CANADA

DEPARTMENT OF MINES

AND

TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 237

GROUND-WATER RESOURCES OF THE RURAL MUNICIPALITY OF GRASS LAKE, NO. 381 SASKATCHEWAN

Records collected by C. O. Hage

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

OTTAWA

1947

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DEPARTMENT OF MINES AND RESOURCES

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BUREAU OF GEOLOGY AND TOPOGRAPHY

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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 and Variegated Beds......................................	12
Ribstone Creek formation	13
Rural Municipality of Grass Lake, No. 381, Saskatchewan	16
Physical features	16
Geology	16
Water supply	16
Township 37, range 23, west 3rd meridian	16
" 37, " 24, " " "	17
" 37, " 25, " " "	17
" 38, " 23, " " "	18
" 38, " 24, " " "	18
" 38, " 25, " " "	18
" 39, " 23, " " "	18
" 39, " 24, " " "	19
" 39, " 25, " " "	19
Analyses of water samples	20
Records of wells in Rural Municipality of Grass Lake, No. 381, Saskatchewan	21

Illustrations

Map - Rural Municipality of Grass Lake, No. 381, 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 Pale and 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 distribution 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 lards 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 (SO_4), 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 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.sec10, 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	-	233	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	1,230	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 GRASS LAKE, NO. 381, SASKATCHEWAN

Physical Features

The dry depressions formerly occupied by End and Ear Lakes are prominent physiographic features of this municipality. End Lake, like Muddy Lake to the east, is perhaps the more striking of the two as it is entirely surrounded, except for an outlet on the northeast end, by hills rising 150 to 200 feet above the lake bottom. It is undoubtedly a depression formed in the Pale Beds, and is similar to many cirque-shaped depressions found elsewhere in present exposures of these beds. Other lakes in the area are also in depressions, but these are low areas in the glacial drift. The ridge between Ear Lake and Muddy Lake depressions is only a mile or so wide, but the appearance of a ridge is not so marked when viewed from the west as from the east in the low depression of Muddy Lake, which is more than 200 feet below the level of the bottom of Ear Lake. The remainder of the municipality is gently rolling prairie land.

Geology

Pale Beds underlie the drift cover of the municipality. They outcrop on the ridge to the west and south of End Lake and to the east of Ear Lake at elevations up to 2,100 feet, and also in the northwest part of tp. 37, rge. 24, and in the southeast part of tp. 38, rge. 25. Seams of coal of rather poor quality occur in these beds.

Water Supply

Although the drift is quite variable in thickness in this municipality many wells obtain water from sand and gravel beds in it. Mostly these beds show very little regularity of elevation, and are probably small, lens-like bodies of rather limited extent. The water in them is supplied by downward percolation of rain. Below the drift many wells have encountered water-bearing sands in the Pale Beds. These show a considerable range in elevation according to locality, but a few sand horizons, though not productive in every well, have a widespread distribution in beds that, apparently, are nearly horizontal. One well, in tp. 37, rge. 23, at a depth of 400 feet reached what is thought to be a sand in the Ribstone Creek formation at an elevation of 1,600 feet. This well does not flow, as do a number of other wells that produce water from the same level, and the reason is not apparent, as the water only rises to an elevation of 1,920 feet whereas in a well on NE. sec. 33, tp. 37, rge. 22, the water rises from what is considered to be the same horizon to above 2,100 feet.

Township 37, Range 23. The glacial channel in tp. 36, rge. 23, cannot be traced northward into this township. If present it must lie west of the well on NE. section 17, which encountered a streak of coal in the Pale Beds at a depth of 212 feet, or an elevation of 2,042 feet, and continued in this formation to 1,954 feet. If the channel follows a northwest course it should occur in about section 30. Both wells on this section are in glacial sands, but are too high to prove the presence of a channel even if it were there. In a well 117 feet deep on NW. section 24, coal occurs at an elevation of 2,081 feet, showing that the well at this level is in Pale Beds. A few wells above this elevation obtain water from irregularly distributed sands in the drift, but the main source of supply is from sands in the Pale Beds. One well, 350 feet deep on NE. section 2, obtains water at an elevation of 1,840 feet. This presumably is low in the Pale Beds, or in the underlying Variegated Beds. Another well, 400 feet deep on SE. section 13, obtains soft water from an elevation of 1,600 feet presumably in Ribstone Creek sands.

