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GEOLOGICAL SURVEY OF CANADA
WATER SUPPLY PAPER No. 235

GROUND-WATER RESOURCES OF THE RURAL MUNICIPALITY OF REFORD NO. 379 SASKATCHEWAN

Records Collected by C. O. Hage.
Compilation by G. S. Hume and C. O. Hage.

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DEPARTMENT OF MINES AND RESOURCES

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GEOLOGICAL SURVEY

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CONTENTS

	Page
Introduction	1
Publication of results	1
How to use report	2
Glossary of terms used	2
Bedrock formations of west-central Saskatchewan and east-central Alberta	4
Water analyses	9
Introduction	9
Discussion of chemical determinations	9
Mineral constituents present	9
Water analyses in relation to geology	11
Glacial drift	11
Bearpaw formation	12
Pale Beds	12
Variegated Beds	13
Ribstone Creek formation	13
Rural Municipality of Reford, No. 379, Saskatchewan	16
Physical features	16
Geology	16
Water Supply	
Township 37, range 18, west 3rd meridian	16
" 37, " 19, " " "	16
" 37, " 20, east of Tramping Lake and west 3rd meridian	17
" 38, " 18, " " "	17
" 38, " 19, " " "	17
" 38, " 20, east of Tramping Lake and west 3rd meridian	17
" 39, " 18, " " "	17
" 39, " 19, " " "	18
East half township 39, range 20, west 3rd meridian	18
Analyses of water samples	19
Records of wells in Rural Municipality of Reford, No. 379, Saskatchewan	20

Illustrations

Map - Rural Municipality of Reford, No. 379, Saskatchewan:

Figure 1. Map showing bedrock geology;

2. Map showing topography and the location and types of wells.

INTRODUCTION

Information on the ground-water resources of east-central Alberta and western Saskatchewan was collected, mostly in 1935, during the progress of geological investigations for oil and gas. The region studied extends from Edmonton in the west to Battleford in the east, and from township 32 on the south to township 59 in western Alberta, township 63 in eastern Alberta, and in part as far north as township 56 in western Saskatchewan.

This region is crossed by North Saskatchewan and Battle Rivers, and includes other more or less permanent streams. Most of the lakes within the area, however, are alkaline, and water is obtained in wells from two sources, namely, from water-bearing sands in surface or glacial deposits, and from sands in the underlying bedrock.

A division has been made in the well records, in so far as possible, between glacial and bedrock water-bearing sands. In investigations for oil and gas, however, the bedrock wells were used to trace the lateral extent of geological formations, with the result that the records deal more particularly with this type of well. No detailed studies were made of the glacial materials in relation to the water supply, nor were the glacial deposits mapped adequately for this purpose. In almost all of the region investigated in Alberta, and in all but the northeast part of the region studied in Saskatchewan, water can be obtained from bedrock. In a few places, however, the water from the shallower bedrock sands is unsatisfactory, and deeper drilling may be necessary.

The water records were obtained mostly from the well owners, some of whom had acquired the land after the water supply had been found, and hence had no personal knowledge of the water-bearing beds that had been encountered in their wells. Also the elevations of the wells were taken by aneroid barometer and are, consequently, only approximate. In spite of these defects, however, it is hoped that the publication of these water records may prove of value to farmers, town authorities, and drillers in their efforts to obtain water supplies adequate for their needs.

In collecting this information several field parties were employed. These were under the direction of Professors R. L. Rutherford and P. S. Warren of the University of Alberta, C. H. Crickmay of Vancouver, and C. O. Hage, until recently a member of the Geological Survey. The oil and gas investigations of which these water records are a part were undertaken under the general supervision of G. S. Hume.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that in Saskatchewan cover each municipality, and in Alberta cover each square block of sixteen townships beginning at the 4th meridian and lying between the correction lines. The secretary-treasurer of each municipality in Saskatchewan and Alberta will be supplied with the information covering that municipality. Copies of the reports will also be available for study at offices of the Provincial and Federal Government Departments. Further assistance in the interpretation of the reports may be obtained by applying to the Chief Geologist, Geological Survey, Ottawa. Technical terms used in the reports are defined in the glossary.

How to Use the Report

Anyone desiring information concering ground water in any particular locality will find the available data listed in the well records. These should be consulted to see if a supply of water is likely to be found in shallow wells sunk in the glacial drift, or whether a better supply may be obtained at greater depth in the underlying bedrock formations. The wells in glacial drift commonly show no regional level, as the sands or gravels in which the water occurs are irregularly distributed and of limited extent. As the surface of the ground is uneven, the best means of comparing water wells is by the elevations of their water-bearing beds. For any particular well this elevation is obtained by subtracting the figure for the depth of the well to the water-bearing bed from that for the surface elevation at the well. For convenience both the elevation of the wells and the elevation of the water-bearing bed or beds in each well are given in the well record tables. Where water is obtained from bedrock, the name of the formation in which the water-bearing sand occurs is also listed in these tables, and this information should be used in conjunction with that provided on bedrock formations, pages 4 to 8, which describes these formations and gives their thickness and sequence. Where the level of the water-bearing sand is known, its depth at any point can easily be calculated by substracting its elevation, as given in the well record tables, from the elevation of the surface at that point.

With each report is a map consisting of two figures. Figure 1 shows the bedrock formations that will be encountered beneath the unconsolidated surface deposits. Figure 2 shows the position of all wells for which records are available, the class of well at each location, and the contour line or lines of equal surface elevation. The elevation at any location can thus be roughly judged from the nearest contour line, and the records of the wells show at what levels water is likely to be encountered. The depth of the well can then be calculated, and some information on the character and quantity of water can be obtained from a study of the records of surrounding wells.

GLOSSARY OF TERMS USED

Alkaline. The term "alkaline" has been applied rather loosely to some ground waters that have a peculiar and disagreeable taste. In the Prairie Provinces, water that is commonly described as alkaline usually contains a large amount of sodium sulphate and magnesium sulphate, the principal constituents of Glauber's salt and Epsom salts respectively. Most of the so called alkaline waters are more correctly termed sulphate waters, many of which may be used for stock without ill effect. Water that tastes strongly of common salt is described as salty.

Alluvium. Deposits of earth, clay, silt, sand, gravel, and other material on the flood plains of modern streams and in lake beds.

Aquifer or Water-bearing Horizon. A porous bed, lens, or pocket in unconsolidated deposits or in bedrock that carries water.

Buried pre-Glacial Stream Channels. A channel carved into bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Coal Seam. The same as a coal bed. A deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-Sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or a relatively steep slope separating level or gently sloping areas.

Flood Plain. A flat part in a river valley ordinarily above water but covered by water when the river is in flood.

Glacial Drift. The loose, unconsolidated surface deposits of sand, gravel, and clay, or a mixture of these, that were deposited by the continental ice-sheet. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. The glacial drift occurs in several forms:

(1) Ground Moraine. A boulder clay or till plain (includes areas where the glacial drift is very thin and the surface uneven).

(2) Terminal Moraine or Moraine. A hilly tract of country formed by glacial drift that was laid down at the margin of the continental ice-sheet during its retreat. The surface is characterized by irregular hills and undrained basins.

(3) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(4) Glacial Lake Deposits. Sand and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. Sub-surface water, or water that occurs below the surface of the land.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it is first encountered.

Impervious or Impermeable. Beds, such as fine clays or shale, are considered to be impervious or impermeable when they do not permit of the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious when they permit of the perceptible passage or movement of ground water, as for example porous sands, gravel, and sandstone.

Pre-Glacial Land Surface. The surface of the land before it was covered by the continental ice-sheet.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet.

Unconsolidated Deposits. The mantle or covering of alluvium and glacial drift consisting of loose sand, gravel, clay, and boulders that overlie the bedrock.

Water-table. The upper limit of the part of the ground wholly saturated with water. This may be very near the surface or many feet below it.

Wells. Holes sunk into the earth so as to reach a supply of water. When no water is obtained they are referred to as dry holes. Wells in which water is encountered are of three classes:

(1) Wells in which the water is under sufficient pressure to flow above the surface of the ground.

