CANADA

DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH

BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY

WATER SUPPLY PAPER NO. 285

GROUND-WATER RESOURCES OF PICKERING TOWNSHIP, ONTARIO COUNTY, ONTARIO

By

J. F. Caley T. H. Clark, and E. B. Owen

OTTAWA

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PART I

INTRODUCTION

This report deals with the ground-water conditions of part of an area in southern Ontario investigated by the Geological Survey in 1936 and 1937. The entire area covers approximately 800 square miles. It consists of King, Markham, Scarborough, Vaughan, and Whitchurch townships, York county; Albion and Toronto Gore townships, Peel county; and Pickering township, Ontario county.[1]

A gradually diminishing annual rainfall over the 5-year period 1931 to 1936, culminating in the extremely dry season of 1936, brought about a lowering of the ground-water level that resulted in serious water shortages in many localities. Many farmers found themselves virtually without water, and the supplies of some villages dwindled to quite insufficient amounts. The water supplies throughout the entire area are derived for the most part from ground water. The principal object of this report is, consequently, to aid those who are in need of new or further supplies.

As the ground water is directly related to the geology, both bedrock and superficial deposits were studied and mapped. All available information pertaining to some 8,700 wells was recorded and 230 water samples were collected for analysis. T. H. Clark (1936) and H. N. Hainstock (1937) mapped the superficial geology, and also directed the collection of water data. Dr. Clark was ably assisted in the field by J. H. Douglas, J. W. Britton, D. K. Stadleman, G. W. Matheson, M. E. Woods, and E. C. S. Gould, and Mr. Hainstock by J. H. Douglas, P. D. Bugg, M. E. Woods, W. B. Gray, E. A. Gray, W. E. Tweed, and J. P. Clancy. J. F. Caley, assisted by M. C. Gardiner, studied the bedrock formations.

Thanks are here extended to the farmers throughout the area for their co-operation and willingness to supply information regarding their wells. Valuable assistance was given by the well drillers and by several municipal authorities who willingly supplied all available data.

To H. C. Rickaby, Deputy Minister of Mines for Ontario, and R. B. Harkness, Ontario Natural Gas Commissioner, thanks are here expressed for their hearty co-operation in the work.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports covering each township in the area. Township authorities will be supplied with the information covering their respective townships. In addition, pertinent data on each well have been compiled, and may be obtained from either the Chief Geologist, Geological Survey, Ottawa, or the Provincial Geologist, Ontario Department of Mines, Toronto. When requesting such additional information, the applicant should clearly state the exact location, giving the lot and concession of the district about which data are required.

With each report is a map consisting of two figures: Figure 1 shows the surface formations that will be encountered, and Figure 2 shows the position of all wells for which records are available, together with the class of well at each location.

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1. The material contained in Part I of this report refers to the entire area comprising all the townships mentioned. The general discussion of ground water is universally applicable. Part II deals specifically with the ground-water conditions of one township.

GLOSSARY OF TERMS USED

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

Aquifer. A geologic formation or structure that transmits water in sufficient quantity to satisfy pumping wells and springs.

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.

Contour. A line on a map passing through 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 with water when the river is in flood.

Glacial Drift. A general term. It includes all the loose unconsolidated materials that were deposited by the continental ice-sheet, or by waters associated with it. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. Glacial drift occurs in several forms:

(1) Terminal Moraine or Moraine. A ridge or series of ridges formed by glacial drift that was laid down at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Kame Moraine. Assorted deposits of sand and gravel laid down at or close to the ice margin. The topography is similar to that of a terminal moraine.

(3) Drumlin. A smooth, oval hill composed mainly of glacial till, which has its long axis parallel to the direction of ice movement at thattplace.

(4) Ground Moraine. A boulder clay or till plain deposited at the base of the ice-sheet. The topography may vary from flat to gently rolling.

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

(6) Shore Line. A discontinuous escarpment, which indicates the former margin of a glacial lake.

(7) Bay-mouth Bar. A ridge of interbedded sands and gravels formed across the mouth of a glacial-lake bay.

(8) Glacial-lake Deposits. Sand, silt, and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. The sub-surface water below the water-table in the zone of saturation.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was 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 or permeable 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 or glacial drift consisting of loose sand, gravel, clay, silt, and boulders that overlie the bedrock.

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

Perched Water. Water separated from an underlying body of ground water by unsaturated rock.

Wells. Holes sunk into the earth so as to reach a supply of water. Whenmno water is obtained they are referred to as dry holes. Wells are divided into four classes:

(1) Flowing Artesian Wells. Wells in which water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian Wells. Wells in which the water is under hydrostatic pressure sufficient to raise it above the level of the aquifer but not above the level of the ground at the well.

(3) Non-artesian wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are intermittently dry.

GENERAL DISCUSSION OF GROUND WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams as run-off; part evaporates either directly from the surface and from the upper mantle of soil, or indirectly through transpiration of plants; and the remainder sinks into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that sinks below the ground will depend largely upon the type of soil or surface rock, and on the topography; more water will sink into sand and gravel

for example, than into clay; if, on the other hand, the region is hilly and dissected by numerous streams, more water will be immediately drained from the surface than in a relatively flat area. Light, continued precipitation will furnish more water to the underground supply than brief torrential floods, during which the run-off may be nearly equal to the precipitation. Moisture falling on frozen ground will not usually find its way below the surface, and, therefore, will not materially replenish the ground-water supplies. Light rains falling during the growing season may be wholly absorbed by plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity.

Because of the large consumption of ground water in settled areas, it may seem surprising that precipitation can furnish an adequate supply. However, when it is borne in mind that a layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 imperial gallons, and that the annual precipitation in this area, for example, is about 30 inches, it will be seen that each year some 435,600,000 gallons fall on each square mile. If we estimate that only 10 per cent of this, namely 43,560,000 gallons, is contributed to the underground supplies, it will be seen that the annual recharge for the entire area of 800 square miles is 34,848,000,000 gallons. The annual consumption of water in this area is not known, but an estimate based upon per capita consumption shows it to be only about one-tenth of the annual recharge as estimated above. It seems reasonable then, to conclude that precipitation is adequate to furnish supplies of ground water for the area.