Township 37, Range 24. The edge of the ridge of Pale Beds beneath the drift, in tp. 36, rge. 24, is not so apparent in this area, as in many places Pale Beds are encountered in the wells at relatively high elevations. This is especially so in SE. section 23, where a thin streak of coal was reported at a depth of 130 feet or an elevation of 2,119 feet. With one exception, all the wells of which records are available show that at higher elevations than this the water comes from glacial sands or gravel, so that presumably the base of the drift is only slightly above an elevation of 2,120 feet. Local sand bodies of considerable size appear to occur in the drift, as for example at an elevation of 2,180 to 2,185 feet in sections 29, 32, and 33, and at an elevation of about 2,135 feet in two wells rather close together on sections 21 and 28. Another such sand body may be present in sections 5, 6, and 15, at an elevation of 2,170 feet, and still another on sections 2 and 3 at an elevation of about 2,265 feet, although the well on section 2 apparently went through this sand without finding water. The trend of these sand deposits seems to be northeast and southwest, probably indicating that they were small outwash deposits in front of a stagnant glacier.

Several water-bearing sands occur in the Pale Beds. The highest of these is at an elevation of 2,075 to 2,090 feet in a well 169 feet deep on NE. section 9, and a well 260 feet deep on SW. section 17. The next deeper horizon has an elevation of about 2,000 feet in two wells, 275 and 288 feet deep, on section 7, and a third horizon, about 30 feet deeper, occurs in a well 245 feet deep on SE. section 14 and in a well 278 feet deep on SW. section 23. In this last well a streak of coal was reported at a depth of 100 feet, or at an elevation of 2,150 feet, which must represent a high point on the surface of the Pale Beds. On section 33 Pale Beds with coal outcrop above an elevation of 2,000 feet.

Township 37, Range 25. The glacial deposits appear to be much thicker in this area than in the range to the east, and only three wells are known to have penetrated them. A few of the wells in the drift are apparently from the same local horizons, but the individual water-bearing deposits show no great lateral extent. One horizon at an elevation of 2,240 to 2,250 feet occurs in wells on SE. section 5, NE. section 17, NE. section 19, and SW. section 27. Another, at an elevation of 2,180 to 2,190 feet, occurs on SE. section 16, SE. section 23, SE. section 26, SE. section 30, and NW. section 36. Still another, at an elevation of 2,140 to 2,150 feet, occurs on SE. section 13, NE. section 16, NE. section 20, and NE. section 24. In a general way these deposits show a northeast trend, particularly the one at elevations between 2,180 and 2,190 feet, and the probability is that they were formed as outwash sand and gravel deposits in front of glacial ice, and were not very persistent even locally. They are, therefore, not wholly dependable as sources of water even within the area where they are known to be present. Only two wells in this area penetrate the drift to water-bearing sands in the Pale Beds. One of these, 263 feet deep on NE. section 12, encountered a streak of coal at a depth of 250 feet, and, 13 feet deeper, reached a water horizon at an elevation of 1,993 feet. This horizon yields soft, brownish coloured water. Another well, yielding similar water was drilled to a depth of 351 feet on NE. section 4, the water coming from an horizon reported to be 50 feet deeper than the other. In the range to the east several wells produced water from the Pale Beds at elevations of from 1,970 to 2,000 feet, so that the upper horizon here is evidently a continuous aquifer of considerable lateral extent.

Township 38, Range 23. In the southwest part of this township a glacial gravel and sand deposit at an elevation of 2,130 to 2,140 feet yields water. It is known from four wells on sections 4, 5, and 7, the deepest well being 65 feet. Below the glacial deposits other wells get water in sands in the Pale Beds. One of these wells sunk 8 feet on the dry bottom of Ear Lake struck coal, presumably in Pale Beds, and with it obtained water that flows, rising 2 feet above the surface. It appears probable that the water is held in the sand by a cover of lake silts, but the head for the water is not apparent although on the east bank of the dry lake the land rises 100 to 150 feet above lake-bottom level. The beds, however, are thought to be so nearly horizontal that it is not known how higher land could have any effect on the water supply in a sand bed beneath the Lake. Quite a number of wells produce water from the Pale Beds at elevations of from 1,975 to 2,096 feet, with very little apparent uniformity in the productive horizon of the various wells.

Township 38, Range 24. In this area the Pale Beds are encountered in several wells at elevations above 2,200 feet. One well, on SE. section 6, is reported to have encountered gravel at a depth of 118 feet. In view of the fact that a well on NW. sect. 32, tp. 37, rge. 24, encountered a coal seam at 102 feet at the same elevation there is a reasonable doubt about the accuracy of the report, and it seems more probable that the well on SE. section 6 bottomed in Pale Beds as the water from it is soft. Also it occurs at an elevation of 2,185 feet, which is presumed to be in Pale Beds in still another well on NE. section 16. A few wells in the northern part of the township apparently are in glacial materials at elevations below the top of the Pale Beds in the southern part, so that it is assumed the surface of the Pale Beds slopes to the north and that the glacial materials increase correspondingly in thickness. The horizons that produce water in the Pale Beds vary in elevation from 2,252 to 2,217 feet, with the lower horizon already referred to at 2,185 feet.