(2) Wells in which the water is under pressure but does not rise to the surface.

(3) Wells in which the water does not rise above the water table.

BEDROCK FORMATIONS OF WEST-CENTRAL SASKATCHEWAN AND EAST-CENTRAL ALBERTA

The formations that outcrop in west-central Saskatchewan are an extension of similar formations that occur in east-central Alberta. They are of Upper Cretaceious age, and consist entirely of relatively soft shales and sands, with some bands of hard sandstone and layers of ironstone nodules. The succession, character, and estimated thickness of the formations are shown in the following table:

Formation	Character	Thickness Feet
Edmonton	Grey to white, bentonitic sands and sandstones with grey and greenish shales; coal seams prominent in some areas, as at Castor, Alberta.	1,000 to 1,150
Bearpaw	Dark shales, green sands with smooth black chert pebbles; partly non-marine, with white bentonitic sands, carbonaceous shales or thin coal seams similar to those in Pale Beds; shales at certain horizons contain lobster claw nodules and marine fossils; at other horizons are abundant selenite crystals.	300 to 600 thins rapidly to the north-west
Pale and Variegated Beds	Light grey sands with bentonite; soft, dark grey and light grey shales with selenite and ironstone; carbonaceous shales and coal seams; abundant selenite crystals in certain layers.	950 to 1,000 in Czar-Tit Hills area; may be thinner elsewhere
Birch Lake	Grey sand and sandstone in upper part; middle part of shales and sandy shales, thinly laminated; lower part with grey and yellow weathering sands; oyster bed commonly at base.	100 in west, but less to east and south
Grizzly Bear	Mostly dark grey shale of marine origin, with a few minor sand horizons; selenite crystals and nodules up to 6 or 8 inches in diameter	Maximum, 100
Ribstone Creek	Grey sands and sandstones at the top and bottom, with intermediate sands and shales; thin coal seam in the vicinity of Wainwright; mostly non-marine, but middle shale in some areas is marine.	Maximum, 325 at Viking; thins eastward
Lea Park	Dark grey shales and sandy shales with nodules of ironstone; a sand 70 feet thick 110 feet below the top of the formation in the Ribstone area, Alberta.	950 to 1,100

Edmonton Formation

The name Edmonton formation was first applied to the beds containing coal in the Edmonton area, and later to the same beds in adjoining areas. The formation has a total thickness of 1,000 to 1,150 feet, but is bevelled off eastward and the east edge of the formation

follows a northwest line from Coronation through Tofield to a point on North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. No Edmonton beds occur northeast of this line, but the formation becomes progressively thicker to the southwest due to the fact that the beds incline in that direction and the surface bevels across them.

The Edmonton formation consists of poorly bedded grey and greenish clay shales, coal seams, and sands and sandstones that contain clay and a white material known as bentonite. This material when wet is very sticky and swells greatly in volume, and when dry tends to give a white appearance to the beds containing it. Such beds are relatively impervious to water, and at the surface produce the "burns" of barren ground where vegetation is scanty or absent.

Water is relatively abundant in the Edmonton formation, which contains much sand, commonly in the form of isolated lenses distributed irregularly through the formation. Consequently, there is little uniformity in the depth of wells even within a small area. Water also occurs commonly with coal seams and, unlike the sand lenses, these beds are much more regular and persistent. In contrast with the water from the bentonitic sands, which is generally "soft", water from the coal seams, as the water from the shallow surface deposits, may be "hard". The basal beds of the Edmonton formation usually contain fresh water, but this may become brackish locally where the underlying Bearpaw beds contain highly alkaline or salty water.

Bearpaw Formation

In southern Alberta, where the Bearpaw formation is thickest, the beds composing it are mainly shales that have been deposited in sea water. In the area north of township 32 the formation thins to the northwest and becomes a shoreline deposit composed of shales containing bentonite, impure sands, and thin coal seams. In some areas, as at Ryley and near Monitor, and in the Neutral Hills, the Bearpaw contains pebble beds. At Ryley these are consolidated into a conglomerate, but mostly the pebbles are loosely distributed in shale or sandy beds.

In the area immediately north of township 32 the Bearpaw occupies a widespread belt beneath the glacial drift, but farther northwest the belt narrows, and at Ryley and northwestward it is only a few miles wide. This belt crosses North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. Bearpaw beds form the main bedrock deposits of the Neutral Hills. Farther south, where they have an exposed thickness of at least 400 feet, they contain green sands, and beds of marine shale interfinger with the bentonitic shales and sands of the underlying formation. To the north, on the banks of North Saskatchewan River, the division between the Bearpaw and the overlying and underlying formations is indefinite, and the thickness of beds of Bearpaw age is relatively small.

The water in the Ryley area is from the Bearpaw formation, and is salty. In other areas to the south the marine Bearpaw formation carries green sand beds that yield fresh water, but commonly a much better supply is found by drilling through the Bearpaw into the underlying Pale Beds.

In Saskatchewan, Bearpaw beds occur southeast of Maclin and south of Luseland and Kerrobert. Only the basal beds are present, and these contain green sands that are commonly water-bearing.

Pale and Variegated Beds

Underlying the Bearpaw formation is a succession of bentonitic sands, shales, and sandy shales containing a few coal seams. The upper part of this succession, due to the bentonitic content, is commonly light coloured and has been described as the Pale Beds, whereas the lower

part is darker, and is known as Variegated Beds. In part, dark shales are present in both Pale and Variegated Beds; others are greenish, grey, brown, and dark chocolate, carbonaceous types. The sands may also be yellow, but where bentonite is present it imparts a light colour to the beds. Both Pale and Variegated Beds are characterized by the presence of thin seams of ironstone, commonly dark reddish, but in part purplish, Selenite (gypsum) crystals are, in places, abundant in the shales.

The best sections of Pale Beds exposed in the region are in the Tit Hills, southwest of Czar. These hills carry a thin capping of Bearpaw shales, beneath which, and around Bruce Lake, more than 200 feet of Pale Beds are exposed. The total thickness of Pale and Variegated Beds in the Tit Hills area is about 970 feet. Variegated Beds outcrop near Hawkins on the Canadian National Railway west of Wainwright, but no area exposes the complete succession, which is considered to comprise about 200 feet of beds.

Records of wells drilled into the Pale and Variegated Beds do not, in general, indicate lateral persistence of sands for long distances, nor any uniform average depth to water-bearing sands in a local area. This points to the conclusion that the sands are mainly local lenses, but as such lenses are numerous, few wells fail to obtain water. In the Cadogan area many flowing wells have been obtained from sands about midway in the succession. In western Saskatchewan Paleland Variegated Beds occur over a wide area from Maclin and Kerrobert northeast through Wilkie to the Eagle Hills, south of Battleford. Numerous outcrops occur in the area south of Unity at Muddy Lake, but south and east around Biggar these beds are almost wholly concealed by glacial drift.

The water from the sands of the Pale and Variegated Beds is generally soft. The supply, apparently, is dependent in part on the size of the sand body that contains the water and in part on the ease with which water may be replenished in the sand. Small sand lenses surrounded by shales may be filled with water that has infiltrated into them, but when tapped by a well the supply may be very slowly replenished. In many instances such wells yield only a small supply, although this is commonly persistent and regular.

Birch Lake Formation

The Birch Lake formation underlies the Variegated Beds, but in many areas the division is not sharp. The type area of the formation is along the north shore of Birch Lake south of Innisfree, where a section 65 feet thick, composed mostly of sand, is exposed. The total thickness of the formation in this area is about 100 feet, and although this is dominantly sand a central part is composed of alternating thin sand and shale beds. At the base of the formation, in a number of places, is an oyster bed, and this is exposed in a road cut in a section 73 feet thick on the east side of Buffalo Coulée in sec. 3, tp. 47, rge. 7, W. 4th mer. In both upper and lower parts of the formation the sand is commonly massive and outcrops tend to consolidate into hard, nodular masses from a foot to a few feet in diameter. Apparently these are formed through the deposition of salts from the water that finds an outlet at the outcrops. In fact, in some areas the sand may be traced along the side of a hill by the presence of small springs or nodular masses of sandstone.

