. 3 ff.

* "Water Supply." p. 5. Approval of an application to dam Clear Lake.

* "Irrigation." p. 10. Statistics and other administrative details.

* "Irrigation Convention." pp. 10-12. Includes resolutions passed urging the government to conduct investigations.

* Appendix No. 11. "Report of John Stewart, D.L.S., C.E., Commissioner and Chief Engineer of Irrigation." pp. 43-44. Canadian irrigation surveys. Includes summaries of work of the two engineering parties sent into the field, under Messrs. Burley and Sauder, respectively, and some administrative details.

* Appendix No. 12. "Report of P.M. Sauder" on the work of his party. pp. 44-45.
"Hydrographic Work." pp. 44-45.
"Inspections." p. 45. Includes inspection of:
Applications for water rights;
Proposed locations for irrigation land purchases;
Reservoir sites set apart by Order in Council;
Licensed irrigation works.

* Appendix No. 13. "Report of Ralph J. Burley" on the work of his party. pp. 45-46. Inspection and hydrographic work.

Annual report for the year 1909, Ottawa, 1909.

"Report of the Deputy Minister of the Interior, 1908-9." p. ix ff.
"Forestry and Irrigation." pp. xxxv-xxxvi.
* p. xxxvi, paragraphs 4-5. Stream measurements and irrigation developments of the year.

Part III. "Surveys."
"Report of the Surveyor General." p. 3 ff.
"Miscellaneous Surveys." p. 5.
* Paragraph 8. Mr. Thibaudeau's investigation of water powers in Alberta.
(Note: The above reference states, "A mass of valuable information is furnished by [Mr. Thibaudeau's] report and the maps to accompany it, which are published herewith." This report was not located by the bibliographer in this annual report of the department.)

Part VII. "Forestry and Irrigation."
"Report of the Superintendent of Forestry and Irrigation." R.H. Campbell. p. 3. ff.
* "Irrigation." pp. 11-20.
Progress of irrigation development. pp. 11-15.
General.
"The Southern Alberta Land Company."
"Alberta Railway and Irrigation Company's Irrigation Project."
"Canadian Pacific Railway Company's Irrigation Project."
"The Aylwin Scheme."
Problems in granting irrigation licenses. pp. 15-16.
"Reservoir Sites." p. 17.
"Drainage." pp. 17-18.
"Accounts." p. 18.
"Hydrographic Survey." pp. 18-19.
"Irrigation Map." pp. 19-20.

* Appendix No. 18. "Canadian Irrigation Surveys. Report of John Stewart, D.L.S., C.E., Commissioner and Chief Engineer of Irrigation." pp. 83-84. Includes summaries of work of the two engineering parties sent into the field, under Messrs. Burley and Sauder, respectively, and some administrative details.

* Appendix No. 19. Report of Ralph J. Burley on the work of his party and on the progress of irrigation development in the Cypress Hills district during the season past. pp. 84-87.
Inspections.
"Hydrographic Work."
"Reservoirs.
* Appendix No. 20. Report of P.M. Sauder on the work of his party. pp. 87-89. Includes inspection and hydrographic work.
* Appendix No. 21. "Hydrographic Surveys. (Appendix to report of Superintendent of Forestry.) Extracts from a Report of P.M. Sauder, on the Hydrographic Work of the United States Geological Survey and the Necessity for the Organization of Similar Work in Canada (January, 1908)." pp. 90-96.
"Organization and Scope of Work."
"Field Methods of Measuring Stream Flow."
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Annual report for the year 1910, Ottawa, 1910

"Report of the Deputy Minister of the Interior, 1909-10." p. ix ff.
* "Irrigation." p. xxxvi. Irrigation development and stream measurement.
(Note: The above section contains the statement that "The result of the season's work [in stream measurement] is now being published as a separate bulletin.")
Part III. "Surveys."
"Report of the Surveyor General." p. 3 ff.
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* p. 8, paragraph 3. Examination by Mr. Thibaudeau of potential sites for storage reservoirs for irrigation and other purposes.
Part VII. "Forestry and Irrigation."
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* "Conventions." p. 3.
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Appendix No. 20. "Canadian Irrigation Surveys. Report of John Stewart, D.L.S., C.E., Commissioner and Chief Engineer of Irrigation, for the fiscal year 1909-10." pp. 65-66. Includes summaries of the work of the two engineering parties sent into the field, under Messrs. Burley and Tempest, respectively, and some administrative details.