Township 38, Range 25. Most of the wells in this township are in glacial materials, but a few reach sands in the underlying Pale Beds. In some wells the information is not sufficient to enable sands in glacial materials to be distinguished from sands in the Pale Beds. At a depth of 46 feet a well on SE. section 13 encountered a small coal seam in the Pale Beds at an elevation of 2,253 feet. Also a seam of lignite outcrops on the south bank of the coulee on SW. section 12, at an elevation of 2,170 feet. It is consequently certain that Pale Beds underlie the area and provide water-bearing sands at no great depth. A zone of sand beds occurs in the drift between elevations of 2,250 and 2,290 feet, with other scattered sand beds both above and below it. Information in the well records, however, is not sufficient to predict the depth to the water-bearing sands in the drift at any location prior to drilling. The deepest well in this area is on SW. section 24, where, at a depth of 385 feet or an elevation of 1,899 feet, a water-bearing sand was struck, presumably in the Pale Beds. A similar sand was encountered in a well on NE. sec. 14, tp. 36, rge. 23, at a depth of 367 feet or an elevation of 1,900 feet, and was found to yield only a limited amount of water. The well was consequently deepened to 412 feet, or an elevation of 1,855 feet.

Township 39, Range 23. Many outcrops of Pale Beds appear to the south and west of the dry basin formerly occupied by Ear Lake in the eastern part of the area. The drift, however, increases in thickness to the west, and on NW. section 18, at a depth of 56 feet or an elevation of 2,152 feet, glacial gravel was encountered in a well. Gravel was also struck at an elevation of 2,125 feet in a well 25 feet deep on NE. section 20, but may not represent the base of the drift, as outcrops are known only up to an elevation of about 2,100 feet. Wells on NW. section 9, SE. section 28, and NW. section 35 respectively, obtain water at an elevation of about 2,090 feet, and it is probable that this horizon is in the Pale Beds. On SE. section 15, a spring issues from a sand in the Pale Beds at an elevation of 1,996 feet, but no wells in this area appear to have found water at this level. Sands in the Pale Beds have, however, yielded water at lower levels in several wells.

Township 39, Range 24. In this township most, if not all of the wells for which records are available obtain their water from gravel and sand beds in the glacial drift. Apparently a zone of gravel and sand beds lies between elevations of 2,130 and 2,190 feet, but other sands occur at both higher and lower levels, though without any recognized regularity in elevation from place to place. It is certain, however, that a further supply of water could be obtained by drilling wells into the underlying Pale Beds, and it may be that certain of the wells have already tapped this source. The well records, however, do not indicate the thickness of the drift nor do they distinguish sands in the Pale Beds, if such were reached, from sands in the glacial drift. Two wells, one 105 feet deep on NE. section 24, and the other 82 feet deep on SE. section 30, obtained water at 2,111 and 2,116 feet respectively. This correspondence in elevation suggests a common aquifer for the two wells, and as coal was encountered in the range to the west in a well on SE. section 20 at an elevation of 2,115 feet, there is a possibility that these wells tapped a sand in the Pale Beds.

Township 39, Range 25. Gravel occurs in a well 78 feet deep in this township on NW. section 31 at an elevation of 2,149 feet, whereas coal, presumably in the Pale Beds, occurs at a depth of 60 feet, or an elevation of 2,115 feet, on SE. section 20. The base of the drift, therefore, probably falls between these levels in the northwest part of this township. The wells in the drift show little regularity in the level of the water-bearing beds, although one horizon occurs in wells on SW. section 13, NW. section 18, and NW. section 24 at an elevation of about 2,140 feet. The aquifer could not, however, be continuous between these wells without being encountered in other wells intermediate in position. In a well 83 feet deep, on SE. section 20, water was found in the Pale Beds at an elevation of 2,092 feet. Apparently the same aquifer occurs in a well, 103 feet deep, on NW. section 8, although in this well the water is reported as alkaline whereas the water from the Pale Beds is usually of good quality. A still deeper sand horizon, at an elevation of 2,010 to 2,020 feet, occurs in NE. section 3, SW. section 22, and NW. section 28, and is approximately the same horizon as that encountered in SW. sec. 7, tp. 37, rge. 24.

ANALYSES OF WATER SAMPLES FROM RURAL MUNICIPALITY OF GRASS LAKE, No. 381, SASKATCHEWAN.