In most regions of the world where precipitation is effective, there is an underground horizon known as the ground-water level or "water-table", which is the upper surface of the zone of water-saturation. Water that sinks into the ground finds its way downward to where it either reaches this water-table or comes in contact with an impervious layer of rock. Such a layer may stop further downward percolation, resulting in perched water. If the water-table is at or near the surface, there will be a lake or swamp; if it is cut by a valley, there will be a stream in the valley.

All rocks are to some degree porous, that is, the individual grains or particles of which they are composed are partly surrounded by minute open spaces or pores. Water stored within the rocks fills these spaces. A fine-grained rock such as shale, limestone, or clay may have such small pores that the contained water will not flow readily, and wells sunk in such rocks may obtain little or no supply of water. Such rocks are considered impervious. Those rocks on the other hand that readily yield their water to wells are called water-bearing beds or aquifers. Sand and gravel, porous sandstone, and sand form good aquifers. A clean gravel constitutes one of the best types of aquifer, as it is sufficiently porous to yield its water freely.

Many shallow wells that derive their water from below the water-table have become dry. In many cases this is due to the lowering of the water-table below the bottom of the well. So long as the annual recharge is equal to or greater than the loss through consumption and underground drainage, there will be no lowering of the water-table, and hence wells sunk below this level will have a permanent supply. If, however, the annual precipitation were to decline over a period of years, the quantity of water available for recharging the underground supply would necessarily decrease, and if it were to decrease to a point where loss through consumption and underground drainage was greater than the annual recharge, the level of the water-table would be lowered and some wells would go dry. Such a decline in precipitation occurred in the general area under consideration during the 5-year period 1929 to 1935.

Although springs are utilized in some parts of this

area, the chief method of recovering ground water is by means of wells. The quantity of water obtained from springs is usually small, but the town of Markham, with a population of about 1,700, obtains its public water supply from such a source. Two types of wells are in common use, namely dug wells and drilled wells, the former outnumbering the latter by about ten to one. In places where the aquifer yields its water slowly, dug wells, because of their greater storage capacity, are more satisfactory than drilled wells. However, if proper precautions are not taken, dug wells are more likely to become contaminated by polluted surface waters, especially in barnyards. Ground water for industrial and commercial uses, where large quantities are required, is commonly obtained from the deeper drilled wells. When drilling such wells, the more shallow and perhaps smaller supplies can be cased off and drilling continued to where adequate supplies are encountered.

The wells have been classified as artesian and non-artesian, and artesian wells are subdivided into flowing artesian and non-flowing artesian. A fourth class, called intermittent non-artesian, comprises those wells that dry up periodically.

DESCRIPTIONS OF FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Bedrock Formations

The bedrock formations that underlie the area are listed in the following table:[1]

[1] Caley, J. F.: Palaeozoic Geology of the Toronto-Hamilton area, Ontario, Geol. Surv., Canada, Mem. 244, p. 12 (1940).

Table of Formations

System	Formation	Thickness (Feet)	Lithology
Silurian	Lockport	151 ±	Light grey dolomite; some brownish, bituminous, dolomite at top.
	Medina	74 ±	Red, green, and grey shale; grey, sandy, and shaly dolomite (Cabot Head); grey, magnesian and argillaceous limestone (Manitoulin); grey sandstone (Whirlpool).
Ordovician	Queenston	340 - 400	Red, in part sandy, shale.
	Meaford	120 ±	Grey, bluish, and brownish shale, with thin layers of limestone; calcareous sandstone and arenaceous shale.
	Dundas	550 ±	Grey and blue shale; thin, sandy beds; thin, lenticular, limestone beds.

	Billings	100 - 250	Dark grey to nearly black, slightly bituminous shale.
	Trenton and Black River	550	Chiefly grey limestone, in places dolomitic and shaly; sandstone and arkose at the base.
Precambrian			Granitic and altered volcanic and sedimentary rocks.

Precambrian

These rocks consist of granitic and altered volcanic and sedimentary formations that underlie the Palaeozoic sediments unconformably. They are not an important source of water in the area. Water contained in these rocks probably occurs in joints and fissures. From the few wells that have reached the Precambrian, the water is reported to be highly mineralized.

Trenton and Black River Formations

The Trenton and Black River formations consist predominantly of grey and blue-grey limestone, and are at least 550 feet thick. Thin layers of shale occur in some parts of the succession, and dolomitic limestone may be present in the lower part of the Black River beds. Coarse sandstone or arkose, resting unconformably on the Precambrian, is known to occur in some localities.

Water found in these rocks occurs in cracks, fissures, or solution channels, and along bedding planes. The limestone itself is too fine grained and compact to be water yielding, but the coarse sandstone or arkose may contain a considerable quantity of water. Water derived from these formations is commonly highly mineralized and unfit for domestic use.

Collingwood Formation

The Collingwood formation consists of dark grey to black, fine-grained, thin-bedded, bituminous shale. It is about 30 feet thick. Water recoverable from these rocks occurs largely in fractures and along bedding planes; the shale itself is too fine grained to yield its water freely. The water obtained is usually too saline for either domestic or stock purposes.

Billings Formation

The Billings formation is a thin, and evenly bedded, soft, bituminous shale that weathers dark grey, bluish, or even yellowish. On fresh surfaces it is dark grey to nearly black, with distinct brown and green shades in many places. Much pyrite occurs in the darker parts.

The shales are exposed on both Rouge and Little Rouge Rivers a short distance above highway No. 2. They also outcrop on Duffin Creek, where they may be seen on lot 15, cons. II and III, and on lot 13, con. IV, Pickering tp. No other exposures of this formation occur in the area, but the shales underlie all that part east of a line joining the mouth of Rouge River and Lemonville.

Some water occurs along the bedding planes of this formation, but the quantity recoverable is small and the water saline.

Dundas Formation

The Dundas formation is prevailingly a bluish grey, thin-bedded shale that weathers somewhat lighter. There is, however, some variation from compact, blue, argillaceous shale to buff or yellowish, silty, and frequently arenaceous rock. Hard bands, both calcareous and arenaceous, occur interbedded with the shale; they rarely exceed a foot in thickness, the average being only a few inches. The formation is about 550 feet thick. It outcrops on Humber and West Humber Rivers in Vaughan and Toronto Gore townships respectively, and underlies the drift throughout most of Vaughan and King townships together with the western part of Whitchurch,, Markham, and Scarborough townships and a small part of each of Albion and Toronto Gore townships.

