SPRINGS IN SOUTHERN
MANITOBA

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Springs are common in some parts of Manitoba and often form interesting features on an otherwise monotonous terrain. The springs occur under various geological and physiographic conditions and their discharge and water quality varies over a wide range. The main intent of this report is to provide an overview of springs in Manitoba for persons interested in the esthetic, ecological and practical aspects of springs. However, the technical aspect has not been totally ignored and technical data, mainly water quality analyses available in published reports and in files of the Water Resources Branch, are also included and can be found in the Appendix.

DEFINITION

According to Webster's New Collegiate Dictionary, a spring is "a source of water issuing from the ground". To the American Geological Institute (1976) a spring is "a place where, without the agency of man, water flows from a rock or soil upon the land or into a body of surface water". In Davis' and De Weist's (1966) opinion "any natural surface discharge of water large enough to flow in a small rivulet can be called a spring." Todd (1959) emphasizes that "a spring is a concentrated discharge of groundwater appearing at the ground surface as a current of flowing water and "springs should be distinguished from a seepage area, which indicate a slower movement of groundwater to the ground surface."

Combining the various definitions, a spring is a place where under natural conditions groundwater emerges at ground surface or in a body of surface water and starts to flow on the surface or merges with surface water.
WHAT CAUSES SPRINGS?

To understand what causes springs one must have an idea of groundwater movement and storage. Some of the unconsolidated subsurface materials and rocks contain openings through which groundwater can move at a fairly high rate. The most common unconsolidated materials allowing appreciable groundwater movement are sand and gravel. Groundwater movement through most rocks takes place along fractures and bedding planes. Fractures and bedding planes are common in shale and limestone but are rather scarce in granite and other hard rocks. Sandstone may transmit water through openings between the sand grains as well as along fractures.

Unconsolidated materials and rocks that transmit water in appreciable quantities for practical use are called aquifers. Some unconsolidated materials such as clay and glacial till have very low permeability and they retard groundwater movement. They are called aquitards and aquicludes depending on how effectively they impede groundwater movement. Similarly rocks with no or very few fractures or other openings act as aquitards and aquicludes. The most common rocks that restrict groundwater movement are soft clayey shales, massive unfractured dolomite, granite and other igneous rocks.

Some aquifers have no confining, low permeability layer of impermeable material between the water surface in the aquifer and the ground surface. These are called unconfined or water table aquifers. Other aquifers are overlain by materials that restrict groundwater movement and therefore the water is confined and is under pressure. Consequently they are called confined aquifers or artesian aquifers.

If the source of a spring is an unconfined aquifer it is called a gravity spring. A spring connected to a confined aquifer is called an artesian spring.

Gravity springs are caused by topographic lows such as valleys, escarpments and depressions that are lower than the watertable of the aquifer. The water simply spills out from the aquifer and creates a
Gravity springs may occur along the sides of valleys and along the base of escarpments and at the base of ridges. The Assiniboin River between Brandon and Portage la Prairie cuts a deep valley (Figure 2) through extensive unconfined aquifers and therefore springs are common in the Valley, particularly in the Spruce Woods Forest and Cihle areas. Gravity springs are also found along the Manitoba Escarpment in the Riding, Dack and Westepin Mountains areas where they issue from sand and gravel ridges and fractured shale aquifers along the Escarpment (Figure 3). Gravity springs also occur along the slopes of the uplands of Sandilands and Agassiz Forest Reserves, e.g., upper reaches of Pine Creek and its tributaries at Piner.

Artesian springs occur in places where the pressure in the aquifer is high enough to lift water from the aquifer above ground level and where the confining layer is too thin or too weak to withstand the artesian pressure and the water can break through it and emerge at surface (Figure 4). The pressure in the artesian aquifer can be above ground level because of topographic conditions or because of low permeability zones in the aquifer which interfere with groundwater flow similarly to a dam in a river and cause high artesian pressure above the "dam". These conditions exist in the vicinity of Oak Hammock Marsh Wildlife Management area (Figure 5) and east of Winnipeg along Region Road north of Carven Road. Artesian springs can occur considerable distance from any upland and in very flat areas, e.g., the area in the vicinity of Oak Hammock Marsh is very flat, yet some high discharge springs can be found in the area, (Figure 6).