The Birch Lake formation occurs under the drift and in outcrops in a large area south of North Saskatchewan River and northeast of a line from Willingdon to Innisfree and Minburn. East of this area the southwest boundary is more irregular, but outcrops are persistent on the banks of Battle River from a few miles north of Hardisty to and beyond the mouth of Grizzly Bear Coulée in tp. 47, rge. 5. It is believed, too, that a large area near Edgerton and Chauvin is underlain by the Birch Lake formation and that it extends southeastward into Saskatchewan around Manitou Lake and southeast to Vera.

It is thought that the Birch Lake formation thins eastward from its type section at Birch Lake, and that it loses its identity in western Saskatchewan. Deep wells drilled at Czar, Castor, and elsewhere no longer show the Birch Lake as a clearly recognizable sand formation, so that its southern limit beneath younger formations is unknown. Wherever it occurs as a sand, however, it is water-bearing, although in some areas the sand is apparently too fine to yield any considerable volume of water. In other areas, however, it persistently yields good wells. There is no apparent uniformity in the character of the water, which is either hard or soft in different wells in the same general area. Direct contact with surface waters that contain calcium sulphates may in time change a "soft" water well to a "hard" water well, and many wells are not sufficiently cased to prevent the percolation of water from surface sands into the well, and hence into the deeper, soft water producing sands. In part this accounts for the change in character of the water in a well, a feature that has been noticed by many well owners.

Grizzly Bear Formation

The type locality for the Grizzly Bear formation, which underlies the Birch Lake beds, is near the mouth of Grizzly Bear Coulée, a tributary of Battle River with outlet in tp. 47, rge. 5. The formation is mainly composed of dark shales that were deposited in sea water. At the mouth of Grizzly Bear Coulée two shale sections, each about 100 feet thick, are separated by a zone of thin sand beds. It is now recognized that the upper section is the Grizzly Bear shale, and that the lower one, very similar in character and also deposited in sea water, occurs in the next lower formation, the Ribstone Creek. The Grizzly Bear shale contains a thin nodular zone about 50 feet above the base, that is, at about the centre of the formation. This zone is sandy, and is believed to yield water in various wells. Other thin sands, in places water-bearing, are also present. The impervious nature of the Grizzly Bear shales makes the overlying Birch Lake sand a strong acquifer, as water collects in the sand above the shale. The contact of the Birch Lake and Grizzly Bear formations can be traced in some places by the occurrence of springs issuing from the base of the Birch Lake sand even where this is not exposed.

Grizzly Bear shales occur in a road cut on the south side of Battle River near the highway bridge at Fabyan. The shales in this area are about 100 feet thick. It is thought they extend as far west as the Viking gas field, where they have been recognized in samples from deep wells. It is probable, however, that the shales thin westward and thicken eastward so that their general form is a wedge between both higher and lower sand beds. The position of the thin edge of the wedge to the west is unknown, but evidently the Grizzly Bear marine shale underlies a large area in east-central Alberta extending into Saskatchewan mainly in the area south of Battle River.

Ribstone Creek Formation

The type area of the Ribstone Creek formation is on Ribstone Creek near its junction with Battle River in tp. 45, rge. 1, W. 4th mer. At this place the lower sand beds of the formation are well exposed. The upper part of the lower sand member of this formation outcrops on the north side of Battle River, in the northeast part of sec. 26, tp. 47, rge. 5, near the mouth of Grizzly Bear Coulée. Above it, higher on the bank and at a short distance from the river, there is a 12 foot zone of carbonaceous and coaly beds in two layers, each about 2 feet thick, separated by 8 feet of shale. Above this are 90 feet of dark shales that are thought to have been deposited in sea water, that is, they are marine shales. These marine shales in turn are overlain by a sandy zone about 20 feet thick containing oysters in the basal part. This sandy zone is the upper sand member of the Ribstone Creek formation.

It thickens to the east and west from the Grizzly Bear area but is probably at no place much more than 50 feet thick.

The lower sand member of the Ribstone Creek formation also varies in thickness from a minimum of about 25 feet. On the banks of Vermilion Creek, north of Mannville, the basal sand is at least 60, and may be 75,feet thick. It is overlain by shaly sand and sandy shale beds, which replace the shale beds in the central part of the formation as exposed at the mouth of Grizzly Bear Coulée. In the Wainwright area, where the formation has been drilled in deep wells, the basal sand is 60 feet thick, with the central part composed of shale containing sand streaks. The upper sand member is about 20 feet thick in this area. The total thickness of the formation in the Wainwright area is 100 to 200 feet, but this increases to the west and in the Viking area exceeds 300 feet.

The Ribstone Creek formation is widely exposed in a northwest-trending belt in east-central Alberta. The southwest boundary of this northwest-trending belt passes through the mouth of Grizzly Bear Coulée in tp. 47, rge. 5, and beyond to the Two Hills area in tp. 54, rge. 12, whereas the northeast boundary crosses North Saskatchewan River southwest of Elk Point and extends northwest to include an area slightly north of St. Paul des Metis and Vilna to tp. 60, rge. 14. Within this belt water wells are common in the Ribstone Creek sands, which are almost without exception water-bearing in some part of the formation. The limits of the belt to the northeast determine the limits of water from this source, but to the southwest of the belt, as here outlined, water may be obtained in this formation by drilling through the younger beds that overlie it. The Ribstone Creek sands are a prolific source of water in many places and hence the distributinn of this formation is of considerable economic importance. Where the formation consists of upper and lower sands with a central shale zone only the sands are water-bearing, although thin sand members may occur in the shale. Where the formation is largely sand the distribution of water may be in any part of the formation, although the upper and lower sands are perhaps the better aquifers. To the east of Alberta, along Battle River and Big Coulée in Saskatchewan, the Ribstone Creek sands are marine. Marine conditions apparently become more prevalent to the southeast and it is believed that in this direction the sands are gradually replaced by marine shales. Thus at some distance southeast of Battleford the Ribstone Creek formation loses its identity and its equivalents are shales in a marine succession.

Lea Park Formation

The Lea Park formation is largely a marine shale, and only in the upper 180 feet is there any water. In the Dina area south of Lloydminster the upper beds of the Lea Park consist of silty shales about 110 feet thick underlain by silty sands 70 feet thick. Below these sands are marine shales only, and these yield no fresh water either in east-central Alberta or west-central Saskatchewan. The sand in the upper Lea Park formation is thus the lowest freshwater aquifer within a very large area. The extent of this sand in the Lea Park, particularly to the northeast, is not known, but as the strata in east-central Alberta have a southwest inclination, progressively lower beds occur at the surface to the northeast. Thus at a short distance beyond the northeast boundary of the Ribstone Creek formation, as previously outlined, the sand in the upper Lea Park reaches the surface, and represents the last bedrock aquifer in that direction. Farther northeast water must be obtained from glacial or surface deposits only. In Alberta this area without fresh water in the bedrock includes the country north of North Saskatchewan River in the vicinity of Frog Lake and a large area extending to and beyond Beaver River. In this area, however, more fresh water streams are present than farther south, and bush lands

help to retain the surface waters. The area northeast of North Saskatchewan River in Saskatchewan is almost wholly within the Lea Park formation, where water can be found only in surface deposits.

WATER ANALYSES

Introduction

Analyses were made of water samples collected from a large number of wells in west-central Saskatchewan. Their purpose was to determine the chemical characteristics of the waters from different geological horizons, and thereby assist in making correlations of the strata in which the waters occur. Although this was the main objective of the analyses, it was also realized that a knowledge of the mineral content of the water is of interest and value to the consumer. The analyses were all made in the laboratory of the Water Supply and Borings Section of the Geological Survey, Ottawa.

