INDUSTRIAL WATERS OF CANADA

Report on Investigations, 1934 to 1943

(Revised edition of Report 807)

BY

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PREFACE

The investigation of the quality of Canadian waters used or available for industry was begun in 1934. Accounts of the work accomplished were first published in five interim reports in mimeographed form, the first issued in 1936 covering the work in 1934 and 1935, and others each subsequent year until 1942, when an edition of 2,500 copies of Report No. 807 "Industrial Waters of Canada" was published. This embodied the information contained in the first five interim reports and certain additional information. In 1944, interim report No. 6 containing the analyses of surface and civic waters collected in 1941, 1942, and 1943, was issued in mimeographed form.

Owing to the large demand, Report No. 807 is now out of print. With the reversion of industry to peace-time pursuits and the establishment of new industries in different centres throughout Canada, the demand for such information as the report contained has been increasing. It is to meet this demand that the present revised edition has been issued, the major revision being the addition of the information contained in interim report No. 6. The revised report (No. 819) contains tabulations of analyses of 930 samples of waters, 278 of these being surface waters and 652 being civic water supplies.

The continuous investigation of industrial waters, as carried out in most industrial countries, is recognized as being of great importance not only to industry, but to civic authorities as well. The information thus obtained is of special importance in the establishment of new industries and to new or rapidly expanding municipal centres.

Owing to the pressure of more urgent work the Bureau of Mines was forced to curtail its investigations on industrial waters from 1941 to the end of the war. This work, however, is now being actively resumed and broadened as to scope under the direction of J. F. J. Thomas.

Grateful acknowledgment is made to W. D. Collins, Chemist in charge of Quality Waters Division of the United States Geological Survey, and to A. V. De Laporte, Chemical Engineer of the Ontario Department of Public Health, for their co-operation, which, especially at the beginning of the investigation, was of valuable help in carrying out the work. Acknowledgment is also made to J. F. J. Thomas of the Bureau of Mines for his contributions to and assistance in this revised edition.

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Industrial Waters of Canada

Investigations 1934 to 1943

INTRODUCTION

Water owes its usefulness and its peculiar characteristics both to its physical properties and to its chemical inertness. Conditions of temperature and vapour pressure determine whether it occurs as a solid, a liquid, or as a vapour.

In nature, water is in constant circulation from the ocean to the land and back; the sun's heat and the wind cause evaporation from the earth's surface and the ocean, and part of this vapour is distributed over the land by the circulation of the air. Eventually, it is precipitated as rain or snow to accumulate in hollows forming ponds or lakes, snowfields and glaciers, or to flow in streams from higher to lower levels under the action of gravity. This natural circulation of water from low to high levels, and its return to low places on the solid surface of the land, is of prime importance to the inhabitants of the earth.

This natural circulation of water from ocean to land and back makes possible the development of water power, including the immense hydro-electric plants on which mining and many other important industries depend.

Water during its circulation from ocean and back to ocean does not remain pure; it gradually dissolves various, more or less soluble mineral salts from the soil. Sometimes the quantities of salts dissolved are large, especially when the water has passed deep into the earth's crust before reappearing at the surface on its journey towards the sea; again, the quantity of salt dissolved may be relatively small, especially in the water that migrates across the surface of the land. In addition to dissolving mineral salts, migrating water may become charged with organic matter of either animal or vegetable origin, with gases absorbed from the air or caused by the decomposition of organic matter, and with suspended and colloidal matter of various origins.

Water is the most important of all mineral resources since life cannot, and few industries, if any, can function without its aid. Among its many uses in industry may be mentioned the following: a solvent in chemical processes, such as soap manufacture, dyeing, fermentation, manufacture of sugar, tanning, in the manufacture of textiles, pulp and paper, and in baking; in ore dressing; as a vehicle for conveyance of pulped material; for cleansing; for cooling; for the distribution of heat and power, either thermo-dynamic or hydraulic; fire extinguishing. One of the questions asked by a manufacturer when choosing a new site for a plant is "What is the quality of the local water supply?"

Salts, gases, and organic matter, either in solution or in suspension, are often deleterious in industrial processes and cause serious operating problems with consequent increased cost of production. Waters in different localities are never exactly alike; moreover, a water from the same source, whether lake, river, or ground water, does not remain constant but changes in composition and concentration of impurities not only seasonally but even over longer periods.

Some waters are much better adapted for certain industries than others, and for this reason the Department of Mines in 1934 began a systematic study of the waters of Canada that are in use or are available for use, both domestically and industrially, greater stress being laid on the industrial side.

Few waterworks laboratories are in a position to furnish a complete mineral analysis of their raw and treated waters. Their laboratory work is confined chiefly to plant control in operation of the purification processes, with the object of produc-

ing a clear sparkling water safe for human consumption. Leading industrialists admit that insufficient attention is given to the composition of their water, the reason generally advanced being that water is an abundant and cheap commodity and its impurities, in most cases, are not easily detected except by chemical analysis. Water analysis belongs to the more difficult tasks confronting the chemist; it calls for special training to get satisfactory results, not so much on account of complexity in the composition of waters, but because much greater accuracy and analytical skill is needed than for analysing other minerals. For example, the difference in results permissible between duplicate analyses of an ore would be regarded as a very serious error in a water analysis. At many plants the laboratory staffs have neither the time nor the equipment for these exacting and time-absorbing analyses.

Because of this very scanty information as regards the quality of the industrial and domestic waters in Canada, requests have been made from many quarters for a nationwide survey of these waters. Such a survey must be of a continuous nature to show seasonal and longer variations.

The term *natural water* as used in this report refers to rain water, surface water and ground water. *Surface waters* are waters in creeks, rivers, ponds, and lakes. *Ground waters* are sub-surface waters, springs, and wells. Any of these waters processed for consumption are termed *treated waters*.

PREVIOUS INVESTIGATIONS

Canada

Samples of natural waters from streams, springs, and wells have been analysed in the laboratory of the Mines Branch, Department of Mines, from time to time. In 1917 a report was published by the Department on the "Mineral Springs of Canada," Part I, dealing with the radio-activity of Canadian mineral springs.[1] This was followed in 1918 by Part II on the chemical character of Canadian springs.[2] In 1919 an investigation was started by the Geological Survey on Canadian surface waters, commencing with the Fraser Valley. A number of samples were collected from the Fraser River at New Westminster and analysed. The investigation was discontinued, however, in the spring of the following year and no systematic investigation of Canadian water was again attempted until 1934, when the industrial waters investigation was started.

Great Britain

In Great Britain analyses of many water supplies are available from the publications of the Royal Board of Health, and the Metropolitan Water Board which, in its thirty-three annual reports, has published many water analyses. The treatise "Examination of Waters and Water Supplies" by Thresh, Beale, and Suckling[3] includes analyses of waters from 650 localities in Great Britain.

United States

In the United States the examination of surface and ground waters is conducted by the Quality Waters Division of the United States Geological Survey. The work is conducted by a large laboratory and field staff and has been carried on for many years, the first water-supply paper having been published in 1896. Since then, numerous reports have been issued containing many thousands of water analyses.

Other Countries

Information as regards investigation of waters by the government services in other countries is not available, but judging from the proceedings at the International Congress of Water Purification at Liège, Belgium, in 1939, similar investigatory work appears to be general in most countries where sanitary control prevails.

[1] Satterly, John and Elworthy, R.T.: Mines Branch, Dept. of Mines, Canada, Bull. 16, (1917).
[2] Elworthy, R.T.: Mines Branch, Dept. of Mines, Canada, Bull. 20 (1918).
[3] Thresh, Beale, and Suckling: "The Examination of Waters and Water Supplies," pp. 337-405.

DESCRIPTION OF PRESENT INVESTIGATION

The present investigation is a systematic study of the various waters of Canada in use, or available for use, either domestic or industrial, greater stress being laid on the industrial side. Information has been collected and correlated about the water needed by industries on the one hand and the quality of certain Canadian waters on the other.

The following course of procedure has been adopted:—

1. Sampling and complete chemical analysis of surface waters of industrial importance.

2. Sampling and partial analysis of civic water supplies.

3. The gathering of information from manufacturers who are large consumers of water, concerning problems that arise from the quality of the water used in their manufacturing processes.

4. The preparation of a water-hardness map of Canada.

The work thus far completed comprises analyses of 930 samples of water, 278 of these being surface waters and 652 being civic water supplies. Up to 1938 the civic waters were analysed for total hardness, calcium, magnesium, and alkalinity, the information being tabulated and plotted on a hardness map; but frequent demands for more complete analyses of these supplies have since led to the adoption of the following extra determinations, colour, residue on evaporation dried at 110°C., silica, iron, bicarbonate, sulphate, chloride, and nitrate.

Six interim reports were issued as the work progressed, the first published in 1936 covering the work completed in 1934 and 1935, and the sixth in 1944. These reports, besides giving tabulated analyses of natural and treated waters, discuss the general character of waters, outline the methods of analysis, furnish tabulations and diagrams compiled from data of public water supplies, hardness maps for Eastern and Western Canada, and correlate the results with the requirements of purity of waters used in certain industries, as well as the deleterious effects of impurities in some Canadian waters in certain manufacturing processes.

METHODS OF RECORDING WATER ANALYSES

No standard method of reporting results of water analyses has, as yet, been adopted in Canada or elsewhere, although the consensus of opinion is that this would be advantageous to all concerned.

In water analyses, constituents are reported as *grains per gallon*, but it is seldom clear whether the Imperial or the United States gallon is meant; in *parts per hundred thousand*, and in *parts per million*. Some report the bases as basic radicals, others as oxides, and the same with the acids, or as hypothetical combinations. Thus, results of an analysis reported by different methods are not comparable by the recipient unless he is in a position to recalculate the results, which is time-consuming and tedious. The same criticism also applies to methods of making analyses, for which there appears to be no standardization.

In Great Britain the Royal Board of Health has published a report on methods of analysing waters that would be accepted presumably as standard. Regarding methods of reporting analyses there appears to be no standard for expressing chemical results. The necessity for such a standard was discussed by Messrs. A. H. Waddington and C. L. Howard Humphry at the Sessional Meeting of the Institution of Sanitary Engineers at London,[1] October 18, 1934. As far as can be learned this has not been followed up.

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[1] Journal of the Institute of Sanitary Engineers, Nov. 1934, pp. 346, 351.

In the United States the Geological Survey has worked out methods of reporting results of water analysis. These are accepted as standards by many industrial works and laboratories. Information regarding improvements of old methods and devising new, more accurate, and simplified methods is published from time to time.

Originating from a convention at New York in June, 1895, continuous efforts have been directed towards obtaining uniformity in methods of water analysis, and at the Minneapolis meeting of the American Public Health Association in 1899, a committee was appointed with this objective. The results of the work of this committee have been embodied in eight editions of "Standard Methods of Water Analysis," a work first published in 1905, the eighth edition appearing in 1936. In the preparation of the editions subsequent to the fifth edition, "Committee No. 1" of the American Water Works Association collaborated, the preparation of the last two editions being further facilitated by the establishment of a "Joint Editorial Committee," on which Canada is represented by one member. This work is now entitled "Standard Methods for the Examination of Water and Sewage," and is published at the New York office of the American Public Health Association. The methods outlined are adopted generally by Boards of Health in the United States and Canada.

A similar committee was appointed in 1935 by the Canadian Public Health Association and by the Council of the Canadian Institute of Chemistry[1] to study standardization of methods of analysis, methods of reporting analytical results, and classification of industrial and municipal waters. It was named "The Committee on Chemical Water Standards". This Committee has contributed in no small way to the literature of the chemistry of waters, made many recommendations of standards, and issued yearly progress reports to the councils of the above associations.

METHODS OF ANALYSIS ADOPTED

In the absence of recognized Canadian standards, the Department decided to follow the methods of analysis, and methods of reporting analyses, as practised by the United States Geological Survey; that is, results are reported in parts per million, bases as basic radicals, acids as acid radicals, alkalinity as calcium carbonate ($CaCO_3$); hardness as total hardness, and carbonate hardness and non-carbonate hardness expressed as calcium carbonate ($CaCO_3$).

An outline of the methods of analysis used in determining the various constituents in the reported waters is given in the following pages.

Suspended Matter

The bottle containing the sample is shaken well and a measured volume of the water, usually half a litre, is filtered on an asbestos mat in a Gooch crucible, dried at 110°C., and weighed. Difficulty in obtaining a clear filtrate may occur with finely divided suspended matter. Again, when large amounts are present a smaller quantity of the sample may be advisable, in which case the quantity of water required for determination of total dissolved solids is drawn off and filtered from the sample bottle after the bulk of the solids have been allowed to settle out.

Residue on Evaporation

This determination has in the past been erroneously named *Total Dissolved Solids*. Inasmuch as bicarbonates of the alkaline earths do not exist in solid form and those of the alkalis decompose as do some organic compounds when dried at

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[1] Canadian Chemistry and Metallurgy, January 1935, p. 9.

the required temperature the determination does not represent the total dissolved solids in a water, hence the adoption of the above nomenclature by the Joint Editorial Committee on Standard Water Analysis.

In determining the residue on evaporation, a quantity of water, depending on its purity, is measured off and evaporated in a platinum dish on a water bath to dryness, then placed in an air bath for one hour maintaining a temperature at 110° C., cooled in a desiccator and weighed. It is replaced in the air bath and weighing repeated until a constant weight has been obtained.

Silica

In the case of nitrate being present in a quantity exceeding 2 milligrams the total solids should be transferred to a silica or porcelain dish, because the free chlorine formed in adding dilute hydrochloric acid will attack a platinum dish. If there be less than 2 milligrams the procedure is to take up with water, add 1 millilitre of hydrochloric acid (1 : 1) and evaporate to dryness. The residue is moistened with a few drops of hydrochloric acid and taken up with hot water. In the case of large amounts of calcium sulphate, which dissolves with difficulty, this operation will have to be repeated, often with the addition of several millilitres of hydrochloric acid. It is filtered and washed with hot water and the precipitate dried, ignited in a platinum crucible and weighed. Silica is volatilized in the usual way with hydrofluoric acid and a drop of sulphuric acid on the hot plate, after which it is ignited and weighed, the difference between the two weighings being silica. Any residue remaining in the platinum dish is dissolved in hydrochloric acid and added to the filtrate.

Iron

To determine iron, heat the filtrate from the silica determination to boiling and add ammonium hydroxide in slight excess. If only a few drops of hydrochloric acid were added to the residue on evaporation, 1 millilitre of (1 : 1) hydrochloric acid is added to redissolve the precipitate and the solution is again made alkaline with ammonium hydroxide. After allowing it to stand on a water bath for half an hour, it is filtered and washed. Reprecipitation may be necessary in most cases to prevent occlusions. The precipitate is dissolved with water and 1 millilitre of strong hydrochloric acid. One millilitre of strong nitric acid is added to the solution, diluted to a volume of 50 to 100 millilitres, when 5 millilitres of a 2 per cent solution of ammonium thiocyanate is added to the sample and standards and it is nesslerized.

A method for determining iron, published in the Journal of the American Chemical Society in August, 1927, was investigated by the "Committee on Chemical Water Standards," which recommends it as yielding very satisfactory results. The following are the details of the procedure:—

To a 50-millilitre sample of water (or if a smaller sample, diluted to 50 millilitres) add 2 millilitres of a 20 per cent solution of citric acid. Boil 5 minutes. Transfer to a 50-millilitre Nessler tube, cool, and make up to the 50-millilitre mark. Add 2 drops (0·1 ml.) thioglycollic acid and make alkaline with about 2·5 millilitres of ammonia (10 per cent w/v or 36 per cent v/v). Mix by pouring into a small flask and back into the Nessler tube. After 5 minutes compare with a series of prepared standards, or with standard disks in the B.D.H. Lovibond nesslerizer.

If the colour of the sample proves to be too high for the standard it may be diluted and an aliquot portion used, provided proportional amounts of the reagents are added, or the sample may be divided in two or more Nessler tubes without diluting and the sum of the readings taken. If the water is coloured or if there is a turbidity that does not go into solution on boiling with citric acid, the original water may be placed beneath the standard disks of the nesslerizer for comparison.

The nesslerizer should be facing the north window. The marking of the disk represents the actual amount of iron (Fe) producing the colour in the test. Thus, if a colour equivalent to 10 is produced in the test with 50 millilitres of solution, the solution contains 0.2 part of iron per million.

The method is not applicable in the presence of zinc in an amount greater than 10 milligrams zinc chloride per 50-millilitre sample, as this metal depresses the intensity of the colour. The reaction is not appreciably disturbed by relatively large amounts of aluminium, calcium, magnesium, or alkali metals, and sulphates, phosphates, and nitrates do not interfere.

Owing to the very high price of the thioglycollic acid a colour disk is preferable as a comparator to a series of prepared standards.

The filtrate from the iron precipitate is mixed and divided into two equal parts, one for the determination of calcium and magnesium, the other for sulphate and alkalis.

Calcium

To determine calcium add 5 to 10 millilitres of ammonium oxalate and hydrochloric acid until clear. Then boil and add ammonium hydrate until alkaline and all calcium is precipitated. Allow to stand in the water bath for about two hours or until the supernatant liquid is clear. Then filter, dry, ignite, first slowly, then to white heat on a blast lamp or in an electric muffle furnace, cool, and weigh.

Magnesium

For the determination of magnesium, add to the filtrate from the calcium determination 10 millilitres of a 10 per cent solution of sodium ammonium phosphate; add hydrochloric acid until the solution is clear, and cool on ice, then add ammonium hydrate slowly while stirring until the solution is alkaline. Continue stirring until a crystalline precipitate is formed and add slowly an excess of 20 millilitres of ammonium hydrate. Allow to stand in a cool place over night, then filter and wash with a 3 per cent solution of ammonium hydrate, dry the precipitate, ignite, and weigh.

Sulphate

To the portion reserved for the determination of sulphate and alkalis add a sufficient amount of hydrochloric acid to make it slightly acid. Boil, adding slowly 5 to 8 millilitres of hot 10 per cent barium chloride solution, with constant stirring. Allow to stand over night on steam bath, filter, wash thoroughly with hot water, ignite, and weigh the precipitate.

Alkalis

To the filtrate from the sulphate determination an excess of ammonium hydrate and an excess of ammonium carbonate are added. Heat until the precipitate becomes crystalline and settles well. Filter, wash thoroughly, and reject precipitated carbonates. Evaporate the filtrate to dryness and heat gently below redness to volatilize all ammonium salts. Take up in a small volume of hot water and add in slight excess barium hydroxide solution; filter, and wash. Evaporate to dryness, drive off ammonium salts as before, take up in a little hot water, filter, and add ammonium hydrate and ammonium carbonate. If precipitate appears, filter, and repeat the treatment. When no precipitate is produced filter into a small platinum dish, add an excess of hydrochloric acid, evaporate to dryness, drive off the ammonium salt, heat just below redness, and weigh. Great care must be taken in the

final treatment of volatilization of the ammonium salts. The very thin film of sodium and potassium chloride spread over the bottom of the platinum dish is likely to volatilize should the temperature become too high and considerable skill is needed in maintaining the required temperature, because sufficient heat must be applied to remove the ammonium salts and water, yet the sodium and potassium salts must remain intact. It is well to repeat the heating and weighing until constant weight is obtained. Then take up in a few millilitres of water and filter through small filter paper, wash, and place the filter paper in the dish, dry, ignite carefully, and weigh. The difference between the weights is sodium and potassium chlorides.

Potassium

Alkalis are usually reported in waters as sodium chloride. If a determination of potassium be desired it can be determined in the filtrate from the last operation for alkalis by the well known methods using platinic chloride or perchlorate to separate the potassium from the sodium.

Bicarbonate

To 100 millilitres of water in a porcelain dish add 5 drops of methyl red indicator, and run in from a burette sufficient N/50 sulphuric acid to give a distinct red colour. Heat to boiling, when the red colour will disappear, and continue boiling for 3 to 4 minutes. Then add drop by drop N/50 sulphuric acid by means of a heavy glass rod until a permanent red colour is obtained

Millilitre reading $\times$ 10 = alkalinity as $CaCO_3$;

Alkalinity as $CaCO_3 \times 1 \cdot 22 = HCO_3$.

Alkalinity should be determined immediately after the sample bottle has been opened, because the action of air will change the equilibria of hydroxide, carbonate, and bicarbonate.

Free Carbon Dioxide

The determination of free carbon dioxide, as distinguished from the half bound and wholly bound, is made by titrating 100 millilitres of the sample in a short-form, 100-millilitre Nessler tube, with N/44 sodium hydroxide, using 10 drops of phenolphthalein as indicator, stirring gently until a faint permanent pink colour is produced. The free carbonic acid (CO_2), in parts per million, is equal to 10 times the number of millilitres used.

Chloride

In determining chloride, 50 millilitres of the sample is titrated with a silver nitrate solution of which 1 millilitre corresponds to $0 \cdot 5$ milligram of chloride radical, using 1 millilitre of 5 per cent potassium chromate solution as indicator. For samples high in chlorides, 100 parts per million and over, a smaller portion is pipetted off and diluted to 50 millilitres, and for samples less than 5 parts per million of chloride a larger amount is used and concentrated to 50 millilitres by evaporation.

The end point of the reaction is not easily detected. It can be facilitated by the use of yellow glasses by the chemist, or by working under yellow light. A correction of $0 \cdot 1$ millilitre of the titrating solution is usual, but it is better for each chemist to determine his own correction for the end point. Acid water should be neutralized with sodium carbonate using litmus as indicator, and alkaline waters with standard sulphuric acid with phenolphthalein as indicator. Hydrogen sulphide, when present, must be removed by aerating or boiling.

Nitrate

For the determination of nitrate, 50 millilitres of the sample is evaporated to dryness simultaneously with solutions of known nitrate content for comparison, ranging from 0·015 to 0·15 milligram of nitrate (NO₃). It is better not to carry the evaporation to dryness but to remove the dishes from the water bath when only a couple of drops remain, since this facilitates subsequent solution in the reagent. When cool, 1 millilitre of phenol disulphonic acid is added to the sample and to the standard and rubbed thoroughly with a glass rod. It should be diluted carefully, cooled, and an excess of ammonium hydrate added. The presence of nitrate develops a yellow colour. It is transferred to a Nessler tube and compared with standards.

Phenol disulphonic acid is prepared by dissolving 25 grams of pure white phenol in 150 millilitres of concentrated sulphuric acid, adding 75 millilitres of fuming sulphuric acid. The solution should be heated for two hours at about 100° C.

Coloured waters of 10 parts per million and over should be decolorized by adding 3 millilitres of aluminium hydrate, stirring well, allowing to stand for a few minutes, filtering, and washing. If a water is high in chlorides, 30 parts per million and over, silver sulphate is added until all chloride but 0·1 milligram is precipitated.

Hardness

Hardness in water, often reported as soap-consuming power, is caused by any constituent that will form an insoluble soap, but is usually due to calcium and magnesium. It is determined by titration with a soap solution until a permanent lather is formed. A more accurate method, which has been followed in this investigation, is by calculation, the calcium in parts per million being multiplied by 2·5 and the magnesium by 4·1, the sum being then reported as total hardness expressed as calcium carbonate (CaCO₃). The non-carbonate hardness is obtained by multiplying the bicarbonate in parts per million by 0·82 and subtracting the product from the total hardness. This presupposes that the bicarbonate is not present as alkali bicarbonate, a condition not unusual in ground waters. Hardness caused by calcium and magnesium bicarbonate is termed carbonate hardness. The terms *carbonate hardness* and *non-carbonate hardness* are roughly equivalent to the old terms *temporary hardness* and *permanent hardness*.

Dissolved Oxygen

The following method by Millar, modified by A. V. DeLaporte, for determining dissolved oxygen has been used in this investigation. It has the advantage of being rapid, accurate, and suitable for work in the field. It is, however, not applicable to waters abnormally deficient in oxygen. DeLaporte finds that where less than 0·5 millilitre of oxygen per litre is present an error is introduced from the amount of ferrous ammonium sulphate required to dissipate the colour of the methylene blue.

Reagents. (a) Methylene blue solution, 0·1 gram of methylene blue in 100 millilitres of distilled water.

(b) Ferrous ammonium sulphate solution, 0·3103 gram of ferrous ammonium sulphate crystals, and 1 millilitre of concentrated sulphuric acid, made up to 100 millilitres.

(c) Alkaline tartrate solution, 60 grams of caustic soda and 175 grams of sodium-potassium tartrate (Rochelle salts) dissolved in 500 millilitres of water.

Analysis. Fifty millilitres of the sample is pipetted into a 100-millilitre short-form Nessler tube, being introduced below a cover of paraffin oil, and 5 millilitres of solution (c) and one drop of solution (a) are added. Then, from a 10-millilitre

graduated pipette, solution (b) is run in just below the surface of the liquid, and is gently stirred with the pipette, until the colour is just discharged. The pipette reading gives the number of millilitres of oxygen per litre.

One millilitre of oxygen per litre = $1 \cdot 43$ parts per million of oxygen.

Theoretically, 1 millilitre of solution (b) does not equal 1 millilitre of oxygen when working on 50 millilitres of the sample, but the above strength gives approximately correct results.

The analyst should test his ferrous sulphate solution against water of known content of oxygen, preferably distilled water shaken with air until saturation; take the temperature reading, and refer to Roscoe and Lunt's table (Sutton's Volumetric Analysis, page 618, twelfth edition) for the amount of oxygen present.

Turbidity

One gram of Pear's precipitated fuller's earth of 200-mesh fineness suspended in 1,000 millilitres of water is the accepted standard and produces a turbidity of 1,000 parts per million. In this investigation the Hellige turbidimeter has been used.

Colour

Colour is reported in parts per million on the basis of a solution of $1 \cdot 245$ grams of potassium chloroplatinate (K_2PtCl_6), containing $0 \cdot 5$ gram of platinum and 1 gram of crystallized cobalt chloride ($CoCl_2.H_2O$) containing $0 \cdot 25$ gram of cobalt in 100 millilitres of concentrated hydrochloric acid, and diluting to 1,000 millilitres with distilled water. This solution has a colour intensity of 500 parts per million.

Coloured disks have been used in this investigation for the determination of colour intensity.

Hydrogen-ion Concentration

Hydrogen-ion concentration is an important determination essential to the operators of filtration plants, chemical works using large amounts of water, the flotation process, boiler plants, etc. It is expressed in the Sörensen's unit as pH. The success of the flocculation in water purification depends to a great extent on the pH value, which varies with different waters. By correction of the hydrogen-ion concentration to the desired pH value a water can be made to respond more effectively to the formation of the floc.

The pH value of a water is a negative exponent of the concentration of hydrogen-ion in grams per litre. A low value of pH means a high concentration of hydrogen-ions or acidity, and a high value of pH indicates a low concentration of hydrogen-ions or alkalinity. A neutral water has a pH value of $7 \cdot 0$.

The determination of pH value in waters was made by comparison with standard indicators in a Hellige apparatus for field work and in a La Motte for regular laboratory work.

As the pH value changes with time of standing, it should be determined at the time of sampling.

IMPURITIES IN NATURAL WATERS AND THEIR ORIGIN

Water is the purest of all our natural resources. A water of $99 \cdot 7$ per cent purity or carrying 3,000 parts per million of residue on evaporation is indeed an inferior water, inapplicable to many industrial uses without previous purification; yet, any other natural mineral product of similar purity available in large quantities is al-

most unknown. In industry high standards of purity are set for the waters used, and, as the arts progress these become more stringent because higher purity of the products and absence of any discoloration of material is demanded, otherwise the manufactured goods are penalized as regards price. How important the purity of water used in manufacture can be to the purity of a manufactured product is evident when one considers the enormous quantities of water used by some industries, often many hundred times that of any raw material used. In an industrial water, impurities even in comparatively small quantities, if precipitated or absorbed, accumulate and may seriously impair the quality of the manufactured product and the economy of the process.