**MAN MADE SPRINGS**

Although the discharge of water from a spring nearly always is likely to be caused by natural conditions the reason why it exists may not be natural at all; the spring may be caused by man.

Artesian springs have been found in areas where the confining layer is thick enough to prevent groundwater from breaking through it.
FIGURE 2: ASSINTROINE RIVER VALLEY HYDROGEOLOGICAL SETTING.
FIGURE 5: HYDROGEOLOGICAL SETTING BETWEEN INTERLAKE REGION UPLAND AND RED RIVER.
under natural conditions. Upon closer inspection of such a spring one can find a well casing or pieces of it at the bottom of the spring or in the pool at the spring. The casing is clear evidence that the spring once was a flowing well that has been abandoned. In some cases no casing or other evidence of a well can be found in the spring. However, if the geological conditions are such that a natural orifice through the confining layer is not likely, a well or a test hole is likely the cause of the spring. Springs caused by abandoned wells are not unusual in the flowing artesian well areas in the Interlake Region.

An interesting aspect of these man made springs is that the orifice through the confining layer can be readily sealed and the discharge of the spring stopped. In other words, the natural conditions, which did not have a spring, can be restored.

Man made springs can be caused by various excavations, which reduce the thickness of the confining layer or cut into aquifers. If an excavation such as a drain, canal or borrow pit happens to be in an area where artesian flowing conditions exist and the confining layer is barely thick enough to contain the artesian pressure, reducing the confining layer may cause blowouts or springs in the bottom of the excavations (Fig. 7). Blowouts and resulting springs in excavations may also occur where under natural conditions the water level due to artesian pressure is below ground level, i.e., there could be no springs under natural conditions, but if the water level is above the bottom of the excavation, a blowout can take place.

Man made springs can occur along road cuts where deep cuts are made in valley sides and aquifers are intercepted (Figure 8). This can have a detrimental affect on existing springs and wells in the vicinity.

Man made springs caused by excavations, if they cause problems, often cannot be readily stopped and prevention of them by judicious planning may be far less expensive than repairs after the springs break out.
FIGURE 6: SPRING POND IN INTERLAKE LOWLAND AREA: DIAMETER OF POND ABOUT 10 m, DISCHARGE IN THE 50 L/s - 100 L/s RANGE.
FIGURE 8: EFFECT OF A ROAD CUT ON AN AQUIFER, WATER TABLE, SPRINGS AND WELLS.
PHYSIOGRAPHIC SETTING

In the discussion on what causes springs it was indicated that some springs are caused by topographic features that expose aquifers. Consequently springs are common along river valley sides, glacial spillway sides and on and along the base of escarpments. A good example of a valley cutting through an aquifer and springs along a valley side is the Assiniboine Valley east of Brandon (Figure 2). Springs are common along the Manitoba Escarpment in the Riding Mountain and Duck Mountain areas (Figure 3).

Numerous small and some of the most spectacular artesian springs in Manitoba occur in low flat areas, sometimes a considerable distance from uplands. Examples of this type of physiographic setting are Poplar and Blue springs (Locations Bel-14-2E, 8-16-3W) and three springs in SW6-12-3E in the Interlake Region (Figure 9).

Gravity springs are fairly common along ancient beach ridges on the slopes and at the base of Manitoba Escarpment. Some of these springs are indicated by signs along Highway No. 10, north of Dauphin.

Springs can also occur below water in streams and lakes. Unless the discharge is substantial and the stream is clear and shallow they are difficult to detect. Usually they are indicated by "craters" and swirling sand in the stream or lake bed. Water in some spring-fed lakes may have a bluish or greenish tinge. Some springs can be noticed at low water level in the bottom of Assiniboine River from a lookout point along the trail to the Carberry Sand Hills in Spruce Woods Provincial Park.