Appendix No. 21. Report of Ralph J. Burley, Inspecting Engineer, pp. 67-73. The following topics are dealt with, though not necessarily in the following order:

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Inspections.

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- General.
- "Battle Creek."
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Suggestions for improvement of irrigation administration and surveys.

Progress of irrigation development.

Appendix No. 22. Report of J.S. Tempest, Inspecting Engineer, on the work of his party during the year 1909-1910. pp. 74-77. Deals with inspections and progress in irrigation development observed thereby, surveys, and hydrographic observations,

Annual report for the year 1911. Ottawa, 1911.

"Report of the Deputy Minister of the Interior, 1910-11." p. ix ff.

* "Irrigation." pp. xxxix-xl. Water supply in the Western Prairie Provinces.

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"Correction, Restoration and Miscellaneous Surveys." p. 6.

* Paragraph 9. Survey of a water-power site at Cole Falls on the Saskatchewan River,
* Paragraph 10. Water-power surveys by Mr. Thibaudeau of Winnipeg and English Rivers.

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* "Irrigation." p. 17.
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  - Irrigation in the western states of the United States.
* "Hydrographic Surveys." pp. 17-18.
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No. 21. "Report of John Stewart, Commissioner and Chief Engineer of Irrigation." pp. 101-103. Includes summaries of the work of the four engineering parties sent into the field, under Messrs. Burley, Fletcher, Tempest, and MacKinnon, respectively, and some administrative details.

No. 22. Report of J.S. Tempest, Irrigation Inspection Engineer in southern Alberta, for the year 1910-1911. pp. 103-104. Deals with inspections, surveys, hydrographic observations, and irrigation during the season, as well as some suggestions.

No. 23. Report of Ralph J. Burley on the inspection and hydrographic work done under his and Mr. Fletcher's direction, and on the progress of irrigation development in the Cypress Hills district, during the year ending March 31, 1911, together with some suggestions. pp. 105-107.

★ "Hydrographic Surveys." No. 24. Report of P.M. Sauder, Chief Hydrographer, on the work of the Hydrographic Survey during year ending March 31, 1911. pp. 108-115.
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No. 25. "Report of the Milk and St. Mary Rivers Investigation, 1910-11, by F.H. Peters, C.E.," pp. 116-118. (Stream measurement data were not included in this report, but were to be included in the Chief Hydrographer's "Report of Progress of Stream Measurements.")

<u>Annual report for the year 1912</u>, Ottawa, 1912.

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★ "Irrigation and Hydrographic Surveys." p. xxxix.
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* "Irrigation and Hydrograhic Surveys." pp. 162-244. (The "annual report of the work done ... during the year 1911 on Irrigation and Canadian Irrigation Surveys," submitted by F.H. Peters.)

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"Tables of Precipitation and Temperature in Alberta and Saskatchewan." pp. 233-244. The period dealt with is 1895-1911, and the tables are given for 16 stations.

B. <u>Annual Reports on Irrigation, 1902 and 1906-07</u>.

* Canada Department of the Interior, <u>Irrigation in the North-west Territories of Canada</u>, 1902, Canada Department of the Interior, Ottawa, 1903, 137pp.
"Introduction," pp. 7-8.
"Area, Boundaries and Description of Semi-Arid Portion of North-west Territories." pp. 9-10.
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The Irrigation District Ordinance.

(Note: It appears to be the purpose of this report to cover irrigation up to and including 1902, and not just the 1902 season.)

Canada Department of the Interior, Irrigation in the Provinces of Alberta and Saskatchewan, 1906 and 1907. Canada Department of the Interior, Ottawa, 1908, 84 pp.

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Canada Department of the Interior, <u>Natural resources of the Prairie Provinces, a brief compilation respecting the development of Manitoba, Saskatchewan and Alberta, 1923</u>, Canada Department of the Interior, Natural Resources Intelligence Service, Ottawa, 1923, 57 pp.

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Section 19. Of Direct Historical Interest.
Especially or only:
File No. 10. History of Surveys in the Province of Alberta.