The purest water found in nature is dew, hoar-frost, and rain water, yet many rain waters are far from pure. This is supported by investigatory work in many localities from a great number of analyses on samples of rain water. A casual inspection of these will show that rain water is a long way from being pure, notwithstanding the cherished idea in the public mind that "water from heaven must be pure". Drops of rain falling through the atmosphere absorb matter in amounts depending largely upon the locality and its influence on the purity of the atmosphere. Above large manufacturing areas the air is often laden with dust of all kinds, soot, silica, silicates, sulphates and carbonates, oxides of sulphur and nitrogen, hydrogen sulphide, ammonia, organic matter, etc. These are absorbed in the falling rain or snow, resulting in a very inferior water. Near the sea-coast, rain carries a quantity of sea salt absorbed from the spray that at times reaches 15 parts per million, but the amount naturally diminishes upon going inland, although spray from the ocean may be carried for many miles. Systematic sampling and analysis for chloride in rain water falling at the city of Troy, N.Y., showed a variation in chloride of from $1 \cdot 05$ to 3 parts per million,[1] the average for the year being $1 \cdot 64$ parts per million, more than for many of our northern and western surface waters.

Even in places where there is no factory pollution of the air, and well inland, the rain water shows appreciable amounts of dissolved and adsorbed matter.

The falling raindrops first pick up the normal atmospheric gaseous and solid impurities. The nitrogen is generally ignored, being a neutral gas, but oxygen is an important impurity in the water on account of its corrosive action. The amount of oxygen dissolved will vary with the temperature of the rain water and so will the carbon dioxide, but the latter, although quantitatively a relatively insignificant constituent of the atmosphere, forming normally only $0 \cdot 03$ per cent of the atmosphere, and as much as $0 \cdot 08$ to $0 \cdot 1$ per cent above the larger cities and manufacturing areas, because of its many times greater solubility in water than oxygen, will be dissolved in the falling drops of rain in appreciable quantities. Carbonic acid (carbon dioxide in aqueous solution) and oxygen in a water play an important part in dissolving certain minerals of the earth's crust with which they come in contact. Other gaseous impurities are ozone, oxides of nitrogen and sulphur, hydrogen sulphide, and ammonia. Oxides of nitrogen and ozone are probably formed during thunder-storms. The solid matters adsorbed from the atmosphere are cosmic and terrestrial dust, which vary in composition according to locality, but usually consist of silica and silicates, carbonates, sulphates, and oxides of the more common metals, chlorides of alkalis, and organic matter such as pollen, decayed vegetable and animal matter and spores of fungi. Any or all of these have been found even in the mid-ocean atmosphere, although in much smaller quantities than inland.[2]

As almost all known substances are soluble, at least to some extent in water, there would appear to be no limit to the number of chemical compounds to be expected in natural waters. The impurities of a natural water depend on the minerals

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[1] Mason, Wm. P.: Water Supply, p. 247.
[2] Pollitt, Alan A.: Technology of Water, p. 12.

and organic substances with which it has come in contact during its course to the larger rivers and bodies of water and ultimately to the ocean.

In most natural waters the impurities usually correspond to those most common in the earth's crust, not, however, proportionately, because some salts and substances are more soluble in water than others. They may be classified as follows:—

Inorganic Matter:

1. In suspension: clay, soil wash, and silt from erosion.
2. In pseudo solution (colloidal): silica, ferric hydrate, alumina, alkaline earths.
3. In solution: solids—iron, manganese, calcium, magnesium, alkalis, carbonates, bicarbonates, phosphates, sulphates, chlorides, nitrates, and nitrites; gases—carbon dioxide, oxygen, nitrogen, oxides of sulphur, hydrogen sulphide.

Organic Matter:

1. In suspension: organic soil wash, decomposing organic matter.
2. In pseudo solution (colloidal): organic wastes, vegetable colours, organic acids.
3. In solution: vegetable colours, organic acids, soluble organic wastes, ammonia, nitrates, and nitrites.

Living Organisms:

Algæ diatoms and other plant forms, bacteria, minute animal forms.

Suspended matter. Suspended matter is derived from erosion of the earth's surface by the water on its course to the sea. The quantities thus carried away from the land are so enormous that the waste of the earth's surface caused by man pales into insignificance. Investigations made of the United States' rivers[1] show that the Colorado River has an annual discharge of suspended silt of 338,000,000 tons, in addition to 4,550,000 tons of common salt, 3,740,000 tons of Glauber's salt, and 4,800,000 tons of Epsom salt held in solution; and the Mississippi River discharges suspended silt to the amount of 443,730,000 tons. But, stupendous as this erosion of the earth's surface may seem, it is estimated that it will require 760 years to remove one inch of the entire surface of the United States. There has been no corresponding systematic investigation for Canadian rivers.

Suspended matter in an industrial water gives rise to many problems and, whether of organic or inorganic origin, must be removed by sedimentation, in many cases supplemented by coagulation and filtration.

Matter in colloidal solution. Colloidal matter of inorganic origin, such as the hydrates of iron and alumina, usually occurs in small quantities. Silica, however, may be present in appreciable quantity, the highest value found so far in the investigation of Canadian waters being 37·5 parts per million, but quite a number range from 10·0 to 25·0 parts per million. The state of silica in natural waters is not definitely known, but, in reports of analyses, it is generally assumed to be colloidal, taking no part in the equilibrium between acids and bases.[2] Silica is objectionable in an industrial water, especially in boiler waters, since it forms a hard boiler scale difficult to remove. Organic matter in colloidal state causes many industrial operating problems, such as discoloration on white and lighter-coloured materials (paper, textiles, or paints), foaming and priming in steam boilers, etc., and must be precipitated by coagulation and separated off.

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[1] U. S. Geol. Surv., Water Paper 274.

[2] U. S. Geol. Surv., Water Supply Paper 658, p. 5, by W. D. Collins, W. L. Lamar, A. W. Lohr.

Matter in solution. The gases dissolved by a water play an important part in dissolving mineral matter from the earth's crust. These gases in water cause corrosion of metals, oxygen and carbon dioxide, especially in combination, forming a very active corrosive agent. They are present already in the falling rain-drops and are dissolved later in the water from the air or through decomposition of organic matter.

Carbonates of iron, calcium, and magnesium are practically insoluble in water but readily form soluble bicarbonates with carbonic acid.

$$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$$
$$MgCO_3 + CO_2 + H_2O = Mg(HCO_3)_2$$
$$FeCO_3 + CO_2 + H_2O = Fe(HCO_3)_2$$
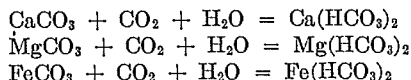
Similarly, dissolved carbon dioxide can act upon pyrite (FeS_2) and other sulphide minerals according to the equation:—

$$FeS_2 + 2CO_2 + 2H_2O = Fe(HCO_3)_2 + H_2S + S$$
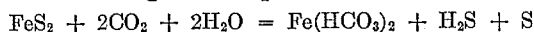
Oxygen also acts on pyrite and sulphide minerals according to the formulæ:—

$$FeS_2 + 2O_2 = FeSO_4 + S$$
$$2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4$$
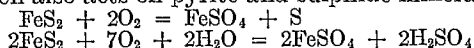
In the former case the excess sulphur remains in the free state; in the latter as sulphuric acid, the form usually found in sulphide ore mines in the acid mine water.

Iron and alkaline earths also form salts with the humus acids' group. The presence of humates in waters is the reason why waters highly coloured by peaty (humus) substances on analysis will not balance their bases against the acids, but show an excess of bases, although the waters may be distinctly acid. Humates do not readily break up with the usual $N/50$ sulphuric acid on titration. Furthermore, the determination of bound humic acid in such small quantities as are present in a water is difficult to carry out with the accuracy required for a water analysis.

Bicarbonates usually constitute the bulk of the soluble mineral salts in most natural waters, next in importance being sulphate of lime dissolved by contact with gypsum, and then smaller quantities of chlorides and nitrates of alkalis.

Much slower is the rate of solution from granites and other silicate igneous rocks. The carbonic acid slowly decomposes the rock, part of which dissolves in the water and part of which remains in suspension or in the colloidal state.

Gases. The gases dissolved in water during the formation and precipitation of the rain-drops are oxygen, carbon dioxide, nitrogen, ozone, etc. Industrial districts add largely to the gaseous impurities of the air, especially carbon dioxide, oxides of sulphur, and hydrogen sulphide. Some or all of these are also added by nature to the atmosphere above volcanoes, hot springs, and natural gas discharges, eventually to be absorbed by the rain, and the same gases, formed by decomposition of organic matter and some minerals, will dissolve in surface or ground waters. Gases dissolved in waters are objectionable in all manufacturing processes; those gases possessing taste and odour being especially so in the production of food products and in civic waters. Gases in waters cause reverse reactions in chemical processes; and many dissolved gases are powerful corrosive agents, causing destruction of metal and painted surfaces.

Organic matter. Organic matter is adsorbed from the atmosphere by the rain, but to a much greater extent from the decomposition of vegetable and animal matter, humus matter from peat bogs and muskegs, soil wash, and plant growth in the water. It is decidedly objectionable in an industrial water and gives rise to many manufacturing problems; discoloration of fabrics and fibres, interference in dyeing, and foaming in boilers. Animal organic substances cause grease spots on paper and fabric that will not take the ink or the dye. Many forms of organic matter impart an unpleasant taste and odour, objectionable in civic waters and in the manufacture of food products, and cause putrefaction in the fermentation and tanning processes.

EFFECT OF CERTAIN IMPURITIES IN WATERS ON SOME INDUSTRIAL PROCESSES

The industries are heavy consumers of water, every process being dependent on this commodity at some stage; especially so the chemical industry, water being the most important of all our chemicals. Its uses are varied: as a solvent, as a diluent, in ore dressing, for cleansing, as a conveyer and distributor of pulped material, in transmission of heat, for cooling, fire extinguishing, and for power—both thermo-dynamic and hydraulic.

The quantity of water used by many industries is enormous, many times, in some cases hundreds of times that of any other raw material used in the process. The water consumption of a fair-sized pulp or paper mill or a large ore-concentrating plant would be adequate to supply a fairly large city.

Owing to the large quantities of water used in processing, for example, ore concentrates, paper, sugar, textiles, or leather, it is evident that impurities present even in small quantities may accumulate by precipitation or concentration to cause very serious operating problems. Salts and other impurities in the water may react detrimentally on substances in the course of processing. Discoloration may be caused by the presence of iron, manganese, copper, and dissolved organic matter; offensive tastes and odours may be developed by impurities such as sulphides and other sulphur compounds, iron, algæ and other organic matter, magnesium chloride and sulphate. Calcium and magnesium salts if present in amounts over $90 \cdot 0$ parts per million cause scale formation in boilers and hot water conduits, and waste of cleansing material (soaps) in laundry and textile work, besides which they may cause inferior textile products from precipitated insoluble soaps adhering to the fabric, etc. Many impurities in a water have an adverse effect on dyeing; on the crystallization of salts from their solution; in metal plating; in the manufacture of mirrors, etc. Some impurities also cause or accelerate corrosion. ·

The following is a brief account of the effect of impurities and of certain characteristics of waters on some manufacturing processes.

Mining Industry

From the earliest days of mining, water has been the main agent for separating the precious metals and the more valuable ores from their gangue; and it still remains such whenever an ore is associated with a large proportion of foreign matter. The volume of water used in the concentration of an ore is very large. One large western flotation plant, for example, uses 16,000 tons ($3 \cdot 2$ million gallons) of water per day. Scarcity of water would severely hamper such an industry and the water from the Dorr settlers would have to be used over again. Most of the water could be circulated were it not for the chemicals added in the flotation process, which would accumulate to undesirable proportions. In consequence, only 6,000 of the 16,000 tons of the water required for the above plant can be reclaimed, and the rest must be discharged to waste.

For the concentration of ores by flotation it is usual that the water used be alkaline. Alkaline waters facilitate the settling of pulp and slime after grinding with water, thus saving time. Alkaline water is essential for most of the flotation reagents and their chemical action on the minerals. Cyanides of the alkaline metals are distinctly alkaline in their reaction, and would decompose in contact with acids in the water, with consequent loss of an expensive reagent. Waters are rendered alkaline in ore dressing by the addition of alkali reagents in sufficient quantity to raise the pH value usually to $9 \cdot 0$ or $9 \cdot 5$. The reagent may be fed to the mill water as milk of lime (calcium hydrate), as free lime in the form of powder (calcium oxide), or as soda ash. Soda ash is preferable in flotation as the lime is likely to precipitate ·

and form a coating of calcium carbonate on the particles of ore, interfering with their wetting by the flotation chemicals. Lime is the usual reagent for raising the pH value of the mill water at gold mines using the cyanide process, and it has the advantage of being one of our cheapest chemicals.

The alkalinity may be determined in the mill by direct titration with 1/50 normal sulphuric acid using methyl orange as indicator on 100 millilitres of the sample, or by determination of the hydrogen-ion concentration (pH value). A correction of the pH value can then be made by the addition of lime or soda until the desired hydrogen-ion concentration is reached.

As a general rule, it may be stated that waters used in the mineral industry, either by flotation or cyaniding, should be free from organic matter and of not too high a content of mineral salts.

Distilled Water

It has been shown previously that all waters, even rain waters, contain more or less dissolved and solid matter and gases absorbed by the water during its journey from ocean to land and back to ocean. To obtain pure water, therefore, distillation becomes necessary. More recently, a water comparable to distilled water for many uses is prepared by treatment with certain anion and cation-exchange resins.

Large quantities of distilled water are manufactured usually in auxiliary plants in connection with manufacturing processes, hence it is difficult to arrive at a figure of the production for the Dominion. Distilled water has a most varied application in industry, being used, for example, in the manufacture of pure chemicals and drugs, in photography, as a diluent of spirituous liquors, in the manufacture of ice, in storage batteries, in the manufacture of yeast, potable waters and soft drinks, and in the plating of mirrors. It is used not only when the purity of the products is essential, but also when the process is very sensitive to certain constituents of the water, as in the following interesting cases.

Silver plating on glass for the manufacture of mirrors is so extremely sensitive to iron that no upper limit can be set for the iron in the water used for the preparation of the silvering solution. At a mirror-plating works using 300 gallons of distilled water per day, it has been found that the slightest trace of iron makes the silver deposit black and granular; and once, when a 2-inch iron pipe connection was attached to the end of the worm of the still condenser, several batches of silver solution were ruined before the cause of the trouble could be traced.

In the manufacture of yeast, sulphates of the alkaline earths retard the fermentation, and alkali sulphates and chlorides somewhat less. Softening the water with soda, sodium zeolite, etc., does not help since the sulphates of lime and magnesia will only be replaced by larger quantities of alkali sulphates. A yeast manufacturer using the waters of the Lower Great Lakes, even when treated, will suffer a loss of time of as much as five to six hours per batch. Manufacturers of yeast have, therefore, found it economical to use distilled water.

The manufacturer of distilled water requires a pure, raw water, low in calcium and magnesium carbonates, which are objectionable inasmuch as they cause scaling of the tubes in the still that is troublesome to remove, and previous softening is preferable. The raw water should be free from taste and odour because the substances causing these may distil over and make the product unfit, especially for potable products.

Pulp and Paper Industry

Pulp and paper mills are among the heaviest consumers of water, which is used in the processes for the conveyance and distribution of pulped material, for cleaning, heating, and as a solvent, hence its purity has an important bearing on the quality of the final product. Owing to the very large quantities of water used, its

treatment becomes an important item in the cost of production, especially in the case of highly coloured waters that impart a yellowish tint to the product. If very white paper is required, the higher price obtained for the product may well pay for the treatment of the process water. Other objectionable impurities in the water are sand, slime, vegetable and mineral matters, iron, manganese, lime, and magnesia.

Suspended solids affect the mechanical efficiency of the plant, by clogging screens, save-alls, wires, etc., and, in the case of sand, by forming pin-holes in the paper. Large quantities of suspended matter will lessen the brightness and decrease the strength of the paper, creating danger of breaks with consequent deterioration of the stock. Animal matters cause grease spots that will not take colour or printing ink. These troubles may lead to the closing of the plant during a heavy run-off, causing loss of production, higher labour cost, loss of stock, and increased replacement of felt.

It is a distinct disadvantage to use hard water in processing wood pulp, particularly sulphite paper, because insoluble calcium and magnesium resinates are formed; these are deposited on the fibre and make subsequent bleaching difficult. In the soda pulp process hard waters are also objectionable because calcium and magnesium salts are precipitated by the caustic soda and carry down colouring matters that are difficult to bleach. In the colouring of paper soft water is desirable because precipitated carbonates form lakes with the dyes.

When sizing with resin, the mineral salts react with the size, forming insoluble resinates which have no sizing action. Furthermore, according to some investigators[1] the salts present in the water affect the colloidal condition of the size, tending to make the resin gather into large particles, thereby reducing the covering power of the size.

Iron is undesirable in the process water as it may precipitate and rust-stain the paper. It should not exceed $0 \cdot 2$ part per million,[2] preferably much less than that. For high-grade paper in which colour is a primary consideration, water containing less than $0 \cdot 1$ part per million of iron is desirable.

Manganese is more troublesome than iron because of black oxide, which may cause clogging of pipe-lines, discoloration of the pulp fibre, and which is detrimental to the stability of the resin size. Manganese dioxide[3] in the absence of acid reaction is an adhesive and forms with calcium chloride a cement-like substance that clogs drain holes. The content of manganese in the process water should not exceed $0 \cdot 05$ part per million.

Textile Industry

The presence of alkaline earths and iron in water used in the textile industry is objectionable, for in the cleansing process the detergent will precipitate insoluble soaps that adhere to the fibre of the fabric. Iron and manganese cause staining. These impurities are most objectionable for alkaline dyes and must be removed by the usual methods of water treatment. Calcium, magnesium, iron, and aluminium precipitate on the fibre rendering the fabric lustreless and of poor quality. Of these, iron and aluminium are the most objectionable; iron, because it will precipitate with the dye to form dark stains, and aluminium, because it forms a scum on the fabric that leaves a spotty appearance when brushed off. Aluminium also acts as a mordant to the fibre and forms lake colours of different tints.

In the manufacture of artificial silk and cellophane, iron in the water is objectionable since it hastens the maturing of shredded cellulose after the treatment with caustic soda. Normally, 90 hours are required for the maturing of the alkali cellulose and the routine of the process is adjusted accordingly, but if the time factor be

[1] Tappi Special Enquiry No. 298, p. 42.
[2] Tappi Special Enquiry No. 298, p. 43.
[3] Tappi Special Enquiry No. 298, p. 36.

variable whole batches of this material might not be processed in time, with consequent loss of production and material. The process water must, therefore, be low in iron; if not, the iron must be removed by the usual treatments, aeration, filtration, etc., before use.

In the silk industry the process of de-gumming, washing, and dyeing differs only in detail from that of other textile processes. In the weighting of silk, however, the quality of the water plays an important part. Weighting of silk is possible because of the tubular structure of the silk thread, which contains two capillaries. The artificial silk threads, rayon and celanese, are solid and cannot be weighted. The amount of weighting of silk is usually calculated on a basis of ounces per pound of raw silk and expressed between limiting variations of 2 ounces, and it is further reckoned that one pound of raw silk is equivalent to 12 ounces of pure silk.

Many methods are used in weighting silk, but the most popular appears to be the tin-silico-phosphate method. It is evident that, as all these chemicals are readily precipitated by carbonates, the process water must not be hard nor contain free carbon dioxide. Any calcium or magnesium salt in neutral or alkaline solution precipitates the phosphate as insoluble metaphosphate that will not weight the silk but covers the fibre causing a lustreless surface to the fabric. Hard waters also form insoluble soaps during the boil-off process that settle on the fabric when it is washed in a soap solution, and, adhering to the cloth, will be broken up by the action of tin chloride, to leave oily spots on the silk that cannot be weighted, nor will these spots take the dye.

Manufacture of Felt Hats

Felt hats are made from rabbit fur that has first been cleaned and then the coarse hair removed, after which it is soaked with water and pressed into large cones. These are felted by successive shrinkings accomplished by wetting and drying between cloth until the desired density of the felt is obtained, when they are pressed into hat shapes. Since the water added to the felt is evaporated, any impurities it may contain will concentrate and remain in the felt, affecting the softness and lustre of the product. Very hard waters or waters containing organic matter must be avoided. Zeolite or soda softening will not improve the condition, as the alkaline earths removed would only be replaced by a larger quantity of alkali salts.

Soap Manufacturing

If hard water be used in the preparation of alkaline liquors in soap manufacture, wastage of alkali occurs through the precipitation of calcium and magnesium salts forming insoluble soaps that become included in the soap, resulting in an inferior product. The same applies to the boiling of the soap if hard water be added at this stage. The boiling is essential in order to attain the proper degree of hydration and to neutralize the fatty acids such as oleic, stearic, and coconut oil.[1] Hard waters are, therefore, most undesirable; in fact, hardness of water is often termed soap-consuming power, the proportion per part per million being $0 \cdot 1$ pound per 1,000 gallons of water.

To users of soap, as in the textile industry dealt with above, in the laundry industry, and in the home, hard water causes waste of soap, because the soap will have no detergent quality until it has softened the water to zero hardness. Since other water softeners are much cheaper than soap, it may pay a community to soften its civic water even though only a very small part of the water is used for cleansing with soap. It has been estimated that for a water of 250 parts per million hardness, the waste of soap would amount to $5 to $10 per annum for a household of five persons.[2]

[1] Pollitt, Alan A.: Technology of Water, pp. 58-59.
[2] Mason, Wm. P.: Examination of Water, p. 30.

Domestic Water

In the home a good, clear, soft water contributes to comfort and lightens the burden of housekeeping. Water containing iron and manganese causes staining on laundered materials, white porcelain, and enamelled receptacles that is difficult or impossible to remove. Hard water is unpleasant for washing and gives poor results in laundry work, owing not only to waste of soap but to the fact that the precipitated insoluble soap adheres to the fabric and imparts an unattractive greyish colour, as well as rendering it rough to the touch. Hard water, moreover, causes scaling in hot water tanks and pipes that adds to the householder's plumbing bill. Many householders, therefore, in districts where the waters are hard, install water-softening devices in their homes, which, apart from the comfort derived from soft water, is also good economy. Small water-softening plants are simple to operate and are comparatively low in first cost, and the saving in soap more than pays for the cost of softening the water. However, as reported below, certain soft waters may be excessively corrosive to the household plumbing.

Manufacture of Ice

Water used for the manufacture of ice must be pure. Calcium and magnesium cause opacity of the ice; organic matter, iron and manganese, discoloration; and other mineral matter such as alkalis, uneven freezing. In the ordinary methods of manufacture the water is frozen as a whole, the cake of ice formed in the mould thickening upwards from the bottom and from the sides. As the ice crystals build up and grow towards the top and the centre, they exclude the impurities, which become concentrated in the centre of the cake, and will eventually freeze provided the temperature is sufficiently low. From this condition, especially when soluble or insoluble organic matters, iron, or manganese are present, results a coloured core and an unattractive ice cake. Since sodium salts are as troublesome as those of calcium and magnesium—the concentrated salt solution requiring much lower temperature to solidify—it has been customary in treating hard waters high in calcium and magnesium bicarbonates to remove these only, by precipitation with milk of lime as carbonates.

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$$
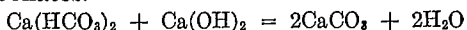
The above difficulties, however, do not arise in such freezing methods as are similar to nature, in which ice forms on vertical freezing plates suspended in cold water.

If high-grade ice is required, distilled water, or water demineralized by exchange resins, is used.

Brewing Industry

From the earliest days of the brewing industry, breweries were built near suitable sources of water, and the water in certain districts, therefore, determined the characteristics of the beers made. For example, the wells at Burton-on-Trent are known for giving the best ales; Dublin and London for stout and porter; and Munich, Pilsen, and Dortmund for lager beer. This still holds and the type of water is an important factor in choosing the site of a brewery.

Water used in brewing, therefore, must be carefully analysed and adjusted to the desired mineral content; the proper balance between the various mineral salts is important to ensure the desired action of the enzymes in the mashing process, a good fermentation, and satisfactorily maturing beer.

For light ales, a water of medium hardness, largely calcium sulphate, is required; and for dark beers and porters, soft waters. In general, waters should be free from organic matter, and should be colourless and odourless. Deficient aeration retards and may even prevent fermentation, resulting in rotting the grain.

The advantages of calcium sulphate in waters for brewing pale ales are several; it does not precipitate the carbonates and it neutralizes the acidity of the wort and the beer; it facilitates the production of peptones and amides during the brewing proper. Further, it causes albuminoids to coagulate in readily separable form during the boiling of the wort, resulting in a clear and good-keeping product.

Bicarbonates are undesirable because they precipitate the phosphoric acid, an essential food for yeast, and thus retard the fermentation. Magnesium sulphate is not desirable because it retards the extraction of the malt and imparts an unpleasant taste to the product, owing to the formation of amyloin.[1] Common salt and potassium chloride are generally beneficial, lending a flavour to the beer noticeably lacking when they are absent. Too much salt, or over 350 parts per million, deters the production and the activity of the yeast.

A water with an iron content in excess of $0 \cdot 1$ part per million is undesirable, since the presence of iron may impart an unpleasant taste and odour and a greenish tint to the beer.

Distillery Industry

The criteria of suitability applied to water for producing a superior product in brewing are equally adopted by some distillers, especially in the United Kingdom where the waters from certain springs are credited with yielding superior grades of liquor. The springs used at some distilleries are closely guarded against contamination and the water is led to the plants in wooden pipes. The effect of the various impurities in the preparation of the mash for brewing applies to the malt preparation for the distilling process: owing to the greater concentration of distillery products the effect would be much greater. For beers and ales the fermentation mashes are adjusted to produce a content of alcohol of about 5 per cent by weight, whereas for distillery products the fermentation is carried to the highest possible alcohol concentration. The most concentrated alcoholic mashes usually contain from 12 to 15 per cent alcohol by volume, although as high as somewhat above 17 per cent alcohol is obtainable from grape juice and sugar solution. Impurities that retard germination and reduce the activity of the fermentation, such as iron, carbonates of lime and magnesia, and calcium chloride should, therefore, be avoided. Organic matter is likely to cause putrefaction during the fermentation of the grain. This, in combination with calcium sulphate, may cause the formation of hydrogen sulphide, which would impart an offensive taste and odour to the distilled spirit.

In diluting the spirituous distillates to the desired content of proof spirit, the water used must be free from calcium and magnesium salts, which would be precipitated by the alcohol, causing cloudiness, and so, in the absence of clear, soft waters, distilled water is regularly used as a diluent in the distilleries.

Tanning Industry

Compared with the amount of tannin extracted in the tanning liquors, the quantity of water used for this, as well as for other purposes in the tanning industry, is very large. Thus, impurities in a water that are precipitated by tannin have an important bearing on the success and the economy of the tanning process. With the exception of the sodium salts, tannin will precipitate all metals that normally occur in natural waters.[2] Lime, magnesia, and iron in the leaching vats result in loss of tannin and, by forming a coating on the leached material, interfere with the extraction. Iron forms dark-coloured precipitates with tannin, ranging from black to dark blue and green according to the origin of the tannin. Any such precipitate reaching the tanning pits causes reduced tanning efficiency and discoloured leather.

[1] Pollitt, Alan A.: Technology of Water, p. 45.
[2] Pollitt, Alan A.: Technology of Water.