No.	¼ Sec.	Tp.	Rge.	Depth in feet	Elev. of Aquifer	Total dissolved solids	Constituents as Analysed: Ca	Mg	Na	SO_4	Cl.	Alk.	Total Hardness	Constituents as Calculated in assumed Combinations: $CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl.	Source of
55	SE 13	37	23	400	1800	1400	7	4	505	443	84	550	25	18		14		546	656	139	Pale Beds
56	NE 17	37	23	300	1954	1180	21	13	413	316	47	605	105	53		45		528	468	78	Pale Beds
57	SE 14	37	24	245	1970	1060	7	9	366	291	29	505	30	18		31		477	431	48	Pale Beds
58	NE 9	37	24	169	2078	740	43	15	215	148	12	465	170	108		52		313	219	20	Pale Beds
59	SW 7	37	24	288	2000	940	21	13	306	180	28	545	30	53		45		464	266	46	Pale Beds
60	NE 4	37	25	351	1943	840	14	9	284	111	17	550	25	35		31		506	164	28	Pale Beds
61	SW 24	38	25	385	1900	1020	7	4	354	242	11	585	25	18		14		530	358	18	Pale Beds
62	NE 16	38	24	87	2217	940	71	28	184	414	21	230	360	178		44	74		525	35	Similar to Bearpaw water
63	NE 9	38	23	110	2038	1120	7	7	419	234	16	690	35	18		24		682	346	26	Pale Beds
64	SE 21	38	23	20	1992	1260	14	11	437	295	79	610	75	35		38		562	437	130	Pale Beds
48	NE 34	39	23	234	1935	1260	14	4	437	472	42	450	35	35		14		422	698	69	Pale Beds
49	NE 24	39	24	105	2111	1220	93	28	267	484	23	390	400	233		97		45	716	38	Pale Beds
50	NE 3	39	25	330	1938	1020	7	4	365	107	27	675	20	18		14		679	158	45	Pale Beds

RECORD OF WELLS IN RURAL MUNICIPALITY OF GRASS LAKE, No. 381, SASKATCHEWAN.

Well No.	LOCATION ¼ Sec.	Tp.	Rge.	Mer.	Type of Well	Depth of Well	Altitude of Well	WATER LEVEL Above (+) or Below (-) Surface	Elev. Above Sea Level	PRINCIPAL WATER-BEARING BED Depth Ft.	Elev.	Geol. Horizon	Character of Water	Use to Which Water Is Put[x]	Yield & Remarks
1	N.E. 2	37	23	3	Drilled	350	2194	-80	2114	350	1844	Pale or variegated Beds	Soft	D.S.	Sufficient
2	S.E. 3	"	"	"	"	175	2223	-73	2150	82	2141	Sand			Good supply
										175	2048	Pale Beds	Hard	"	Sand trouble
3	S.W. 4	"	"	"	Bored	93	2316	-20	2296	93	2223	Sand	Soft	"	Sufficient
4	S.W. 6	"	"	"	"	84	2311	-50	2261	84	2227	"	Hard	"	"
5	N.E.10	"	"	"	"	128	2204	-50	2154	128	2076	Pale Beds	Soft	"	Limited
6	S.E.12	"	"	"	"	90	2197			90	2107	" " sand	Hard	"	"
7	S.E.13	"	"	"	Drilled	400	2000	-80	1920	400	1600	Ribstone Ck.	Soft	"	Abundant (Gas 300').
8	N.W.14	"	"	"	Bored	55	2145	-40	2105	55	2090	Clay	"	"	Sufficient
9	S.E.15	"	"	"	"	150	2211	-50	2161	150	2061	Sand	"	"	"
10	N.E.17	"	"	"	Drilled	300	2254	-112	2142	212	2042	Pale Beds	"		Coal at 212'.
										267	1987	" "	"		
										300	1954	" "	"	D.S.	Good supply
11	S.E.18	"	"	"	Bored	80	2201	-65	2136	80	2121		"	"	Sufficient
12	S.E.21	"	"	"	"	117	2198	-57	2141	117	2081	Pale Beds	"	"	" Coal at 117'.
13	N.W.24	"	"	"	"	45	2128	-25	2103	45	2083	" "	"	"	Sufficient
14	S.E.27	"	"	"	"	90	2151			90	2061	Pale Beds?	Hard	"	"
15	S.E.28	"	"	"	"	160	2211	-80	2131	160	2051	Pale Beds	Soft	"	"
16	N.E.28	"	"	"	"	180	2187	-40	2147	180	2007	" "	" Brown	"	"
17	N.W.30	"	"	"	"	140	2244	-120	2124	140	2104	Glacial	"	"	Waters 15 head stock.
18	S.E.30	"	"	"	"	91	2223	-83	2140	91	2132	" sand	Hard	"	" 45 " "
19	N.E.33	"	"	"	"	130	2166	-60	2106	130	2036	Pale Beds	"	"	Good supply
1	N.W. 1	37	24	3	Bored	70	2288	-50	2238	70	2218	Glacial clay	Hard	D.S.	Sufficient
2	N.E. 2	"	"	"	Dug	25	2293	-20	2273	25	2268	" sand	"	"	Abundant
3	S.E. 2	"	"	"	Bored	65	2301	-25	2276	65	2236	" clay	"	"	Good supply
4	S.E. 3	"	"	"	"	46	2312	-20	2292	46	2266	Glacial	"	"	Waters 65 head of stock.
5	S.W. 4	"	"	"	"	80	2280	- 6	2274	80	2200	" sand	"	"	Good supply
6	N.W. 5	"	"	"	"	100	2267	-20	2247	100	2167	Sand	Soft	"	Sufficient
7	S.W. 6	"	"	"	"	90	2260	-15	2245	90	2170	Glacial clay	Hard	"	"
8	S.W. 7	"	"	"	Drilled	288	2287	-80	2207	288	1999	Pale Beds	Soft, brown	"	" Coal at 260'.