Discussion of Chemical Determinations

The dissolved mineral constituents vary with the material encountered by the water in its migration to the reservoir bed. The mineral salts present are referred to as the total dissolved solids, and they represent the residue when the water is completely evaporated. This is expressed quantitatively as "parts per million", which refers to the proportion by weight in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called "radicals", and these are expressed as such in the chemical analyses. In the one group is included the metallic elements of calcium (Ca), magnesium (Mg), and sodium (Na), and in the other group are the sulphate (SO4), chloride (Cl), and carbonate (CO_3) radicals.

The analyses indicate only the amounts of the previously mentioned radicals, thus neglecting any silica, alumina, potash, or iron that may be present. It will be noticed that in most instances the total solids are accounted for by the sum total of the radicals as shown by the analyses. Actually, the residue when the water is completely evaporated still retains some combined water of crystallization, so that the figures for the "total solids" are higher than the sum total of the radicals as determined. These radicals are also "calculated in assumed combinations" to indicate the theoretical amounts of different salts present in the water. The same method was followed in each analysis, so that the table presents a consistent record of the different compounds present.

Mineral Constituents Present

Calcium. Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief source being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$).

Magnesium. Magnesium (Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the mineral. The sulphate of magnesia ($MgSO_4$) combines with water to form "Epsom salts" and renders the water unwholesome if present in large amounts.

Sodium. Sodium (Na) is derived from a number of the important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form "Glauber's salt" and excessive amounts make the water unsuitable for drinking purposes. Sodium carbonate (Na_2CO_3) or "black alkali" waters are mostly soft, the degree of softness depending upon the ratio

of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation purposes[1]. Sodium sulphate is less

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1 "The extreme limit of salts for irrigation is taken to be 70 parts per 100,000, but plants will not tolerate more than 10 to 20 parts per 100,000 of black alkali (alkaline carbonates and bicarbonates)" Frank Dixey in "A Practical Handbook of Water Supply", Thos. Murby & Co., 1931, p. 254.

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harmful.

Sulphates. The sulphate (SO_4) salts referred to in these analyses are calcium sulphate ($CaSO_4$), magnesium sulphate ($MgSO_4$), and sodium sulphate (Na_2SO_4).

Chloride. Chlorine (Cl) is with a few exceptions, expressed as sodium chloride (NaCl), that is, common table salt. It is found in all of the analyses, most of the waters containing less than 200 parts per million, but some as much as 2,000 or 3 ,000 parts. These waters have a brackish taste.

Alkalinity. The alkalinity determined in these water analyses is based on the assumption that the only salts present in the samples that will neutralize acids are carbonates, and that, consequently, the degree of alkalinity is proportional to the amount of the carbonate radical (CO_3) present.

Hardness. The hardness of water is the total hardness, and has been determined by the amount of a standard soap solution required to form a lather that will stand up (persist) for 2 minutes. Hardness is of two kinds, temporary and permanent. Temporary hardness is caused by calcium and magnesium bicarbonates, which are soluble in water but are precipitated as insoluble normal carbonates by boiling, as shown by the scale that forms in teakettles. Permanent hardness is caused by the presence of calcium and magnesium sulphates, and is not removed by boiling. The two forms of hardness are not distinguished in the water analyses. Waters grade from very soft to very hard, and can be classified according to the following system[2]:

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2 The "Examination of Waters and Water Supplies", Thresh & Beale, page 21, Fourth Ed. 1933 .

A water under 50 degrees (that is, parts per million) of hardness may be said to be very soft.
A water with 50 to 100 degrees of hardness may be said to be moderately soft.
A water with 100 to 150 degrees of hardness may be said to be moderately hard.
A water with more than 200 and less than 300 degress of hardness may be said to be hard.
A water with more than 300 degrees of hardness may be said to be very hard.

Hard waters are usually high in calcium carbonate. Almost all of the waters from the glacial drift are of this type, especially those not associated with sand and gravel deposits that come close to the surface.

In soft water the calcium carbonate has been replaced by sodium carbonate, due to natural reagents present in the sand and clays. Bentonite and glauconite are two such reagents known to be present. Montmorillinite, one of the clay-forming minerals, has the same property of softening water, owing to the absorbed sodium that is available for chemical reaction[1].

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1 Piper, A. M. "Ground Water in Southwestern Pennsylvania", Penn. Geol. Surv., 4th series.

If surface water reaches the lower sands by percolating through the higher beds it may be highly charged with calcium salts before reaching the bedrock formations containing bentonite or glauconite. The completeness of the exchange of calcium carbonate for sodium carbonate will, therefore, depend upon the length of time that the water is in contact with the softening reagent, and also upon the amount of this material present. The rate of movement of underground water will, consequently, be a factor in determining the extent of the reaction.

The amount of iron present in the water was not determined, owing to the possibilities of contamination from the iron casings in the wells. Iron is present in most waters, but the amount may be small. Upon exposure to air a red precipitate forms, the water becomes acid, and, hence, has a corrosive action. When iron is present in large amounts the water has an inky taste.

WATER ANALYSES IN RELATION TO GEOLOGY

Glacial Drift

The quality of the water from glacial drift depends largely on the nature of the deposit from which it comes and on the depth of the aquifer below the surface. Glacial deposits may be divided roughly into three types.

(1). Sand and gravel beds that form the surface deposit, such as outwash material and glacial lake sands.

(2). Buried outwash and interglacial deposits between two tills of boulder clay.

(3). Pockets or lenses of sand and gravel irregularly distributed through the till.

Water from surface sand deposits is normally low in dissolved salts, the total being generally less than 1,000 parts per million. Where large amounts of limestone occur in the glacial sand and gravel beds a characteristic constituent of the glacial water is calcium carbonate, the amount present varying from 300 to 700 parts per million.

Water from buried outwash deposits contains more dissolved salts than the surface sands, as the water in order to reach them has to percolate through overlying till. Rain water contains carbonic acid, which acts as a solvent and dissolves a great deal of calcium, magnesium, and sodium from the rock-forming minerals. Sulphate salts are commonly present, though their proportions vary greatly in the different waters. The shales that are incorporated in the drift are high in calcium sulphate, so that the amount of shale present will modify the quality of the water. The oxidized upper part of the drift contains less sulphate than the deeper, less oxidized boulder clay. The character of the water in the buried outwash deposits will, therefore, depend largely on the composition and amount of till that overlies it.

Water from irregularly distributed sand and gravel beds will vary in its content of dissolved salts depending upon the character of the material surrounding the reservoir beds. As the water in this type of deposit does not flow to any marked extent, it is apt to be more highly impregnated with soluble salts than where the underground movement is more rapid. Soft water in the drift is mostly confined to shallow wells in sands low in calcium carbonate. Waters from glacial lake clays are sometimes high in soluble salts. The sample from a well in glacial lake clay on N.W. $\frac{1}{4}$ sec. 27, tp. 42, rge. 17, has 11,040 parts per million of soluble salts, largely magnesium sulphate and sodium sulphate. The sample from SE. $\frac{1}{4}$ sec. 13, tp. 42, rge. 16, which is believed to come from glacial lake silts, has a very different composition. The total solids in it are only 440 parts per million, of which 250 are calcium carbonate. The great difference in these waters is due to the high soluble salt content that is associated with the lake clays but absent in the silts. Average drift water contains between 1,000 and 3,000 parts per million of dissolved mineral salts.

Bearpaw Formation

The Bearpaw formation consists of dark marine shales and beds of green sand. Water from these sands has a total solid count ranging from 300 to 1,600 parts per million and a hardness of more than 300 degrees. Calcium carbonate is very marked in all samples, due, perhaps, to the proximity of the water sands to the glacial drift. Sodium sulphate is the chief salt present, followed by calcium carbonate, magnesium sulphate, magnesium carbonate, and sodium chloride in decreasing amounts. These waters are distinguished from the overlying drift waters by being relatively low in total dissolved solids, and in containing no calcium sulphate and only moderate amounts of sodium sulphate, magnesium sulphate, and magnesium carbonate.