If water used in liming the hides contains an appreciable quantity of calcium bicarbonate it precipitates on the hide, and if not removed it makes the de-liming difficult and interferes with the tanning proper, causing brown stains on the leather, due to the oxidation of tannate of lime. Calcium carbonate introduced in this way is very difficult to remove in the acid bath. Bicarbonate of magnesia has a similar effect in the tanning pits, forming readily oxidizable tannates. Sulphates of calcium and magnesium are not harmful and are sometimes added to the water by the tanners. Waters rich in alkali carbonates or in free carbon dioxide bring about the same complications by precipitating the lime in the liming process. Free carbon dioxide up to $5 \cdot 0$ parts per million is not unusual, especially in the northern soft waters; but natural waters rich in alkali carbonates are comparatively rare in Canada. Waters contaminated with organic matter and bacteria are especially harmful in the soaking of the leather, as putrefaction is likely to set in and destroy the tissue of the hide.

Sugar Industry

Raw sugar refineries, cane and beet sugar factories, are heavy consumers of water, especially the last mentioned, for, besides being used as a solvent in extracting the sugar, it is used for cleansing the beets, and for conveyance of the beets from the storage sheds to the factory and of the spent pulp away from the factory, as well as for the production of very large quantities of steam. As milk of lime is added in the process for precipitating soluble organic matter extracted from the cosettes (sliced beets) in the diffusion, bicarbonates of calcium and magnesium do not greatly interfere in moderately hard waters, but waters very high in bicarbonates of the alkaline earths may adversely affect the extraction of the sugar from the cosettes, because when heat is applied calcium carbonate precipitates and coats the surfaces. Sulphates and chlorides of calcium and magnesium and alkali salts, however, are detrimental, holding up an appreciable quantity of sugar in the syrups and molasses. One part of salt will hold in solution five parts of sugar in the massecuite (crystallization from the sugar boiler) and subsequent crystallization from the molasses that has been separated from the sugar crystals by centrifuging. Treatment of water by removing the lime and magnesia by soda or zeolite only aggravates the condition, because it requires a greater quantity of alkali bases to replace those of the alkaline earths and since they act in a similar way they decrease still further the yield of crystallizable sugar obtainable from the concentrated juices and molasses.

In the final treatment of molasses by the osmose process, part of the alkali salts and some soluble organic salts are removed by diffusion through a parchment diaphragm from the hot non-crystallizable molasses running on one side of the diaphragm to the hot water flowing on the other side, making two more crystallizations possible after the syrup has been boiled down to the desired concentration. The water used in this process must be clear and not too hard, as calcium carbonate is likely to precipitate in the hot water and clog and reduce the porosity of the parchment membrane, upon which the principle of this process is primarily based.

Bakery Industry

In bread-making, about equal parts of flour and water are used. That so little attention has been given to the quality of the water is astonishing in view of the fact that the manufacture of bread is a large and important industry. It may be because water is a cheap commodity and that a clear, sparkling water is popularly regarded as free from foreign matter. Nevertheless, certain impurities in a water have important effects on the process of baking bread. The literature on water, in relation to the fermentation of dough, is more popular than scientific, with the result that much confusion exists in the trade concerning this subject.

The problem in practice is the adjustment of the conditions of fermentation to the best use of the local water, not the reverse. Treatment of water is rarely necessary except in localities where the composition is decidedly unsuitable. Corrective reagents are often added at the time of mixing without any expensive treatment of the water. Chemists, who have conducted experiments on waters from bakeries in connection with the manufacture of yeast, aver that it is exceptional to find one that is wholly unsatisfactory. Any potable water is usually suitable. A water of medium hardness, largely calcium sulphate, seems desirable. Dr. H. A. Kohman of the University of Pittsburgh made a study of the effects of mineral salts on the fermentation of dough and of how those contained in natural waters influence the process of the manufacture of bread.[1] Of a large number of substances he studied, surprisingly few have a really significant effect upon the fermentation. The salts of mineral acids, such as chlorides, nitrates, nitrites, and sulphates, which are of common occurrence in water, are almost without effect unless combined with a metal that influences fermentation. This is equally true of phosphates, which is surprising, for they are essential to fermentation. This quasi-paradox may be explained by the fact that flour is relatively rich in these substances, and, therefore, adequately supplies the phosphate requirements of the yeast. Sulphides, however, are particularly objectionable in bread-making. A very small quantity of potassium sulphide renders the dough so sticky that it is impossible to make bread from it.

The carbonates are especially common in natural waters and, as a class, they neutralize the dough and thus interfere with fermentation. The carbonates of the alkali metals are especially harmful, but waters containing them are comparatively rare in Canada.

Sodium chloride is added to bread in much larger quantities than it generally occurs in waters, but in some localities may be present in such concentration as to warrant its being taken into account in the manufacture of bread. Next in importance in the alkali group are the salts of potash. The significance of these salts in the life and growth of yeast is indicated by its ash, analysis of which, according to Netscherlich, shows that potash constitutes about 35 per cent. Calcium chloride has a marked effect in raising the dough. The addition of 3·5 grams of calcium chloride per 1,000 grams of flour increases the volume of the loaf 15·5 per cent. Bakers' bread is usually light—if not indeed too light—hence the volume itself is not important. The increased activity of the yeast, due to added calcium chloride, can be taken advantage of either by shortening the time of fermentation or by effecting economy in the amount of yeast required. From the small quantities of calcium chloride present in civic water supplies, there is little likelihood of much effect on the fermentation of the dough, but it should be beneficial.

Canning Industry

In canning meat a clear water free from organic matter is needed, but hard water does not appear to be injurious to the curing and preparation of meat for consumption.

In canning fruit and vegetables the only vegetable adversely affected by hard water is the pea, which tends to harden and acquires a mealy taste. The turbid juice often found in canned peas is not due to calcium salts precipitated from the water, but to starchy matter. Hard water is, however, beneficial to vegetables and fruits that tend to soften in canning—string beans, peaches, pears, etc.—because it hardens the product, making it crisp and retentive of its shape. Calcium sulphate toughens the vegetable.

[1] Bakers Weekly, Oct. 2, 1915.

Starch Industry

. . In the process of manufacturing, starch is sensitive to coloration, and, since the product must be perfectly white, waters containing iron, manganese, or organic matter (especially those of the humus series) require purification by aeration or flocculation with alum, and filtration.

Glue Manufacture

Glue is made from odd ends of hide, and sometimes from bone. Hard water retards the breaking up of the tissue, wherefore such waters should be softened before being used in boiling glue.

Boiler Waters

For steam-raising, water should be free from sedimentary matter, should contain none, or only a very small quantity of dissolved gases (carbon dioxide and oxygen), and the smaller the amounts of salts in solution the better, especially such salts as precipitate on heating and on concentration. The impurities in a water, their concentration on heating, and the operation and design of the boiler will largely determine the extent of the trouble arising from corrosion, formation of scale, caustic embrittlement, priming, and foaming.

Waters containing carbonic acid or other acids cause corrosion, especially by condensed acid steam, particularly in turbines, steampipes and steam auxiliaries. This carbonic acid may arise from the breakdown of bicarbonate salts or from free carbon dioxide dissolved in the water. Under certain operating conditions carbonates may also break down to give hydroxide and free carbon dioxide. Acids may be formed by the hydrolysis of certain salts, particularly calcium and magnesium chlorides in concentrated solutions, liberating free hydrochloric acid that may pit and even perforate the boiler above the water level.

Nitrates are undesirable in boiler feed waters because they are reduced by the iron of the boiler plates and are given off as ammonia with the steam. Under certain conditions nitric acid may also be formed. Sulphuric acid may be formed at times from improper use of coagulants in the feed water, and acid may also arise from the breakdown of vegetable and animal oils used for lubrication or from organic matter.

Dissolved oxygen in the water accelerates corrosive attack and the presence of carbonic acid accelerates the effect of dissolved oxygen.

Bicarbonates of calcium, magnesium, and iron are readily precipitated on heating and, if present in large amounts, form scale on the plates and tubes; but in smaller amounts, usually set at a maximum carbonate hardness of 90 parts per million and less, the insoluble deposit is precipitated as a sludge that can be blown down. Other salts, like calcium sulphate, deposit and crystallize out when the boiler water becomes concentrated and form a hard scale that is difficult to remove. Failure of the metal by scale deposition may occur either by overheating of the plates and tubes, by pitting corrosion under the scale, or by weakening of the plate from the fire side by oxidation of the overheated metal. Mineral oil in the water may in a similar manner deposit on the tubes and plates and cause trouble from overheating.

In some cases a slight deposit of scale is beneficial, as it forms a protective coating against corrosion. Silicates have been mentioned for such protection, but silica if present in boiler water in any appreciable quantity is deposited with the alkaline earths to form a very hard and tough scale, most difficult to remove. Silica is also said to accelerate the action of caustic alkali in causing intercrystalline corrosion. Potassium salts are said to be more harmful than sodium salts, increasing the amount of iron oxide deposited and in turn increasing the caustic attack on boiler iron.

Too alkaline a water may cause increased corrosion and the particular type of attack known as intercrystalline corrosion or caustic embrittlement. Certain compounds are added to the water to inhibit this attack, such as sodium sulphate, sodium nitrate, sulphite liquor, and Quebracho tannin.

Many of the above objectionable salts may be removed by the usual water-softening and conditioning processes, but as certain processes only replace the alkaline earths by the alkalis the total concentration of soluble salts remains. As the water evaporates these concentrate and crystallize out, unless the boiler is regularly blown down. High total dissolved solids in feed water cause foaming and bumping with carry-over into the steam, due to the denser solution becoming super-heated and then going into violent ebullition.

Corrosion

Corrosion does not occur in pure water free from dissolved gases and foreign matter. Some corrosive agents in water are more active than others; some are inactive or less active singly but active jointly with other agents; others that are active singly become much more active in combination with another agent.

The electrochemical theory is now generally accepted as explaining such corrosive phenomena. In brief, this theory, which is based on fundamental chemical and electrochemical concepts, postulates that when a metal is immersed in an electrolyte (e.g. natural water) ions tend to flow from the metal into the solution at anodic areas, due to the solution potential of the metal displacing the hydrogen ions of the water at the cathodic areas in accordance with the following equation:[1]

$$(1)\ Fe(metal) + 2H^+ (ionic) \rightarrow Fe^{++} (ionic) + 2H (atomic)$$

The law of mass action states that a proportion of water is always partially dissociated so that there are always present free hydrogen or H^+ ions and free hydroxyl or OH^- ions and the concentration of the H ions $\times$ the concentration of the OH^- ions is always a constant. From this basic law the pH (logarithm of the reciprocal of the hydrogen ion concentration) is derived.

If the solution potential, H^+ ion concentration, etc., are favourable, e.g. with certain metals in acid solution, the hydrogen of equation (1) is displaced as a gas. Under conditions usual in neutral solutions such as waters a monomolecular film of atomic hydrogen is established on the metal surface. This separates the water from the metal, polarizing the electrochemical cell. Various metals have different overvoltages which under certain conditions determine whether polarization will occur or hydrogen gas be evolved. Anything therefore that will remove this film of atomic hydrogen (depolarization) accelerates the corrosion process. The atomic hydrogen may then be removed in either of the following ways:

$$(2)\ 2H (atomic) \rightarrow H_2 (molecular\ gas)$$
$$(3)\ 2H (atomic) + \tfrac{1}{2}O_2 (dissolved) \rightarrow H_2O (liquid\ water)$$
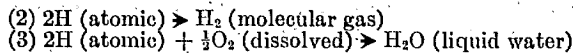
In most solutions equation (1) is faster than equation (2) or (3) which then control. In natural waters equation (3) is the major controlling reaction and the depolarizer is the dissolved oxygen in the water.

Various other factors influence the rate of attack. With waters there are three main zones of reaction: The alkaline zone, with pH greater than 10, where the type and amount of protective coating formed usually controls the rate; the neutral zone, with pH 4·3 to 10, where the dissolved oxygen concentration of the water controls; and the acid zone, with pH less than 4·3, where the H^+ ion concentration usually is most important.

[1] Corrosion—Causes and Prevention; F. N. Speller, (1926), p. 22.

Dissolved carbon dioxide in water forms carbonic acid, a weakly dissociated acid, which accelerates the rate of attack mainly by increasing the H^+ ion concentration (lowering pH) thus furthering reactions (1) and (2). Carbonic acid may react with the iron to form iron carbonate (Fe $(HCO_3)_2$) which is then oxidized by dissolved oxygen to form rust, releasing the carbon dioxide which again reacts with iron and so on until all oxidizing agents are used up. Even with carbonic acid the action is mainly in the neutral zone and the oxygen concentration of the solution controls the rate of attack.

Other salts may inhibit or accelerate corrosion in various ways. Some salts like magnesium chloride hydrolyze in water to give hydrochloric acid; while other salts such as nitrates may react as oxidizers or depolarizers similar to dissolved oxygen.

Any salt which by reaction with the dissolving metal, e.g. iron, precipitates the metal salt at the point of iron solution, i.e. at the anode of the reaction, may cause stifling of the attack. The dissolved iron may be oxidized by dissolved oxygen in the water and the rust so precipitated may carry down some calcium, magnesium, or other insoluble material that may have considerable influence on the structure of the coating. If the coating so deposited is loose and non-adherent, under ordinary conditions the rate of attack may be accelerated locally to cause pitting, but, on the other hand, if it is uniformly dense and adherent it may cut down the attack. Any scale-forming salt may so deposit a protective coating on the iron. Dissolved carbon dioxide (carbonic acid), on the other hand, may accelerate attack by holding in solution such scale-forming salts, thus preventing the formation of protective coatings.

All acids, sulphates of iron and aluminium, calcium chloride and nitrate, and magnesium chloride and sulphate are common salts in water which are classed as corrosive agents.

The rate of attack increases, within limits, with the temperature and with increased rate of flow or turbulence. Hot waters with low pH are, therefore, especially corrosive. Soft waters usually contain considerable quantities of dissolved gases and are more corrosive than hard waters, as the latter can, under proper conditions, deposit a protective coating, as above noted.

With natural waters the method used to decrease the corrosivity of the water will depend on many factors, but since in most waters dissolved oxygen is the controlling factor a common treatment is the removal of dissolved gases from the water and increase in the pH value of the water.

For boiler feed waters, preheating or mechanical deaeration will remove most of the dissolved gases. With large industrial plants or civic supplies preheating is not applicable. In some cases, mechanical deaeration is used and free carbon dioxide is generally removed by aeration, or the carbonic acid is neutralized with lime, soda, phosphate, or other chemical. By this treatment, as well as by the use of a number of boiler compounds on the market, the acidity of the boiler water can be neutralized, raising the alkalinity to the desired pH value.

In waters there is an equilibrium as follows:

$$Ca(HCO_3)_2 = CaCO_3 + CO_2 + H_2O$$

which is dependent on pH and alkalinity. Any carbon dioxide in excess of that required to maintain this equilibrium at the pH and temperature concerned is termed "aggressive carbon dioxide," which is very active in corrosion reactions.

Present practice is to maintain a water in equilibrium with calcium carbonate so that there is no aggressive carbon dioxide and so that the water will not deposit any scale or dissolve any existing protective scale or coating. This is done by maintaining the alkalinity and pH.

There are other materials, sometimes added to waters, which in various ways inhibit attack on the metal, e.g. silicates, phosphates, etc.

BRIEF DESCRIPTION OF METHODS OF WATER PURIFICATION AND THEIR CHEMISTRY

During the earliest stages of water purification England and Germany led in the development of water technique, but in later years full credit must also be given to the United States' engineers, who have contributed largely to the working out and perfection of methods now widely applied. This may be attributed to the fact that the United States has had to contend with highly polluted waters; in many plants waters now being successfully treated would have been regarded as impossible some years ago.

Some industries have their own plants for the purification of their water supply, but, to-day, many are large consumers of municipal water; therefore, when new municipal waterworks are being planned, consideration should be given to the quality of water for industrial use.

Industrial waters must be clear, colourless, low in turbidity, low in organic matter, and low in iron, manganese, calcium, magnesium, chlorides, and sulphates. Maximum limits for these impurities naturally vary according to the requirements of different users. In treating Canadian municipal waters, except in the case of three supplies that have sodium zeolite treatment, no softening processes are in use. A clear, sparkling water free from bacterial contamination is supplied and the softening process is left for the consumer to deal with, whether industrial or domestic. It is often argued that the saving in soap alone well pays for the cost of the softening process, besides giving the consumer the comfort of soft water; but, since only a small part of civic water requires softening—the great bulk being used for sanitary flushing, cooling, watering, street flushing, etc.—each case must be judged individually, as is done in some Canadian areas that have very hard waters.

In the purification of natural, raw waters the following impurities have to be wholly or partly removed; suspended matter, organic acids or other organic matter imparting unpleasant odour or taste, bacteria, soluble mineral substances such as salts of calcium, magnesium, manganese, iron, free carbon dioxide, hydrogen sulphide, and other less common impurities. For their removal or limitation the following methods of purification have been applied:—

(1) Sedimentation for the removal of the coarser slime and silt.

(2) Sand filtration for the removal of finer particles of the lesser grain classes, and flocculation of the mucous and colloidal matter and floating particles.

(3) Filtration through activated carbon for the removal of taste and odour, or the use of other deodorizing agents, such as ammonia, chloramine, chlorine dioxide, excess chlorine, and the absorption of the excess of chlorine.

(4) Chlorination mainly for sterilization, but also for facilitating chemical precipitation and for removal of taste and odour.

(5) Aeration for precipitation of iron and manganese and the removal of soluble gases, hydrogen sulphide, carbon dioxide, etc.

(6) Softening methods, including precipitation with chemicals for the removal of iron, manganese, calcium, and magnesium; and zeolite and other exchange resin filtering.

(7) Coagulation, for the removal of organic substances, colour, bacteria, fine slime, substances with taste and odour, iron, manganese, silica, etc., eventually in connection with softening and demanganesing, including precipitation by aluminium and iron salts with or without addition of lime or alkalis at low or high pH value.

(8) Correction of the composition of the water to lessen its corrosiveness, especially against iron, by addition of alkali, phosphate, silicates, etc.

(1) Sedimentation:

Sedimentation can be considered only as an auxiliary method to be applied before the actual purification process, and is used only for water of high content of slime, for example for river water that permanently or intermittently, in case of heavy precipitation, may carry large quantities of suspended organic or inorganic matter. The sedimentation basins are as a rule built large enough to allow settling of coarse, suspended matter within from 2 to 24 hours. Pre-sedimentation facilitates the subsequent purification, as it lessens the load on the filters. Sedimentation and storage also serves to mix waters from several sources; it permits the running to waste of waters that have become heavily contaminated or turbid during spring run-off, etc.

Natural sedimentation basins exist in which water collects from smaller streams and brooks, but algæ are often prolific in these giving the water an unpleasant taste, usually fishy or earthy, and an offensive odour, thus complicating the process at the waterworks. An effective preventive of the growth of algæ is copper sulphate systematically sprayed over the entire surface of the impounded water. The distribution of the chemical must be uniform and not spotty, because if only part of the copper sulphate is adsorbed by algæ, part of the remainder will be deposited on the iron conduits and when it breaks away will cause red water. On no account must copper remain in solution in the water, on sanitary as well as on technical grounds. Natural storage and sedimentation does, however, reduce the number of disease-producing bacteria in a water.

Sedimentation is almost always used in conjunction with chemical precipitation, in order to lessen the load on the filters. Many large waterworks are equipped with slime separators.

(2) Sand Filtration:

Sand filters were first used in 1829 for the purification of the water supply for the City of London, and were of the slow-filtering type. These, although considerably improved in many respects since then, are now in use only at a few waterworks; other methods being applied for new water-supplies.

The demerit of the slow sand filter is its low capacity per unit of area; a plant supplying a large population covers an extensive area, which saddles it with very heavy outlay in real estate. Furthermore, this method is unsuitable for combination with chemical precipitation, coagulation, and activated carbon. Although efficient for removal of taste and odour, they are said to be unsatisfactory for the removal of colour from highly coloured waters (greater than 30 parts per million), or for turbid waters. Rapid sand filters have, therefore, become general; they are made up of coarser sand and, since they work with greater head, the rate of the filtration is from 50 to 100 times greater, and, consequently, they occupy a comparatively small area of land. They can then be economically placed under cover, a disadvantage for the larger, slow sand filters in colder climates. The action of a sand filter is mainly mechanical at the start, solid particles being held by the sand; but in course of time it becomes active as the sand grains become coated with a gelatinous deposit that facilitates colloid chemical adsorption, whereby to a certain extent smaller particles, like bacteria, will be removed.

The coagulation of colloidal particles is also facilitated by forcing them to come into contact with each other. Such activating is especially noticeable in filters in combination with chemical precipitation using iron and aluminium salts as reagents. An improvement in the efficiency of the filter is always recorded after it has been in operation for some time, which is partly attributed to the deposit of filtered substances covering the surface of the filter-bed. As this deposit increases, the resistance to filtering will also increase, so that frequent cleanings are necessary,

wherefore the filters are equipped with flushing arrangements, to operate by what is termed backwash. The frequency of backwash will naturally depend on the purity of the raw water; daily backwashing is a general rule for filters used in combination with chemical purification, but in some cases backwashes may be found necessary twice daily.

In building up a filter the selection of the sand is of importance. Fine sand, especially when used in conjunction with chemical purification, may form a crust whereby the filter becomes useless. Too coarse a sand, on the other hand, lowers the efficiency of the purification and leaves turbid water. As a general rule, medium coarse sand is preferable, as it obviates too frequent backwashes and because the deposit will penetrate deeper into the filtering bed. Various other materials have been advocated as substitutes for sand as a filtering medium, for example, anthracite coal and magnetite, but sand is still most generally used.

(3) *Removal of Taste and Odour:*

There are only four different sensations of taste—sour, sweet, salt, and bitter, all other seeming sensations of flavour in potable or edible substances being usually produced by odour. Tastes and odours in waters are produced by the growth and decay of algæ, by vegetable and animal matter, or by gases like hydrogen sulphide, sulphur dioxide, carbon dioxide, or ammonia. Some mineral salts if present in sufficiently large quantity, for example, common salt, Glauber's salt, Epsom salt, magnesium choride, and iron salts, the latter even in small quantities, will produce salty and bitter tastes in odourless waters. Certain trade wastes and effluents will taste and produce an odour in water, even when present in extremely minute quantities.

Several chemicals are applied for the removal of odour and taste from waters, of which may be mentioned chlorine, chloramine, activated carbon, and chlorine dioxide. The chloramine treatment may use chlorine with anhydrous ammonia, aqua ammonia, ammonium chloride or ammonium sulphate. Aeration, coagulation, and filtration, bleaching clays, potassium permanganate, ozone, and Fuller's earth have all been used to remove odours and tastes from waters.

Superchlorination, whereby excess chlorine is added to a water followed by dechlorination, is an effective method for removal of objectionable tastes from waters. Excess chlorine oxidizes and removes the taste-producing substance, whereas the chloramine treatment prevents chloro substitution tastes from forming but does not remove them. Normal chlorination may leave $0 \cdot 1$ to $0 \cdot 2$ part per million chlorine after 30 minutes, while superchlorination may leave $0 \cdot 75$ part per million chlorine after 2 hours' contact. In some waters small amounts of chlorine added for sterilization, e.g. $0 \cdot 3$ part per million may bring out tastes and odours not previously detectable, especially with phenols, which, if present even in the most minute traces, will provoke a decided taste of phenol on chlorination. The presence in waters of minute quantities of iodides conduces to an "iodoform" taste on chlorination and is especially noticeable when iodized common salt is used for cooking or medication when dissolved in water containing free chlorine. Activated carbon has the advantage of a very great adsorptive capacity for removing tastes and odours, and adds no new substance to the water. It is supplied in hard granular form, but because of its high price it is not at present economical to use in the filter beds, and is used as a separate filter for after-treatment. The carbon of such filters can be regenerated.

Activated carbon may also be added to the pretreated water in a very finely ground state by means of injectors, in quantities ranging from 1 to 14 parts per million, thus bringing about an intimate mixture, in which the surface of contact is naturally greater and the adsorption of odorous and tasting substances is facilitated by the longer contact of the water with the carbon. The carbon afterwards collects

on the filter as a film, which also acts in an adsorptive capacity. This method, however, is dependent upon a price for the activated carbon within the economical limits of the process, because regeneration of the carbon could hardly be contemplated.

A new chemical, chlorine dioxide, has recently been advocated for the removal of tastes and odours. It is used in conjunction with chlorine as the sterilization agent.

(4) Chlorination:

The process of chlorination has become so general that there are indeed comparatively few waterworks pumping surface water that are not equipped for it. In Canada, ground waters on the whole are free from bacterial contamination, and from many supplies the untreated water can be distributed with safety to the consumer, though a few have equipment for continuous or intermittent chlorination in accordance with requirement.

Chlorine is one of the most powerful disinfectants and on this account has found a wide application in the technique of water purification. At one time it was added in the form of hypochlorite—commonly termed bleaching powder—but is now applied almost solely in the form of liquid chlorine. The amount required for complete sterilization will depend on the impurity of the water, but it is generally accepted that there should be an excess of chlorine, after the adsorption has been completed, of 0.1 to 0.2 part per million. Nevertheless, in strongly contaminated waters it has become more and more the practice to adopt superchlorination with subsequent removal of the excess which imparts a chemical taste and odour to the water. Several reagents may be used for the removal of chlorine, such as sulphurous acid, sulphites, thiosulphates, and ammonia, but in later years activated carbon has been found preferable for reasons already stated. Long storage and exposure to sunlight will also dechlorinate waters.

Superchlorination will yield absolutely effective sterilization, although with some waters high in organic matter or having strong bacterial contamination it is not unusual, in order to make doubly sure, to repeat the chlorination. Chlorination before and after coagulation and filtration is sometimes practised; prechlorination is considered by some authorities to improve coagulation, especially of iron and manganese salts. It is said to aid in the removal of hydrogen sulphide and to assist in the control of algæ growth on filters. Superchlorination and subsequent de-chlorination by special reagents are said to have proved effective means for the removal of odoriferous and tasting substances as discussed above.

(5) Aeration:

Aeration dates back to the earliest days of water purification. It has in the past been applied to ground waters with a high content of iron and manganese, and for the dissipation of dissolved gases of offensive taste and odour like hydrogen sulphide. The method consists in spraying the water either through a number of fountains, or over a lattice made of wood, or on coke. Mechanical means or compressed air are seldom used. Substances removed by aeration are hydrogen sulphide and iron, also carbon dioxide, which latter, however, is difficult to remove completely. Manganese is only partly precipitated with the iron and requires longer time. Iron in a water is usually present as ferrous salt, bicarbonate and colloidal hydrates, and by aerating is converted into ferric hydrate, which is precipitated. In the case of ferrous sulphate or chloride a conversion to ferric salts will prove ineffective because these salts are soluble, and not so easily hydrolysed at low pH value. Iron may also combine with the humus acids forming humates, which remain either in actual or colloidal solution and do not flocculate readily, so that aeration is not

applicable for their removal. Neutral or weakly alkaline waters (pH 7·0) containing little or no organic matter respond most favourably to this method of treatment; but, in cases where iron cannot be removed by aerating, it may be precipitated at low pH value with aluminium sulphate as ferric salts after chlorination, or at high pH value with lime or soda supplemented with addition of iron salt and subsequent chlorination.

(6) Softening Processes:

The hardness of water is popularly described as the amount of soap precipitated as insoluble soaps by the salts of metals, expressed in terms of calcium carbonate. Calcium and magnesium are the main causes of hardness in a water; many other metals such as iron, zinc, or aluminium form insoluble soaps, but these are selomd present in natural waters in appreciable quantities.