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

Well No.															
9	N.W. 7	37	24	3	Drilled	275	2277	-80	2197	275	2002	Pale Beds Sand	Soft br.	D.S.	Good supply
10	S.E. 9	"	"	"	Bored	100	2259	-20	2239	20	2239	Glacial	Hard	"	Poor "
11	N.E. 9	"	"	"	"	169	2247	-44	2203	169	2078	**Pale Beds sand**	Soft	"	Abundant. Coal at 169'
12	N.W.10	"	"	"	"	75	2219	-30	2189	75	2144	Blue sand	Hard Poor	"	Sufficient
13	S.E.12	"	"	"	"	84	2292			84	2208		"	"	Limited
14	S.E.14	"	"	"	Drilled	245	2215	-25	2190	245	1970	Pale Beds	Soft	"	Good supply
15	S.W.15	"	"	"	Bored	55	2221	-40	2181	55	2166	Sand	Hard	"	Limited
16	S.W.17	"	"	"	Drilled	260	2252			260	1992	Pale Beds	Soft br.	"	Good supply
17	N.E.21	"	"	"	Bored	75	2212	-72	2140	75	2137	Hard pan	Hard	"	Limited
18	S.W.23	"	"	"	Drilled	278	2251	-50	2201	278	1973	Pale Beds	Soft	"	Sufficient. Coal at 100'.
19	S.E.23	"	"	"	Bored	130	2249	-85	2164	130	2119	" "	"	"	" Coal at 130'.
20	N.W.25	"	"	"	"	110	2265	-90	2175	110	2155		Hard	"	Poor supply
21	S.E.28	"	"	"	"	74	2207	-20	2187	74	2133	**Glacial gravel**		"	Sufficient
22	S.W.29	"	"	"	"	75	2257			75	2182	"	"	"	"
23	N.W.32	"	"	"	"	102	2287	-60	2227	102	2185	Sand	Soft	"	" . Coal at 10[illegible]
24	S.E.33	"	"	"	"	64	2247	-56	2191	64	2183	Gravel	"	"	"
25	N.E.35	"	"	"	"	80	2237	-48	2189	80	2157	Hardpan sand	Hard	"	"
26	S.W.35	"	"	"	"	110	2236	-50	2186	110	2126	Sand	Soft	"	"
1	S.W. 1	37	25	3	Bored	80	2283			80	2203	Sand	Hard	D.S.	Sufficient
2	N.E. 4	"	"	"	Drilled	351	2294	-50	2244	351	1943	Pale Beds sand	Soft br.	"	"
3	N.E. 5	"	"	"	Bored	65	2278			65	2213	Sand	Hard	"	"
4	S.E. 5	"	"	"	Dug	40	2282			40	2242	"	"	"	"
5	S.W. 9	"	"	"	Bored	120	2272			120	2152	"	"	"	"
6	N.E.10	"	"	"	"	44	2256			44	2212		"	"	"
7	N.E.12	"	"	"	Drilled	263	2256	-65	2191	263	1993	Pale Beds	Soft br.	"	" Coal at 250'
8	S.E.13	"	"	"	Bored	90	2235	-40	2195	90	2145		Hard	"	"
9	S.W.14	"	"	"	"	42	2242	-30	2212	42	2200	Sand	"	"	Limited
10	N.E.16	"	"	"	"	110	2262			110	2152	"	"	"	Sufficient
11	S.E.16	"	"	"	"	55	2238			55	2183	"	"	"	"
12	N.E.17	"	"	"	"	33	2280			33	2247	**Glacial gravel**	"	"	"
13	S.E.17	"	"	"	"	80	2292			80	2212	Sand	"	"	"
14	N.E.19	"	"	"	"	108	2352	- 8	2344	108	2244	"	"	"	Limited
15	N.E.20	"	"	"	"	84	2241	-10	2231	84	2157	Hard clay	" Alk.	"	"
16	S.E.23	"	"	"	"	52	2220			52	2168	Sand	"	"	Sufficient
17	N.E.24	"	"	"	"	100	2240			100	2140	Glacial	"	D.	Poor supply
18	S.E.26	"	"	"	Dug	83	2275			83	2192	" sand	"	D.S.	" "