Springs usually are visualized as pools of crystal clear bubbling water from which a small stream issues. In Manitoba some springs in the Interlake Region, as shown in the photograph in Figure 10 have this picturesque setting. However, more often the appearance of springs and conditions around them are quite different. Because fresh-water springs enhance the growth of vegetation often they are hidden in tall grass and weeds and are surrounded by dense growth of shrubs and trees. If the discharge of the spring is low it is lost in the
FIGURE 9: SPRINGS IN A LOW, FLAT AREA IN THE INTERLAKE REGION.
Figure 10: (a) Spring and stream issuing from it, and (b) Schematic drawing of hydrogeological setting of the spring (location, Section 6, Twp. 15, Range 3E).
vegetation and, especially in summer, there is no pool of water and no
distinct discharge point. The saturated decaying vegetation may form
a swamp around the spring. Thus the springs may look more like peat
bogs and only the discharge of clear water from the bog instead of
the typical brownish swamp water may be an indication of the presence
of springs. Such swamp-surrounded springs or swamps caused by springs
are common in the headwater area of Rat River, Pine Creek and Sprague
Creek south of Woodridge on the slopes of the Sandhills upland in
southeastern corner of Manitoba.

**SPRING DISCHARGE**

The discharge of springs in Manitoba varies over a wide range;
the discharge of some springs is very low and barely noticeable even at
close range, and, on the other end of the scale, the flow of some springs
is high enough to start a fair size stream (Figure 11).

The rate of flow from a spring depends on several conditions
and combinations thereof. For gravity springs the discharge depends
mainly on the transmissivity of the source aquifer, particularly at
the point of discharge. If the transmissivity is low the movement of water
in it is slow and consequently the discharge of the springs is low. High
transmissivity aquifers can transmit water at a high rate, if there is
adequate hydraulic gradient. Consequently, if the discharge is concen-
trated at one point, i.e., in one spring, the flow can be high (Figure 12).

The flow from artesian springs in addition to transmissivity
of the aquifer is also strongly affected by the artesian pressure or head
above the spring's orifice level. If the head is well above ground level
springs issuing from an even moderately permeable aquifer would have high
discharge rates. On the other hand, if the head is barely above ground
level a high transmissivity aquifer would flow at a low rate. Of course,
if both artesian pressure and transmissivity of an aquifer are high the
result is a very high discharge rate. The flow rate of a spring can also
be affected by the orifice size in the confining layer. If the orifice
is small it will restrict discharge.
FIGURE 11: CREEK ISSUING FROM THE SPRING, FIGURE 10, DISCHARGE ABOUT 100 L/s (0.1 m³/s), THE WIDTH OF THE CREEK IS ABOUT 1 m.
FIGURE 12: FAIRLY HIGH DISCHARGE GRAVITY SPRING ISSUING FROM BANK OF ASSINIBOINE RIVER.
This can happen where discharge is through cracks in hard rock.

Since spring discharge is affected by artesian pressure in confined aquifers and water table in unconfined aquifers, which change seasonally and also over longer periods of time, the flow rate from springs can change seasonally and over a period of several years. If the head at an artesian spring is only slightly above ground level, minor decrease in the pressure can reduce the flow considerably or stop it altogether.

The reduction of the artesian pressure or lowering of water table is usually caused by natural conditions, e.g., lack of recharge to the aquifers. However, in some areas the detrimental effect on artesian pressure and water table can be the result of man's activities, e.g., groundwater development for use in the vicinity of springs (see Spring Protection).

The discharge rates range from less than 0.1 L/s for very small springs to 100 L/s or more for large or high discharge springs. In terms of water supply the discharge of very small springs is adequate for domestic needs for a few families and the very large springs could supply a city of about 30,000. Only a few springs in Manitoba discharge 100 L/s or more during periods of high discharge. The large springs are located in the Interlake Region about 15 km northeast of Stonewall in Section 6-15-3E and about 12 km west of Arborg in Section 9-22-1E (Figure 13). The reason for the scarcity of large springs is that only rarely all the conditions necessary to cause them such as high transmissivity, high head, large recharge area, and adequate recharge rate coincide. Usually one or more of the conditions necessary for high flow springs are missing. Consequently, low or medium flow springs that discharge a few litres or a few tens of litres per second are far more common than the 100 L/s springs.
FIGURE 13: LOCATIONS OF SPRINGS REFERRED TO IN THE TEXT.
INTERMITTENT SPRINGS

Not all springs discharge continuously. Probably the most common intermittent springs are those that flow in the spring and early summer, usually dry up during late summer and winter, and start flowing again in the next spring. Other springs may flow for years and be dormant for years. Intermittent springs are caused by water table or external pressure changes in the aquifers feeding the springs, that, in turn, depend on recharge conditions.