Water occurs along the bedding and joint planes of the shales, but the rock itself is too dense to yield its water readily to wells. Where the formation occurs at or near the surface, small quantities of water suitable for domestic needs may be obtained from the upper 50 feet. Water obtained deeper in the formation is commonly too saline for either domestic or stock uses.

Meaford Formation

The Meaford formation as a whole consists of grey to bluish and even brownish, fissile shale with interstratified hard layers that vary in composition from impure calcareous sandstone to rather pure crystalline limestone. It is exposed on a smallltributary of West Humber River in Toronto Gore and underlies the glacial drift near the extreme western part of the area. It is known to be about 115 feet thick on Credit River a short distance southwest of the area.

The shale of this formation is too compact to be a good source of water. Wells penetrating the formation have yielded moderate cuantities of water presumably from bedding planes and joint cracks, but in most instances the water is saline and not suitable for domestic needs.

Queenston Formation

The Queenston formation consists of brick-red, thin-bedded, compact shale. It does not outcrop in the present area, but underlies the glacial drift in the northwest part of Albion and Toronto Gore townships. The rock is a very poor source of water. It has been penetrated by a few wells, but the quantity of water obtained is small and commonly too saline for domestic use.

Medina Formation

The Medina formation overlies the Queenston, and forms the basal part of the Silurian system in Ontario. It has been divided into three members, which, in ascending order, are: Whirlpool sandstone, Manitoulin dolomite, and Cabot Head shale.

Whirlpool Member. This member is typically a resistant, light grey, fine to medium-grained sandstone. It usually occurs in beds of considerable thickness, but, where seen in its entirety, the upper few feet are commonly more thinly bedded than the lower part. Wave marks are common, but are best developed in the upper, thinner beds. The sandstone outcrops in the northwestern corner of Albion township, where it lies at the base of the Niagara escarpment. Its

thickness within the area is not known, but wells drilled for natural gas a few miles to the west of the area show 20 feet of sandstone present. No wells have penetrated this rock, so that its water-bearing properties are not definitely known. However, where it lies below the water-table this type of rock should form a good aquifer, due to its relatively high porosity.

Manitoulin Member. This member does not outcrop within the area, but, as seen a few miles to the west, it consists essentially of buff weathering, grey, magnesian limestone, in part argillaceous, and disposed in even beds from 2 to 8 inches thick. The lower few feet show thin interbeds of soft grey or bluish grey shale from 2 to 4 inches thick. This rock underlies the glacial drift in the northwestern part of Albion township, and is about 25 feet thick.

Small quantities of water can be expected to occur along bedding planes and in solution cavities in this rock, but, as none of the wells examined penetrates this member, little definite information is available regarding its water-bearing properties.

Cabot Head Member. This member consists typically of red, green, and grey shales, sandy dolomite, shaly dolomite and ferruginous limy beds. It does not outcrop within the area, but can be seen in the railway cut at Limehouse a few miles to the west. It underlies the glacial drift only in the extreme northwest part of Albion township and is at least 40 feet thick. The shales do not form good aquifers due to their fine-grained texture, and the calcareous beds are few and too thin to hold much water. None of the wells examined penetrates the Cabot Head beds, but they are not thought to be an important source of water in the area.

Lockport Formation

The Lockport formation consists of magnesian limestone and dolomite, commonly light grey to bluish, fine to coarsely crystalline, in places quite porous, and disposed in beds from 2 to 4 feet thick, with both thicker and thinner beds locally developed. Jointing is general throughout the formation; it is commonly vertical but very irregular. Weathered surfaces may show joint cracks as much as a foot wide. These rocks may be seen in the extreme northwest part of Albion township, where they constitute the upper, cliff-forming member of the Niagara escarpment. The formation is perhaps 150 feet thick, with only the lower 50 feet occurring in the area of this report.

Appreciable quantities of water may occur in joint cracks, in solution cavities, and along bedding planes in this formation. Wells encountering these openings yield sufficient water for farm requirements. Numerous springs issue at the base of the Lockport formation where the contact with the underlying impervious Cabot Head is exposed by the topography. Some of these springs are reported to flow as much as 3,000 gallons an hour.

Unconsolidated Deposits

During the Pleistocene or glacial epoch, great accumulations of ice formed at various centres in northern Canada. This ice moved out in all directions from these centres and covered large regions with what has been called the continental ice-sheet. As the ice advanced, it picked up great quantities of loose rock debris, which was deposited when the ice finally melted. This material is unconsolidated, and is commonly

called glacial drift. The ice-sheet advanced and retreated several times and on each retreat left an accumulation of drift on the surface over which it passed.

The area was entirely covered by one or more continental ice-sheets during Pleistocene time, and the final retreat of the ice left the bedrock surface covered to a variable depth with a mantle of glacial drift. This drift, together with flood plain deposits of alluvium, constitutes the unconsolidated deposits in the area. Most of the glacial drift consists of boulders and pebbles of various compositions and sizes embedded in a matrix of clay to form a more or less impervious mass known as boulder clay. Irregularly intermingled with this impervious mass, and also lying above, below, and between successive boulder-clay sheets, are beds, pockets, and lenses of sands and gravels that form the water-bearing members or aquifers of the drift. The following types of unconsolidated deposits occur in the area: (1) ground moraine; (2) terminal moraine; (3) kame moraine; (4) outwash sand and gravel; (5) glacial-lake deposits; (6) interglacial deposits; and (7) alluvium.

Ground Moraine. This type of glacial drift is chiefly boulder clay laid down at the base of the ice-sheet, and consists of a heterogeneous mixture of clay, boulders, and pebbles enclosing irregularly distributed lenses and pockets of water-laid sand and gravel.

Pore spaces in the boulder clay are very small, and much of the contained water is not recoverable through wells. However, where the clay is sandy, small domestic supplies may be obtained from it, and larger supplies, for industrial or municipal purposes, can be expected from the included lenses and pockets of sand and gravel.

At most places in the ground-moraine areas, water is obtained at depths of about 40 feet or less, but owing to the heterogeneous character of the deposits, it is not possible to predict the depth at which water may be encountered in any particular locality.

Terminal Moraine. Part of the load carried by the continental ice-sheet was dropped at its front or margin during pauses in the general retreat of the melting glacier. This load consisted of material gathered during the advance of the ice-sheet, and was deposited as a mixture of boulder clay, silt, sand, and gravel. Streams flowing from the melting ice carried away a large part of the silt, sand, and finer gravel, leaving chiefly compacted boulder clay and heaps of loose boulders as terminal moraine. In general, such material carries very little recoverable water, except where small lenses of sand or gravel are present.