Well No.															
19	S.W.27	37	25	3	Bored	31	2275	-20	2255	31	2244		Hard	D.S.	Sufficient
20	S.E.30	"	"	"	"	110	2308			110	2198	Sand	"	"	"
21	N.W.31	"	"	"	Dug	37	2329	-35	2294	37	2292	**Glacial gravel**	"	"	Limited
22	S.E.32	"	"	"	"	26	2331	-16	2315	26	2305	Glacial	"	"	Good supply
23	N.W.32	"	"	"	"	62	2349	-40	2309	62	2287	"	"	"	Limited
24	N.W.35	"	"	"	Bored	50	2308	-48	2260	50	2258	Gravel	"	"	Poor supply
25	N.W.36	"	"	"		78	2269	-22	2247	78	2191		"	"	Sufficient
1	S.W. 3	38	23	3	Bored	60	2170	-55	2115	60	2110		Soft	D. S.	Sufficient
2	N.E. 4	"	"	"	"	30	2164			30	2134		Hard	"	"
3	S.E. 5	"	"	"	"	65	2208	-50	2158	65	2143	Gravel	"	"	"
4	N.W. 5	"	"	"	"	58	2190			58	2132		Soft	"	Good supply
5	N.E. 7	"	"	"	"	50	2187	-48	2139	50	2137	**Glacial sand**	Hard	"	Sufficient
6	N.E. 9	"	"	"	"	110	2148	-100	2048	110	2038	**Pale Beds.**	Soft	"	"
7	S.E.13	"	"	"	"	122	2099	-60	2039	122	1977	Pale Beds	"	"	Limited. Coal - 90' Thin
8	N.W.16	"	"	"	"	122	2160	-32	2128	122	2038	" "	"	"	Sufficient " 122' Coal Seams
9	S.E.17	"	"	"	"	117	2171	-97	2074	117	2054	" "	"	"	Sufficient
10	S.E.20	"	"	"	"	90	2158	-70	2088	90	2068	" "	Hard	"	Limited
11	S.E.21	"	"	"	"	20	2112	-16	2096	20	2090		Soft	"	"
12	N.W.21	"	"	"	"	70	2144	-20	2124	70	2074	" "	"	"	" Coal at 70'.
13	S.W.22	"	"	"	Dug	8	2104	+ 2	2106	8	2096	" "	"	S.	Flows slowly. Coal at 8'.
14	S.E.24	"	"	"	"	15	1953	-10	1943	15	1938		Hard	D.S.	Sufficient
15	N.E.32	"	"	"	Bored	35	2110	-33	2077	35	2075	Clay	"	"	"
16	N.E.35	"	"	"	Dug	25	1889			25	1864	Sand		"	Poor supply
1	S.E. 3	38	24	3	Bored	84	2234	-24	2210	84	2150	Pale Beds	Hard	D.S.	Good supply. Coal with water.
2	S.W. 4	"	"	"	"	46	2267			46	2221		"	"	Poor supply
3	S.E. 6	"	"	"	"	118	2305	-58	2247	118	2187	Gravel?	Soft	"	Good "
4	N.W. 9	"	"	"	"	82	2320	-40	2280	82	2238	Pale Beds	Hard	"	" " Coal with water
5	N.W.10	"	"	"	"	40	2275			40	2235		"	"	" "
6	S.W.12	"	"	"	"	65	2227			65	2162	Clay	" Bitter	"	Sufficient
7	S.W.13	"	"	"	"	88	2252	-60	2192	88	2164		Soft	"	"
8	S.E.14	"	"	"	Dug	50	2284	-18	2266	50	2234		Hard	"	"
9	N.E.16	"	"	"	Bored	87	2304	-27	2277	87	2217	Pale Beds	Soft	D.	" Water with coal
10	N.E.16	"	"	"	"	90	2275±			90	2185	" "	"	D.S.	"
11	S.W.17	"	"	"	"	68	2297	-33	2264	68	2229	" "	Hard	"	" " " "
12	S.E.19	"	"	"	"	50	2285			50	2235	" "	"	"	" " " "
13	N.W.19	"	"	"	"	50	2296	-20	2276	50	2246	" "	"	"	" " " "