The hydrographs in Figure 14 and 15 show that typically groundwater levels are high in the spring and decline from one spring peak to the recovery of the next spring. In addition to the seasonal fluctuation there are shorter period fluctuations which may last several days or hours, and long term trends, which may continue for several years. If the ground level elevation at a spring happens to be between the elevation of the peak of the groundwater level in the aquifer and the lower level of it, the spring will flow at high levels and dry up at the lower levels (Fig. 16).

Some springs dry up during the growth season every summer and start flowing in late fall after it ends. This phenomenon can be related to water consumption by vegetation, particularly trees. Dense growth of trees can consume (transpire) large quantities of water, i.e., the trees act like pumps dewatering the aquifer. The dewatering causes a decrease in groundwater level and termination of spring discharge. The effect of vegetation on springs, of course, can happen only in areas where the aquifers are near ground level and can be reached by roots.

SPRING WATER QUALITY

"Spring water usually is considered to be pure, wholesome and much better in quality than well or other water. The fact is, spring water is nothing but groundwater and there is little difference
Figure 14: Groundwater level hydrograph for an unconfined aquifer near Hartney in southwestern Manitoba.
between it and nearby well water (Hattie, 1981).

In Manitoba, spring water ranges from fresh water with very low mineral concentration to brines two or three times saltier than sea water. Why is it so?

The reason for the great differences in spring water chemistry is the fact that spring waters originate under widely different conditions and in different areas.

The water of some springs originates as precipitation, mainly snowmelt and spring rain, over an area adjacent to the spring and the distance the water travels from the point where it enters the aquifer may range from a few tens of metres to a few kilometres at the most. Thus the water is in contact with the soil for relatively short periods of time (from a few days to several years) and, if the material happens to be very insoluble such as quartz or granitic sand and gravel, the groundwater is low in mineral content and water in a spring issuing from the aquifer has low mineral content. Such conditions exist at the spring adjacent to P.T.H. 216 at the north end of Hlinner Ridge (Figure 13, Spring No. 1). Similar conditions exist at other springs in Agassiz and Belair Forest area.

At other springs the distances travelled by groundwater are longer and the aquifer materials are more soluble. For example, the water issuing from the springs in the Interlake area originates as precipitation over the upland between the lakes (Figure 5). The water there may travel tens of kilometres before emerging as a spring. The rock in the area comprises limestone and dolostone, which are more soluble than quartz and granite sand and gravel. Consequently the water is somewhat more mineralized but still quite fresh and of good to excellent quality. Chemical analyses of water from several springs issuing from sand and gravel and carbonate rock aquifers are listed in Tables 1 and 2 in the Appendix.

A situation where water in an aquifer originates as precipitation over the aquifer in which it is found or not more than several tens of kilometres from it constitutes a local groundwater flow system. Numerous local flow systems exist in Manitoba. In areal extent they may range from a few hectares to more than 100 square kilometres.
In some groundwater flow systems, water travels for hundreds of kilometres through various materials, the flow systems may extend over thousands of square kilometres and the travelling time is measured in thousands of years. These extensive flow systems are called regional flow systems. Water in the deep regional flow system generally in a highly mineralized brine. The regional flow systems are at considerable depth and generally they do not affect water quality in the local flow systems that exist above the regional systems (Figure 3). However, in some areas, water from the regional systems emerges at ground surface and mixes with water in local systems.

The mineral concentration in some deep formation waters (van Everdingen, 1971) in Western Manitoba ranges from 200 000 to 300 000 mg/L. (Appendix, Table 6) and it is 100 to 1000 times higher than in the local flow systems. Indications are that as the very highly mineralized waters move easterly they mix with less mineralized waters which dilute the deep formation waters.

In areas where groundwater quality is affected by the regional flow systems, spring water is highly mineralized and brine springs are common. These conditions exist in extensive areas along the western shore of Lake Winnipegosis around Dawson Bay and at some locations on the east shore of Lake Winnipegosis. The total dissolved solids concentration in the brine springs ranges from 25 000 to 63 000 mg/L (Appendix, Tables 3 & 4). Fortunately the discharge of the salt springs is low and, consequently, they have no "appreciable effect on the salinity of the rivers into which they flow" (Kitchin and others, 1969).