Kame Moraine. The hilly region in the extreme north part of Markham and Vaughan townships is composed of boulder clay, sand, and gravel. Exposures show in road cuts at or near the tops of the hills; some of these are of sand, others of boulder clay. At one place a 6-foot layer of boulder clay overlies well-bedded sand, and wedges out southward; it is overlain by still more sand. This hilly area probably represents a terminal moraine, the sand and gravel being a mixture of outwash and kame deposits resulting from local readvances of the ice-front during its general retreat.

The typical terminal moraine part of the hilly region contains favourable aquifers at depth, but shallow wells do not, in general, yield adequate supplies. Water is obtained at depths of from 38 to 150 feet, with the deeper wells producing the more permanent and larger supplies. In the sand and gravel areas, however, where the

deposits represent outwash and kame conditions, domestic supplies are obtained within about 17 feet of the surface.

Outwash Sand and Gravel. Sand and gravel carried out from the front of the melting ice-sheet and deposited on plains at or near such a front may form important aquifers. These deposits are porous, and readily absorb rain falling upon them. If they rest on impervious clay, which would prevent downward percolation of the water, they may become saturated to within a few feet of the surface. Shallow wells in such deposits can be expected to yield adequate domestic supplies. If the deposits are thick and contain extensive gravel lenses, they may yield supplies sufficient for industrial or municipal uses.

Glacial-lake Deposits. These deposits include the silt, sand, and gravel deposited in glacial Lake Iroquois. Most of the deposits consist of fine sand and silt, with the gravel occurring in the form of bay-mouth bars. The sandy deposits vary from a thin veneer to at least 10 feet in thickness; the gravel deposits reach a thickness of 40 feet. Such deposits are very porous, and will yield their water freely to shallow dug wells.

Interglacial Deposits. These deposits are exposed in Scarborough and Pickering townships, along the shore of Lake Ontario, where they consist typically of stratified sand overlying a grey, peaty clay. The clay is almost impervious and very little water can be expected from it. The stratified sand, however, does contain water, and springs issue from the contact of the sand and underlying clay in the cliffs along Lake Ontario. Unless the sand is so fine as to partly clog wells that are dug or drilled in it, a fair supply of water should be obtained.

Alluvium. Alluvial deposits consist of clay, silt, sand, and gravel laid down as flood-plain deposits along the valley bottoms of many streams. Locally these deposits may become very extensive. The water-bearing properties of alluvial deposits are variable, but, in general, such deposits form favourable aquifers. They are porous, and readily yield a part of their contained water, although, in places their porosity may be greatly reduced by the presence of fine silt and clay. This type of deposit may be expected to yield moderate domestic supplies through shallow wells, and larger supplies if the deposits are extensive.

WATER ANALYSES

Both the kind and quantity of mineral matter dissolved in a natural water depend largely upon the structure and chemical composition of the rocks with which the water has been in contact. Water may be polluted by organic matter or its decomposition products.

Two hundred and eighty samples of well water from the

area were analysed for their mineral content in the laboratory of the Water Supply and Borings Section, Geological Survey, Department of Mines and Resources, Ottawa. The analyses are given in parts per million, that is, in parts by weight of the constituents in 1,000,000 parts by volume of water. No examination was made for bacteria, and hence a water that may be termed suitable for use on a basis of its mineral content might be condemned by reason of its bacterial content. Bacteriological analyses are made by the Provincial Department of Health, Toronto. As a rule, waters high in bacteria have been contaminated by polluted surface water.

The following mineral constituents include all that are normally found in natural waters in quantities sufficient to have any practical effect on the value of waters for ordinary uses.

Silica (SiO_2) is dissolved in small quantities from almost all rocks. It is not objectionable except in so far as it contributes to the formation of boiler scale.

Iron (Fe) in combination is dissolved from many rocks as well as from iron sulphide deposits with which the water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable, but separates as the hydrated oxide upon exposure of the water to the atmosphere. Excessive iron in water causes staining on porcelain or enamelled ware, and renders the water unsuitable for laundry purposes. In the table of analyses accompanying this report, alumina is included with the iron and both are reported as the oxides.

Calcium (Ca) is dissolved from almost all rocks, though in greater quantities from limestone, dolomite, and gypsum. Magnesium (Mg) is similarly dissolved from many rocks, but particularly from dolomite. These constituents impart hardness to water and are active in contributing to the formation of boiler scale. The sulphate of magnesia ($MgSO_4$) combines with water to form "Epsom salts", and renders the water unwholesome if present in large amounts. Calcium salts in minor quantities have no injurious effects.

Sodium (Na) is found in all natural waters in various combinations, though its salts constitute only a small part of the total dissolved mineral matter in most waters in humid regions. Sodium salts may be present as a result of pollution by sewage, or of contamination by sea water either directly or with that enclosed in marine sediments. No estimate of potassium (K) has been made, and any that may be present has been included as sodium. Moderate quantities of these constituents have little effect upon the suitability of a water for ordinary uses, but waters containing sodium in excess of about 100 parts a million may require careful operation of steam boilers to prevent foaming. Waters containing large quantities of sodium salts are injurious to crops and are, therefore, unfit for irrigation. The quantity of sodium salts may be so large as to render a water unfit for nearly all uses.

Sulphate (SO_4) is dissolved from deposits such as gypsum and sodium sulphate. It is also formed by oxidation of iron sulphides and is, therefore, found in mine waters. Sulphate, in combination with calcium and magnesium, causes formation of boiler scale; it also increases the cost of softening the water.

Chloride (Cl) is a constituent of all natural waters and is dissolved in small quantities from rocks. Waters from wells that penetrate brines or salt deposits contain large quantities of chloride, usually as sodium chloride (common salt) and less commonly as calcium chloride and magnesium chloride. Sodium

chloride is a characteristic constituent of sewage, and any locally abnormal quantity suggests pollution from this source. However, such abnormal quantities should not, in themselves, be taken as positive proof of pollution in view of the many sources from which chloride may be derived. Chlorides impart a salty taste to water, and if present much in excess of 300 parts a million, render it unfit for domestic use.