Water softening can be accomplished by four main methods:—

(a) Precipitation with lime, without addition of soda ash but with subsequent introduction of substances to cause flocculation.

(b) Precipitation with lime and soda ash, and subsequent addition of substances causing flocculation. This is applicable to waters with high or comparatively high non-carbonate hardness.

(c) Precipitation with sodium phosphate. Owing to the high price of the reagent this is used only for special purification in conjunction with or as an after-treatment to (a) and (b).

(d) Sodium zeolite filtration. This is suitable for medium hard waters and for after-treatment to (a) and (b). This is also applied to smaller units for domestic houses in localities where the waters are very hard.

The choice of method will depend on the composition of the water, the degree of hardness desired, and the cost. By methods (c) and (d) the hardness can be completely removed, whereas by (a) and (b) it is rarely possible to attain an efficiency beyond reduction to 30 parts per million, but as a rule about 70 parts per million may be considered satisfactory. This will be dealt with later.

Methods (a) and (b) are based on the following schematic reactions:—

(1) $CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$

(2) $Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$

(3) $Mg(HCO_3)_2 + 2Ca(OH)_2 = Mg(OH)_2 + 2CaCO_3 + 2H_2O$

(4) $MgCl_2 + Ca(OH)_2 = Mg(OH)_2 + CaCl_2$

(5) $CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl$

In accordance with these formulæ it should be possible to get rid of all free carbonic acid (CO_2) and all bicarbonate hardness as an insoluble calcium carbonate without adding any new substance to the water. Sodium carbonate, however, will be required to precipitate the calcium salts in combination with strong acids, sodium replacing the calcium that was in solution and, by double conversion, the magnesium salts of strong acids. It appears most simple, but in the manipulation many difficulties are encountered, and, as previously mentioned, the reactions are far from complete. The explanation given is that calcium and magnesium carbonates are not absolutely insoluble and that their solubility is largely dependent on the pH value, i.e. the hydrogen-ion concentration and the presence of other ions.

This is supported by calculations of pH-Ca-ions and pH-Mg-ions, which have been fully investigated by Bertil Groth, detailed calculations having been made

and equilibria curves plotted.[1] Somewhat similar studies on chemical equilibria in water, particularly that between pH-carbonates-hydroxides, have been made by several other investigators, principally from the standpoint of the saturation index of water, for example W. F. Langelier [2], [3], T. E. Larson and A. M. Buswell [4], and D. S. McKinney [5].

The deduction from these calculations and equilibria curves is that magnesium hydrate, $Mg(OH)_2$, does not begin to precipitate before the optimum of pH for the precipitation of calcium has been passed. Consequently, if it be desirable to precipitate magnesium in a water with calcium hydrate, $Ca(OH)_2$, a certain excess of calcium hydrate must be added and thus what has been gained in softening by precipitation of magnesium is lost by the increasing amount of calcium ions remaining in solution. It is not economical therefore to precipitate magnesium with lime alone, but sodium carbonate should be added as well: with the lime $(Ca(OH)_2)$ this is converted into insoluble calcium carbonate $(CaCO_3)$ and soluble caustic soda (NaOH). The amount of lime and soda required can be calculated with fair accuracy from the analysis of each individual water; it is preferable to recalculate the analytical data in magnesium equivalent.

As mentioned above, however, many difficulties are encountered in practice, and the precipitation is far from complete as might be expected from theoretical calculations. Calcium carbonate possesses a tendency to hold itself in supersaturated colloidal solution and, especially in the presence of sodium, forms complex carbonates of higher solubility. The precipitation is much facilitated by strong contact action between the solution and the slime already precipitated, as is to be expected in the case of supersaturated colloidal solutions, and, also to an appreciable extent, by the addition of substances that form voluminous insoluble compounds with calcium and magnesium, for example aluminium sulphate and sodium aluminate, forming insoluble calcium and magnesium aluminates. By this method the contents of calcium and magnesium are reduced appreciably more than stoicheiometrically calculated, and it is evident the precipitate carries down with it soluble calcium and magnesium compounds, in colloidal form. Silica (SiO_2) is also precipitated, which is of importance especially in the purification of boiler feed-water. Consequently, the precipitation methods applied in practice may vary. For each type of water the most economical and suitable method can be determined only by chemical analysis, by small-scale experimental runs, and by calculating the cost. Other means of varying methods (a) and (b) to produce a water with lower hardness than stoicheiometrically possible are: (1) the hot process—the solubility of calcium and magnesium salts is lower in hot waters; (2) the use of some excess lime and recarbonation; and (3) split treatment, whereby only a portion of the water is treated and this is mixed with the raw water. With the latter method, a given quantity of chemicals reduces hardness more than otherwise.

Trisodium phosphate, method (c), has been used for the past two or three decades in washing material at the home and for water softening. With a very slight excess of phosphate, sometimes in combination with sodium hydrate, an almost perfect softening is obtained, because the calcium phosphate thus formed is almost completely insoluble. Magnesium can also be almost entirely removed. As previously mentioned, the rather high price of the phosphate precludes its more general application as a water softener.

Sodium zeolite, method (d), has been in use for many years for water softening, and its use is increasing, especially as a finishing process with the lime-soda procedure. For waters of medium hardness it is used extensively in laundries, boiler plants, homes, etc. It must, however, be observed that although lime, magnesia, and iron

[1] Teknisk Tidskrift, Stockholm, Sweden, Chemical Section 161, pp. 89-90
[2] Langelier, W. F.: Jour. A.W.W.A. 28: 150 (1936).
[3] Langelier, W. F.: Jour. A.W.W.A. 38: 169 (1946).
[4] Larson, T. E. and A. M. Buswell: Jour. A.W.W.A. 34: 1667 (1942)
[5] McKinney, D. S.: Ind. Eng. Chem. Vol. 3(2) (1931).

are removed, actually its content of dissolved solids is increased, because an amount of alkali salts equivalent to the hardness caused by the above metals goes into solution, and the equivalent weights of sodium and potassium are higher than those of calcium and magnesium. Therefore, it is not especially satisfactory for applications where the total amount of salts in solution is objectionable, e.g. boilers. For water of 850 to 1,000 parts per million or greater hardness, the lime or lime-soda process is recommended, as it reduces both the total solids and hardness.

The zeolite used on filter beds is in a granular form and is regenerated with sodium chloride. Zeolite is a sodium aluminium silicate, which according to Gans[1] includes aluminate residues, the group — Al(ONa)OH or $=$ AlONa. When sodium (Na) is thus combined it is interchangeable with calcium and magnesium, but not so if it is combined with group $\equiv$ Si — ONa. Other theories ascribe the interchange solely or mainly to colloid-chemical reactions.

Some zeolites are capable of combining to a certain extent with iron (Fe) and manganese (Mn). Zeolites are found in nature, but are now generally made synthetically, and of late years have been much improved as regards strength, capacity, and duration of contact. The original sodium zeolites were natural silicates (greensands) which were stable only within a narrow range of pH. Synthetic zeolites or carbonaceous zeolites were developed later that were stable over a wide pH range, permitting operation to be extended to the hydrogen cycle. Thus, inorganic salts in solution could be converted to their corresponding mineral acids by replacement of the metal cations by hydrogen ions and the bed regenerated with acids. Zeolite is to a certain extent sensitive to the pH value of water, inasmuch as a water of low pH value, for example with free carbonic acid (CO_2), will in course of time act in a corroding or decomposing manner on the zeolite, which will impair the durability of the filtering bed. If, however, the pH value is so high that the limit of solubility of calcium carbonate has been exceeded, the carbonate will precipitate on the zeolite bed and clog the filter. Therefore, a turbid water or a water high in iron and/or manganese should not be applied to the sodium zeolite bed until the water has been treated; otherwise the filter bed is impaired.

Zeolite-softened waters may be more corrosive because of the removal of all salts that form a protective film or coating on the metal surface.

More recently it has been found that certain synthetic resins, the so-called anion exchangers, are capable of removing anions (acids) from a solution of salts. It is thus possible by first subjecting a solution of salt to a base-exchange resin (replacement by hydrogen ion) and then passing this acidic solution through the anion exchanger to almost completely remove the salt and so obtain water similar to distilled water.

(7) *Coagulation Process:*

Surface waters as a rule require purification, because they generally contain greater or less quantities of organic matter. Methods of purification are of interest in this country, because it possesses vast supplies of soft, highly coloured waters containing humus matter, especially those from our northern rivers, which after chemical purification yield a water good for all purposes, technical as well as municipal. The water supplied at Ottawa by the Civic Water Purification Plant furnishes indisputable evidence of what excellent results can be obtained from a raw water highly coloured by humus.

The precipitants used for organic matter are alum and ferric salts, both easily hydrolysed. For reasons of economy only sulphates and chlorides can be considered. In the hydrolysis of aluminium and iron salts their hydrates are formed.

[1] Chemische Industrie, Vol. 32, pp. 197-200.

Aluminium is amphoteric, i.e. it may produce $Al^{\cdots}$ ions eventually $Al(OH)^{\cdot\cdot}$ or negative aluminate ions $Al(OH)_2O^1$: Thus the following equilibrium equation is obtained:—

$$H^+ + Al(OH)_2O^- \underset{\longrightarrow}{\lessgtr} Al(OH)_3 \underset{\longrightarrow}{\lessgtr} Al(OH)^+_2 + OH^1$$
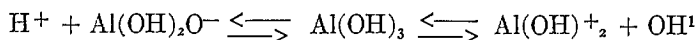
If $H^{\cdot}$ ions are removed from the solution, thus raising the pH value, the aluminium oxide hydrate will go into solution as aluminate; if OH^1 ions are removed, i.e. lowering the pH value, the aluminium will go into solution as aluminium salt. Consequently, aluminium hydrate has its lowest solubility at a particular hydrogen-ion concentration. This hydrogen-ion concentration with pure aluminium hydrate corresponds to a pH value of about $5 \cdot 5$ to $6 \cdot 0$. The solubility of aluminium hydrate within this interval is very insignificant, and even within an appreciably greater interval the rate of solubility is so low, that in the case of commercial water purification it need not operate within such narrow limits.

If aluminium sulphate be added to pure water there will be no precipitate and the pH value decreases to $4 \cdot 0$. If alkali be added in the form of lime (CaO), sodium oxide (Na_2O), or sodium carbonate (Na_2CO_3), until the pH value increases to about $5 \cdot 5$ to $6 \cdot 0$, complete precipitation is obtained of aluminium hydrate. At low pH value the hydrate contains some basic sulphates, at higher pH values it is almost free from such salts.

Whether a natural water will react with aluminium sulphate to form hydrates depends, therefore, on its alkali content which must be sufficiently high to give an adequately high pH value with the required quantity of aluminium sulphate; otherwise alkali must be added in the form of lime, lye, or soda. On the other hand, if the water contains sufficient quantities of carbonates with simultaneously high pH value, the latter after addition of a quantity of aluminium sulphate, within commercial limits, might not decrease sufficiently to attain the optimum for precipitation. In such case it may be necessary to add acid or to revert to purification with iron salts at high pH value.

When aluminium hydrate is precipitated certain organic matter in the water is adsorbed and a voluminous flocculent precipitate is formed. Many theories exist as regards the origin of these precipitates, the most likely explanation being that in the adsorption purely chemical compounds are formed. This applies especially to certain organic substances in water of acid character, for example the humic acids and closely related substances.

The speed with which the floc is formed largely depends on the character of the water, the pH value, the amount of aluminium sulphate added, the temperature, and on stirring. Different organic substances, to a very unequal extent, hasten the flocculation and require various pH values. The speed at which the floc is formed usually increases with the amount of aluminium sulphate added, that is, up to a certain limit. For reasons of economy and to avoid unnecessarily large amounts of sulphate ions in the water the quantity of aluminium sulphate added is as a rule kept down to from 30 to 60 parts per million. Strongly contaminated waters, however, may require larger amounts.

In order to hasten the flocculation it is of importance that the colloidal particles first formed come into intimate contact with one another. This is facilitated by stirring, but also by increasing the temperature, because owing to the decrease in the viscosity the movement of the molecules is accelerated. Operators of water purification plants, therefore, find precipitation by means of flocculation to be more rapid and to yield better results during the summer. It is of especial importance that stirring be continued after the alum has been added for some time, depending on conditions, but preferably one hour, if a satisfactory and rapid flocculation is to be attained, a matter often overlooked. The stirring, however, must not be so vigorous that the floc is torn. The time allowed for coagulation and sedimentation

should be generous enough to ensure perfect settling, otherwise lack of clarity of the water results, a heavy extra load is put on the filter requiring frequent backwashes, and deposits form on the sand grains necessitating chemical cleansing of the sand.

It has been shown that the optimum for flocculation of aluminium hydrate is at rather low pH value. At higher pH values, for example 7·0, it is very difficult to obtain satisfactory and rapid flocculation with many waters, and impossible with those high in humus matter. For this class of water it has proved more advantageous to use ferric salts at comparatively high pH value. Ferric hydrate does not possess amphoteric properties, for which reason it is applicable to both high and low pH values. If a water be clouded by finely divided clay slime, which does not settle on quiescence, or contains an appreciable amount of coloured organic substance, ferrous sulphate is often simultaneously added with other chemicals. This is converted into ferrous hydrate, which at high pH value rapidly oxidizes by the oxygen in the air to ferric hydrate forming a voluminous and mucous precipitate with occlusions of finely divided clay slime, as well as flocculated organic substances of higher molecular weight. In recent years the direct application of ferric salts has become more general; they are produced at the waterworks by oxidation of the ferrous salts by chlorination. The ferric salts are deliquescent and therefore unsuitable for bulk freight. The content of organic substances is reduced less at a high pH value than at low pH value, apparently because certain organic substances form soluble salts that do not flocculate. Superchlorination of water has been found to contribute actively to precipitation. The flocculation becomes more rapid and the organic matter is more completely separated. Besides aluminium sulphate only ferric salts and sodium aluminate have won wide application. In most cases a small quantity of sodium aluminate with aluminium sulphate speeds up the formation of the floc.

Ferrous salts, ferric chloride, and chlorinated copperas all present some trouble due to corrosivity and deliquescence during plant handling.

Ferric sulphate of alum, ammonia alum, and sodium silicate have all been advocated for use as coagulants in various waters. The latter is said to hasten coagulation when used with 60 per cent alum. It cannot be satisfactorily used with the ferric salts, but it is said to not increase appreciably the silica content of a water.

The pH value of purified water in acid precipitation will be low, and it is, therefore, desirable or necessary to increase it in order to prevent corrosion in the conduit system.

(8) Correction of Water to Reduce its Corrosiveness:

Corrosion by water causes heavy economic waste by destruction of conduits, valves, tanks, and other containers. Red water stains clothing and makes unsightly discoloration on plumbing fixtures. Rust tuberculation or heavy deposition of scale decreases the flow in conduits and pipes, causing increased pumping costs and eventually cleaning or replacement of the blocked pipes.

In a previous section of this report it has been shown that soft waters of low pH value are especially corrosive if they contain fairly large quantities of dissolved carbon dioxide and oxygen. These waters do not deposit a scale that might give protective cover to the metal. Corrosion is accelerated by higher temperature, hence hot water pipes and tanks corrode more rapidly than those holding cold water. Hot waters high in free carbon dioxide are especially corrosive to galvanized tanks and piping. The obvious course in correcting a water to lessen its corrosiveness would be to raise the pH value, and reduce or remove the carbonic acid and dissolved oxygen.

Prevention of corrosion can be attained either by a protective cover of paint, cement, coal-tar preparation, etc., by the use of metals resistant to corrosion, or by correcting the water chemically.

As stated in the section dealing with aeration, carbon dioxide can be reduced but not entirely removed by that process. Oxygen can be reduced by preheating the water, but this would be applicable only to boiler waters or where hot water is used in the process, so that for certain corrosive waters treatment with chemicals would become essential. In many industrial applications dissolved gases are removed from waters by the use of vacuum (cold water deaeration) or by heat and pressure (hot water deaeration). In the latter the incoming water is subjected to steam in the form of a spray or from an atomizer.

Residual oxygen in water is removable by chemicals such as freshly precipitated ferrous hydroxide or sodium sulphite; iron scrap, zinc scrap, or carbon and zinc together have also been used in so-called deactivators for the removal of residual amounts of dissolved oxygen.

Lime in the form of quicklime (CaO), or as milk of lime ($Ca(OH)_2$), is generally applied as an inhibitor of corrosive attack by waters containing dissolved gases. It combines with the carbonic acid in accordance with the following formulæ:—

$$Ca(OH)_2 + 2CO_2 = Ca(HCO_3)_2$$

forming soluble calcium bicarbonate. By further addition of lime insoluble calcium carbonate will be precipitated according to the reaction:—

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$$
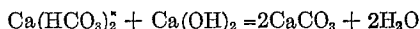
For most waters a pH value of $8 \cdot 1$ is the optimum at which most of the free carbon dioxide is neutralized, but complete neutralization is not necessary, the objective being to neutralize enough of it to bring about the desired pH value. Present-day practice in many plants adds a sufficient amount of lime so that the water is in equilibrium with respect to calcium carbonate, a procedure recommended by Baylis, who is largely responsible for the development of the use of lime for the purpose of reducing the corrosiveness of water.[1] At equilibrium, the water does not deposit carbonate, nor does it dissolve existing carbonate scale.[2] When such treatment is first applied a slight supersaturation can be maintained for a long enough period to deposit a light carbonate scale in the pipe-lines, after which the water is kept in balance. Such treatment needs careful control to prevent undesired deposits, caused by too much supersaturation, but slight irregularities will not matter, because if the water is undersaturated at times, tending to dissolve calcium carbonate, this will be counterbalanced during such times when supersaturation occurs.

The lime treatment, if applied after filtration, will form some deposit in the filtered-water storage reservoir. If applied before filtration, consideration must be given to the possible unfavourable effect of the increased pH value on coagulation, if alum is used.[3]

Soda ash is being used by some operators to neutralize the carbonic acid, and is applied when increase in hardness is not desirable. For some waters high in carbon dioxide the bulk of the carbon dioxide can be removed by aeration before neutralization with lime or soda.

Sodium silicate is added to water to retard its corrosiveness. It is considered that sodium oxide in the silicate combines with the carbonic acid forming a bicarbonate, and the silica deposits on the pipe; it may combine with zinc on the galvanized pipe or with magnesium in the water to form a protective coating.

Owing to the high price of sodium silicate as compared with lime and soda it is not economical to use this chemical when the content of carbon dioxide is high. For such waters it is found more practicable to use a mixture of soda ash and sili-

[1] Baylis, John R.: "Treatment of Water for Corrosion"; Journal of American Water Works Association. Vol. 27, pp. 220 to 234 (Feb. 1935.)

[2] Langelier, W.F.: "The Analytical Control of Anti-Corrosion Water Treatment", Jour A.W.W.A., 28: 1500 (1936).

[3] Ryan, William J.: "Water Treatment and Purification", p. 215.

cate. Soft waters low in carbon dioxide are most suited to the use of the treatment with sodium silicate. The addition of sodium silicate to water as a retarder of corrosion has been practised by many large consumers such as the City of Birmingham, England, and New York City. In the latter city, where the water is corrosive, having a carbon dioxide content of $2 \cdot 0$ parts per million, good results are obtained with the addition of about $0 \cdot 3$ to $0 \cdot 5$ pound of 40° Bé. sodium silicate per 1,000 gallons of water. This neutralizes the carbonic acid, increases the alkalinity by 5 to 8 parts per million, and the silica, 15 to 25 parts per million, and raises the pH value from $7 \cdot 0$ to $8 \cdot 3$. The potability of the water is not impaired in any way, but consideration must be given to the increased silica content, causing trouble in boilers, as remarked above.[1]

Certain polyphosphates, principally the sodium hexametaphosphate, are also used alone or in combination with silicates, etc., as inhibitors of corrosion. The hexametaphosphate is also used as a preventive for red water. The hexametaphosphate in amounts of $0 \cdot 5$ to 5 parts per million has proved effective with various waters. It also prevents after-precipitation of $CaCO_3$ on filters and in pipes, by reason of the formation of a complex salt with the calcium ion.

SAMPLING OF NATURAL AND TREATED WATERS

During the period 1934 to 1943, 278 samples of surface waters were collected at the key stations on large lakes and rivers of industrial importance, and complete analyses have been made. The samples taken from civic water supplies number 652 and were given partial analyses. The determinations made are enumerated on pages 73 to 109 of this report.

In an investigation on the quality of waters the essential part of the report is the tabulated analyses. It may be pointed out that although many analyses have been made, the places from which the samples were obtained are also numerous, and, consequently, many waters, especially those from Western Canada, have been analysed for mineral content for the first time, and a greater number have been analysed only twice. Furthermore, many of these samples have been analysed for hardness only, and even in the industrialized areas of Canada the present number of analyses is inadequate. For an investigation of this nature it is imperative to accumulate the greatest possible number of analyses, because in all waters, even from such large bodies as the Great Lakes, marked seasonal and periodical variations occur in the concentration and in the composition, and only by frequent sampling and analysis can the investigation be kept up to date and become of real value. Resampling may appear unnecessary to the layman where analytical results of samples from the same source, collected at different times, are fairly concordant, with but slight variation in composition. Yet, at times these variations may be considerable, and even small variations in quantity of certain constituents may cause serious operating problems for some industrial processes and influence the choice and success of any method of treatment. For example, the water of the St. Lawrence River is a surface water comparatively constant in composition, nevertheless some industries on its banks have experienced problems due to seasonal variation in certain constituents of the water, which under ordinary circumstances would be considered of little significance. It is essential, therefore, to determine even slight variations, and this can be accomplished only by frequent sampling and analyses.

On the other hand, in some waters the variations in composition are great, and an average of several analyses would give little enlightenment; each individual analysis, therefore, has been tabulated, stating the date of sampling and the conditions under which it was done.

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[1] Ryan, William J.: "Water Treatment and Purification", p. 221.

In other countries where similar investigations have been in progress for many years, analyses of natural waters are published in tabulated form representing one sample for each month or every 10 days (usually made up of composites of daily samples), and the averages are calculated for the year.

This is not practicable in Canada at present, since it would involve the employment of a large staff both in the field and in the laboratory, for each key station would require the collection of 365 samples yearly and 12 analyses of the composite monthly samples. In this investigation surface waters are collected representing high, mean, and low gauge at key stations at strategical positions where samples are the most representative, in many cases being taken from the intake pipe at a pumping station or waterworks, where the water is discharged into a well, or where a special sampling device is attached to the raw water pipe. When chemicals are added in the well, and in the absence of sampling device, or when key stations have no adjacent pumping station, the sampling is done midstream from a bridge, or from a boat. Lake water is sampled at a distance far enough out to be safe from shore contamination and disturbances, usually a couple of miles offshore.

A special sampler has been devised for this purpose consisting of a brass cylinder of about one-gallon capacity, which is lowered into the water, open at both ends, to the desired depth where it is closed by a tug on the rope. No air from the sampler or otherwise can come in contact with the water sample. This is of importance for the field analysis because the amount of dissolved oxygen and free carbon dioxide must be determined at the time of sampling, since they are subject to change on standing. Other determinations made in the field for the same reason are hydrogen-ion concentration, or pH value, and temperature. The object of recording the temperature is to be able to determine the degree of saturation of dissolved oxygen, which varies with the temperature, ranging from $10 \cdot 2$ millilitres of oxygen per litre at 0°C. to $5 \cdot 3$ millilitres at 30° C. in distilled water at 760-millimetre pressure.[1] The temperature variation of waters is also of some importance to industries using the water for cooling purposes. If the sample be taken from a sampling cock on the intake pipe at a pumping station, a special sample is taken for the determination of dissolved gases (O_2 and CO_2) and pH value by attaching one end of a rubber tube to the cock and the other end to the tip of a separating funnel. The water is allowed to run slowly through the funnel from the bottom up and to overflow for some time. It is then turned off and the separating funnel is closed at both ends. The sample thus collected is run into a Nessler tube under a neutral oil seal to the 50-millilitre mark and the determination is made without the sample's coming into contact with the atmosphere, all reagents and the titration solution being added below the oil cover. There are various other devices for sampling of waters for the determination of dissolved gases.

Civic water supplies are sampled at the pumping stations and at the waterworks. Every attempt is made to keep the information of the quality of civic water supplies up to date through inquiries at the offices of the city engineers and waterworks' officials, concerning changes in water treatment, new water supplies developed, chemicals added, etc.

[1] Sutton Volumetric Analyses, Roscoe-Lunt Tables, p. 618.

CHARACTER OF THE WATERS EXAMINED

Surface Waters

Of the untreated waters examined but few samples were from the Maritime Provinces, where most cities and towns are situated on tidal estuaries of rivers and brackish waters extend 20 miles more or less upstream, thus rendering the river waters of little or no industrial value. The Nipisiguit and Southwest Miramichi Rivers are good, soft industrial waters. The St. John and Northwest Miramichi Rivers and Grand Lake are also soft but of rather high intensity of colour. Other waters in Nova Scotia and New Brunswick, supplied from small lakes, rivers, and springs, are soft, but give rise to manufacturing problems, usually corrosion due to the content of dissolved carbon dioxide and oxygen, in some cases colour, and in a few cases algæ. Colour and algæ can be corrected by known methods; corrosion, however, is a more serious problem and for some time past has been subject to extensive investigations by large manufacturing concerns.

The Quebec surface waters are preponderantly soft, except those of the St. Lawrence River, which is medium hard and low in colour. The Richelieu River is an excellent industrial water, soft, and low in colour; the St. Francis, St. Maurice, St. Charles Rivers, and the Lake St. John watershed are also soft, but highly coloured.

The natural waters of eastern Ontario are soft to medium hard and of high intensity of colour except the St. Lawrence River, which is hard, and low in colour. South of Georgian Bay, from Lake Simcoe westward the waters are hard and very hard for both surface and ground waters. Especially hard are the waters of the Grand and Thames Rivers and those of the watershed discharging into the southern part of Georgian Bay, but all are of low intensity of colour.

In northern Ontario, the waters of the Abitibi and Mattagami Rivers and tributaries are medium hard and soft, with very high intensities of colour, reported at times as high as 250 parts per million. The same characteristics, as regards colour and hardness, appear to apply to most lakes that supply water to the mining industry. Of the northern waters flowing south, those of the Ottawa River, Lake Timiskaming, and Lake Nipissing are soft to very soft with colour ranging from 40 to 75 parts per million. The Ottawa River water is one of the more unstable in composition of our surface waters, analysis showing a wide range in the following characteristics and constituents: pH 6·7 to 7·0, colour 25 to 70 parts per million, turbidity 5 to 90 and higher at the freshet, alkalinity 8 to 43 parts per million, and total hardness 11 to 55 parts per million; that is, a change in concentration of 100 per cent and over may be expected for any of these constituents.

In western Ontario, of the lakes and rivers investigated, the Rainy River is soft to very soft with an intensity of colour of 40 to 45 parts per million; the Wabigoon River, medium hard with colour, from 20 to 40 parts per million; Lake of the Woods, soft to medium hard, with 20 to 40 parts per million colour intensity; and the Nipigon River, medium hard with 20 parts per million colour intensity. The water of the Nipigon River is represented by one analysis only.