The springs with excellent to good water quality resulting from readily recharged local flow systems and the brine springs strongly influenced by the regional flow systems are at the extreme ends of water quality in springs. At many springs groundwater flow system conditions fall somewhere in between these extremes and, therefore, water quality also is likely to be somewhere between good and unpotable.
FIGURE 16: EFFECT OF GROUNDWATER LEVEL (POTENTIALISTIC SURFACE) FLUCTUATIONS ON INTERMITTENT SPRINGS.

a) HIGHLY GROUNDWATER LEVEL.
b) LOW GROUNDWATER LEVEL.
BRINE SPRINGS

Since early settlement in Manitoba there has been considerable interest in the highly mineralized water or brine springs along the shores of Lake Winnipegosis. One of the first investigators of the springs was Tyrell (1902) who inspected and described the springs and obtained samples for chemical analyses. Later investigations of the springs were carried out by Cole (1915) and Cameron (1930, 1949). The latest inventory of the brine springs was carried out by Manitoba Mines Branch in 1973 (Stephenson, 1974). In 1984 Wadlo (1984) investigated six springs in the brine spring area. The locations of the brine springs are indicated in Figure 13 and the chemical analyses of water from a number of the springs are listed in Tables 3, 4 and 5, (Appendix). In the brine spring waters the main dissolved mineral is sodium chloride or common salt; in most of the springs sodium chloride constitutes 90 to 93 percent of the dissolved solids. The total dissolved solids concentration ranges from 25,000 to 63,000 mg/l. By comparison water in deep formation waters in Manitoba contains 95 to 97 percent of sodium chloride and the total dissolved solids concentration can be more than 300,000 mg/l. (Van Everdingen, 1971).

Production of common salt by evaporation of brines from these mineral springs was the first mineral industry in what is now Manitoba (Cameron, 1949). Production started in about 1880 from several springs along the west shore of Lake Winnipegosis. By 1876 Monkman’s Springs which had become the centre of the industry was producing more than 80,000 kg (1000 bushels) a year (op. cit.). Production ceased shortly after 1876 because it was more economical to import rock salt from Ontario.

The discharge of the salt springs is low; at most of the brine springs it is less than one litre per second. Of 13 springs inspected by Cameron (1949) the highest discharge was 4.6 l/s.

According to Stephenson (1974) flow rates for most of the 46 springs inspected in 1973 the estimated flow was less than 0.2 l/s. The flow, however, appeared to be well below maximum (op. cit.). In general, the brine springs are more conspicuous by the lack of green vegetation or any vegetation at all than by discharge of water. The only plant that thrives around the brine springs is red sagebrush.
(Salicornia rubra) that can readily be recognized by its red foliage. Around some springs lush growth of salt grass can be found (Cameron, 1949).

TELEMETRY

At the point of discharge spring water temperature should be the same as groundwater temperature in the aquifers in the surrounding area. In general, groundwater temperature in wells in southern Manitoba is between 5.5°C and 6.0°C. Consequently water temperature in most springs should be in the same range.

Charrom (1974) reports that spring water temperature of 3.5°C and well water temperature as low as 3.0°C have been observed in southern Manitoba. These lower temperatures occur under exceptional conditions. The lower well and spring water temperatures seem to be related to exceptionally rapid recharge of aquifers by snowmelt.

A short distance from the spring orifice the spring water temperature is likely to be considerably higher or lower depending on the ambient temperature, particularly if the discharge is very low and the temperature difference is large, e.g. on a hot day.

Groundwater temperature, in general, under natural conditions does not have significant seasonal changes. Hence, spring water temperature at the orifice also will be practically constant and one should not be surprised by the coldness of spring water in the hot days in July.