Well No.															
14	N.W.20	38	24	3	Bored	48	2274	-13	2261	48	2226	Pale Beds	Hard	D.S.	Sufficient. Coal.
15	S.E.23	"	"	"	"	57	2260	-50	2210	57	2203	Sand	"	"	Poor supply
16	S.W.23	"	"	"	"	42	2294	-17	2277	42	2252	Pale Beds	Soft	"	Thin coal seems 25' down.
17	S.E.25	"	"	"	Dug	40	2236			40	2196		Hard	"	Sufficient.
18	S.E.28	"	"	"	Bored	60	2286	-40	2246	60	2226	Sand, gravel	"	D.M.	Good supply
19	S.W.31	"	"	"	Dug	22	2254	-12	2242	22	2232		"	D.S.	
20	N.E.36	"	"	"	Bored	43	2218	-33	2185	43	2175	Sand	"	"	Sufficient
1	S.E. 1	38	25	3	Bored	99	2291			99	2192	Pale Beds	Soft br.	D.S.	Good supply. Coal.
2	S.W. 3	"	"	"	Dug	35	2344	-10	2334	35	2309		Hard	"	Sufficient
3	N.W. 4	"	"	"	Bored	65	2354	-61	2293	65	2289	**Glacial sand**	"	"	Sand trouble.
4	N.E. 6	"	"	"	Drilled	250	2361	-95	2266	230	2131	Pale Beds			
										250	2111	" "	Soft	"	Good supply
5	N.W. 8	"	"	"	Bored	85	2390	-83	2307	85	2305	Sand	Hard	"	Poor "
6	N.E. 9	"	"	"	Dug	50	2328	-30	2298	50	2278		"	"	" "
7	N. W10	"	"	"	Bored	38	2320	-26	2294	38	2282	Clay	"	"	Sufficient
8	N.E.12	"	"	"	"	52	2268	-15	2253	52	2216	Pale Beds	"	"	" Coal.
9	S.E.13	"	"	"	"	46	2299	-39	2260	46	2253	" "	Soft	"	Waters 190 Head. Coal.
10	S.E.14	"	"	"	"	110	2312	-65	2247	110	2202	Sand	Hard	"	Sufficient
11	S.W.16	"	"	"	"	67	2350			67	2283	Clay	"	"	"
12	N.W.17	"	"	"	"	65	2366	-49	2317	65	2301	"	"	"	"
13	S.E.18	"	"	"	"	90	2384	-70	2314	90	2294	"		"	"
14	N.E.19	"	"	"	"	66	2355	-36	2319	66	2289	Sand	Hard	"	"
15	S.E.21	"	"	"	"	24	2295	-21	2274	24	2271		"	"	"
16	S.W.24	"	"	"	Drilled	385	2284	-75	2209	385	1899	**Pale Beds.**	Soft	"	Abundant
17	N.E.25	"	"	"	Bored	60	2267	-30	2237	60	2207	Sand	"	"	Sufficient
18	N.E.28	"	"	"	"	21	2287	-15	2272	21	2266	"	Hard	"	"
19	N.E.32	"	"	"	"	50	2324	-46	2278	50	2274	"	"	"	Limited
20	N.W.32	"	"	"	"	40	2369	-30	2339	40	2329	"	"	"	Sufficient
21	S.W.35	"	"	"	"	120	2284	-70	2214	120	2164	"	Soft	"	"
1	N.W. 4	39	23	3	Bored	40	2159	-10	2149	40	2119	**Glacial sand.**	Hard	D.S.	Sufficient
2	N.E. 4	"	"	"	"	84	2106	-60	2046	84	2022		Soft	"	"
3	N.W. 9	"	"	"	"	75	2165		Low	75	2090	Blue clay	Hard	"	Poor supply
4	N.W.12	"	"	"	"	65	1986	-50	1936	65	1921	Pale Beds	Soft br.	"	Sufficient
5	N.E.12	"	"	"	"	40	1924	-20	1904	40	1884		Hard	"	"
6	S.W.13	"	"	"	"	60	2007		Low	60	1947	Sand & clay	"	D.	Poor supply
7	[illegible].E.15	"	"	"	"	40	1954	-35	1919	40	1914	Pale Beds	" br.	D.S.	Sufficient. Coal with water.