It is interesting to note the variations in hardness of the water in the Great Lakes. A diagram, Figure 1, shows graphically the increase and decrease in total hardness of the water travelling from Port Arthur to tidewater. Sorel has been accepted as the end point, because the tide extends into Lake St. Peter as far as Three Rivers. A previous diagram was published in No. 2 Interim Report on Industrial Waters of Canada in 1937. Analyses of samples taken to the end of 1940 have been added and the averages of the analyses of the samples from the various key stations have been compiled and plotted in Figure 1. Examining the two diagrams, it will be noticed that the changes are but slight, showing, however,

less marked variations on the diagram for the St. Lawrence waters. In compiling the second diagram only untreated waters have been considered and, in order to obtain a more representative figure for Lake Ontario and the St. Lawrence River, averages have been calculated from the analyses of samples collected at Oakville, Toronto, and Kingston for Lake Ontario; Prescott, Cornwall, and Valleyfield for the upper St. Lawrence.
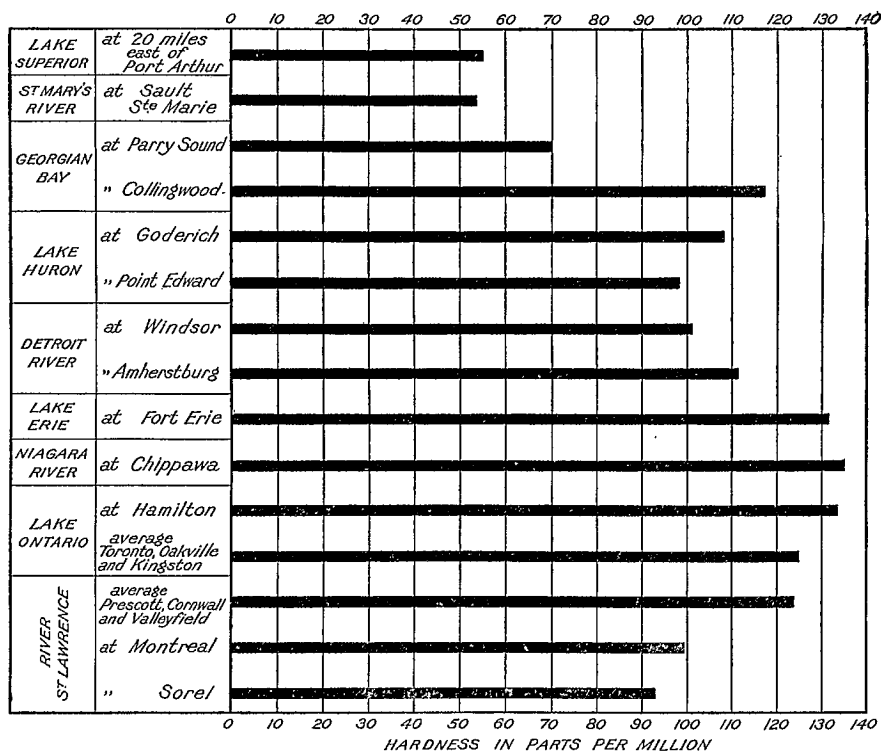
FIGURE 1. Diagram showing variations of total hardness, in parts per million, of the waters of the Great Lakes basin.

The water of Lake Superior, 20 miles east of Port Arthur, has a hardness of 54·7 parts per million and is slightly harder than at Sault Ste. Marie at 53·3 parts per million. The locality is represented by one sample only; a sample taken 4 miles southeast of Port Arthur had a hardness of 55·7 parts per million. A slightly harder water may be expected in that part of Lake Superior, owing to the heavy discharge from the Nipigon River with a hardness of 90 parts per million. The Lake Superior water below Sault Ste. Marie is diverted in three directions, to Lake Michigan (with which this report is not concerned), to Lake Huron, and through the North Channel to Georgian Bay. The water running through Lake Huron receives water of very high hardness from tributaries in the State of Michigan, noticeable already at St. Ignace, Michigan, where there is an increase in hardness to 82 parts per million.[1] Mention may be made of the tributaries, the Shiwassie River, the Cass River, and the Flint River, which drain into Saginaw Bay and have hardnesses of 221, 178, and 298 parts per million, respectively.[2]

Georgian Bay receives from the northern tributaries waters softer than that of the Lake Superior water, notably from the French River, discharging the waters

[1] Clarke, F. W.: U. S. Geol. Surv., Professional Paper 135, p. 12.
[2] Collins, W. D.: U. S. Geol. Surv., Water Supply Paper 658, p. 77.

from Lake Nipissing—analysis of which is tabled under the Atlantic Watershed—wherefore dilution is to be expected. This dilution, however, is counterbalanced at the southern end of Georgian Bay by a number of tributaries: the Severn, draining the Couchiching and Simcoe Lakes of hard water; and the Sydenham and several smaller tributaries increasing the hardness of the Georgian Bay water appreciably. At Collingwood, the Georgian Bay water has a hardness of 117 parts per million; flowing north it mixes with the softer waters, and at Parry Sound the hardness is 70 parts per million.

The mixture of the Lake Huron waters of various concentrations appears incomplete even as far south as Goderich where the water has a hardness of 108·3 parts per million, as compared with 98·3 parts per million for Lake St. Clair at Point Edward.

The Detroit River at Walkerville shows an increase in hardness to 101·3 parts per million. The difference, 3 parts per million, is slight and might be due to analytical error or in the sampling. Nevertheless, analyses of samples taken at Point Edward and at Walkerville at 12-hour intervals show consistently slightly lower total hardness for the Point Edward water, which should be correct, since tributaries to Lake St. Clair, notably the Thames, although comparatively small in volume, have very hard waters. At Amherstburg, there appears an increase in hardness of 9·6 parts per million, which might be expected from the very large quantities of effluence and the heavy factory waste from densely populated and industrial districts.

Lake Erie shows a sharp increase in hardness, the samples analysed off Port Colborne and off Fort Erie having an average hardness of 131·8 parts per million. Tributaries to Lake Erie all have very hard waters, Huron River, Wolf Creek, Raisin River, and Maumee River, on the United States side, having 298, 245, and 207 parts per million total hardness[1]; and even harder water being received from the drainage and tributaries from the Province of Ontario, for example, the Grand River, with variations in hardness ranging from 225 to 420 parts per million.

The peak in concentration for hardness appears to be reached at Niagara Falls and Hamilton with hardnesses of 135 and 134·1 parts per million, respectively.

Lake Ontario shows a marked drop in hardness recorded for an average of the samples collected at Toronto, Oakville, and Kingston at 125·0 parts per million. Of the three places, Toronto shows the lowest average, which appears odd owing to the heavy effluence from such a large manufacturing city and the very hard water of the Don River running through the city. The samples of Toronto water, however, were taken from the intake pipe at the Island Water Works and drawn from a depth of 90 feet, at which level, in all probability, the water is unaffected. The water-works' officials state that there is a marked change in the composition of the water, especially in regard to the bacterial content, when an easterly wind is blowing, which would indicate admixture with Toronto waste water.

The St. Lawrence River water from Kingston to Lake St. Louis shows a slight drop in hardness to 123·6, the average of samples collected at Prescott, Cornwall, and Valleyfield. This might be expected, since the tributaries from the State of New York discharge soft waters. The Oswegatchie River at Ogdensburg has a hardness of only 50 parts per million.[2] No tributaries of importance come from the Canadian side.

A true average of the hardness of the St. Lawrence water at Montreal is difficult to obtain unless numerous samples be collected throughout the year. The hardness of 18 samples so far collected and analysed range from 74 to 126 parts per million, averaging for all waters 101·6, and for the raw waters 98·3 per million. This great range in hardness is due to the soft and coloured water of the Ottawa River, the largest tributary of the St. Lawrence, part of which enters at Lake St.

[1] U. S. Geol. Surv., Water Supply Paper 658, p. 105.
[2] U. S. Geol. Surv., Professional Paper 135 (1924) p. 25.

Louis. The two waters do not mix so readily as might be supposed but run for many miles before complete mixture has been accomplished.

A parallel case, often quoted, is that of the blue Mississippi and the white Missouri, which after joining run for miles with a sharp dividing line between the two waters and much farther before complete mixture has been attained.

The bulk of the water used by almost one and one-half million consumers of the City of Montreal and adjoining districts is drawn from above the Lachine Rapids. At high gauge of the Ottawa River the flow is rapid and deflects the St. Lawrence current. The Ottawa River water, soft and coloured, enters the conduits of the Montreal waterworks, affecting the quality of the supply accordingly. Although soft water is generally desired and is economical the Ottawa River water, as seen by the tabulated analyses, is rather highly coloured, thus incurring a much more expensive method of treatment than what would be required for the clear, colourless water of the St. Lawrence River.

It is doubtful whether a thorough mixture is accomplished even below the Lachine Rapids, as two samples collected within one hour at St. Lambert and at Longueuil showed on analysis a marked difference in hardness.

Fifty miles below Montreal, above Sorel, the hardness is 93·0 parts per million, which no doubt represents a uniform mixture, as the difference in hardness of several samples collected was not appreciable. This is, however, no check on the average hardness of the Montreal water supply, because a large part of the Ottawa River water enters the St. Lawrence at the foot of Montreal Island.

The waters west of Lake Superior were investigated as far as the Columbia River at Golden, British Columbia, in 1937; and in 1939 the same territory was again covered, including the whole of British Columbia with the exception of the northern areas drained by the Skeena and Bulkley Rivers, which have not been investigated. Hence, the analyses of the western waters are represented by very few analyses for each key station—two to three for those of the Prairie Provinces and one for those of British Columbia.

It was suggested in the 1937 investigation, Interim Report No. 3, in the absence of previous official records of analyses, that the prolonged drought in the Prairie Provinces might have affected the quality of the western waters and the analyses made then might represent abnormally high concentrations. Judging from the following year's investigation, this appears not to be the case. The Red River and the Assiniboine River, which gave the highest concentration of the western surface waters, show no marked difference in most constituents, except for the content of chlorides in the Red River, which was very much reduced; otherwise, the two samples taken two months apart differ in composition no more than might be expected seasonally, and the same may be said of the other large arteries, the two Saskatchewans, the Bow, Elbow, and Red Deer Rivers.

The British Columbia surface waters, apart from the Columbia and Fraser Rivers, are not represented by previous official analyses, wherefore comparison is impossible. The Columbia River at Golden shows somewhat higher concentration for 1938 than for 1937. Of the two samples taken in July the analysis of the Trail key station sample shows less concentration than that from Golden, although the latter is about 400 miles up river. The dilution may be due to appreciable inflow of glacial water during the summer season, but with so few analyses on record no conclusions should be drawn. Systematic sampling and analyses of the Fraser River were made by the Department of Mines in 1909, and reveal large variation in concentration as well as in composition. Of the two samples taken at Hope and Mission in July, 1938, the analysis of the former shows an abnormally high content of alkali and chloride, compared with any previous record, and is likely to be incidental. A second sample was, therefore, taken at the same key station in December, and revealed on analysis a very low content of alkali and chloride, appreciably

lower than any of our 1909 records. On the whole, the 1909 records of analyses, except for the minimum low-gauge water for April 26 to May 23, show appreciably lower concentration than the 1938 analyses. Analyses of the samples taken at Hope and Mission are not comparable because tributaries enter the Fraser River between these two places.

Civic Water Supplies

The composition of civic water supplies, where the waters are treated, depends much on the chemicals added in the purification processes and on the method of treatment. When lime is added to waters having a high content of bicarbonate of calcium and magnesium, these constituents will be reduced and the waters will be softer; if lime be added to soft waters, with no or small amounts of bicarbonates, in order to raise the pH value for the prevention of corrosion, there will be an increase in hardness. Ammonium sulphate, sodium thiosulphate, soda, alum, and chlorine will increase the alkali, sulphate, carbonate, and chlorine ions, and sodium zeolite treatment will displace the calcium and magnesium ions with alkali ions. Purification of waters is more prevalent for surface than for ground waters in Canada.

Of the springs examined, those yielding hard and soft waters are about equal in number; but the wells, with very few exceptions and most of these in the Maritime Provinces and Quebec, yield hard and very hard waters. The waters from springs and wells are not, as a rule, purified. A few supplies have intermittent chlorination when necessary, and if they are mixed with surface water when the supply in the wells and springs becomes low. In the Prairie Provinces most civic water supplies are drawn from reservoirs, smaller lakes, rivers, and wells. Contrary to expectation, of the 22 supplies examined in 1938, 14 showed on analysis higher total hardness, and 8, lower total hardness than for 1937. The average hardness for all supplies in that area was 260 parts per million for 1937, as compared with 276·5 parts per million for 1938, the increase in hardness being higher for ground waters than for surface waters. The apparent paradox that 1937 was the last of a series of drought years, whereas rains were fairly plentiful in many parts of the Prairie Provinces in 1938, may be explainable by the fact that after the prolonged drought it would require time for the soil to absorb the precipitation in 1938 so that it could penetrate to the depth of the ground-water table and cause dilution.

The British Columbia civic waters are on the whole very good industrial waters, low in colour and iron, preponderantly soft to medium hard, and most of them can be distributed to the consumers without previous treatment.

DISTRIBUTION OF HARD WATERS

Hardness Maps

A hardness map for Eastern Canada appeared in Interim Report No. 2 in 1937, and for the whole of Canada in Interim Report No. 5 in 1940. Since the compilation of the last map, additional information regarding the hardness of civic water supplies has been obtained, which in some cases has changed the average of the hardness of some supplies to other hardness classes, and a few new supplies have been added to the map. Owing to crowding of the places on the map where the density of the population is heavy, the map has been enlarged and is now printed in two sections: Figure 2—the Maritime Provinces, Quebec, and Ontario; and Figure 3—Western Canada. The hardness maps in this report represent the distribution of the various hardnesses of civic waters for the whole of Canada, with the exception of the northern part of British Columbia and of the Yukon, which have not been investigated.
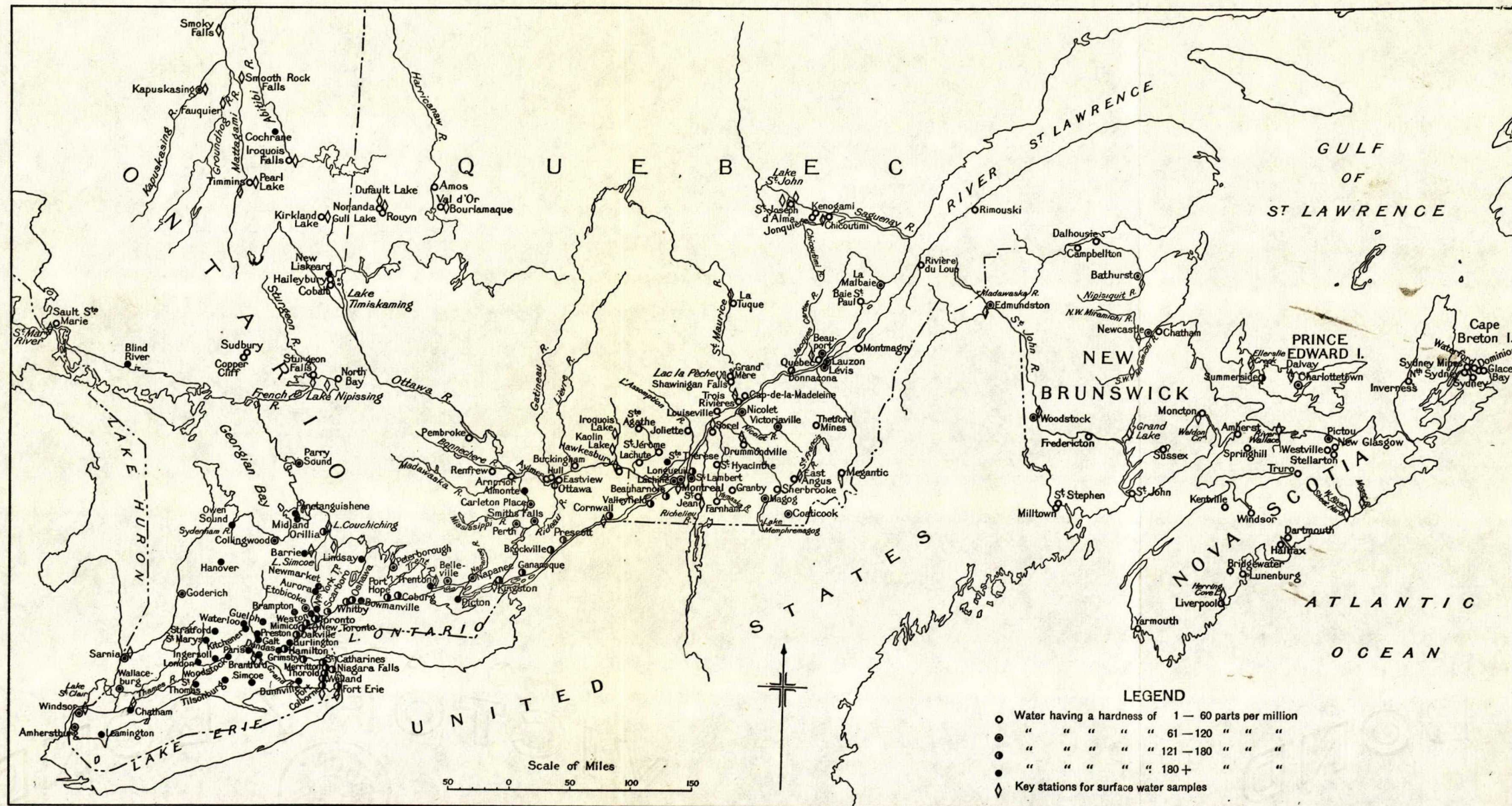
FIGURE 2. Map of Eastern Canada showing distribution of the larger civic water supplies according to hardness.

LEGEND

○ Water having a hardness of 1 — 60 parts per million
◔ " " " " " 61 — 120 " "
◑ " " " " " 121 — 180 " "
● " " " " " 180+ " "
◇ Key stations for surface water samples

Scale of Miles
50 0 50 100 150
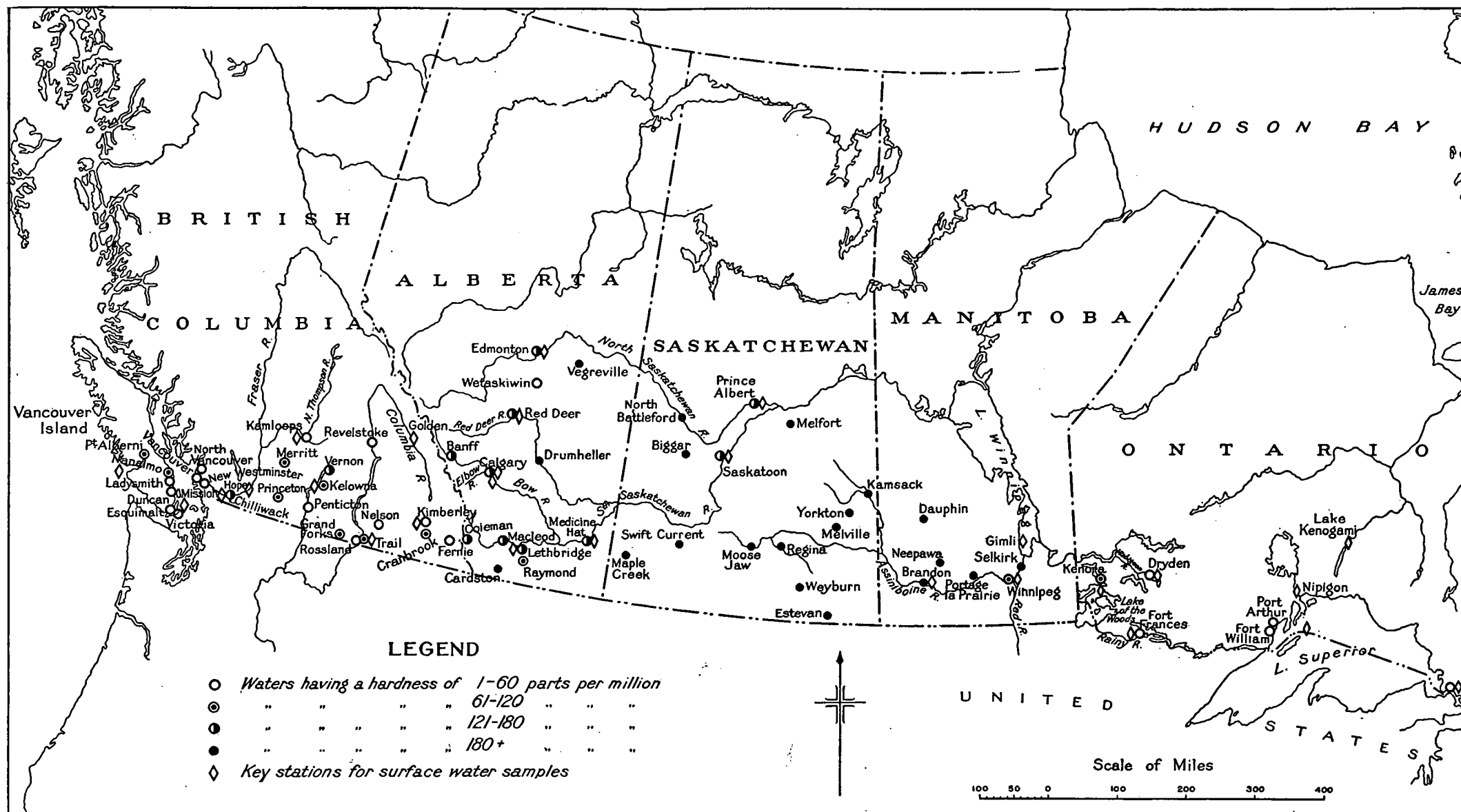
FIGURE 3. Map of Western Canada showing distribution of the larger civic water supplies according to hardness.

In compiling the data for a hardness map the United States Geological Survey's investigation on "Industrial Utility of Public Water Supplies," Water Supply Paper 658 (1932), pages 12 to 19, comprises analyses of 670 centres of 20,000 inhabitants and over, including, however, several smaller communities so that a better distribution of results over the less densely populated states might be obtained. These 670 places contain 46·2 per cent of the population of the United States.

Since Canada has only 31 places of 20,000 inhabitants and over, the adoption of this as a minimum unit would furnish inadequate data. For the eastern part of Canada, that is east of Sault Ste. Marie exclusive of the northern mining and industrial areas in Ontario and Quebec, therefore, a population of 3,000 and over has been chosen; and, for the rest of the country, 2,000 and over, giving a total of 237 supplies distributing water to 300 places and representing 52·4 per cent of the population of Canada. The minimum of 2,000 inhabitants and over for Western and Northern Canada has been chosen because of the comparatively sparse population and the existence of only a few larger cities and towns. The ratio is not thereby increased to any appreciable extent, but it does give a better geographical distribution of the various industrial and civic waters, for, of the 83 supplies reported, only 4 places in northern Ontario and Quebec, 1 in Manitoba, 4 in Saskatchewan, 6 in Alberta, and 6 in British Columbia have less than 3,000 inhabitants. A few places of less than 2,000 inhabitants have had to be included in order to have certain districts represented on the map, or to show where the water supplies are of industrial importance.

The population figures for the cities and towns used to compile these data represent the total numbers of persons served, because many supplies distribute their water beyond the city or town limits to adjacent suburbs, smaller towns and villages the populations of which are not included in the census statistics. These figures have been obtained from Engineering and Contract Records, March 27, 1940, pages 55 to 82. For the total population of the Dominion and for the provinces, the figures given are taken from the Bureau of Statistics' estimate for 1939, as these give a more accurate proportion of the population served and the total population than the 1931 census. In this more recent revision, no effort was made to correct these figures on the basis of the 1941 census, since, owing to concentration and shifting of population due to the war, a true representation of the population locale is not considered obtainable.

Many systems for reporting hardness are found in the technical literature. That adopted by the United States Geological Survey has been chosen for the Industrial Waters Investigation because many waters are international, some rivers flowing through both countries. It is as follows:—

Total hardness, p.p.m., as calcium carbonate ($CaCO_3$)

1 to 60...Soft water
61 to 120..Medium hard water
121 to 180...Hard water
181..Very hard water

Subdivisions of these may be made as the hardness approaches the upper or lower limit set, for example: 30 parts per million and less may be termed very soft water; 65 parts per million, medium hard to soft; 125 parts per million, hard to medium hard; 175 parts per million, hard to very hard, etc.

TABLE I

Number of People in Various Provinces (1939) Served by Waters Investigated

Province	Number of places served	Number of supplies	Population	Population served	Percentage of population served
Nova Scotia................	23	20	554,000	228,493	41·2
New Brunswick............	14	12	451,000	137,235	30·4
Prince Edward Island........	2	2	95,000	18,000	18·9
Quebec....................	73	52	3,210,000	2,086,892	65·0
Ontario...................	119	96	3,752,000	2,290,556	61·0
Manitoba..................	12	6	727,000	314,910	43·3
Saskatchewan..............	14	14	945,000	161,534	17·1
Alberta...................	13	13	789,000	219,135	27·8
British Columbia...........	30	22	774,000	461,580	59·6
Total...............	300	237	11,297,000	5,918,335	52·4

In the preparation of the hardness maps the writer has departed from the usual method of shading from white for the soft waters to dark for the very hard waters for areas defined by the political boundaries of provinces or states, as the case may be, because of the possible inference that by stepping across a border line into another province the water would suddenly change in hardness. A province, moreover, might be.dominated by one single large supply, like that of Winnipeg, which is of medium hardness, and all other supplies in Manitoba are very hard waters. Likewise in the Province of Quebec, Montreal and adjacent districts have medium hard water, and practically all the rest of the province is supplied with soft waters. A better way would be to shade the districts in conformity with the distribution of the waters irrespective of political division; but, as insufficient data are available, the waters investigated serving only 52·4 per cent of the population, this again might lead to false deductions from the map.

The water supplies have, consequently, been plotted on the map by means of symbols indicating the range of hardness of the water for each particular place. The reader at a glance can perceive the geographical distribution of the hardness of the various water supplies for the Dominion.

Distribution of the Various Hardnesses of the Larger Canadian Water Supplies

The computation of results of analyses showing the hardness[1] of the larger public water supplies in Canada has been summarized in Tables II, III, and IV; in the hardness maps, Figures 2 and 3; and in the diagram and table, Figure 4. Interpreting these data it must be borne in mind that they relate only to 52·4 per cent of the total population of Canada, served by the larger supplies that have been sampled and analysed in this investigation. Three of the provinces exceed this ratio, whereas the other six are appreciably less (*see* Table I).

Examining Table IV, it is clear that the proportion of persons served by ground waters in the Dominion is small, only 4·0 per cent of the total population or 7·6 per cent of the population served by the supplies studied. This is partly due to the densely populated districts on the shores of the Great Lakes and the more important rivers and lakes that supply the large cities, but were complete data available for all supplies the ground water ratio would be much higher because in the rural districts and smaller communities the inhabitants are usually served by wells or springs.

[1] Based on analyses of samples collected to the end of 1940.

As regards the hardness of the water supplies, the ground waters especially in the Province of Ontario and the Prairie Provinces are preponderantly very hard, and the average for the whole of Canada very hard, whereas the surface waters are hard and medium hard. In the Prairie Provinces, surface waters in Manitoba are very hard with the exception of the medium hard Winnipeg supply derived from the Lake of the Woods watershed; and the ground waters are also very hard, represented by one supply only. Saskatchewan has very hard ground and surface waters except the supplies from the two Saskatchewan Rivers, which are hard to medium hard. Alberta waters are, on an average, hard, but less so than those of Saskatchewan. British Columbia has preponderantly soft and medium hard waters, the three largest supplies being very soft water, all supplies but one being surface water.