Pale Beds

Pale Beds underlie the Bearpaw formation. Total solids in waters from these beds vary from 700 to 1,300 parts per million. The water is, in most instances, soft, as it contains sodium carbonate in excess of calcium and magnesium carbonates, but when mixed with surface water high in calcium carbonate, it will become hard. The high concentration of sodium salts, especially sodium carbonate, in contrast with the calcium and magnesium salts distinguishes this water from that in Bearpaw sands. The Pale Beds include much bentonite, and it is this mineral that acts as a water softener within the formation. The following analyses are typical of waters from the Pale Beds:

Salts	SE. sec. 16, tp.38, rge. 21	NE. sec. 3, tp.39, rge. 25,	SW. sec. 7, tp.37, rge.24,	SE. sec. 21 tp. 38,rge.23
$CaCO_3$	73	18	53	35
$CaSO_4$	-	-	-	-
$MgCO_3$	52	14	45	38
$MgSO_4$	-	-	-	-
Na_2CO_3	297	679	464	562
Na_2SO_4	297	158	266	437

NaCl	31	45	46	130
Total solids	760	1,020	940	1,260
Hardness	100	20	30	75

Variegated Beds

In Senlac Rural Municipality, Saskatchewan, are a number of wells that have water very similar in character to that found in the Bearpaw formation. These wells tap an horizon that corresponds with the Variegated Beds in Alberta, although they have not been separated from the Pale Beds. They are less bentonitic than the Pale Beds and darker in colour. The water is hard and has a low dissolved solid content. The three analyses given below show a great deal of similarity and suggest a common horizon.

Salts	NW. sec. 21, tp.41, rge.26	NW. sec. 3, tp.41, rge.28	SE. sec. 28, tp.40, rge.28
$CaCO_3$	250	305	125
$CaSO_4$	-	-	-
$MgCO_3$	1109	80	155
$MgSO_4$	149	104	69
Na_2CO_3	-	-	-
Na_2SO_4	98	132	386
NaCl	12	12	18
Total solids	640	640	780
Hardness	600	600	500

Ribstone Creek Formation

Chemical analyses of water from the Ribstone Creek formation vary more than in the Pale Beds, the reason being that at several different horizons the sediments show considerable lateral variation. The formation includes both marine and non-marine beds, thin coal seams being present in the basal part of the formation around Paynton, whereas south of Lashburn, on Battle River, marine fossils were found in strata considered to be at approximately the same horizon. The water analyses show similarities within limited areas, but long distance correlations cannot be made safely except for the saline waters that occur in the flowing wells at Vera, Muddy Lake, and at the south end of Tramping Lake. Analyses of these waters are given in the following table:

Salts	SE. sec. 25, tp. 41, rge. 24	SE. sec. 22, tp. 41, rge. 24,	NE. sec. 36, tp. 41, rge. 24,	SW. sec. 7 tp. 41, rge. 24,	SE. sec. 30, tp. 38, rge. 22,	SW. sec 10, tp. 35, rge. 20,
$CaCO_3$	73	73	73	198	108	90
$CaSO_4$	-	-	-	-	-	-
$MgCO_3$	38	38	38	52	69	52
$MgSO_4$	-	-	-	-	-	-

Na_2CO_3	129	119	129	11	106	125
Na_2SO_4	55	55	61	61	49	43
NaCl	2,929	3,036	2,690	2,863	3,531	3,861
Total solids	3,840	3, 460	3,120	3,200	3,860	4,460
Hardness	135	90	110	100	130	130

The similarity in these anlayses suggests a common source bed. The distance between the Tramping Lake well and the Vera wells is about 40 miles. This water, which is thought to come from the basal sand of the Ribstone Creek formation, is not typical of water from the same stratigraphical horizon in the vicinity of Battle River, one reason being, possibly, that at Battle River the stream has cut through the Ribstone Creek formation exposing the sand members along its banks. This may cause a more rapid movement of the underground water in this area than farther south, and it is known that the rate of flow is a controlling factor that governs the change of calcium carbonate to sodium carbonate when the softening reagents of bentonite or glauconite are present in the sand.

Some of the soft waters from the Ribstone Creek formation cannot be distinguished from those of the Pale Beds, whereas others are quite different. The following analyses illustratetsome of the different types of water from this formation:

Salts	Se.sec. 11, tp. 46, rge. 28	Ind.Agent Little Pine I.R.	SW.sec. 24, tp. 46, rge. 21	NE.sec. 36, tp. 43, rge. 18	Se.sec. 26. tp. 43, rge. 18	NE.sec. 36. tp. 41, rge. 24	NW.sec. 22. tp. 42. rge. 23
$CaCO_3$	90	90	410	73	35	73	125
$CaSO_4$	-	-	-	-	-	-	-
$MgCO_3$	97	59	168	38	31	38	97
$MgSO_4$	-	-	64	-	-	-	-
Na_2CO_3	217	392	-	283	592	129	196
Na_2SO_4	1,644	777	2,518	225	522	61	1,541
NaCl	249	63	76	12	83	2,690	71
Total solids	2,220	1,340	3,000	620	1,260	3,120	1,900
Hardness	280	160	750	110	35	110	600

The above chemical analyses show such a wide range in the dissolved salts present in the different waters in the Ribstone Creek formation that they cannot be used for correlation purposes over a large area.

Conclusions

(1) In most instances water from glacial drift is quite different from water from bedrock.

(2) Some of the bedrock horizons carry waters that show definite chemical characteristics.

(3) Most waters from glacial till carry total solids amounting to between 1,000 andn3,000 parts per million.

(4) Bedrock waters are commonly low in dissolved salts. Exceptions to this are to be found in water from the Ribstone Creek formation.

(5) Water from the Bearpaw formation is hard. An average of ten wells gave a total solid content of 1,100 parts per million.

(6) Water from the Variegated Beds resembles that from the Bearpaw formation.

(7) Waters from the Pale Beds is mostly soft. An average of ten wells gave a total solid of 1,000 parts per million.

(8) All soft waters contain sodium carbonate (Na_2CO_3), which is present in water from the Pale Beds and Ribstone Creek formations but absent from the Bearpaw formation and Variegated Beds.

RURAL MUNICIPALITY OF REFORD, NO. 379, SASKATCHEWAN

Physical Features

Reford Municipality is a plain-like or very gently rolling country bounded on the southwest by the deep valley of Tramping Lake. Several lakes, including Coldspring, Aroma, and Landis, occupy a broad, southerly draining valley, but the lakes have no stream connections. Other than a small area of sandy land to the northwest of Aroma Lake and west of Coldspring Lake, the soil is in general good for farming.

Geology

The entire municipality is covered by glacial drift, so that no outcrops of bedrock appear. A considerable deposit of gravel occurs north of Cathkin, and gravel has been reported in several wells but forms no widespread deposits. Pale Beds underlie the drift and have been penetrated in a few deep wells.

Water Supply

The main source of water is from sand and gravel beds irregularly distributed through the drift, but a few wells have penetrated to the underlying formations and have found water-bearing sands at various depths. No widespread water-bearing beds are known in the drift, so that the depths to water at any locality cannot be predicted. In a few areas there is evidence of a grouping of numerous sand and gravel beds into a single water-bearing zone, but even in these areas there is apparently very little connection between the separate sand or gravel bodies encountered, as the water rises to quite different elevations in different wells. The source of all water in the drift is rain.

Township 37, Range 18. All the wells in this township are in glacial drift. To the west of Landis, in the central part of the township, is a lake more than 2 miles long that has an elevation of 2,077 feet. Several wells in the township obtain their water at elevations of from 2,070 to 2,110 feet, and one near the lake, on section 22, obtains its water from an elevation of about 2,050 feet. This aquifer is apparently, in the zone of sand beds already referred to, though the average elevation of the aquifers in other wells is around 2,090 feet. It would seem, therefore, that the depression occupied by the lake cuts through this zone of water-bearing sands, and no doubt the lake may owe its permanency in part to this fact. Presumably this sandy zone offers a source of water for the entire township. Here, as in other areas, the top of the zone is probably less well defined than the lower limits, as higher in the drift the sand bodies are not as numerous and more irregularly distributed. Thus, wells that obtain water at the higher elevations in the drift show a much greater variation in the levels of their aquifers than in the deeper wells. No doubt too, as indicated by regional evidence, still lower aquifers exist in this area than have been reached by any wells.