The term "total dissolved solids" is applied to the residue obtained when a sample of water is evaporated to dryness. Waters are considered high in dissolved mineral solids when they contain more than 500 parts a million. Waters containing up to 500 parts a million may be accepted for domestic use provided they are otherwise satisfactory, but a content of 1,000 parts a million does not prohibit domestic use if no better supply is available. Residents accustomed to the waters may use those that carry much more than 1,000 parts a million of total dissolved solids without inconvenience, although persons not used to highly mineralized waters would find them objectionable.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, the amount of soap that must first be used to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness, and is classified as "permanent hardness" and "temporary hardness". Permanent hardness remains after the water has been boiled. It is caused by mineral salts that cannot be removed from solution by boiling, but it can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing large quantities of sodium carbonate and small amounts of calcium and magnesium compounds are soft, but if the latter compounds are present in large quantities the water is hard. The following table[1] to be

[1]Thresh, J. C. and Beale, J. F., "The Examination of Waters and Water Supplies", London, 1925, p. 21.

may be used to indicate the degree of hardness of a water:

Total Hardness

Parts per million	Character
0- 50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 +	Very hard

The water samples analysed were taken from depths of from 7 to 462 feet, and with 51 exceptions all are from glacial drift. They show little variation in either the total dissolved solids or the quantities of the individual constituents. As far as mineral content is concerned, the waters are quite suitable for domestic and stock purposes as well as for most industrial uses. Softening would be desirable for laundry purposes. None of the drift waters analysed contains sufficient salts to render it injurious to crops and so unsuitable for irrigation.

PART II

PICKERING TOWNSHIP, ONTARIO COUNTY, ONTARIO

Physical Features

Pickering township is situated in the southwest part of Ontario county, and has an area of approximately 118 square miles. The village of Pickering, the largest of a number of small municipalities within the township, lies about 20 miles northeast of the city of Toronto.

The surface of the township is fairly flat, though numerous, low, rounded hills produce a gently undulating aspect in many localities. Elevations increase gradually northward from 245 feet above sea-level at Lake Ontario to 825 feet at the boundary between concessions VIII and IX. An irregular, hilly region in the eastern part of concession IX rises to an elevation of more than 1,050 feet. The most prominent topographic feature in the township is a discontinuous ridge or bluff, which represents the former shoreline of glacial Lake Iroquois. This old shoreline has been studied and described by A.P. Coleman[1]. The Iroquois shoreline trends northeasterly across the

[1] Coleman, A.P.: Ont. Dept. of Mines, vol. XLV, Pt. VII, 1936, pp. 1-36

township, dividing it into two relatively equal parts. In general, it follows the 475- and 500-foot contour lines. The area to the south of the shoreline is more level than that to the north, due largely to the deposition of glacial-lake sands and silts carried from the higher ground to the north.

Rouge River, Petticoat Creek, and Duffin Creek, together with their numerous small tributaries, cross the township in a general southerly direction. Many of the smaller creeks that are dependent upon ground water for their flow are dry, or nearly so, except at times of spring floods or after heavy and prolonged rains. Except in places where the creeks have cut through the Iroquois shoreline, the valleys have gently sloping sides, with stream beds less than 50 feet below the surrounding country. In many places the smaller valleys lose their identity or become mere ditches in the surface.

Geology

Bedrock Formations. Pickering township is entirely underlain by the Billings formation of Ordovician age. These rocks consist of thin-bedded, dark grey to nearly black, soft, bituminous shale. Outcrops of the Billings occur along Rouge River, in lots 33 and 34, rge 1, just north of highway no. 2, and along the east branch of Duffin Creek in lots 15 and 16, con. II; lot 15, con. III; and lot 13, con IV.

Unconsolidated Deposits. The greater part of the glacial drift in the area to the north of the Iroquois shoreline is ground moraine. This consists chiefly of a heterogeneous mixture of clay, boulders, and pebbles enclosing irregularly distributed lenses and pockets of water-laid sand and gravel. The hilly region in the extreme northeast part of the township is composed of boulder clay with sand and gravel. This material probably represents part of a terminal moraine

that formed during a local readvance of the ice-sheet. A second, less pronounced terminal moraine extends northeasterly across the northern half of the township. The relief of this moraine is so slight that in places it is extremely difficult to distinguish it from the ground moraine. A series of north-trending hills, south of the Iroquois shoreline, indicate what may be a third terminal moraine. The hills are composed almost entirely of glacial till. Definite shorelines marking lower stages of glacial Lake Iroquois are common in this region. The most prominent follows the 350-foot contour line. These shorelines are not accompanied by the usual glacial-lake shore deposits, such as gravel beaches or bay-mouth bars, but are indicated by the steepness of their slopes and by the presence of washed-out boulders on or at the base of the slopes. The greater part of the area lying south of the Iroquois shoreline is covered by deposits of clay, silt, sand, and gravel, laid down in the waters of glacial Lake Iroquois. The thickness of these deposits is not known.

Several large deposits of well stratified gravel occur along the Iroquois shoreline. They represent bay-mouth bars that were built by wave action across the mouths of bays in glacial Lake Iroquois. The largest of these deposits occurs in the extreme southern part of lots 32 to 35, con. II; smaller deposits occur in lot 15, con. IV, and in lots 4 and 5, con. V. In 1937 the gravel in these deposits was being used as railway ballast.

Alluvial deposits of clay, silt, sand, and gravel occur along the flooded plains of almost all the streams in the township, but are not of great thickness. A large flat area in lots 19 to 30, con. VIII, has been mapped as alluvium. This deposit is very thin, and consists of a veneer of fine sand overlying boulder clay.

The thickness of the unconsolidated deposits in Pickering township varies from a few feet in areas where bedrock outcrops appear to about 280 feet in the north and northwest parts. The following table indicates the minimum thickness of drift at several localities.

Well No.	Concession	Lot	Depth Feet	Aquifer
1	R.II	15	29*	Shale
2	R.II	30	23*	
5	R.I	34	60*	
4	R.I	1	44*	
4	R.I	8	70	Clay
4	R.I	12	65*	Shale
11	R.I	22	9*	
7	R.I	23	16*	
9	I	2	51*	
16	I	13	25*	
5	I	15	18*	
16	I	25	125	Drift
12	I	32	140	
2	II	1	30*	Shale
6	II	9	190	Clay
38	II	16	20*	Shale
7	II	20	91	Drift
8	II	30	130	
4	II	34	250	
8	III	6	60	Sand
7	III	32	100	

Well No.	Concession	Lot	Depth Feet	Aquifer
11	IV	30	72	Drift
4	V	15	280	
12	V	27	148	Quicksand
7	VI	10	150	
2	VI	25	140	
6	VII	6	104	Sand
14	VII	10	126	
4	VIII	6	100	
12	VIII	16	140	Sand and gravel
1	VIII	21	117	Gravel
1	XI	15	183	Clay
43	IX	18	100	Sand

* To bedrock.