TABLE II

Number of Persons, in Thousands, Using Water of Different Degrees of Hardness, from Large Public Supplies in Canada (1939)

Hardness, parts per million	Surface water	Ground water	Total
1– 20	513·2	10·8	524·0
21– 30	430·5	13·8	444·3
31– 40	259·4	11·7	271·1
41– 50	93·6	12·0	105·6
51– 60	324·1	5·0	329·1
61– 80	67·6	1·5	69·1
81–100	370·2	20·2	390·4
101–120	1,633·8	24·9	1,658·7
121–180	1,549·3	24·5	1,573·8
181–250	49·7	52·6	102·3
251–400	138·3	123·6	261·9
401–600	1·9	119·1	121·0
601 +	....	67·2	67·2
Total	5,431·6	486·9	5,918·5

In Table III the hardness data have been summarized from the analyses of each province, by calculating the weighted average for hardness of the surface water supplies, of the ground water supplies, and of both under the heading "All Supplies."

To calculate the weighted average hardness of the surface water supplies, the average hardness of each supply was multiplied by the number of consumers, and the sum of these products was divided by the sum of the number of consumers.[1]

A similar calculation was made for the ground waters. The totals of the products for surface water and ground water were added, and this sum was divided by the total numbers of consumers, to obtain the weighted average hardness of all supplies of a province.

The results compiled in Table III are graphically shown in Figure 4.

The weighted averages for the Maritime Provinces are the most uniform, Nova Scotia, with the exception of the Pictou supply, which is medium hard, having very soft water, well within the limit of that classification. Windsor and Yarmouth have the softest waters so far sampled and analysed in this investigation. Prince Edward Island is represented by two supplies only, of a weighted average of medium hard water, being very near to hard. In New Brunswick, both surface and ground waters are soft.

The Province of Quebec has a weighted average of medium hard, and is much dominated by the Montreal St. Lawrence district, within which comparatively small area is located about 50 per cent of its population. Elsewhere in the province the waters are prevailingly soft, both surface and ground waters.

[1] U. S. Geol. Surv., Water Supply Paper 658, p. 15.

TABLE III

Weighted Average Hardness of Water from Large Public Supplies

	Surface Supplies			Ground Water			All Supplies		
	Average hardness, as CaCO$_3$, parts per million	Population served		Average hardness, as CaCO$_3$, parts per million	Population served		Average hardness, as CaCO$_3$, parts per million	Population served	
Province		Thousands	Percentage of total population of province		Thousands	Percentage of total population of province		Thousands	Percentage of total population of province
Nova Scotia....................	19·6	219·0	39·5	56·0	9·5	1·7	21·1	228·5	41·2
New Brunswick..............	40·8	123·6	27·4	55·0	13·6	3·0	42·3	137·2	30·4
Prince Edward Island........				119·2	18·0	18·9	119·2	18·0	18·9
Quebec......................	87·0	2,041·0	63·6	60·1	45·9	1·4	86·3	2,086·9	65·0
Ontario.....................	122·5	1,998·9	53·2	350·6	291·7	7·8	151·9	2,290·6	61·0
Manitoba....................	116·5	311·4	42·8	648·0	3·5	0·5	122·0	314·9	43·3
Saskatchewan...............	264·9	69·2	7·3	589·9	92·3	9·8	450·7	161·5	17·1
Alberta.....................	152·4	213·2	27·0	121·2	5·9	0·8	151·8	219·1	27·8
British Columbia............	26·7	455·1	58·8	112·2	6·5	0·8	27·9	461·6	59·6
Canada.....................	97·8	5,431·4	48·1	343·8	486·9	4·3	118·0	5,918·3	52·4
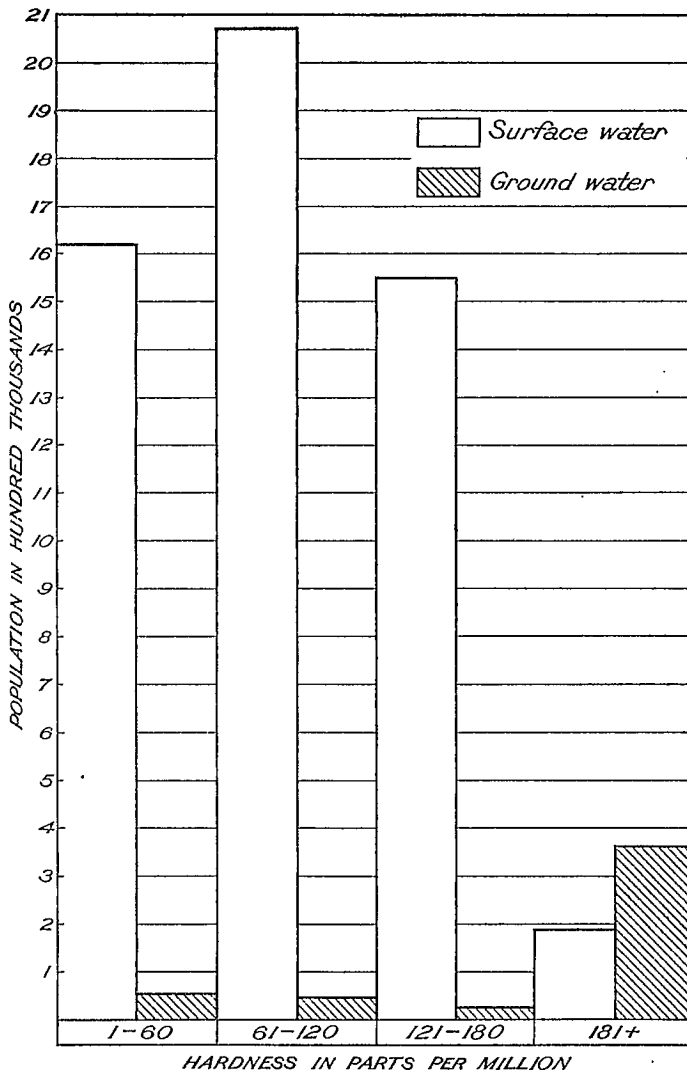
FIGURE 4. Diagram showing number of persons using water of certain degrees of hardness from large public supply systems.

Range of hardness in parts per million	Population in thousands		
	Surface	Ground	Total
1 – 60.................	1,620·8	53·3	1,674·1
61 – 120.................	2,071·6	46·6	2,118·2
121 – 180.................	1,549·3	24·5	1,573·8
181 +...................	189·9	362·5	552·4
Total..............	5,431·6	486·9	5,918·5

For Ontario the weighted average is hard water, but water supplies of all degrees of hardness exist in the province, from the soft water of the northern and northwestern supplies, the medium hard waters around Lake Huron, the hard waters following Lake Erie, Lake Ontario, and the St. Lawrence River, and the very hard waters found in the southwestern part of the province. Practically all the ground waters are very hard.

Of the Prairie Provinces the weighted average is hard water for Manitoba and Alberta, and very hard water for Saskatchewan. The Manitoba surface water is medium hard, but, as previously explained, this is due to the large supply drawn from the Lake of the Woods in Ontario.

The weighted average of ground waters is very hard for Saskatchewan and for the one supply reported for Manitoba, and hard to medium for Alberta.

For British Columbia the weighted average of all supplies is very soft, with ground water from one supply only of medium hardness.

Table IV shows the sources of public water supplies, the method of treatment of the waters at the various distributing stations, and the number of consumers in Canada receiving surface and ground waters treated and untreated.

TABLE IV

Source and Treatment of Public Water Supplies in Cities and Towns of 3,000 Inhabitants and over in Eastern Canada, and 2,000 and Over in Western Canada (1939)

Source and treatment	Number of places supplied	Number of supplies	Population Served	
			Thousands	Percentage of the total population of Canada
Surface Waters:				
No treatment....................	52	43	649·7	5·8
Chlorination only.................	72	55	1,146·6	10·2
Filtration.......................	117	85	3,665·5	32·4
Ground Waters:				
No treatment....................	46	44	295.7	2·6
Chlorination only.................	6	5	121·8	1·1
Filtration.......................	5	3	16·3	0·1
Zeolite treatment................	2	2	22·9	0·2
Total......................	300	237	5,918·5	52·4

TABLE V

Analyses* of Surface Waters

ATLANTIC WATERSHED

Sample No	641	214	323	324	643	732	642	733	639	730	798	640	731	797	325	638	729	803
Date of Sampling	5/9/39	2/7/35	4/6/36	5/6/36	29/8/39	16/8/40	25/8/39	12/8/40	29/7/39	29/7/40	30/8/41	29/7/39	29/7/40	30/8/41	3/6/36	28/7/39	24/9/40	8/9/41
Source	Herring Cove Lake	St. John River					Grand Lake, N.B.		S.W. Miramichi River			N.W. Miramichi River			Nipisiguit River			
Locality	Brooklyn, N.S.	Edmundston, N.B.		Woodstock, N.B.			Near Newcastle Creek	Off Robert Point	Quarryville, N.B.			Redbank, N.B.			Bathurst, N.B.			
Sample collected	Depth sample, midlake	Depth sample, midstream		Intake waterworks	Depth sample, midstream		Depth sample, 2 miles from shore		Depth sample, midstream			Depth sample, midstream			Intake pipe at pulp mill			
Gauge	High	Mean	Mean	Mean	Low	Low	High	High	Mean	Mean	High	Mean	Mean	High	Mean	Low	Mean	High
Temperature, °C	23·0	16·0	15·0	12·0	23·0	22·0	26·0	18·0	24·0	15·0	20·0	24·0	14·0	20·0	16·0	25·0	13·5	18·3
pH	5·8	7·1	6·8	7·5	7·3	7·8	7·0	7·0	7·3	6·9	7·1	7·3	6·9	7·0	6·8	7·2	7·0	6·7
Dissolved oxygen......ml./l.	5·3	6·3	6·6	6·5	6·5	5·4	5·6	6·1	6·0	6·6	6·3	6·0	6·6	6·1	7·0	6·2	6·9	6·1
Free carbon dioxide (CO₂)......p.p.m.	5·0	1·0	2·5	None	1·0	None	3·0	1·5	None	1·5	0·5	None	1·0	1·0	None	None	0·5	2·0
Turbidity...................."	None	None	None	None	1·0	None	None	None	None	None	None	None	None	None	None	None	None	None
Colour...................."	70·0	30·0	60·0	50·0	65·0	35·0	85·5	None	20·0	75·0	50·0	40·0	70·0	40·0	30·0	25·0	40·0	25·0
Alkalinity as CaCO₃............"	None	20·5	25·5	34·0	36·0	60·0	4·5	2·8	15·5	4·0	9·2	8·5	1·0	7·0	12·1	13·0	4·5	4·5
Suspended matter............."	4·0	None	2·6	0·6	3·6	1·6	1·9	7·6	1·7	3·0	4·1	2·2	1·5	3·6	None	1·0	2·3	1·3
Residue on evaporation dried at 110°C............."	31·2	56·6	68·2	67·6	86·2	107·1	48·7	40·8	40·0	38·7	48·0	34·6	35·3	41·8	30·0	36·6	39·0	43·1
Silica (SiO₂)...................."	1·6	5·0	5·8	3·4	5·6	5·2	2·2	7·4	4·0	4·7	4·6	5·6	4·2	5·3	3·8	5·2	9·6	7·4
Iron (Fe)...................."	0·56	0·50	0·11	0·09	0·12	0·10	0·23	0·12	0·07	0·50	0·28	0·10	0·08	0·32	0·10	0·05	0·10	0·05
Calcium (Ca)...................."	2·2	7·1	16·1	12·9	16·5	21·4	4·8	2·9	10·7	4·2	6·7	6·8	3·8	6·0	4·2	10·4	5·0	5·3
Magnesium (Mg)...................."	3·9	1·3	2·3	2·0	6·6	6·3	4·9	1·4	3·3	1·0	1·7	4·4	1·1	1·6	1·5	3·1	1·4	1·9
Alkalis as sodium (Na)........."	5·3	1·7	7·7	2·6	3·5	3·2	6·3	4·8	4·5	2·0	3·1	5·1	2·4	1·9	....	4·1	2·4	3·3
Hydrocarbonate (HCO₃)........"	None	25·0	31·1	41·5	43·9	73·2	5·5	3·4	18·9	4·9	11·2	10·4	1·2	8·5	14·8	15·9	5·5	5·5
Sulphate (SO₄)...................."	2·7	4·1	8·2	10·3	7·8	9·5	6·4	6·3	4·5	3·6	8·4	4·1	3·9	6·5	5·2	5·4	6·4	5·0
Chloride (Cl)...................."	7·0	1·0	15·5	3·5	1·0	2·5	3·5	3·0	1·0	0·5	0·6	1·0	0·5	0·6	2·5	1·0	3·5	5·0
Nitrate (NO₃)...................."	0·62	0·60	0·88	0·24	0·44	0·53	0·27	0·88	0·44	0·62	0·4	1·77	0·35	0·40	0·24	0·44	0·88	0·40
Hardness as CaCO₃ calculated:																		
Total hardness............."	21·5	23·1	49·7	40·5	68·4	79·3	32·1	13·0	40·3	14·6	23·8	35·0	14·0	21·6	16·7	38·7	18·2	21·1
Carbonate hardness........"	None	20·5	25·5	34·0	36·0	60·0	4·5	2·8	15·5	4·0	9·2	8·5	1·0	7·0	12·1	13·0	4·5	4·5
Noncarbonate hardness....."	21·5	2·6	24·2	6·5	32·4	19·3	27·6	10·2	24·8	10·6	14·6	26·5	13·0	14·6	4·6	25·7	13·7	16·6
Calcium hardness..........."	5·5	17·8	40·3	32·3	41·3	53·5	12·0	7·3	26·8	10·5	16·8	17·0	9·5	15·0	10·5	26·0	12·5	13·3
Magnesium hardness........"	16·0	5·3	9·4	8·2	27·1	25·8	20·1	5·7	13·5	4·1	7·0	18·0	4·5	6·6	6·2	12·7	5·7	7·8

* Mr. H. Mercier assisted in making the following analyses.

TABLE V—Continued

Analyses* of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

Sample No.	791[1]	792	793	794	795	796	804[2]	805	806	807	808	809	810	811
Date of sampling	8/8/41	8/8/41	13/8/41	13/8/41	28/8/41	28/8/41	16/10/41	16/10/41	16/10/41	16/10/41	16/10/41	16/10/41	16/10/41	16/10/41
Source	Pollett River		North River	Petit-codiac River	Little River	Turtle Creek	Lime-hurner Lake	Welch Lake	Kerr Lake	St. Patrick Lake	Johnson Lake	Gihson Lake	Bona-parte Lake	Crecy Lake
Locality	River Glade, N.B.	¼ mile S. of Pollett River Village, N.B.	5 miles N. of Petit-codiac, N.B.	Salis-hury, N.B.	Upper Cover-dale, N.B.	5 miles from outlet; N.B.	Chain of lakes 7 miles from St. Andrews, Charlotte county, N.B.							
Sample collected	Depth sample, from hridge	Depth sample, from hridge	Depth sample, from hridge	Depth sample, mid-stream	Depth sample, from hridge	Depth sample, mid-stream	Depth sample, midlake	Depth sample, midlake	Depth sample, midlake	Depth sample, midlake	Depth sample, mi dlake	Depth sample, midlake	Depth sample, midlake	Depth sample, midlake
Gauge	Low	Low	High	High	High	High								
Temperature, °C	26·0	19·0	20·0	19·0	20·0	20·0	14·2	13·7	14·0	13.8	14·3	14·2	14·7	13·8
pH	7·3	7·5	6·7	7·0	7·4	7·6	6·9	6·7	6·7	6·6	6·5	6·9	6·6	6·7
Dissolved oxygen ml./l.	5·1	5·8	5·2	5·9	6·6	6·6								
Free carhon dioxide (CO_2) p.p.m.	None	None	3·0	1·0	None	None								
Turbidity "	None	6·0	None	15·0	None	7·0	None	None	None	None	None	None	None	None
Colour "	105·0	20·0	200·0	120·0	5·0	10·0	10·0	30·0	25·0	35·0	40·0	15.0	25·0	10·0
Alkalinity as $CaCO_3$ "	21·5	12·5	11·5	8·0	15·0	15·0	6·0	2·5	None	None	6·9	2·5	2·5	None
Suspended matter "	1·2	8·5	1·9	18·1	3·7	13·8	1·7	1·6	1·8	1·9	2·0	1·8	1·4	1·9
Residue on evaporation dried at 110°C "	216·3	46·8	118·0	57·0	46·1	46·5	30·9	35·0	34·4	33·4	39·0	29·4	34·4	23·8
Silica (SiO_2) "	3·5	4·6	3·6	4·4	4·4	3·5	1·6	0·6	2·2	2·2	2·2	1·3	1·5	1·5
Iron (Fe) "	0·07	0·06	0·07	0·07	0·46	0·25	0·03	0·03	0·03	0·02	0·16	0·02	0·02	0·03
Calcium (Ca) "	25·0	7·2	14·3	9·0	7·0	6·5	4·3	3·7	3·4	2·9	3·7	3·7	2·4	2·4
Magnesium (Mg) "	3·0	1·5	2·3	2·5	2·0	1·9	1·7	1·3	1·1	1·2	1·4	1·1	0·7	0·7
Alkalis as sodium (Na) "	34·8	5·5	7·2	8·0	4·1	3·9	4·0	3·3	2·4	2·8	3·0	3·9	3·1	3·6
Hydrocarhonate (HCO_3) "	26·2	15·3	14·0	9·8	18·3	18·3	7·3	3·1	None	None	8·4	3·1	3·1	None
Sulphate (SO_4) "	53·2	7·7	20·2	17·0	7·7	8·4	3·7	3·8	4·9	4·6	4·0	3·7	4·6	4·7
Chloride (Cl) "	45·5	0·5	5·5	10·0	3·7	3·6	2·5	2·0	2·4	2·3	2·1	3·0	2·0	2·5
Nitrate (NO_3) "	0·40	0·09	Trace	0·40	0·60	0·70	0·2	3·4	0·9	0·6	0·6	1·2	0·4	0·6
Hardness as $CaCO_3$ calculated: Total hardness "	74·8	24·2	45·2	32·8	25·7	24·1	17·8	14·6	13·0	12·2	15·0	13·8	14·3	8·9
Carhonate hardness "	21·5	12·5	11·5	8·0	15·0	15·0	6·0	2·5	None	None	6·9	2·5	2·5	None
Noncarhonate hardness "	53·3	11·7	33·7	24·8	10·7	9·1	11·8	12·1	13·0	12·2	8·1	11·3	11·8	8·9
Calcium hardness "	62·5	18·0	35·8	22·5	17·5	16·3	10·8	9·3	8·5	7·3	9·3	9·3	9·8	6·0
Magnesium hardness "	12·3	6·2	9·4	10·3	8·2	7·8	7·0	5·3	4·5	4·9	5·7	4·5	4·5	2·9

[1]Samples 791 to 796 were collected and analysed for the Fisheries Research Board of Canada.
[2]Samples 804 to 811 were collected and field analyses made hy the lahoratory staff of the Fisheries Research Board at St. Andrews Biological Station, N.B.

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

		716¹	717	645	646	719	647	721	648	718	720	722	723	726	724
Sample No		716¹	717	645	646	719	647	721	648	718	720	722	723	726	724
Date of sampling		9/8/40	9/8/40	12/8/39	12/8/39	1/8/40	12/8/39	2/8/40	12/8/39	3/8/40	3/8/40	3/8/40	3/8/40	1/8/40	10/7/40
Source		Malagash Brook	Wallace River, N.S.	Mill Lake Brook	Moser River, at Salmon trap		Gold Mine Creek		West Brook	Second Bear Lake Brook	Johnny Smith's Brook	North Brook	First Bear Lake Brook	West River	Ellerslie Creek
Locality		Tatamagouche, N.S.	—	Moser River Basin, N.S.										Sheet Harbour, N.S.	Ellerslie, P.E.I.
Sample collected		2 miles up-stream	3 miles up-stream	Midstream			500 feet above outlet		Near outlet	2 miles up-stream	On bridge. road to Bear Lake	—	Bear Lake Road	Above dam at mill	One mile from outlet
Gauge		Low	Low	Low	Low	High	Low	Mean	Low	Low	Mean to low	Low	Low	Low	Low
Temperature. °C		23·0	25·5	26·0	25·0	20·5	20·0	18·5	23·0	26·0	18·0	21·5	23·0	20·6	19·0
pH		6·9	7·4	6·1	6·7	6·7	6·0	5·9	6·5	6·4	6·4	6·3	6·0	6·0	7·9
Dissolved oxygen	ml./l.	6·0	5·6	5·2	6·3	5·3	5·3	6·0	5·3	6·4	5·7	6·0	4·3	5·5	6·0
Free carbon dioxide (CO_2)	p.p.m.	2·0	None	3·0	2·0	2·0	5·0	5·0	5·0	2·0	2·0	2·0	4·0	3·0	None
Turbidity	"	7·0	4·0	None	None	None	None	None	None	None	None	None	None	None	None
Colour	"	20·0	20·0	25·0	60·0	80·0	65·0	130·0	65·0	35·0	60·0	80·0	25·0	80·0	50·0
Alkalinity as $CaCO_3$	"	11·3	14·0	0·5	1·0	3·0	None	None	0·5	None	None	11·6	0·5	10·0	72·0
Suspended matter	"	12·3	8·6	3·0	1·8	5·0	None	1·5	0·6	2·0	1·3	3·5	2·3	3·9	5·0
Residue on evaporation dried at 100°C	"	5,358·0	82·2	41·0	32·6	34·4	52·4	51·7	40·3	31·7	76·1	79·0	55·0	44·5	132·5
Silica (SiO_2)	"	3·6	6·6	2·6	2·6	3·6	1·7	4·0	2·9	1·9	6·0	18·6	2·0	2·5	2·3
Iron (Fe)	"	0·18	0·15	0·20	0·15	0·48	0·12	0·12	0·12	0·28	0·18	0·12	0·12	0·06	0·40
Calcium (Ca)	"	22·0	7·2	7·8	4·3	2·6	4·3	3·0	4·3	2·8	1·4	4·6	2·4	8·2	33·8
Magnesium (Mg)	"	190·5	3·2	4·7	3·3	1·2	4·2	1·3	4·9	1·1	1·4	0·7	0·8	1·4	2·3
Alkalis as sodium (Na)	"	1,733·8	10·7	6·4	4·9	4·5	6·4	6·0	7·4	5·0	3·5	4·5	5·2	3·5	6·5
Hydrocarbonate (HCO_3)	"	13·8	17·1	0·6	1·2	3·7	None	None	0·6	None	None	14·2	0·6	12·2	87·8
Sulphate (SO_4)	"	376·7	9·0	5·2	5·7	4·5	5·7	3·7	5·0	2·6	3·0	2·1	4·4	4·1	5·2
Chloride (Cl)	"	2,990·0	22·0	10·0	4·5	4·0	8·5	7·5	7·5	4·0	4·5	4·5	4·5	2·5	11·5
Nitrate (NO_3)	"	0·62	0·20	0·44	0·44	0·35	0·80	0·53	0·35	None	0·35	1·15	0·88	3·54	0·71
P_2O_4	"	0·40	1·03	0·80	0·60	0·54	0·82	0·65	1·32	0·28	0·35	0·61	2·52	2·39	0·75
Hardness as $CaCO_3$ calculated:															
Total hardness	"	836·1	31·1	38·8	24·3	11·4	28·0	12·8	30·9	11·5	9·2	14·4	9·3	26·2	93·9
Carbonate hardness	"	11·3	14·0	0·5	1·0	3·0	None	None	0·5	None	None	11·6	0·5	10·0	72·0
Noncarbonate hardness	"	824·8	17·1	38·3	23·3	8·4	28·0	12·8	30·4	11·5	9·2	2·8	8·8	16·2	21·9
Calcium hardness	"	55·0	18·0	19·5	10·8	6·5	10·8	7·5	10·8	7·0	3·5	11·5	8·8	20·5	84·5
Magnesium hardness	"	781·1	13·1	19·3	13·5	4·9	17·2	5·3	20·1	4·5	5·7	2·9	3·3	5·7	9·4

¹ Nos. 716 to 728 and 645 to 648 collected and analysed for the Fisheries Research Board of Canada.