Township 37, Range 19. The surface elevations in this township are higher than in the township to the east, and in general the wells get their water at higher elevations. An exception is the deep well at Notre Dame Convent in Leipzig, which was drilled to a depth of 426 feet

and presumably bottomed in Pale Beds beneath the drift. The depth to the base of the drift is, however, not known, and no record is available to indicate whether or not water-bearing sands or gravels occur at the base. The wells in the drift show no indication of any widespread aquifer, but deeper drilling might reveal other horizons in the drift, and also should encounter water in the underlying Pale Beds as in the deep well in Leipzig.

Township 37, Range 20, East of Tramping Lake. In general the land surface of this township is fairly level, sloping off gently to Tramping Lake where there is an abrupt descent to lake level. Many wells obtain their water at elevations of between 2,030 and 2,090 feet, with a few at higher elevations. Apparently a well-marked zone of sand and gravel, already mentioned as productive elsewhere, occurs at about these elevations. The few wells that obtain water at higher elevations encounter irregularly distributed water-bearing sands or gravels in the drift. One well, 448 feet deep, obtains water from an elevation of 1,683 feet, probably in Variegated Beds. The water is soft and rises at the maximum to 20 feet from the surface. In this well, as in the one at Leipzig, in the township to the east, no information is available on the thickness of the drift nor as to whether a water-bearing zone occurs there. The aquifer in the Variegated Beds is probably quite widespread.

Township 38, Range 18. About half the wells for which records are available in this township obtain their water at elevations of 2,060 to 2,095 feet, and presumably from the deposit of outwash sands and gravels known to be widely water-bearing in this district. The remainder of the wells have aquifers at higher elevations in the drift, which contains irregularly distributed bodies of water-bearing sands and gravels. No wells penetrate the drift, but water horizons are undoubtedly present in the bedrock, presumed to be Pale and Variegated Beds.

Township 38, Range 19. All wells, with the possible exception of one drilled in Cavell village but now abandoned, obtain their water from irregularly distributed sand and gravel beds in the drift. The one in Cavell, drilled to a depth of 225 feet, obtained plenty of water, but the casing plugged with fine sand. This is a quite common difficulty with certain sand horizons in the Pale Beds, and leads to the belief that this well, at an elevation of 2,025 feet, was in bedrock below the drift. Other aquifers would probably be encountered at still lower elevations in the bedrock formations.

Township 38, Range 20, East of Tramping Lake. One drilled well, 334 feet deep, in this township derived soft water, evidently from the Pale Beds, at an elevation of 1,851 feet. All other wells are believed to be in glacial materials although one, on NE. section 26, bored to a depth of 125 feet obtains water at an elevation of 2,023 feet and may have penetrated the drift. The bottom of this well is about 5 feet above the level of Tramping Lake, and the supply of water in it is poor, but whether it would have obtained more water if deepened a few feet depends on the porosity of the materials through which it would pass. The elevations of the aquifers in the drift show very little uniformity in the wells in this township, although a few occur between 2,065 and 2,095 feet above sea level. The others are higher, and indicate the irregular distribution of sand and gravel bodies in the drift.

Township 39, Range 18. All wells except one in this township obtain their water supply in drift materials at an elevation above 2,100 feet. This indicates a relatively abundant, though irregularly distributed, group of water-bearing sand and gravel beds. Coldspring

Lake, at an elevation of 2,103 feet, is also fed by springs. Lower aquifers may be present in the drift in this township, and sands in the Pale Beds, at quite a considerable depth below the bottom of the deepest present well, would undoubtedly yield water.

Township 39, Range 19. Sand and gravel beds irregularly distributed through the drift provide all the water in this township, although one well reaches an elevation of 2,053 feet and may possibly bottom in Pale Beds. A deeper and more uniform zone of water-bearing sands may occur in the drift in this township, as has the one to the east, and beneath it other aquifers would be expected at various levels in the Pale and Variegated Beds.

East Half Township 39, Range 20. The deepest well, 102 feet, in the east half of this township reaches an elevation of 2,043 feet, and obtains poor water from black mud that may represent the base of the glacial material. All other wells obtain their water from irregularly distributed sand or gravel beds in the drift. Beneath the drift, water would be expected in sand horizons of the Pale and Variegated Beds.

ANALYSES OF WATER SAMPLES FROM RURAL MUNICIPALITY OF REFORD, No.379, SASKATCHEWAN.

No.	¼ Sec.	Tp.	Rge.	Depth in feet	Elev. of Aquifer	Total dissolved solids	Constituents as Analysed						Total Hardness	Constituents as Calculated in assumed Combinations							Source of
							Ca	Mg	Na	SO_4	Cl.	Alk.		$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl.	
19	SW 13	37	18	64	2081	800	122	46	76	254	100	105	700	305		63	139		212	17	Sodium sulphate water from bed Pale Beds.
17	NE 17	37	19	426	1779	2100	107	46	528	1041	53	445	540	268		149	15		1523	87	do
16	SE 22	37	20	448	1683	2120	21	9	756	1091	90	465	65	53		31		397	1615	149	Glacial drift High in MgSO4
15	SW 22	38	20	334	1851	2100	24	20	697	1078	34	485	160	60		69		364	1595	56	
18	NW 12	38	19	70	2180	4120	307	428	166	2538	100	105	3000	105	901		2120		311	165	

RECORD OF WELLS IN RURAL MUNICIPALITY OF REFORD, No.379, SASKATCHEWAN.

Well No.	LOCATION ¼ Sec.	Tp.	Rge.	Mer.	Type of Well	Depth of Well	Altitude of Well	WATER LEVEL Above or Below Surface	WATER LEVEL (+) (-) Elev. Above Sea Level	PRINCIPAL WATER-BEARING BED Depth Ft.	PRINCIPAL WATER-BEARING BED Elev.	PRINCIPAL WATER-BEARING BED Geol. Horizon	Character of Water	Use to Which Water Is Put x	Yield & Remarks
1	S.E. 6	37	18	3	Bored	38	2145	-28	2117	38	2107		Hard Alk.	D.S.	Sufficient
2	S.W. 6	"	"	"	"	55	2158	-23	2135	55	2103	Sand	Hard	"	" for 28 Head
3	S.E. 7	"	"	"	"	53	2146	-28	2118	53	2093		Very Hard	"	Sufficient
4	N.W.10	"	"	"	Dug	30	2113	-27	2086	30	2083	Sand	Hard	"	Poor supply
5	N.E.12	"	"	"	"	32	2130	-29	2101	32	2098	"	"	"	Limited
6	S.W.13	"	"	"	Bored	64	2145	-59	2086	64	2081	" blue	"	"	Sufficient
7	S.E.15	"	"	"	Dug	29	2122	-24	2098	29	2093	Sand	Soft	"	"
8	S.E.17	"	"	"	Bored	51	2127	-20	2107	51	2076		Hard	"	"
9	N.W.22	"	"	"	"	50	2101	-25	2076	50	2051		"	S.	"
10	N.W.24	"	"	"	Dug	26	2133	-18	2115	26	2107		"	D.S.	"
11	S.E.26	"	"	"		28	2132	-18	2114	28	2104	Sand	"	"	"
12	N.W.28	"	"	"	Bored	60	2145	-40	2105	60	2085	"	"	S.	"
13	S.E.29	"	"	"	"	34	2134	-26	2108	25	2109	"	"	D.S.	Limited
14	N.E.30	"	"	"	"	68	2172	-25	2147	68	2104	"	"	"	Sand trouble
15	S.E.30	"	"	"	Dug	36	2157	-30	2127	36	2121	"	" Poor	"	Waters 25 Head.
16	N.W.32	"	"	"	Bored	36	2166			36	2130	"	"	"	Sufficient
17	S.E.32	"	"	"	Dug	35	2148	-30	2118	35	2113	"	"	"	Limited
18	S.E.35	"	"	"	Bored	50	2190	-30	2160	50	2140	"	"	"	Sufficient
19	N.W.36	"	"	"	"	92	2212	-77	2135	92	2120	Glacial	"	"	"
20	N.E.36	"	"	"	Dug	40	2230	-35	2195	40	2190	Sand	"	"	Limited
1	S.E. 2	37	19	3	Bored	60	2160	-20	2140	60	2100		Hard	D.S.	Sufficient
2	N.E. 3	"	"	"	"	37	2161	-20	2141	37	2124		"	"	"
3	N.E. 7	"	"	"	"	60	2171	-50	2121	60	2111	Sand	"	"	Limited
4	S.E.10	"	"	"	Dug	24	2177	-20	2157	24	2153	"	"	"	Sufficient
5	S.E.13	"	"	"	Bored	30	2160	-25	2135	30	2130	Sandy clay	"	"	Limited
6	N.E.17	"	"	"	"	50	2211	-35	2176	50	2161		"	D.	Sufficient. Leipzig Town Well.
7	N.E.17	"	"	"	Drilled	426	2205	-26	2179	426	1779	Pale Beds		D.	Abundant. Notre Dame Convent.