Water Supply

The supply of ground water in Pickering township is not abundant, but in years of normal precipitation it is sufficient for local needs. About 89 per cent of the wells are of the dug type, and about 85 per cent obtain their water supply from depths of 40 feet or less. A survey of the well records shows that about 82 per cent of the wells have a permanent water supply sufficient for the present demands made upon them; the remainder constitute dry holes, wells that go dry periodically, and wells that went dry apparently as a result of the last period of extremely dry weather (1931-1936).

Of the 1,853 producing wells and springs in Pickering township, 1,738 obtain their water from glacial deposits, and the remaining 115 from bedrock. In describing the principal water-bearing beds in the glacial deposits, no account is taken of their age in respect to the successive advances and retreats of the ice-sheet, as the water-bearing properties of the aquifers seem to be independent of their position within the drift.

Sand and gravel pockets and lenses within the glacial drift, as well as glacial-lake deposits of sand and gravel overlying boulder clay, are the chief sources of satisfactory ground water in the township. In most wells the statements of owners and drillers as to the character of the aquifer were accepted. In many wells the principal aquifer is listed as glacial clay, material that normally yields little water. In wells where the yield is considerably greater than should be expected it is possible that the glacial clay may be mixed with sand, or even consist of fine sand or silt with a pore space large enough to yield at least part of its water.

The glacial-lake deposits of silt, sand, and gravel formed south of the Iroquois shoreline usually yield fair supplies of water. Many shallow dug wells obtain their water from these beds. However, in localities where these deposits are thin a considerable number of wells become dry during the autumn and winter, or during a period of prolonged drought. The most satisfactory supply of water obtained at shallow depths occurs in pockets of sand and gravel in the ground and terminal

moraines. These deposits are capable of retaining a large supply of water and of yielding it readily to wells. There is no way of ascertaining where these deposits may occur in the boulder clay, unless they outcrop at the surface or have been located by wells or test borings. Wells that depend upon the slow-yielding boulder clay for their water are not satisfactory. It is probable that these wells go dry not as a result of any fluctuation of the general-ground-water level, but rather as a result of the rate of consumption being greater than the rate at which the clay aquifer will yield water to the wells. Such wells may be easily depleted if drawn upon heavily, but may gradually regain their former water level if allowed to stand unused, or if the consumption is materially reduced.

The Billings shale constitutes a fair source of water supply in Pickering township, and at least 113 wells derive their water from this formation. Most of these wells are located in the south-central part of the township where the glacial drift overlying the bedrock is thin. The average depth is less than 30 feet, although depths of from 70 to 200 feet have been reported. The water from the more shallow wells is satisfactory, but that from the deeper wells contains a large amount of sodium chloride (common salt), which renders it unfit for domestic use. In those areas where the Billings shale is overlain by a thick accumulation of glacial drift, drilling into the shale in search of water is not recommended. A sufficient supply of water, satisfactory for domestic purposes, may be obtained from the shale where it occurs near the surface, but the supply will be small, and might readily be affected by drought conditions.

Two wells, 650 and 700 feet in depth respectively, were reported to have reached the Precambrian rocks. These are well No. 3[1],

[1] Well numbers refer to those wells on which data have been compiled, as indicated on page 2 of this report.

lot 28, rge. II, and well No. 2, lot 30, rge II. The 700-foot well encountered very little water, but the 650-foot well encountered a considerable supply in the coarse sandstone or arkose immediately overlying the Precambrian rocks. This water is under sufficient hydrostatic pressure to overflow the surface, but is too saline to be used. Neither well reported water from the Precambrian rocks.

Buried stream channels could not be recognized from the evidence of the wells. Such channels should contain quantities of sand and gravel, and hence form favourable source beds for large supplies of ground water. The occurrence in a locality of a few drift wells that are appreciably deeper than the average might indicate the presence of an underground channel, but the deep drift wells are scattered throughout the township and hence no reliable conclusions as to the location of buried channels can be drawn.

Small springs are fairly numerous throughout the township. They occur chiefly along the base of the Iroquois shoreline, and near the bases of high knolls where porous sand and gravel beds or lenses resting upon impervious boulder clay are exposed by natural slopes. In general, they are not an important source of ground water, although in places they supply both domestic and livestock needs. Many of the springs, especially those that draw their water from porous beds of limited extent, are intermittent, and, therefore, unsatisfactory.

Seven, flowing artesian wells occur within Pickering township. They range from 24 to 650 feet in depth, and with one exception are all reported to obtain their water from glacial drift. Saline water encountered by the 650-foot well in bedrock is under sufficient hydrostatic pressure to raise it 5 feet above the surface of the ground at the well; but the water is not satisfactory for domestic purposes. Two flowing artesian wells lie south of the Iroquois shoreline; a 250-foot well in lot 34, con. II, and a 27-foot well in lot 7, con. VI. Both these wells obtain their water from gravel beds in the glacial drift. The yield of the 250-foot well is approximately 90 gallons an hour. Two, flowing artesian wells in lots 9 and 11, con. VII, which are respectively 112 and 50 feet deep, tap water-bearing beds of fine sand overlain by a confining bed of impervious clay. The water from the 112-foot well rises a foot above the land surface, and furnishes about 60 gallons an hour. These wells are south of the terminal moraine that extends across the northern half of the township, and it is thought that the higher ground-water level in the moraine may account for the pressure that causes the water to overflow the surface at the wells. Two, flowing artesian wells, in lot 9, con. VIII, and lot 19, con IX, are a short distance south of the terminal moraine that occurs in the northeast part of the township. They are 24 and 38 feet deep respectively. The water is reported to come from gravel lenses enclosed in the boulder clay. It is thought that the possibilities of obtaining flowing artesian wells in the region immediately south of this terminal moraine are fairly good.