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

	727	725	728	715	8	220	334	7	26	208	232	333	345	348	349	632	847
Sample No	727	725	728	715	8	220	334	7	26	208	232	333	345	348	349	632	847
Date of sampling	19/7/40	19/9/40	19/9/40	23/11/40	19/5/34	22/5/35	16/7/36	17/5/34	30/8/34	21/6/35	30/8/35	1/6/36	13/4/37	5/6/37	29/9/37	19/7/39	3/7/42
Source	Well	Long Pond	Dalvay Pond	Weldon Creek	St. Lawrence River			St. Lawrence River									
Locality	Bideford, P.E.I.	Dalvay, P.E.I.		Moncton, N.B.	Sorel, Que.			Montreal, Que.									
Sample collected	Pump	Depth sample		1,000 feet above tidal water	Depth sample, midstream			Intake pipe, Montreal Waterworks, Verdun									
Gauge		Low	Low	Low	High	Mean	Low	High	Low	Mean	Mean	Mean	High	High	Mean	Mean	Mean
Temperature. °C	17·0	24·0	24·0	....	12·0	12·0	20·0	12·0	18·0	19·0	21·0	16·0	4·0	15·0	18·0	21·0	27·0
pH	7·6	8·4	7·8	7·0	7·8	8·0	7·4	7·5	7·6	7·6	7·8	7·6	7·4	7·1	7·5	7·8	7·6
Dissolved oxygen......ml./l.	4·6	5·8	4·8	....	5·2	5·7	6·5	5·0	6·5	6·5	6·5	5·5	9·5	7·0	None	None	6·0
Free carbon dioxide (CO$_2$)....p.p.m.	0·5	None	None	....	1·0	None	1·0	1·5	None	None	1·0	1·0	2·0	1·0	None	None	None
Turbidity	None	None	None	None	20·0	6·0	4·0	None	None	5·0	5·0	3·5	20·0	7·0	6·8	None	38·0
Colour	5·0	35·0	35·0	60·0	25·0	15·0	35·0	5·0	10·0	10·0	10·0	30·0	30·0	5·0	5·0	10·0	20·0
Alkalinity as CaCO$_3$	21·5	55·5	12·0	8·0	74·0	75·5	61·5	58·0	73·7	83·0	78·5	67·0	57·0	73·0	87·6	71·5	67·5
Suspended matter	2·0	4·7	4·6	None	14·8	8·7	5·3	6·6	5·2	8·5	8·0	4·9	13·0	14·5	11·3	3·0	50·0
Residue on evaporation dried at 110°C	82·7	178·9	177·0	120·4	135·5	143·1	113·0	113·6	143·0	152·8	134·0	144·0	114·6	144·7	160·5	172·9	148·0
Silica (SiO$_2$)	2·7	1·9	8·0	9·6	8·0	13·8	8·0	9·7	9·2	5·0	3·7	10·2	1·8	5·4	1·3	1·6	9·0
Iron (Fe)	0·10	0·11	0·05	0·21	0·10	Trace	0·04	0·10	Trace	Trace	Trace	0·04	0·06	0·16	0·16	0·09	0·02
Calcium (Ca)	12·8	14·2	6·4	15·1	27·8	30·0	25·0	22·5	27·6	33·1	28·5	28·2	24·8	31·5	33·3	31·6	32·0
Magnesium (Mg)	2·7	12·4	6·9	3·2	5·8	5·8	6·1	4·4	6·8	6·7	6·9	6·4	6·5	7·0	8·5	3·8	6·8
Alkalis as sodium (Na)	9·0	35·2	39·5	....	5·2	4·7	2·5	3·7	6·1	3·8	7·3	5·0	5·0	5·8	10·4	8·5	10·8
Hydrocarbonate (HCO$_3$)	26·2	67·7	14·6	9·8	90·3	92·1	75·0	70·8	89·9	101·3	95·7	81·7	69·5	89·1	106·9	87·2	82·4
Suphate (SO$_4$)	8·0	9·7	7·7	....	15·5	16·8	15·6	13·0	17·6	13·8	17·5	17·3	16·2	22·0	21·4	20·6	20·8
Chloride (Cl)	22·5	62·5	75·5	9·0	10·2	11·0	10·0	10·0	13·1	13·8	13·0	9·6	9·0	10·0	14·5	14·0	13·4
Nitrate (NO$_3$)	1·42	1·15	3·54	0·60	1·2	0·60	0·88	0·70	0·20	0·30	0·50	1·10	0·80	1·0	0·20	2·21	0·44
P$_2$O$_4$	1·09	1·03	1·11	....													
Hardness as CaCO$_3$ calculated:																	
Total hardness	43·1	86·3	44·3	50·9	93·3	98·8	87·5	74·3	96·9	110·2	99·6	96·7	88·7	107·5	118·2	94·6	107·9
Carbonate hardness	21·5	55·0	12·0	8·0	74·0	75·5	61·5	58·0	73·7	83·0	78·5	67·0	57·0	73·0	87·6	71·5	67·5
Noncarbonate hardness	21·6	31·3	32·3	42·9	19·3	23·3	26·0	16·3	23·2	27·2	21·1	29·7	31·7	34·5	30·6	23·1	40·4
Calcium hardness	32·0	35·5	16·0	37·8	69·5	75·0	62·5	56·3	69·0	82·7	71·3	70·5	62·0	78·8	83·3	79·0	80·0
Magnesium hardness	11·1	50·8	28·3	13·1	23·8	23·8	25·0	18·0	27·9	27·5	28·3	26·2	26·7	28·7	34·9	15·6	27·9

Sample No.	25	231	332	374	463	594	734	801	844	24	230	331	464	484	595	735	846	843
Date of sampling	30/8/34	30/8/35	6/9/36	26/9/37	20/12/37	19/12/38	22/8/40	20/9/41	22/6/42	28/8/34	30/8/35	5/9/36	21/12/37	21/3/38	19/12/38	29/8/40	27/5/42	12/6/42
Source	St. Lawrence River									St. Lawrence River								Georgian Bay
Locality	Cornwall, Ont.									Kingston, Ont.								Collingwood
Sample collected	Depth sample, above rapids									Depth sample, midstream opposite waterworks					Depth sample at waterworks	Depth sample, midstream opposite waterworks	Depth sample, midstream	Intake pipe at waterworks
Gauge	Low	Mean	Low	Low	Mean	Low	Mean	Low	Mean	Low	Mean	Low	Mean	High	Low	Mean	High	High
Temperature, °C	19·0	21·0	18·0	18·0	4·0	6·5	23·0	18·0	12·0	19·0	22·0	20·0	2·0	2·0	4·5	21·0	10·5	14·0
pH	7·7	8·0	8·4	7·8	7·9	8·2	8·0	7·8	8·2	7·8	8·0	8·1	7·9	8·0	8·2	8·1	7·9	8·0
Dissolved oxygen ml./l.	6·5	6·6	7·0	6·5	8·5	8·0	6·3	6·8	7·3	6·5	6·5	6·5	8·9	9·0	8·0	5·4	7·4	7·2
Free carbon dioxide (CO_2) p.p.m.	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None
Turbidity "	None	None	None	None	None	None	None	None	None	None	None	5·0	2·0	None	None	None	None	None
Colour "	None	None	5·0	None	None	None	None	None	5·0	5·0	5·0	None	None	None	None	5·0	5·0	10·0
Alkalinity as $CaCO_3$ "	90·8	90·0	93·0	91·5	92·5	92·0	92·0	86·0	87·5	92·5	93·0	93·5	94·0	91·5	91·5	86·0	80·0	62·5
Suspended matter "	1·7	3·7	2·0	1·7	2·6	2·2	3·1	0·7	5·6	4·2	1·8	7·5	3·8	3·0	1·0	7·3	5·6	None
Residue on evaporation dried at 110°C "	175·9	156·2	169·0	150·6	160·3	162·4	158·5	167·1	176·0	170·0	156·0	161·2	161·8	157·5	162·9	157·8	162·0	102·0
Silica (SiO_2) "	12·2	6·9	16·5	1·8	1·0	1·3	4·1	2·9	3·5	3·6	5·3	8·0	2·2	1·6	3·5	1·5	5·6	5·2
Iron (Fe) "	Trace	0·05	0·03	0·06	0·03	0·06	0·05	0·07	0·03	0·08	0·05	0·06	0·03	0·07	0·06	0·06	0·03	0·02
Calcium (Ca) "	36·0	33·2	36·7	35·5	36·4	37·7	35·7	38·2	39·2	36·8	35·7	35·7	37·0	38·3	38·6	36·4	37·2	22·8
Magnesium (Mg) "	8·0	7·9	8·2	8·5	9·0	8·7	8·5	7·9	7·6	8·0	7·6	8·5	9·2	9·0	8·8	8·4	7·6	6·4
Alkalis as sodium (Na) "	5·7	7·3	6·2	9·0	10·2	10·4	7·5	9·0	10·8	5·1	6·3	6·7	10·2	7·1	10·0	9·5	8·8	4·4
Hydrocarbonate (HCO_3) "	110·7	109·8	113·5	111·6	112·9	112·2	97·0	104·9	106·8	112·9	113·5	114·1	114·7	111·6	111·6	104·9	97·6	76·3
Sulphate (SO_4) "	20·8	18·7	22·2	21·2	22·0	20·0	20·7	23·8	23·6	22·0	18·7	22·7	22·0	22·3	20·2	20·7	23·2	13·2
Chloride (Cl) "	14·5	15·0	16·0	16·0	16·0	17·0	16·5	17·0	17·0	14·2	15·0	16·0	16·0	16·5	17·5	16·5	14·2	2·9
Nitrate (NO_3) "	0·50	0·60	1·32	0·60	0·40	None	1·05	1·40	0·27	0·50	0·60	1·32	0·40	0·35	None	1·95	1·42	0·61
Hardness as $CaCO_3$ calculated — Total hardness "	122·8	115·4	125·4	123·7	127·9	130·0	124·2	127·9	129·2	124·8	120·5	124·2	130·2	132·7	133·6	125·4	124·2	83·2
Carbonate hardness "	90·8	90·0	93·0	91·5	92·5	92·0	79·5	86·0	87·5	92·5	93·0	93·5	94·0	91·5	91·5	86·0	80·0	62·5
Noncarbonate hardness "	32·0	25·4	32·4	32·2	35·4	38·0	44·7	41·9	41·7	32·3	27·5	30·7	36·2	41·2	42·1	39·4	44·2	20·7
Calcium hardness "	90·0	83·0	91·8	88·8	91·0	94·3	89·3	95·5	98·0	92·0	89·3	89·3	89·5	95·8	96·5	91·0	93·0	57·0
Magnesium hardness "	32·8	32·4	33·6	34·9	36·9	35·7	34·9	32·4	31·2	32·8	31·2	34·9	34·7	36·9	36·1	34·4	31·2	26·2

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

Sample No	21	228	330	351	465	485	596	22	227	329	350	466	598
Date of sampling	25/8/34	27/8/35	2/9/36	12/6/37	24/12/37	23/3/38	20/12/38	20/8/34	23/8/35	24/8/36	11/6/37	24/12/37	21/12/38
Source	Lake Ontario							Lake Erie					
Locality	Toronto, Ont.							Fort Erie, Ont.					
Sample collected	Intake pipe at waterworks 70-foot depth							Depth sample at outlet into Niagara River					
Gauge	Low	Mean	Low	High	Low	High	Low	Low	Mean	Low	Mean	Mean	Low
Temperature, °C	8·0	9·0	6·0	4·5	3·0	1·0	4·5	23·0	23·0	23·0	18·0	4·0	3·0
pH	7·7	7·4	7·7	7·7	7·7	7·8	7·7	7·4	8·0	8·0	7·6	7·9	8·0
Dissolved oxygen ml./l.	8·5	8·3	8·9	9·3	8·8	9·2	8·0	6·3	6·0	6·6	5·4	9·0	8·4
Free carbon dioxide (CO2) p.p.m.	None	None	None	None	None	None	None	None	None	None	None	None	None
Turbidity "	10·0	None	None	None	None	None	None	None	None	None	3·0	30·0	15·0
Colour "	None	None	None	None	None	None	None	5·0	5·0	None	5·0	15·0	10·0
Alkalinity as CaCO3 "	92·3	97·5	93·5	90·6	92·5	91·5	93·5	95·5	100·0	96·5	96·0	92·5	98·5
Suspended matter "	11·4	0·9	4·0	1·6	4·2	4·5	1·4	4·0	4·4	11·8	6·0	33·5	17·4
Residue on evaporation dried at 110°C "	158·3	162·3	158·6	169·8	160·0	154·5	164·0	160·1	170·4	163·7	170·0	160·0	164·9
Silica (SiO2) "	4·8	7·7	3·4	2·1	2·0	1·7	4·0	4·0	17·0	8·8	0·6	2·8	2·5
Iron (Fe) "	0·10	None	0·06	0·05	0·06	0·07	0·07	0·08	0·05	0·05	0·06	0·08	0·03
Calcium (Ca) "	34·0	36·8	35·7	38·3	37·5	36·1	40·0	38·0	37·7	36·9	39·5	37·0	39·3
Magnesium (Mg) "	3·6	7·9	8·2	9·1	8·5	8·0	8·9	7·2	8·2	8·5	10·3	8·9	10·0
Alkalis as sodium (Na) "	11·1	6·7	7·6	9·1	9·1	8·1	9·6	5·1	4·6	7·0	9·8	9·3	10·3
Hydrocarbonate (HCO3) "	112·6	119·0	114·1	110·5	112·9	111·6	114·1	116·5	122·0	117·7	117·1	112·9	120·2
Sulphate (SO4) "	10·0	18·0	22·0	28·0	23·0	20·2	21·2	18·4	18·1	22·0	26·6	24·7	23·0
Chloride (Cl) "	14·8	15·0	15·5	15·5	16·5	15·0	17·0	14·5	13·5	16·0	15·5	13·0	16·0
Nitrate (NO3) "	0·90	1·80	1·32	0·90	0·40	0·40	0·20	0·20	0·50	0·62	0·90	0·50	2·0
Hardness as CaCO3 calculated:													
Total hardness "	99·8	124·4	122·9	133·1	128·7	123·1	136·5	124·5	127·9	127·2	141·0	129·0	139·3
Carbonate hardness "	92·3	97·5	93·5	90·6	92·5	91·5	93·5	95·5	100·0	96·5	96·0	92·5	98·5
Noncarbonate hardness "	7·5	26·9	29·4	42·5	36·2	31·6	43·0	29·0	27·9	30·7	45·0	36·5	40·8
Calcium hardness "	85·0	92·0	89·3	95·8	93·8	90·3	100·0	95·0	94·3	92·3	98·8	92·5	98·3
Magnesium hardness "	14·8	32·4	33·6	37·3	34·9	32·8	36·5	29·5	33·6	34·9	42·2	36·5	41·0

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

	19	225	328	354	487	18	224	327	353	326	356	357	557	558
Sample No..	19	225	328	354	487	18	224	327	353	326	356	357	557	558
Date of sampling..................................	31/7/34	18/8/35	17/8/36	15/6/37	23/3/38	29/7/34	17/8/35	15/8/36	16/6/37	11/8/36	18/6/37	5/8/37	19/6/38	21/8/38
Source..	Detroit River					St. Clair River				St. Mary's River				
Locality..	Windsor, Ont.					Point Edward, Ont.				Sault Ste. Marie, Ont.				
Sample collected..................................	Intake pipe at waterworks					Intake pipe at pumping station				Intake pipe at 12-foot depth above rapids				
Gauge...	Low	Mean	Low	Mean	High	Low	Mean	Low	Mean	Mean	Mean	Low	Mean	Low
Temperature, °C...................................	22·0	23·0	25·0	18·0	6·0	21·0	27·0	25·0	17·0	19·0	16·0	18·0	18·0	20·0
pH..	7·7	8·0	8·1	8·1	7·7	7·9	8·0	8·1	8·0	7·5	7·5	7·5	7·1	7·5
Dissolved oxygen...........................ml./l.	4·5	4·9	6·5	7·2	8·0	5·5	6·3	6·6	6·2	7·0	6·5	6·0	6·2	6·5
Free carbon dioxide (CO₂)....................p.p.m.	None	None	None	None	None	None	None	None	None	0·5	1·0	1·0	1·0	None
Turbidity...................................... "	11·0	55·0	30·0	7·0	30·0	None	None	None	None	None	None	None	None	5·0
Colour... "	5·0	5·0	None	None	25·0	5·0	5·0	None	None	5·0	None	None	None	None
Alkalinity as CaCO₃............................ "	79·6	86·0	82·5	83·5	79·0	80·0	85·0	81·0	82·0	43·0	45·5	41·0	40·0	44·0
Suspended matter............................... "	12·5	57·9	38·0	9·3	25·4	1·4	1·7	3·6	1·5	0·3	2·5	1·8	2·0	3·7
Residue on evaporation dried at 110°C.......... "	123·8	114·6	115·2	126·4	113·0	117·6	103·7	111·0	125·0	58·0	66·9	57·5	63·2	65·4
Silica (SiO₂)................................... "	11·8	5·0	6·9	6·7	5·9	1·4	6·2	5·6	9·1	5·5	2·8	3·1	5·6	9·8
Iron (Fe)...................................... "	0·3	0·05	0·09	0·06	0·24	Trace	Trace	0·06	0·06	0·04	0·06	0·07	0·07	0·08
Calcium (Ca).................................. "	27·6	26·1	27·4	30·5	26·1	27·2	27·7	26·4	29·0	12·1	17·0	15·0	13·9	15·0
Magnesium (Mg)................................ "	7·6	7·4	8·0	9·4	7·7	7·2	6·7	7·5	8·5	5·6	4·0	3·7	3·5	4·4
Alkalis as sodium (Na)......................... "	1·1	2·6	2·7	5·5	3·1	1·1	2·3	2·6	3·3	1·5	2·2	3·1	2·0	4·2
Hydrocarbonate (HCO₃)......................... "	97·1	104·9	100·7	101·9	96·4	97·6	103·7	98·8	100·0	52·5	55·5	50·0	48·8	53·7
Sulphate (SO₄)................................. "	11·2	10·9	13·9	16·6	11·8	11·2	10·5	12·0	18·5	7·9	6·2	5·1	7·5	4·7
Chloride (Cl).................................. "	6·9	5·3	6·5	4·6	4·5	4·1	3·5	5·5	3·5	3·0	2·0	1·5	1·5	2·3
Nitrate (NO₃).................................. "	1·80	1·20	1·32	0·40	0·27	1·80	1·20	1·32	0·96	0·88	1·10	0·90	0·08	0·08
Hardness as CaCO₃ calculated:														
Total hardness............................. "	100·2	95·6	101·3	114·8	96·9	97·5	96·8	96·8	107·4	53·3	58·9	52·7	49·2	55·5
Carbonate hardness........................ "	79·6	86·0	82·5	83·5	79·0	80·0	85·0	81·0	82·0	43·0	45·5	41·0	40·0	44·0
Noncarbonate hardness..................... "	20·6	9·6	18·8	31·3	17·9	17·5	11·8	15·8	25·4	10·3	13·4	11·7	9·2	11·5
Calcium hardness.......................... "	69·0	65·3	68·5	76·3	65·3	68·0	69·3	66·0	72·5	30·3	42·5	37·5	34·8	37·5
Magnesium hardness....................... "	31·2	30·3	32·8	38·5	31·6	29·5	27·5	30·8	34·9	23·0	16·4	15·2	14·4	18·0

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

	359	559	900	901	946	947	948	362	216	636	217	215	637	209
Sample No.	359	559	900	901	946	947	948	362	216	636	217	215	637	209
Date of Sampling	4/8/37	19/8/38	16/9/42	17/9/42	11/9/43	12/9/43	13/9/43	2/8/37	12/7/35	22/7/39	12/7/35	10/7/35	24/7/39	26/6/35
Source	Lake Superior	Lake Superior	Lake Superior	Lake Superior	Lake Superior	Lake Superior	Lake Superior	Nipigon River	Lake St. John	Lake St. John	Saguenay River	Chicoutimi River	Chicoutimi River	St. Maurice River
Locality	From steamer, 4 miles south of Port Arthur	From steamer, 20 miles east of Port Arthur	West of Welcome Island	Midway, Fort William-Sault Ste.Marie	Welcome Island	Mid-Lake	Sault Ste.Marie	Nipigon, Ont.	—	—	River-bend, Que.	Chicoutimi, Que.	Chicoutimi, Que.	La Tuque, Que.
Sample collected	18-foot depth	20-foot depth	20-foot depth, from steamer	20-foot depth, from steamer	Depth sample, from steamer	Depth sample, from steamer	Intake pipe, at 12-foot depth, above rapids	Depth sample C.P.R. bridge	Two miles from shore opposite Little Discharge	Two miles from shore opposite Little Discharge	Depth sample, above rapids	Dam at pumping station	Dam at pumping station	Depth sample, mid-stream
Gauge	Low	Low	Mean	Mean	High	High	High	Mean	Mean	High	Mean	Mean	High	Mean
Temperature, °C	10·0	13·0	10·0	10·0	10·0	9·0	19·0	20·0	18·0	18·0	23·0	21·0	20·0	19·0
pH	7·3	7·4	7·4	7·3	7·4	7·4	7·2	8·0	6·6	6·4	6·7	6·5	6·7	6·5
Dissolved oxygen ml./l.	8·1	7·5	.....	.....	.....	.....	.....	6·5	6·5	6·8	5·3	6·5	6·4	6·5
Free carbon dioxide (CO₂) p.p.m.	1·0	None	.....	.....	.....	.....	.....	1·5		4·2				
Turbidity "	None	None	None	None	None	None	None	2·0	None	None	None	None	None	6·0
Colour "	None	None	None	None	10·0	10·0	10·0	20·0	65·0	60·0	65·0	65·0	55·0	70·0
Alkalinity as CaCO₃ "	46·0	38·5	41·5	40·0	40·5	40·0	39·8	82·5	6·3	1·0	5·0	7·0	6·5	5·5
Suspended matter "	0·4	1·7	6·0	5·4	1·6	None	2·0	4·0	1·1	2·2	2·3	1·3	1·3	10·3
Residue on evaporation dried at 110°C "	66·2	68·0	85·0	60·0	171·8	53·6	54·8	108·9	31·0	31·7	29·7	40·0	37·2	36·5
Silica (SiO₂) "	5·3	8·0	3·4	4·2	4·6	1·6	2·2	9·4	3·9	2·6	3·0	3·3	4·0	3·0
Iron (Fe) "	0·04	0·06	0·02	0·02	0·04	0·04	0·04	0·5	Trace	0·07	0·20	Trace	0·10	0·60
Calcium (Ca) "	15·7	14·3	14·4	13·6	28·3	13·7	13·1	28·2	4·7	3·7	3·6	4·6	7·5	4·0
Magnesium (Mg) "	4·0	4·6	4·0	3·2	11·2	3·1	3·5	4·8	1·8	3·7	1·5	0·5	4·3	1·4
Alkalis as sodium (Na) "	3·8	2·9	2·7	2·4	17·6	4·4	4·2	6·8	.....	4·3	.....	.....	5·1	.....
Hydrocarbonate (HCO₃) "	56·1	47·0	50·6	48·8	49·4	48·8	48·6	100·7	7·7	1·2	6·1	8·5	7·9	6·7
Sulphate (SO₄) "	6·4	4·3	6·8	4·0	45·6	4·4	3·7	5·3	3·5	4·3	3·1	4·3	6·1	3·9
Chloride (Cl) "	1·5	1·8	2·0	1·8	0·8	0·7	1·1	1·5	0·5	1·0	0·5	0·5	1·0	0·7
Nitrate (NO₃) "	0·40	0·17	0·44	None	0·89	0·89	1·24	0·40	0·02	0·27	0·60	0·50	0·80	0·90
Hardness as CaCO₃ calculated:														
Total hardness "	55·7	54·7	52·4	47·1	116·7	47·0	47·2	90·2	19·2	24·5	15·2	13·6	36·4	15·7
Carbonate hardness "	46·0	38·5	41·5	40·0	40·5	40·0	39·8	82·5	6·3	1·0	5·0	7·0	6·5	5·5
Noncarbonate hardness "	9·7	16·2	10·9	7·1	76·2	7·0	7·4	7·7	12·9	23·5	10·2	6·6	29·9	10·2
Calcium hardness "	39·3	35·8	36·0	34·0	70·8	34·3	32·8	70·5	11·8	9·3	9·0	11·5	18·8	10·0
Magnesium hardness "	16·4	18·9	16·4	13·1	45·9	12·7	14·4	19·7	7·4	15·2	6·2	2·1	17·6	5·7

Sample No.	11	210	317	633	836	9	211	321	635	802	10	212	12	218	319	644
Date of sampling	25/5/34	26/6/35	13/7/36	21/7/39	1/4/42	20/5/34	27/6/35	11/7/36	20/7/39	15/9/41	27/6/34	22/5/35	18/5/34	15/7/35	2/6/36	30/8/39
Source	St. Maurice River					St. Maurice River					Lac La Pêche		St. Francis River			
Locality	Grand'Mere, Que.					Three Rivers, Que.					Shawinigan Falls. Que.		East Angus, Que.			
Sample collected	Intake pipe at pulp mill					Intake pipe at waterworks					Depth sample, midlake		Depth sample, midstream above pulp mill			
Gauge	High	Mean	Low	Mean	High	High	Mean	Low	Mean	High	High	Mean	High	Mean	Mean	Low
Temperature,°C	12·0	19·0	22·0	19·0	1·0	14·0	18·5	23·0	20·0	18·8	10·0	18·0	12·0	25·5	21·0	23·0
pH	6·5	6·5	6·3	6·5	6·7	6·9	6·4	6·1	6·7	6·7	6·6	7·1	7·4	7·2	7·7	7·0
Dissolved oxygen ml./l.	5·2	6·5	5·5	6·1	......	8·0	7·5	6·1	6·5	5·1	6·7	6·5	7·2	5·4	5·4	6·3
Free carbon dioxide (CO_2) p.p.m.	5·0	3·0	5·0	3·1	......	5·0	2·0	4·0	2·5	1·0	4·0	2·0	4·0	3·0	3·0	1·5
Turbidity "	5·0	5·0	10·0	None	None	5·0	5·0	None	2·5	None	None	None	None	None	14·0	20·0
Colour "	60·0	65·0	65·0	50·0	40·0	60·0	65·0	65·5	55·0	50·0	30·0	20·0	15·0	60·0	60·0	70·0
Alkalinity as $CaCO_3$ "	5·1	5·0	6·5	5·0	6·5	6·0	6·5	5·5	4·5	5·0	16·5	12·0	39·0	22·0	26·5	33·5
Suspended matter "	4·6	5·4	18·0	4·0	4·9	1·3	5·9	2·5	4·8	5·7	4·6	1·3	2·4	0·2	6·9	23·2
Residue on evaporation dried at 110°C "	32·4	39·3	33·8	39·0	41·5	37·9	38·0	35·6	34·2	44·8	59·2	42·9	76·6	55·7	91·9	76·6
Silica (SiO_2) "	4·7	5·5	6·7	None	3·5	7·6	3·3	2·5	4·6	2·9	18·8	6·7	13·8	4·4	17·6	3·6
Iron (Fe) "	0·10	0·05	0·18	0·07	0·07	0·20	0·10	0·18	0·14	0·12	0·02	0·03	None	0·10	0·20	0·15
Calcium (Ca) "	3·6	3·2	5·3	3·7	5·0	4·8	3·9	5·8	4·7	4·6	5·6	8·2	15·6	8·4	8·2	9·1
Magnesium (Mg) "	0·6	1·3	1·7	1·9	1·3	0·4	1·3	1·9	2·1	0·9	0·8	1·1	3·2	3·4	3·2	4·6
Alkalis as sodium (Na) "		......	......	3·0	3·3	......	......	......	3·5	3·1	2·0	......	1·4	......	7·1	3·5
Hydrocarbonate (HCO_3) "	6·2	6·1	7·9	6·1	7·9	7·3	7·0	6·7	5·5	6·1	20·1	14·6	47·6	26·8	32·3	40·9
Sulphate (SO_4) "	3·6	3·9	5·8	4·3	5·8	4·0	3·1	6·7	5·2	6·2	4·8	5·1	9·6	4·1	7·8	5·6
Chloride (Cl) "	Trace	0·2	2·0	0·5	0·7	Trace	0·5	2·1	1·0	0·5	Trace	0·5	3·4	0·8	2·5	1·0
Nitrate (NO_3) "	0·09	0·50	0·24	0·44	0·20	0·20	0·10	1·77	0·44	0·40	0·20	0·60	0·9	1·20	1·32	1·06
Hardness as $CaCO_3$ calculated:																
Total hardness "	11·5	13·3	20·3	17·1	17·8	13·6	15·1	22·3	20·4	15·2	17·3	25·0	52·1	34·9	33·6	41·7
Carbonate hardness "	5·1	5·0	6·5	5·0	6·5	6·0	6·5	5·5	4·5	5·0	16·5	12·0	39·0	22·0	26·5	33·5
Noncarbonate hardness "	6·4	8·3	13·8	12·1	11·3	7·6	8·6	16·8	15·9	10·2	0·8	13·0	13·1	12·9	7·1	8·2
Calcium hardness "	9·0	8·0	13·3	9·3	12·5	12·0	9·8	14·5	11·8	11·5	14·0	20·5	39·0	21·0	20·5	22·8
Magnesium hardness "	2·5	5·3	7·0	7·8	5·3	1·6	5·3	7·8	8·6	3·7	3·3	4·5	13·1	13·9	13·1	18·9