x. D.- Domestic, S.- Stock, Fe.- Iron, Alk.- Alkaline, M.- Municipal.

Well No.															
8	N.W.18	37	19	3	Bored	62	2189			62	2127		Hard	D.S.	Sufficient
9	S.E.19	"	"	"	"	38	2195	-33	2162	38	2157	Sand	"	"	"
10	S.W.23	"	"	"	"	80	2220	-40	2180	80	2140	**Glacial gravel**	"	"	"
11	S.W.28	"	"	"	"	56	2221	-50	2171	56	2165	" "	"	"	"
12	N.E.33	"	"	"	"	60	2243	-30	2213	60	2183		"	"	"
13	N.W.34	"	"	"	"	75	2238	-60	2178	60	2178	**Glacial gravel**	"	"	Limited
14	N.E.35	"	"	"	Dug	18	2216	-14	2202	18	2198	Sand	"	"	Sufficient
15	N.E.36	"	"	"	"	23	2230	-20	2210	23	2207	" gravel	"	"	"
1	N.W. 2	37	20	3	Bored	40	2118	-35	2083	40	2078	Sand	Hard	D.S.	Limited
2	S.W. 3	"	"	"	"	60	2116	-55	2061	60	2056	"	"	D.	Poor supply
3	N.W.10	"	"	"	"	45	2107	-20	2087	45	2062		" Poor	S.	Sufficient
4	N.E.10	"	"	"	"	45	2115	-20	2095	45	2070		"	D.S.	"
5	S.E.11	"	"	"	"	76	2139	-14	2125	76	2063	Gl. gravel	"	"	"
6	N.W.14	"	"	"	Dug	9	2126	- 6	2120	9	2117	Sand	Soft	"	"
7	S.E.15	"	"	"		25	2107	-15	2092	25	2082	"	"	D.	"
8	S.E.20	"	"	"	Bored	62	2095	-52	2043	62	2033	Gravel	Hard	D.S.	"
9	S.E.21	"	"	"	"	32	2101	-20	2081	32	2079	Sand	"	"	"
10	N.E.22	"	"	"	Drilled	448	2131	-20	2111	448	1683	**Variegated beds**	Soft	"	Waters 50 head of stock.
11	S.E.24	"	"	"	Bored	31	2155	-28	2127	31	2124	Sand	Hard	"	Limited
12	S.W.24	"	"	"	"	32	2148	-28	2120	32	2116	Gravel	"	"	Good supply
13	S.W.28	"	"	"	Dug	16	2125			16	2109		Soft	D.	Sufficient
14	S.E.32	"	"	"	Bored	35	2127	-30	2097	35	2092	Sand	Hard	D.S.	"
15	N.W.34	"	"	"	"	86	2157	-80	2077	78	2079	"	" poor	"	Limited. Dry Hole 108' Deep. Many Dry Holes.
16	S.E.34	"	"	"	"	30	2157		Low	30	2127	Sand	Hard poor	"	Sufficient
17	N.W.36	"	"	"	"	80	2158			80	2078	"	Hard	"	Good supply. Flowed at first.
1	S.W. 2	38	18	3	Bored	70	2159	-52	2107	70	2089	Sand Fine	Hard	D.S.	Sufficient
2	N.E. 3	"	"	"	"	71	2151	-41	2110	71	2080	" "	"	"	"
3	N.E. 4	"	"	"	Dug	33	2153	-23	2130	33	2120	**Glacial gravel**	"	"	"
4	S.W. 5	"	"	"	Bored	31	2176	-20	2156	19	2157	" sand	"	"	"
5	S.E. 5	"	"	"	Dug	40	2124	-30	2094	30	2094	" "	"	"	Limited
6	S.E. 6	"	"	"	Bored	99	2163	-20	2143	99	2064	" clay	"	"	Sufficient
7	S.W. 8	"	"	"	"	32	2129	-28	2101	32	2097	" sand	"	"	"
8	N.W.12	"	"	"	"	65	2158	-57	2101	65	2093	" "	"	"	Limited
9	S.W.14	"	"	"	Dug	50	2165	-45	2120	45	2120	" gravel	"	"	"

Well No.															
10	S.W.16	38	18	3	Dug	78	2185	-61	2124	78	2107)		Hard	D.S.	Limited
11	S.E.17	"	"	"	Bored	78	2183	-68	2115	78	2105)	**Glacial gravel.**	"	"	Sufficient
12	S.W.18	"	"	"		35	2166			35	2131)		"	"	"
13	N.W.18	"	"	"	Bored	80	2151	-74	2077	80	2071)		"	"	Poor supply
14	N.W.19	"	"	"	"	85	2167			85	2082	Black clay	"	"	Sufficient
15	N.E.20	"	"	"	"	102	2244	-89	2155	96	2148	" sand	"	"	"
16	N.W.33	"	"	"	"	45	2234	-40	2194	45	2189	Sand	Soft	"	Limited
17	S.W.33	"	"	"	Drilled	200	2261	-160	2101	200	2061	" Fine	Hard	"	" Sand trouble.
1	S.E. 6	38	19	3	Drilled	72	2178	-40	2138	72	2106	Blue sand	Hard	D.S.	
2	N.W. 9	"	"	"	Bored	48	2201	-30	2171	48	2153	Sand	"	"	Sufficient
3	N.E.10	"	"	"		20	2228	-13	2215	13	2215	Gravel	"	"	Limited
4	S.E.11	"	"	"	Bored	54	2241	-35	2206	54	2187	Sand	Soft	"	Sufficient
5	N.W.12	"	"	"	Drilled	225	2250	-100	2150	225	2025	Bedrock ? sand	Hard	D.S.M.	Sand trouble. Cavell Village.
6	N.W.12	"	"	"		70	2225	-65	2160	70	2155	**Glacial sand**	Hard poor	D.	Limited
7	S.E.14	"	"	"	Bored	76	2227	-24	2203	76	2151	Black clay	Hard	D.S.	Waters 10 head
8	S.E.16	"	"	"		40	2213			40	2173	**Glacial sand**	"	"	Sufficient
9	S.W.18	"	"	"	Bored	24	2154	-10	2144	16	2138		"	"	"
10	S.W.19	"	"	"	"	29	2156			29	2127	" gravel	"	"	"
11	N.E.20	"	"	"	Dug	42	2191	-32	2159	42	2149	" sand	" Alk.	S.	Limited
12	S.E.20	"	"	"	Bored	75	2196			75	2121	Blue "	"	D.S.	Sufficient
13	S.W.24	"	"	"	Dug	56	2189			56	2133	Sand	"	"	"
14	S.E.26	"	"	"	Bored	60	2179	-30	2149	60	2119	**Glacial gravel**	"	"	"
15	N.E.28	"	"	"	Dug	12	2158	-10	2148	12	2146	"	Soft	"	Limited
16	N.E.29	"	"	"	Bored	75	2174	-35	2139	75	2099	Clay	Hard	"	Sufficient
17	S.E.32	"	"	"	Dug	45	2177	-25	2152	45	2132	**Glacial gravel**	"	"	"
18	N.W.34	"	"	"		60	2166			60	2106	"	"	"	"
1	N.W. 2	38	20	3	Bored	30	2157	-15	2142	30	2127	**Glacial gravel**	Hard	D.S.	Sufficient
2	N.E. 2	"	"	"	"	60	2158	-30	2128	60	2098	" sand	" Poor	S.	"
3	S.W. 3	"	"	"	"	34	2157	-12	2145	34	2123	Sand	"	D.S.	"
4	S.E.12	"	"	"	"	50	2159	-38	2121	50	2109	**Glacial sand**	"	"	"
5	S.E.13	"	"	"	"	28	2154	-10	2144	16	2138	" "	"	"	"
6	N.W.13	"	"	"	"	40	2159			40	2119	" clay	Poor	S.	
7	S.E.14	"	"	"	"	35	2159	-30	2129	35	2124	" gravel	Hard	D.S.	Sufficient
8	N.E.22	"	"	"	"	99	2183	-83	2100	99	2084	Sand	"	"	"
9	S.W.22	"	"	"	Drilled	334	2185	-112	2073	120	2065				
										334	1851	Sand	Soft	"	"