Well No.															
8	S.E.15	39	23	3	Spring		1996					Pale Beds			
9	N.W.16	"	"	"	Bored	20	2158	-17	2141	20	2138	Sand	Hard	D.	Poor supply
10	N.W.18	"	"	"	"	56	2208	-20	2188	56	2152	Glacial Gravel	"	D.S.	Sufficient
11	N.E.20	"	"	"	Dug	25	2150	-20	2130	25	2125	" "	"	"	"
12	N.W.22	"	"	"	Bored	90	2150	-80	2070	90	2060	Blue sand	"	"	Poor supply
13	N.W.26	"	"	"	"	88	2124	-70	2054	88	2036	Pale Beds	"	"	Good "
14	S.E.28	"	"	"	"	99	2188	-87	2101	99	2089	Sand	Soft	"	Sufficient
15	N.W.31	"	"	"	"	55	2247	-26	2221	30	2217		Hard	"	Good supply
16	S.E.32	"	"	"	"	65	2189	-20	2169	65	2124		"	"	Sufficient
17	N.E.34	"	"	"	Drilled	234	2169	-45	2124	234	1935	Pale Beds	Soft	"	" Coal at 135'.
18	N.W.35	"	"	"	Bored	80	2168			80	2088	Sand	"	"	"
19	N.W.36	"	"	"	Drilled	86	2165	-80	2085	86	2079		Hard	"	Good supply
1	N.W. 5	39	24	3	Bored	90	2272	-20	2252	90	2182		Hard	D.S.	Sufficient
2	N.E. 9	"	"	"	"	40	2241		Low	40	2201			D.	Poor supply
3	S.E.19	"	"	"	"	70	2200	-25	2175	70	2130	Sand gravel	"	D.S.	Sufficient
4	S.W.20	"	"	"	"	32	2195	-20	2175	32	2163	Gravel	"	"	"
5	N.W.21	"	"	"	"	60	2246	-40	2206	60	2186	"	"	"	"
6	S.W.21	"	"	"	"	43	2234	-23	2211	43	2191	"	"	"	"
7	N.W.23	"	"	"	Dug	55	2242	-43	2199	55	2187	"	"	"	Good supply
8	N.E.24	"	"	"	Bored	105	2216	-55	2161	105	2111	Blue sand	"	"	Sufficient
9	N.W.30	"	"	"	"	115	2171	-75	2096	115	2056	Sand	"	"	"
10	S.E.30	"	"	"	"	82	2198			82	2116	"	"	"	"
11	S.E.32	"	"	"	"	80	2238	-78	2160	80	2158	Gravel	"	"	Poor supply
12	N.W.32	"	"	"	"	40	2186	-20	2166	40	2146	Sand "	"	"	Sufficient
13	S.E.33	"	"	"	"	80	2216	-73	2143	80	2136	Gravel	"	D.	Good supply
14	N.E.35	"	"	"	"	75	2229	-65	2164	75	2154		"	D.S.	Limited
1	S.W. 2	39	25	3	Bored	75	2276	-25	2251	75	2201	Gravel	Hard	D.S.	Limited
2	N.E. 3	"	"	"	Drilled	330	2268	-65	2203	250	2018	Pale Beds			
										330	1938	" "		"	Sufficient
3	S.E. 5	"	"	"	Bored	54	2330	-45	2285	54	2276	Sand	Hard	"	"
4	S.E. 7	"	"	"	"	30	2208	-28	2180	30	2178		"	"	Limited. Dry hole 114'
5	S.W. 8	"	"	"	"	103	2196	-30	2166	103	2093	"	" Alk.	S.	Sufficient
6	N.W.12	"	"	"	"	120	2231		Low	120	2111	"	"	D.S.	Limited
7	S.E.12	"	"	"	"	40	2260	-35	2225	40	2220	"	"	"	Sufficient
8	S.W.13	"	"	"	"	58	2199	-25	2174	58	2141	"	"	"	"
9	S.W.16	"	"	"	Dug	12	2242	-10	2232	12	2230	" & gravel	Soft	"	"
10	N.E.17	"	"	"	Bored	30	2186			30	2156	Sand	Hard	D.	Good supply. School

Well No.																
11	N.W.18	39	25	3	Bored	40	2176	-35	2141	40	2136	Sand		D.S.	Sufficient	
12	S.E.20	"	"	"	"	83	2175	-33	2142	83	2092	Pale beds	Hard	"	"	Coal at 60 ft.
13	S.E.21	"	"	"	Drilled	250	2196	-20	2176	250	1946	Pale Beds	Soft	"	Good supply	
14	S.W.22	"	"	"	"	215	2211	-60	2151	200	2011	" "	"	"	" "	
15	N.W.24	"	"	"	Bored	40	2184	-32	2152	40	2144		Hard	"	Sufficient	
16	N.W.28	"	"	"	Drilled	242	2258	-100	2158	242	2016	Pale Beds	Soft	"	"	
17	N.W.31	"	"	"	Bored	78	2227	-53	2174	78	2149	Gravel	Hard	"	"	
18	S.W.33	"	"	"	"	32	2159	-27	2132	32	2127		"	"	"	