PROBLEMS CAUSED BY SPRINGS

It is believed that springs are always beneficial or a blessing and that they could cause no harm or that they could be in any way detrimental. The fact is that in some locations springs can cause considerable problems.
In Manitoba, one of the main problems caused by springs is icing up of stream channels and drains. This happens where the discharge is too low to maintain a live stream in winter. If the discharge is low, at some distance from the spring it freezes. The stream channel or drain then fills up with ice. This causes spreading of the water, which, in turn, enhances cooling and freezing. The ice buildup closes stream channels and drains, fills channels under bridges and plugs culverts and sometimes spreads out on adjacent fields and roads. The net result is no channel when the spring runoff comes and consequent flooding of fields and roads, damaged bridges and other structures. This problem is common in several areas at the base of the Manitoba Escarpment and at the base of the Sandilands Forest, Agassiz Forest Reserve and other uplands in south-eastern Manitoba and in the lower parts of the Interlake Region.

The icing up of drains can be prevented by either stopping the springs completely or by increasing the flow sufficiently to maintain an adequate flow. Both methods have been used by the Manitoba Water Resources Branch. In areas where conditions are favourable, springs (and abandoned flowing wells) have been sealed off and, in other areas, the discharge has been increased by diverting the discharge from numerous low discharge springs to high discharge springs or flowing wells.

Wet fields and soil salinity can be caused by man made springs, i.e., abandoned flowing wells. Swamps and bogs caused by springs were fairly common in the Interlake Region. Many of these man-made springs have been sealed off and the wet areas turned into cultivated fields. If the water issuing from the springs flooding a field is salty, it can cause soil salinization.

Man-made artesian springs usually can be readily sealed off by pumping cement grout into the orifice, which restores the confining layer to its natural state.

Since they are the result of a weakness in the confining layer natural artesian springs usually can not be sealed off. If the spring is sealed at one point, it is likely to break out at some other point. The discharge from artesian springs sometimes can be stopped by building a ring dyke around it. (Figure 17).
FIGURE 17: STOPPING SPRING DISCHARGE BY A RING DYKE AROUND IT.
FLOWING WELLS

What have flowing wells in common with springs? In general, flowing wells are very similar to artesian springs and the same basic hydrogeological conditions must exist at a flowing well as at an artesian spring. The only difference is that the orifice that connects the aquifer to ground surface is natural in a spring and is man-made for a flowing well. Thus, one can expect flowing wells near artesian springs. The converse, however, generally is not true. Flowing wells often are installed in areas where the confining layer is too thick for springs to break out and therefore the existence of flowing wells is not necessarily an indication for favourable conditions for springs.

Dying Up of Springs

In addition to short or long term periodical fluctuations, which are the cause of intermittent springs, water table and artesian pressure of aquifers can decline permanently. If the decline causes the groundwater level of a spring to drop below ground level the spring ceases to flow or it dries up.

The decline of groundwater levels can be caused by natural conditions or it can be the result of man's actions. The natural decline can be caused by decrease in precipitation in the recharge area of an aquifer, erosion that increases discharge from aquifers, earthquakes changing groundwater flow patterns and by percolation by the springs themselves.

Man can cause lower groundwater levels by increased use of groundwater, structures that increase groundwater discharge, diversion of water from recharge areas and by other activities. For example, in the early days of Winnipeg flowing wells existed in some parts of Winnipeg (Johnson, 1934) and just northwest of the city. Increased groundwater consumption has caused the water level in the former flowing well areas to drop well below ground level. If there were
any springs in the area they all have dried up. The discharge from
a number of springs in the Interlake Region that were causing problems
were stopped by installed flowing relief wells along a drain to main-
tain a live stream during the winter.

The effect on groundwater level of a few widely scattered
low yield wells usually is very minimal and it is not noticed. Conse-
quently it is not likely to affect nearby springs. However, concen tra-
tion on many low yield wells in a small area or a few high capacity
wells may cause appreciable decline in groundwater levels and it may
cause drying up of springs.

SPRING PROTECTION

Springs that are used for water supply, are essential to
maintain stream flow, or are desirable for esthetic or ecological
reasons can be protected from detrimental effects caused by ground-
water development or water diversion in adjacent areas by restrict-
ing undesirable groundwater development under the provisions of
the Water Rights Act. Under the provisions of the Water Rights Act
groundwater resources are managed by the Water Resources Branch to
protect groundwater users and to protect the resources.
GLOSSARY

Aquitard A natural material that transmits enough water to be significant on a regional scale but not enough to supply individual wells or springs.