Well No.															
10	S.W.23	38	20	3	Bored	30	2165	-24	2141	30	2135	Sand	Hard	D.S.	Sufficient
11	N.E.25	"	"	"	"	34	2148	-27	2121	34	2114	Gravel	"	"	"
12	S.W.25	"	"	"	"	86	2151	-46	2105	86	2065	Sand	" Poor	S.	"
13	N.W.25	"	"	"	"	42	2148	-17	2131	23	2125	**Glacial sand**	"	D.S.	Good supply
14	N.E.26	"	"	"	"	125	2148			125	2023		"	"	Poor "
15	S.W.26	"	"	"	"	85	2159	-70	2089	85	2074	Clay	" Poor		Sufficient
16	S.E.27	"	"	"	"	87	2181	-80	2101	87	2094	Gravel	" " "	S.	"
17	S.W.36	"	"	"	Dug	15	2150	-11	2139	15	2135	Sand	"	D.S.	"
1	S.W. 1	39	18	3	Bored	64	2313			60	2253	**Glacial clay**	Hard	D.S.	Sufficient
2	N.E. 4	"	"	"	"	108	2228	-80	2148	108	2120	Sand	"	"	"
3	S.E. 6	"	"	"	"	50	2215	-40	2175	40	2175	**Glacial clay**	" Alk.	"	
4	S.W.10	"	"	"	"	70	2205	-68	2137	70	2135	"	"	"	Poor supply
5	N.E.10	"	"	"	Dug	30	2225			30	2195	" gravel	"	"	Sufficient
6	S.W.14	"	"	"	"	30	2224			30	2194	" sand	"	"	"
7	S.W.16	"	"	"	Bored	50	2192			50	2142	Sand	"	"	"
8	N.W.17	"	"	"	Dug	42	2170	-32	2138	42	2128	"	"	"	"
9	N.E.18	"	"	"	Bored	100	2173			80	2093	Blue clay	"	"	"
10	N.W.19	"	"	"	"	90	2193			90	2103	Sand	"	"	"
11	S.W.20	"	"	"	"	50	2185	-35	2150	50	2135		"	"	"
12	N.W.21		"	"	"	38	2207	-28	2179	38	2169	Sand	"	"	"
13	N.E.28	"	"	"	"	38	2214	-26	2188	38	2176	**Glacial gravel**	"	"	"
14	N.E.30	"	"	"	Dug	44	2212			44	2168	Sand	"	"	"
15	N.E.32	"	"	"	Bored	75	2230	-35	2195	75	2155	"	"	"	"
16	N.E.34		"	"	Dug	28	2268	-25	2243	28	2240	"	"	"	"
17	N.E.35	"	"	"	Bored	85	2277	-80	2197	85	2192		"	"	Limited
18	N.W.36	"	"	"	"	118	2272								Dry Hole. School.
19	N.W.36	"	"	"	"	65	2271	-40	2231	65	2206	Clay	"	"	Sufficient
1	N.W. 1	39	19	3	Drilled	125	2158	-25	2133	125	2033	Sand	Hard	D.S.	Sufficient
2	S.E. 4	"	"	"	Bored	46	2171	-24	2147	46	2125		"	"	Limited supply
3	N.E. 4	"	"	"	"	60	2180	-50	2130	60	2120	Gravel	"	"	" "
4	N.E. 4	"	"	"	"	125	2180	-12	2168	125	2055		"	"	
5	S.W. 7	"	"	"	Dug	30	2152	-25	2127	30	2122	Sand	"	"	Limited supply
6	N.W. 8	"	"	"	Bored	40	2143	-12	2131	40	2103	Gravel	"	"	Waters 80 head.
7	S.W. 9	"	"	"	"	80	2170	-20	2150	80	2090	Sand	"	"	Sufficient

Well No.															
8	S.W.10	39	19	3	Dug	-34	2186	-24	2162	34	2152	Sand	Hard	D.S.	Waters 25 head
9	S.W.13	"	"	"	"	-25	2159	-24	2135	25	2134	"	"	"	Limited
10	N.E.15	"	"	"	Bored	-30	2164			30	2134		"	D.	Sufficient
11	S.W.16	"	"	"	"	-60	2178	-25	2153	60	2118	Sand	" Fe.	D.S.	"
12	S.E.16	"	"	"	"	-40	2183		High	40	2143	Gravel	"	'	"
13	S.E.17	"	"	"	"	-40	2144			40	2104	"	"	S.	Poor supply
14	S.E.19	"	"	"	"	-60	2139	-20	2119	60	2079	Sand F.	"	D.S.	Sufficient
15	N.E.23	"	"	"	Dug	-30	2130	-17	2113	30	2100		"	"	"
17	S.E.26	"	"	"	Bored	-30	2135	-20	2115	30	2105	Glacial gravel	"	"	Limited
18	N.E.26	"	"	"	"	-60	2168	- 6	2162	60	2108	" hard pan.	"	"	Sufficient
19	N.W.29	"	"	"	Dug	-30	2140			30	2110	" sand	"	"	"
20	S.W.36	"	"	"	"	-45	2180	-35	2145	45	2135	" "	"	"	"
21	N.E.36	"	"	"	Bored	-35	2194	-18	2176	35	2159	" gravel	" Alk.	"	"
1	S.W. 1	39	20	3	Bored	102	2145	-66	2079	102	2043	Black mud	Poor	S.	Sufficient
2	N.E.12	"	"	"	Dug	30	2154		Low	30	2124		Hard	D.S.	"
3	N.E.14	"	"	"	Bored	90	2150	-85	2065	90	2060		"	"	Limited
4	N.E.22	"	"	"	Dug	16	2163	-13	2150	16	2147	Glacial gravel	"	"	Waters 40 head.
5	S.W.22	"	"	"	"	22	2163		Low	22	2141	Gravel	"	"	Limited
6	N.E.24	"	"	"	Bored	40	2139		"	40	2099	Gravel	" Alk.	S.	Poor supply
7	S.E.24	"	"	"	"	75	2146	-65	2081	75	2071	"	Hard	D.S.	Limited
8	N.E.25	"	"	"	"	50	2143	-48	2095	50	2093		"	"	Sufficient
9	N.E.26	"	"	"	"	30	2159			30	2129	Glacial gravel	" Alk.	"	"
10	S.W.34	"	"	"	"	59	2183			59	2124	Sand, fine	"	"	"
11	N.W.36	"	"	"	Dug	33	2150	-20	2130	33	2117	Clay	" "	"	"