Village Supplies

All the villages of Pickering township obtain their water from privately owned wells, the supply coming from both glacial drift and the Billings shale. Many shallow wells in Pickering and Fairport obtain their water from the upper part of the Billings formation. The water supplies in all communities were reported to be sufficient.

Analyses of Water Samples

Fifty-six samples of well water from Pickering township were analysed for their mineral content in the laboratory of the Geological Survey. The samples were taken from depths of from 5 to 280 feet, and with six possible exceptions are all from glacial drift. Samples Nos. 8, 9, 10, 16, 17, and 23 are of water derived from the Billings shale. The dissolved solids in these waters are greatly in excess of that contained in other samples, due chiefly to a large increase in the sodium chloride content, which gives the water a salty tasteand renders it unsuitable for domestic use. Samples Nos. 1 and 14 were reported to have been obtained from the glacial drift, but in view of their high sodium chloride content it is probable that the water is from the underlying marine shale. Water obtained from the upper 30 feet of the shale, where it is at or near the surface, may be satisfactory, but that obtained at depth in the shale or from the upper part of the shale where it is overlain by a thick accumulation of drift will probably be too saline for use. The waters from the glacial drift were found to be suitable for domestic and farm use. Great care should be taken to prevent contamination of the shallow, dug wells by surface waters. The waters of a number of wells in the area were reported to have a sulphur taste and odour due to the presence of hydrogen sulphide, which may result from the decomposition of sulphates in the drift, or of organic matter in the water.

Amounts* of Dissolved Mineral Matter in Waters Collected in Pickering Township

Constituent	Water from glacial drift (48 analyses)		
	Maximum	Average	Minimum
Total dissolved solids	9,460	305.1	220
Silica	62	12.4	4
Iron (Fe_2O_3) and alumina (Al_2O_3)	20	5.1	2
Calcium	452	72.6	23
Magnesium	312	18.8	6
Sodium	893	25.2	1
Sulphate	344	64.0	11
Chloride	4,780	26	2
Total hardness	1,700	293.5	135

*In parts per million.

CONCLUSIONS

This investigation warrants the following conclusions:

1. Ground-water supplies of Pickering township are not abundant, but are adequate for domestic, stock, and municipal purposes.

2. Precipitation is sufficient to furnish this ground water. In times of drought, or during extended periods of decreased rainfall, annual consumption may be greater than the annual recharge, resulting in a lowering of the water-table. Some wells may go dry at such times, and it may be necessary to deepen those wells so affected.

3. The existence of numerous small streams with relatively shallow valleys indicates that the water-table lies close to the surface. This is borne out by the fact that 85 per cent of the wells are less than 40 feet deep.

4. The water-bearing beds in the glacial drift consist of irregularly distributed lenses and pockets of gravel, sand, and sandy clay.

5. The quality of water derived from the glacial drift is quite suitable for domestic use.

6. Water obtained from the upper 30 feet of the shale, where it is at or near the surface, may be satisfactory, but that obtained at depth in the shale or from the upper part of the shale where it is overlain by a thick accumulation of drift will probably be too saline for use.

7. No water is obtained from the Precambrian formations in Pickering township.

8. It is possible to obtain ground water at nearly all localities throughout the township, but it is not always possible to predict the depth at which favourable aquifers may be reached.

9. The possibilities of obtaining a flowing artesian well in the ground moraine area just south of the large terminal moraine in the northeast part of the township are fairly good.

					Constituents as Analysed									Constituents as Calculated in Assumed Combinations									
Sample Number	Well Number	Con.	Lot	Depth of well in ft.	Total dissolved solids	SiO_2	Fe_2O_3 & Al_2O_3	Ca (Calcium)	Mg (Magnesium)	Na (Sodium)	SO_4 (Sulphate)	Cl (Chlorine)	Alkalinity	Total hardness	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl	$CaCl_2$	$MgCl_2$
1	2	R111	35	37	1,400	8	8	160	59	292	13	470	605	900	400		172	16		741	741		28
2	7	R11	5	42	500	10	4	100	34	39	90	37	330	400	250		67	74		46	61		
3	10	R11	6	18	400	12	4	83	23	8	66	7	240	300	208		27	74		10	12		
4	11	R11	6	22	340	16	6	69	25	49	43	22	305	280	173		85		33	64	36		
5	2	R11	17	85	300	8	2	72	14	25	59	19	205	280	180		21	40		40	31		
6	5	R1	10	35	480	8	4	69	23	64	100	43	240	320	173		56	30		112	71		
7	7	R1	18	42	620	12	4	97	38	29	90	50	295	500	242		45	113			73		8
* 8	3	R1	19	95	460	48	4	34	15	142	18	76	330	220	85		52		193	27	125		
* 9	24	R1	27	103	1,560	4	18	126	44	431	13	490	730	400	315		153		247	19	808		
*10	27	R1	27	212	2,140	12	6	92	31	695	18	690	875	280	230		108		547	27	1,138		
11	4	1	10	19	620	12	4	122	26	24	100	37	305	400	305			127			61		
12	1	1	11	24	300	20	8	52	35	8	31	10	245	300	130		97	35		4	17		
13	3	1	17	13	420	8	4	112	14	12	80	21	245	400	245	48		58			30		4
14	38	1	26	62	1,580	6	6	86	24	565	13	450	890	240	215		83		611	19	743		
15	12	1	32	140	340	62	8	49	17		13	35	130	240	123		6	16					47
*16	3	11	1	60	460	20	6	66	31	35	111	15	230	400	165		55	74		77	25		
*17	4	11	1	70	840	4	4	64	28	271	33	56	750	190	160		97		504	49	92		
18	5	11	1	25	360	8	4	92	12		59	9	195	320	195	48		31					12
19	15	11	8	20	1,060	16	4	140	48	142	344	136	305	800	305	61		238		166	225		
20	6	11	9	190	600	32	8	94	24	73	199	30	265	320	235		25	84		195	50		
21	15	11	10	12	740	32	4	152	8		69	45	275	440	275	98					36	30	
+22	3	11	11	10	600	-	-	-	-	-	-	-	-										
*23	44	11	16	102	9,460	22	20	452	312	893	15	4780	780	1700	780	21					7344	372	122
24	1	11	29	80	360	12	6	29	12	74	148	14	110	180	73		31	15		201	23		
25	4	11	34	250	420	22	8	23	13	125	75	31	260	220	58		45		157	111	51		
26	3	111	7	37	340	8	4	89	12		66	7	195	280	195	37		49					9
27	5	111	9	5	340	8	8	100	6		44	7	220	280	220	41		19					9
28	7	111	32	100	580	24	8	126	21		85	45	250	520	250	88		29					60
29	4	1V	3	25	600	10	6	130	25	48	146	37	325	460	325			124		70	61		
30	12	1V	6	40	660	12	4	155	23	67	154	61	335	400	335	71		114		18	101		
31	1	V	7	21	620	14	6	142	26	23	108	33	355	460	355			129		7	55		

+ Analyses incomplete.
* Samples from the Billings formation.
1 Analyses by F.J. Fraser and A.H. Bray, Geological Survey.