Aquiclude Rocks or unconsolidated materials that store water but do not transmit significant amounts.

Artesian Refers to groundwater under sufficient hydrostatic head to rise above the aquifer containing it.

Artesian Pressure The hydrostatic head, i.e., pressure, which rises water in a well above the level at which it is encountered by the well.

Confining Layer A practically impermeable layer of rock or unconsolidated materials that separates an aquifer from the atmosphere.

Dolomite A mineral, Ca Mg (CO₃)₂; a common rock forming mineral, the mineral forming the rock dolostone.

Flow System Groundwater flow that originates as recharge in a common physiographic environment and moves toward a common discharge area constitutes a groundwater flow system.

Glacial A valley formed by a stream issuing from a glacier or a proglacial lake, i.e., a lake created by a glacier.

Interlake Region The area between Lake Manitoba and Lake Winnipeg.

Hydrostatic Head Pressure of a fluid (water) upon a unit area due to the height at which the surface of the fluid stands above the point where the pressure is determined, e.g., ground level, top of well casing.

Hectare Area of a square 100 meters on side.

Hydrograph A graph showing stage, flow, velocity, or other property of water with respect to time; in respect to groundwater it usually refers to water level (potentiometric surface or water table) in an observation well.
<table>
<thead>
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<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Igneous Rocks</td>
<td>Rocks formed by solidification of hot molten material termed magma; contrasted with sedimentary rocks, which are formed by the accumulation of sediment in water or from air.</td>
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<tr>
<td>mg/L</td>
<td>Milligrams per litre, i.e., thousandth of a gram per litre.</td>
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<td>Permeability</td>
<td>The capacity of a material (rock, unconsolidated material) for transmitting a fluid (water).</td>
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<td>Potentiometric</td>
<td>An imaginary surface that everywhere coincides with the static level of the water in the aquifer (piezometric surface); it is indicated by the level to which water rises in an artesian well.</td>
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<td>Surface</td>
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<td>Recharge,</td>
<td>The quantity of water, expressed as millimetres of water over recharge area that enters an aquifer in a given period of time; usually in a year.</td>
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<td>Groundwater</td>
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<td>Shale</td>
<td>A sedimentary rock in which the constituent particles are dominantly of clay grade.</td>
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<td>Till</td>
<td>A mixture of clay, silt, sand, gravel and boulder size materials deposited by a glacier (in Manitoba, the glaciers of the Ice Age).</td>
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<td>Unconfined</td>
<td>An aquifer overlain by permeable material and in direct contact vertically with the atmosphere.</td>
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<td>Aquifer</td>
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<td>Water Table</td>
<td>The level to which water rises in an unconfined aquifer.</td>
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REFERENCES


APPENDIX
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<tr>
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<th>LOCATION</th>
<th>SPECIFIC CONDUCT.</th>
<th>HARDNESS</th>
<th>TOTAL ALKALI</th>
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L Less than
* Pederlow, 1970
* * Na < C

Note: Locations shown in Figure 13.
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L Less than
* Chiron, 1974

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* After Tyrrell, 1889; others from Cole, 1913 (van der Zeeveld, 1971)
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<th>ANIONS mg/L</th>
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Well locations shown in Figure 13.
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<th>BARIUM Br</th>
<th>BROMIDE</th>
<th>COPPER</th>
<th>FLUORIDE</th>
<th>IODIDE</th>
<th>IRON Fe</th>
<th>LEAD Pb</th>
<th>LITHIUM Li</th>
<th>MANGANESE Mn</th>
<th>SICKLE Ht</th>
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<th>STROMONT</th>
<th>ZINC</th>
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AFTER H. WADEN, 1984
LOCATIONS INDICATED ON MAP FIGURE 13.
L = LESS THAN
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<th>MG(^{2+}) mg/L</th>
<th>NA(^{+}) mg/L</th>
<th>K(^{+}) mg/L</th>
<th>CL(^{-}) mg/L</th>
<th>SO(_4^{2-}) mg/L</th>
<th>NO(_3^{-}) mg/L</th>
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WELL LOCATIONS SHOWN IN FIGURE 11.