					Constituents as Analysed									Constituents as Calculated in Assumed Combinations									
Sample No.	Well No.	Con.	Lot	Depth of well in feet	Total dissolved solids	SiO_2	Fe_2O_3 and Al_2O_3	Ca (Calcium)	Mg (Magnesium)	Na (Sodium)	SO_4 (Sulphate)	Cl (Chlorine)	Alkalinity	Total hardness	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl	$CaCl_2$	$MgCl_2$
32	4	V	15	280	300	12	4	83	12	9	34	12	225	280	208		14	40		3	20		
33	4	V	22	25	640	16	[illegible]	92	36	8	97	53	220	480	220	14		109		20	55		
34	20	V	31	72	380	4	6	54	31	5	34	210	340	135		63	43				13		16
35	6	VI	10	35	600	12	4	106	36	4	69	49	285	560	265		17	86			10		55
36	9	VI	19	30	220	12	6	20	10	42	46	7	125	160	50		35		35	68	12		
37	4	VI	21	20	420	10	6	86	23	16	7[illegible]	37	210	360	210			94			41		16
38	3	VI	23	38	580	14	8	83	50	15	105	55	260	550	207		45	131			38		43
39	2	VI	25	140	400	10	4	94	26		84	9	245	400	235		8	105					12
40	5	VI	28	102	320	12	4	26	18	71	11	15	260	320	65		62		128	16	25		
41	4	VI	30	30	340	4	4	66	20	25	62	17	210	300	165		42	40		44	28		
42	13	VII	3	30	400	8	6	86	23	17	48	41	240	380	215		21	60			43		20
43	6	VII	6	104	300	[illegible]	4	57	14	28	34	7	215	240	143		49		15	50	12		
44	8	VII	6	78	260	14	6	51	19	12	38	8	180	260	128		44	30		21	13		
45	14	VII	10	126	340	8	6	86	25	2	67	9	240	200	215		21	84			5		8
46	2	VII	21	44	640	10	6	106	24	67	99	104	265	420	265			119		3	172		
47	5	VII	28	22	420	14	4	92	23	5	36	10	285	360	230		46	45			12		4
48	3	VIII	1	42	500	12	4	92	23	7	74	29	225	340	225	7		86			18		24
49	1	VIII	7	41	440	8	6	100	17		46	19	245	320	245	7		51					26
50	21	VIII	18	22	340	18	4	63	27	4	41	18	210	320	158		44	51			10		16
51	38	VIII	18	21	520	26	4	86	27	17	69	39	240	320	215		21	86			44		16
52	1	VIII	21	117	260	10	4	57	21	12	48	12	175	260	143		38	50		12	20		
53	5	VIII	30	40	280	10	4	77	16	6	39	8	220	260	192		23	45		4	13		
54	43	IX	18	100	400	10	4	100	23	12	46	18	295	340	250		38	60			30		
55	2	IX	11	25	240	10	4	69	18	3	23	7	220	240	173		39	29			7		4
56	1	IX	15	183	240	14	4	63	16	1	26	2	200	240	158		36	32			3		

Number and character of wells and springs	CONCESSIONS												Total No. in township	Percentage of total
	RIII	RII	RI	I	II	III	IV	V	VI	VII	VIII	IX		
Total number of wells	3	65	302	340	240	118	128	177	152	131	147	170	1973	
Dug	3	52	270	299	213	106	120	158	135	117	129	150	1752	88.8
Driven	0	0	9	0	0	0	0	0	0	0	0	0	9	0.5
Drilled	0	13	19	35	21	9	6	8	10	8	10	14	153	7.7
Springs	0	0	4	6	6	3	2	11	7	6	8	6	59	2.9
Wells 0-40 feet deep	3	41	269	294	207	101	109	149	120	99	130	157	1679	85.1
41-80	0	17	28	31	22	11	15	19	16	27	14	7	207	10.5
81-120	0	3	2	3	5	1	0	1	5	2	2	2	26	1.3
121-160	0	1	1	3	2	0	0	2	4	1	1	0	15	0.7
161-200	0	0	0	0	1	0	0	0	0	0	0	1	2	0.1
Over 200	0	2	1	0	1	0	0	1	0	0	0	0	5	0.2
Depths unknown	0	1	1	9	2	5	4	5	7	2	0	3	39	1.9
Wells that yield hard water	3	64	300	339	238	115	128	175	152	129	145	168	1956	91.4
Soft water	0	1	2	0	1	2	0	1	0	2	2	1	12	0.6
Salty water	0	1	2	3	2	0	0	0	0	0	0	0	8	0.4
Wells with aquifer in sand	1	9	62	62	41	28	24	43	31	21	38	36	396	20.1
In gravel	0	5	24	22	20	13	18	12	28	17	9	26	194	9.8
In clay	0	19	107	143	95	44	66	73	54	61	61	73	796	40.3
In drift[1]	2	22	43	83	68	31	20	48	39	32	39	34	461	23.4
In bedrock	0	6	65	28	15	1	0	0	0	0	0	0	115	5.8
Unknown	0	4	1	1	0	0	0	0	0	0	0	0	6	0.3
Flowing wells	0	1	0	0	1	0	0	0	1	2	1	1	7	0.3
Non-flowing wells	3	64	298	333	233	113	126	165	144	123	138	162	1902	96.4
Wells with permanent supply	3	53	262	302	199	97	117	144	116	75	102	148	1618	82.0
Non-permanent supply	0	11	36	31	34	16	9	21	28	49	36	14	285	14.4
Dry holes	0	0	0	1	1	1	0	1	0	0	0	1	5	0.2
Wells not used	0	8	17	22	111	6	13	15	20	8	8	16	144	7.3

[1] Sand, silt, sandy clay, or sand and gravel.