Sample No	320	845	13	213	322	634	219	318	799	851	800	852	850
Date of sampling	15/7/36	29/7/42	26/5/34	28/6/35	10/7/36	22/7/39	20/7/35	20/6/36	16/9/41	2/7/42	20/9/41	29/6/42	26/6/42
Source	St. Francis River		St. Charles River				Richelieu River				Yamaska River		Magog River
Locality	Drummondville, Que.		Chateau d'Eau, Que.				St. Johns, Que.				Farnham, Que.	St. Hyacinthe, Que.	Sherbrooke, Que.
Sample collected	Depth sample at dam	Depth sample, mid-stream	Depth sample at pumping station				Intake pipe at waterworks				Intake pipe, city waterworks	Intake pipe, city waterworks	Intake pipe, city waterworks
Gauge	Mean	Low	High	Mean	Low	Mean	Mean	....	Low	Mean	Low	Mean	Mean
Temperature. °C	25·0	26·0	11·0	20·0	20·0	21·0	25·0	24·0	13·0	28·0	19·0	27·0	25·0
pH	7·2	7·3	6·8	6·8	7·3	6·8	7·6	7·7	7·3	7·5	7·6	6·8	7·7
Dissolved oxygen .... ml./l.	6·6	5·5	6·7	6·0	6·7	6·6	5·3	6·2	6·1	5·3	5·3	4·8	6·8
Free carbon dioxide (CO_2) .... p.p.m.	3·5	3·0	2·0	1·0	1·5	2·0	1·0	None	None	None	None	3·0	None
Turbidity .... "	2·0	5·0	15·0	2·0	4·0	2·0	None	4·0	None	None	None	209·0	None
Colour .... "	40·0	65·0	60·0	60·0	35·0	35·0	10·0	5·0	5·0	10·0	15·0	60·0	25·0
Alkalinity as $CaCO_3$ .... "	32·5	31·2	14·5	9·5	24·5	7·0	38·0	35·0	37·5	31·3	36·5	15·0	25·0
Suspended matter .... "	6·5	9·0	7·2	6·0	7·2	5·6	1·1	6·8	3·5	8·0	7·5	244·6	6·2
Residue on evaporation dried at 110°C .. "	76·0	77·4	56·0	35·0	75·4	40·0	70·5	72·6	76·6	76·4	100·0	76·2	66·0
Silica (SiO_2) .... "	2·6	2·2	14·6	4·6	21·4	None	6·6	7·8	3·3	8·6	7·4	3·4	6·6
Iron (Fe) .... "	0·22	0·03	None	0·50	0·26	0·20	None	0·10	0·03	0·01	0·02	0·02	0·02
Calcium (Ca) .... "	9·3	17·2	4·8	7·1	8·6	4·3	14·5	15·0	17·0	16·0	13·7	14·4	16·0
Magnesium (Mg) .... "	3·5	3·6	0·8	1·7	1·7	2·2	3·5	4·3	4·5	4·0	3·7	3·2	3·2
Alkalis as sodium (Na) .... "	7·7	5·2	1·4	......	2·7	3·1	......	......	2·7	4·4	4·1	6·0	5·2
Hydrocarbonate (HCO_3) .... "	39·7	38·1	17·7	11·6	29·9	8·5	46·4	42·7	45·8	38·2	44·5	18·3	30·5
Sulphate (SO_4) .... "	6·6	9·2	4·8	5·1	10·9	0·5	8·9	12·9	14·0	12·0	12·6	15·2	7·2
Chloride (Cl) .... "	3·5	1·2	Trace	Trace	2·5	1·5	1·0	3·1	1·0	1·3	4·0	3·1	1·1
Nitrate (NO_3) .... "	0·44	1·20	0·50	0·60	1·32	0·44	0·90	0·16	0·40	0·61	Trace	1·68	0·26
Hardness as $CaCO_3$ calculated:													
Total hardness .... "	37·7	57·8	15·3	24·0	28·5	19·8	50·7	55·1	61·0	56·4	49·5	49·1	53·1
Carbonate hardness .... "	32·5	31·2	14·5	9·5	24·5	7·0	38·0	35·0	37·5	31·3	36·5	15·0	25·0
Noncarbonate hardness .... "	5·2	26·6	0·8	14·5	4·0	12·8	12·7	20·1	23·5	25·1	13·0	34·1	28·1
Calcium hardness .... "	23·3	43·0	12·0	17·8	21·5	10·8	36·3	37·5	42·5	40·0	34·3	36·0	40·0
Magnesium hardness .... "	14·4	14·8	3·3	6·2	7·0	9·0	14·4	17·6	18·5	16·4	15·2	13·1	13·1

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

	1	2	3	207	335	346	347	496	583	584	585	615	616	649	363	612
Sample No.	1	2	3	207	335	346	347	496	583	584	585	615	616	649	363	612
Date of sampling	28/5/34	28/5/34	28/8/34	20/6/35	8/9/36	5/6/37	27/7/37	18/6/38	6/10/38	7/10/38	11/11/38	5/6/39	6/6/39	5/10/39	27/8/37	24/5/39
Source	Ottawa River									China Clay Lake			Rideau River		Lake Timiskaming	
Locality	Hudson, Ont.	Hawkesbury, Ont.								Canada China Clay, Ltd. mill near St. Remi d'Amherst, Que.			Smiths Falls, Ont.		Haileybury, Ont.	
Sample collected	Depth sample, mid-stream	Depth sample, midstream above rapids								At wharf, 6-foot depth	At widest part of lake, 6-foot depth		Depth sample at dam at waterworks		Depth sample 1 mile from shore	
Gauge	High	High	Low	Mean	Low	High	Mean	Above mean	Mean	Mean	Mean	High	High	Low	Mean	High
Temperature, °C	12·0	11·0	20·0	18·6	15·0	16·0	18·0	15·8	12·0	12·0	11·0	16·0	19·0	16·0	27·0	14·0
pH	6·8	6·7	7·0	6·9	7·0	6·8	7·0	6·8	6·9	6·9	7·0	7·1	7·3	7·6	6·7	6·9
Dissolved oxygen ml./l.	5·5	5·1	4·7	6·5	6·5	6·5	6·6	6·2	7·9	None	None	1·0	6·4	7·8	6·8	7·6
Free carbon dioxide (CO_2) p.p.m.	3·0	3·0	5·0	2·0	5·0	3·0	2·0	3·0	1·5	60·0	None	None	3·0	None	2·5	2·0
Turbidity	5·0	5·0	5·0	90·0	2·5	15·0	8·0	10·0	80·0	50·0	None	None	2·0	None	None	12·0
Colour	25·0	55·0	50·0	45·0	45·0	45·0	40·0	50·0	70·0	50·0	10·0	10·0	50·0	40·0	75·0	50·0
Alkalinity as $CaCO_3$	8·3	16·2	16·7	29·0	16·5	22·0	43·0	16·0	21·0	18·0	4·3	6·0	73·0	66·0	12·5	25·0
Suspended matter	12·0	2·9	7·0	75·0	4·6	11·8	9·4	14·0	118·9	52·0	0·4	5·3	5·0	1·4	3·8	15·0
Residue on evaporation dried at 110°C	28·6	52·7	59·3	115·1	71·5	67·1	84·3	54·4	66·6	70·0	27·2	48·7	130·2	112·4	50·7	85·0
Silica (SiO_2)	6·0	6·7	4·1	7·4	2·3	5·6	6·8	7·8	5·7	8·1	0·8	1·4	0·5	1·2	1·4	13·2
Iron (Fe)	0·02	Trace	0·08	0·20	0·12	0·35	0·35	0·28	0·40	1·0	0·03	0·90	0·06	0·07	0·08	0·20
Calcium (Ca)	3·1	6·0	6·4	16·4	8·2	9·8	15·5	10·7	10·7	7·9	5·0	9·9	27·5	25·8	7·5	9·0
Magnesium (Mg)	0·8	1·6	1·6	3·5	3·0	3·7	3·5	3·6	3·6	4·0	2·0	4·2	7·3	9·3	2·8	3·0
Alkalis as sodium (Na)		0·8	1·7			2·7	2·7	4·2	3·4	4·4	4·6	10·9	2·5	5·0	1·1	5·0
Hydrocarbonate (HCO_3)	10·1	19·8	20·4	35·4	20·1	26·8	52·5	19·5	25·6	22·0	5·2	7·3	89·1	80·5	15·3	30·5
Sulphate (SO_4)	2·8	4·5	4·4	12·5	8·3	12·6	6·8	6·2	8·3	9·5	4·5	15·5	14·0	8·9	10·0	5·0
Chloride (Cl)	Trace	1·4	1·4	0·3	3·0	2·0	2·0	1·5	1·0	1·5	1·1	0·5	1·0	1·0	1·5	5·0
Nitrate (NO_3)	0·02	0·40	0·50	0·20	0·70	1·10	1·0	0·44	0·62	0·80	0·09	0·44	0·80	0·80	1·10	1·06
Hardness as $CaCO_3$ calculated: Total hardness	11·1	21·6	22·6	55·4	32·8	39·7	53·2	41·6	41·6	36·2	20·7	42·0	98·7	102·6	30·3	34·8
Carbonate hardness	8·3	16·2	16·7	29·0	16·5	22·0	43·0	16·0	21·0	18·0	4·3	6·0	73·0	66·0	12·5	25·0
Noncarbonate hardness	2·8	5·4	5·9	26·4	16·3	17·7	10·2	25·6	20·6	18·2	16·4	36·0	25·7	36·6	17·8	9·8
Calcium hardness	7·8	15·0	16·0	41·0	20·5	24·5	38·8	26·8	26·8	19·8	12·5	24·8	68·8	64·5	18·8	22·5
Magnesium hardness	3·3	6·6	6·6	14·4	12·3	15·2	14·4	14·8	14·8	16·4	8·2	17·2	29·9	38·1	11·5	12·3

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

	23	229	339	375	236	849	20	266	337	352	467	486	597	736	842
Sample No.	23	229	339	375	236	849	20	266	337	352	467	486	597	736	842
Date of sampling	27/8/34	29/8/35	4/10/36	23/9/37	6/8/36	1/7/42	6/8/34	20/8/35	22/8/36	14/6/37	23/12/37	23/3/38	21/12/38	4/7/40	7/6/42
Source	Trent River				Otonabee River		Grand River								
Locality	Trenton, Ont.				Peterborough, Ont.		Brantford, Ont.								
Sample collected	Intake pipe at Hind and Dauch Paper Mill, 1 mile up-stream				Intake pipe at waterworks		Depth sample, midstream above waterworks								
Gauge	Low	Mean	Low	Mean	Low	High	Low	Mean	Low	Mean	Low	High	Low	Above mean	High
Temperature, °C	22·0	23·0	22·0	18·0	22·0	15·5	23·0	23·0	20·0	27·0	50·0	1·0	4·5	18·0	14·0
pH	7·2	8·2	8·2	7·2	7·7	7·9	7·5	7·4	7·6	7·6	7·8	7·7	7·8	7·3	7·6
Dissolved oxygen ml./l.	6·5	6·9	7·0	6·7	6·5	7·0	5·5	6·3	3·8	6·8	8·5	8·4	7·2	3·5	5·2
Free carbon dioxide (CO_2) p.p.m.	None	None	None	None	None	None	None	None	None	None	None	None	None	1·5	None
Turbidity "	None	None	3·0	8·0	None	None	None	None	None	2·0	10·0	300·0	None	6·2	153·0
Colour "	15·0	20·0	10·0	15·0	20·0	30·0	15·0	15·0	5·0	25·0	25·0	15·0	20·0	15·0	20·0
Alkalinity as $CaCO_3$ "	77·2	88·0	85·0	84·5	69·5	63·5	124·8	178·5	157·5	191·6	253·5	164·0	240·0	198·5	183·0
Suspended matter "	0·8	0·4	5·2	10·3	0·7	6·0	7·8	2·0	5·0	3·5	14·4	201·6	2·0	10·0	226·4
Residue on evaporation dried at 110°C "	156·4	130·0	126·7	128·7	107·1	115·0	402·2	414·2	531·4	391·6	539·0	271·9	470·7	365·7	320·2
Silica (SiO_2) "	4·6	10·0	5·8	5·7	4·4	7·0	7·8	17·9	23·1	3·4	6·5	5·4	6·7	11·8	6·4
Iron (Fe) "	0·10	0·05	0·04	0·07	0·07	0·02	None	0·05	0·12	0·04	0·16	0·07	0·09	0·01	0·01
Calcium (Ca) "	28·4	32·0	31·8	35·0	28·0	31·6	76·6	71·5	100·7	86·5	122·0	65·9	104·7	88·3	69·2
Magnesium (Mg) "	6·4	4·0	4·1	4·5	3·8	3·6	24·4	22·9	31·8	23·3	28·2	15·0	28·1	24·8	18·4
Alkalis as sodium (Na) "	2·3	0·9	3·3	4·1	0·8	6·0	12·8	32·7	16·1	11·4	16·7	8·3	27·6	10·8	4·8
Hydrocarbonate (HCO_3) "	94·2	107·4	103·7	103·1	84·8	77·5	152·3	217·8	192·2	233·8	309·3	200·1	292·8	242·2	223·3
Sulphate (SO_4) "	19·2	8·2	11·8	13·0	11·3	12·4	166·4	136·5	214·8	111·0	148·2	49·8	138·0	93·2	59·6
Chloride (Cl) "	2·6	Trace	3·5	1·2	3·0	1·0	14·5	15·5	25·0	10·0	15·0	7·0	18·3	18·5	8·2
Nitrate (NO_3) "	1·80	1·20	0·88	2·20	0·88	0·26	0·90	1·20	0·62	2·70	0·90	1·56	0·10	4·0	2·21
Hardness as $CaCO_3$ calculated: Total hardness "	97·2	96·4	96·3	106·0	85·6	93·8	291·5	272·7	382·2	311·8	420·6	226·3	377·0	322·5	248·4
Carbonate hardness "	77·2	88·0	85·0	84·5	69·5	63·5	124·8	178·5	157·5	191·6	253·5	164·0	240·0	198·5	183·0
Noncarbonate hardness "	20·0	8·4	11·3	21·5	16·1	30·3	166·7	94·2	224·7	120·2	167·1	62·3	137·0	124·0	65·4
Calcium hardness "	71·0	80·0	79·5	87·5	70·0	79·0	191·5	178·5	251·8	216·3	305·0	164·8	261·8	220·8	173·0
Magnesium hardness "	26·2	16·4	16·8	18·5	15·6	14·8	100·0	93·9	130·4	95·5	115·6	61·5	115·2	101·7	75·4

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Continued

Sample No.	17	223	338	355	488	737	16	222	341	377	787	840	15	22
Date of sampling	28/7/34	17/8/35	18/8/36	15/6/37	25/3/38	10/9/40	19/7/34	12/8/35	16/8/36	22/9/37	14/9/40	30/5/42	17/7/34	12/8/35
Source	Thames River						Lake Simcoe						Lake Couchiching	
Locality	Chatham, Ont.						Seven miles east of Barrie, Ont.		Beaverton, Ont.				Orillia, Ont.	
Sample collected	Depth sample, midstream at waterworks						Depth sample at mouth of Kampenfeldt Bay		Depth sample, 2 miles from shore			Depth sample, 3 miles from shore	Depth sample, 3 miles from shore	
Gauge	Mean	Mean	Low	Mean	High	Mean	High	Mean	Mean	Mean	Low	High	High	Mean
Temperature, °C	27·0	27·0	25·0	23·0	10·0	22·0	20·0	26·0	24·0	13·0	19·0	14·0	22·0	26·0
pH	7·6	7·8	7·9	8·0	7·6	8·1	7·9	8·5	7·9	8·4	8·1	8·4	7·7	8·4
Dissolved oxygen........ml./l.	3·8	5·1	6·2	6·2	7·8	5·0	5·5	6·5	6·5	8·0	6·5	6·7	5·5	6·5
Free carbon dioxide (CO_2)......p.p.m.	4·0	4·0	None	None	None	None	None	None	None	None	None	None	None	None
Turbidity.................."	5·0	10·0	25·0	15·0	308·0	36·0	None	None	None	4·0	None	10·0	None	5·0
Colour...................."	5·0	20·0	10·0	10·0	90·0	35·0	5·0	5·0	10·0	None	1·0	25·0	5·0	5·0
Alkalinity as $CaCO_3$........."	149·0	153·0	154·5	201·0	163·0	214·5	111·0	110·0	112·0	109·0	104·5	119·0	103·3	98·0
Suspended matter..........."	7·8	10·8	29·8	18·7	207·0	44·5	3·2	5·0	3·2	8·4	1·5	19·0	2·8	3·9
Residue on evaporation dried at 110°C...."	333·0	289·1	145·4	342·1	282·0	364·0	182·4	146·3	166·8	157·2	159·9	199·0	122·6	159·4
Silica (SiO_2)............"	7·8	6·5	12·2	5·1	6·4	19·2	7·8	6·0	10·9	3·6	10·3	8·8	4·8	25·0
Iron (Fe).............."	0·60	0·15	0·10	0·06	0·48	0·09	None	0·05	0·05	0·04	0·08	0·02	None	None
Calcium (Ca)..........."	56·4	53·8	64·3	76·8	65·0	83·3	44·1	39·5	40·7	42·0	39·8	48·0	36·0	37·0
Magnesium (Mg)........."	22·4	18·3	29·5	18·4	13·3	18·5	6·7	6·3	4·1	4·1	5·7	7·2	4·8	5·0
Alkalis as sodium (Na)......"	16·7	21·9	54·8	16·1	4·9	12·5	13·6	1·8	11·8	8·0	8·0	3·2	5·3	2·3
Hydrocarbonate (HCO_3)....."	181·8	186·7	188·5	245·2	198·9	261·7	135·4	134·2	136·6	133·0	127·5	145·2	126·1	119·6
Sulphate (SO_4)........."	6·4	59·3	89·4	54·0	34·2	49·5	44·0	13·6	17·1	18·0	18·0	18·0	16·8	14·5
Chloride (Cl)..........."	36·5	28·5	107·0	23·0	4·5	17·5	3·4	0·08	5·5	4·5	6·5	3·4	3·4	3·0
Nitrate (NO_3).........."	0·20	2·70	1·88	0·50	3·50	3·98	0·50	0·08	0·62	1·10	0·62	0·61	0·50	0·08
Hardness as $CaCO_3$ calculated:														
Total hardness.........."	232·8	209·5	281·8	267·4	217·0	284·2	137·8	124·6	118·6	121·8	122·9	149·5	109·7	113·0
Carbonate hardness......."	149·6	153·0	154·5	201·0	163·0	214·5	111·0	110·0	112·0	109·0	104·5	119·0	103·3	98·0
Noncarbonate hardness....."	83·8	56·5	127·3	66·4	54·0	69·7	26·8	14·6	6·6	12·8	18·4	30·5	6·4	15·0
Calcium hardness........."	141·0	134·5	160·8	192·0	162·5	208·3	110·3	98·8	101·8	105·0	99·5	120·0	90·0	92·5
Magnesium hardness......."	91·8	75·0	121·0	75·4	54·5	75·9	27·5	25·8	16·8	16·8	23·4	29·5	19·7	20·5

TABLE V—Continued

Analyses of Surface Waters—Continued

ATLANTIC WATERSHED—Concluded

Sample No	340	364	555	556	613
Date of sampling	8/8/36	9/8/37	17/6/38	25/8/38	26/5/39
Source	Lake Nipissing				
Locality	Sturgeon Falls, Ont.				North Bay, Ont.
Sample collected	Depth sample, 2 miles from shore				
Gauge	Mean	Mean	Mean	Mean	High
Temperature, °C	23·0	26·0	21·0	22·0	13·0
pH	7·3	7·1	6·9	7·0	7·2
Dissolved oxygen ....ml./l.	6·8	6·7	6·1	6·7	7·6
Free carbon dioxide (CO2) .... p.p.m.	1·0	1·0	2·0	1·0	1·5
Turbidity "	None	None	11·0	12·0	None
Colour "	25·0	35·0	35·0	25·0	40·0
Alkalinity as CaCO3 "	20·0	19·5	14·5	16·5	21·5
Suspended matter "	1·2	1·9	7·8	6·0	1·4
Residue on evaporation dried at 110°C "	56·0	53·2	54·0	51·2	65·0
Silica (SiO2) "	6·1	5·5	5·7	2·7	3·0
Iron (Fe) "	0·08	0·14	0·11	0·08	0·15
Calcium (Ca) "	8·9	7·0	10·0	9·0	9·0
Magnesium (Mg) "	2·9	2·9	2·9	3·3	3·6
Alkalis as sodium (Na) "	0·8	4·5	2·5	4·6	3·8
Hydrocarbonate (HCO3) "	24·4	23·8	17·7	20·1	26·2
Sulphate (SO4) "	10·3	11·7	16·4	11·3	8·5
Chloride (Cl) "	2·0	2·0	1·0	1·5	1·0
Nitrate (NO3) "	1·32	0·40	0·17	0·17	1·33
Hardness as CaCO3 calculated:					
Total hardness "	34·2	29·4	36·9	36·0	37·3
Carbonate hardness "	20·0	19·5	14·5	16·5	21·5
Noncarbonate hardness "	14·2	9·9	22·4	19·5	15·8
Calcium hardness "	22·3	17·5	25·0	22·5	22·5
Magnesium hardness "	11·9	11·9	11·9	13·5	14·8

TABLE V—Continued

Analyses of Surface Waters—Continued

SEA WATERS ATLANTIC OCEAN[1]

Sample No	4976	4977	4978	4979	673
Date sampled	4/8/39	7/8/39	9/8/39	20/8/39	15/11/39
Source	Bay of Fundy	St. Mary's Bay, N.S.	Lunenburg, N.S.	Northumberland Strait	Moncton, N.B.
Sample collected	From steamer, midway between Saint John, N.B., and Digby, N.S.	Midway, 2 miles from head of bay	3 miles at sea	Midway between Cape Tormentine, N.B. and Borden, P.E.I.	Estuary Petitcodiac River, opposite mouth of Weldon Creek
Specific gravity at 20°C	1·0242	1·0239	1·0232	1·0224	1·0220
Total dissolved solids dried at 180°C ...... grm./l.	32·918	32·458	31·426	30·024	29·775
Bromine .... grm./l.	0·060	0·059	0·057	0·054	0·053

[1] Analysed by R. A. Rogers.

TABLE V—Continued

Analyses of Surface Waters—Continued

HUDSON BAY WATERSHED

Sample No.	611	371	610	372	614	370	365	606	368	607	609	367	631
Date of sampling	20/5/39	9/9/37	18/5/39	15/9/37	23/5/39	4/9/37	29/8/37	5/5/39	3/9/37	10/5/39	15/5/39	1/9/37	30/5/39
Source	Lac Blouin	Lac Dufault		Gull Lake		Pearl Lake	Abitibi River		Mattagami River				
Locality	Bourlamaque, Que.	7 miles North of Noranda, Que.		Kirkland Lake, Ont.		Timmins, Ont.	Iroquois Falls, Ont.		Smooth Rock Falls, Ont.		Timmins, Ont.	Smoky Falls, Ont.	
Sample collected	Depth sample	Depth sample, 2 miles from shore		Depth sample, midlake		Intake pipe, McIntyre mine	Intake pipe at pulp mill		Intake pipe at pulp mill		Midstream, waterworks	Depth sample, dam at power plant	
Gauge	High	Mean	High	Mean	High	Mean	Mean	High	Low	High	High	Low	High
Temperature, °C	6·0	18·0	5·0	14·0	14·0	20·0	17·0	5·0	20·0	5·0	5·0	20·0	5·0
pH	6·2	6·8	6·1	7·2	7·2	8·1	7·1	7·0	7·1	7·0	6·9	6·7	6·5
Dissolved oxygen ....ml./l.	7·2	7·0	7·5	7·6	7·6	6·6	6·3	8·5	5·8	9·5	7·8	6·5	9·5
Free carbon dioxide (CO_2) ....p.p.m.	3·0	3·0	3·0	2·0	1·5	1·0	3·0	2·5	3·5	1·5	2·0	5·5	3·0
Turbidity	None	None	None	None	None	10·0	20·0	10·0	None	10·5	None	None	2·5
Colour	180·0	40·0	70·0	25·0	25·0	60·0	200·0	130·0	100·0	130·0	90·0	130·0	120·0
Alkalinity as $CaCO_3$	9·5	11·5	6·5	35·0	30·0	68·5	41·5	33·5	41·0	18·5	20·0	47·5	21·5
Suspended matter	3·6	1·2	4·2	0·8	None	15·0	24·0	18·5	3·0	18·3	1·6	3·1	5·5
Residue on evaporation dried at 110°C	70·0	69·6	68·4	72·9	85·0	419·0	113·4	84·4	83·7	61·1	61·9	126·7	75·8
Silica (SiO_2)	2·1	3·3	2·6	1·8	0·5	6·3	16·0	7·1	5·5	3·4	3·7	5·4	1·4
Iron (Fe)	0·75	0·12	0·20	0·11	0·11	0·11	7·50[1]	0·22	0·22	0·23	0·15	0·18	0·15
Calcium (Ca)	7·7	10·0	7·8	15·4	10·8	66·0	17·5	13·4	16·0	10·5	10·4	19·5	11·6
Magnesium (Mg)	2·6	3·9	3·2	5·0	4·5	19·5	7·4	4·5	3·7	3·1	4·3	5·4	4·6
Alkalis as sodium (Na)	2·0	4·0	3·0	3·1	9·3	31·3	5·8	2·1	4·5	5·2	2·3	4·7	2·3
Hydrocarbonate (HCO_3)	11·6	14·0	7·9	42·7	36·6	83·6	50·6	40·9	50·0	22·6	24·4	58·0	26·2
Sulphate (SO_4)	7·0	38·6	34·0	11·1	16·0	186·1	10·3	7·4	4·9	5·2	5·4	7·2	5·9
Chloride (Cl)	3·5	1·5	0·9	1·1	14·3	25·5	1·2	1·5	1·0	0·5	0·9	1·5	0·5
Nitrate (NO_3)	2·0	3·50	1·06	1·10	0·70	0·40	0·60	0·44	0·50	0·44	0·62	0·50	0·27
Hardness as $CaCO_3$ calculated:													
Total hardness	30·0	41·0	32·6	59·0	45·5	245·0	74·1	52·0	55·2	39·0	43·6	70·9	47·9
Carbonate hardness	9·5	11·5	6·5	35·0	30·0	68·5	41·5	33·5	41·0	18·5	20·0	47·5	21·5
Noncarbonate hardness	20·5	29·5	26·1	24·0	15·5	176·5	32·6	18·5	14·2	20·5	23·6	23·4	26·4
Calcium hardness	19·3	25·0	19·5	38·5	27·0	165·0	43·8	33·5	40·0	26·3	26·0	48·8	29·0
Magnesium hardness	10·7	16·0	13·1	20·5	18·5	80·0	30·3	18·5	15·2	12·7	17·6	22·1	18·9

[1] Abnormal conditions as regards Fe content.

TABLE V—Continued

Analyses of Surface Waters—Continued

HUDSON BAY WATERSHED—Continued

Sample No	369	366	608	361	358	560	937	376	563	360	561	562	943	378	569	570	897
Date of sampling	2/9/37	29/8/37	12/5/39	1/8/37	23/6/37	21/6/38	24/6/43	29/7/37	20/8/38	29/7/37	22/6/38	18/8/38	22/8/43	25/6/37	22/6/38	16/8/38	5/9/42
Source	Ground-hog River	Kapuskasing River		Lake Keno-gamisis	Rainy River			Wabigoon River		Lake of the Woods				Red River			
Locality	Fauquier, Ont.	Kapuskasing, Ont.		7 miles from Geraldton, Ont.	Fort Frances, Ont.			Dryden, Ont.		Kenora, Ont.				Winnipeg, Manitoba			
Sample collected	Depth sample, mid-stream	Depth sample, power dam		Intake pipe, Hard Rock gold mine, 7-foot depth	Intake pipe, Fort Frances pulp mill			Intake pipe, pulp mill		Intake pipe, Kenora paper mill			Depth sample, 3 miles south of Kenora	Depth sample, 6-foot, 1 mile above city limits			
Gauge	Low	Low	High	Mean	Mean	High	High	Mean	Mean	High	High	Mean	High	Mean	Mean	Mean	Mean
Temperature, °C	20·0	19·0	4·0	20·0	18·0	20·0	16·0	22·0	22·0	23·0	20·0	22·0	18·0	25·0	24·0	23·0	15·0
pH	7·3	7·2	6·9	7·6	6·8	7·1	7·2	7·3	7·1	7·4	7·4	7·1	7·1	8·0	8·3	8·0	8·0
Dissolved oxygen..........ml./l.	6·0	5·3	9·5	6·7	6·5	6·7	......	6·1	6·3	6·0	6·6	6·2	....	6·5	6·3	5·8	6·5
Free carbon dioxide (CO_2)....p.p.m.	3·0	4·0	2·0	None	2·0	1·5	......	None	None	Trace	None	10·0	....	None	None	None	None
Turbidity	10·0	None	20·0	None	None	7·0	None	2·0	10·0	None	8·0	10·0	None	40·0	24·0	58·0	40·0
Colour	70·0	140·0	135·0	70·0	40·0	45·0	65·0	20·0	40·0	20·0	40·0	40·0	50·0	70·0	80·0	50·0	35·0
Alkalinity as $CaCO_3$	53·0	62·0	26·5	64·5	23·5	15·0	17·0	64·5	43·5	47·0	44·0	43·5	47·1	182·5	210·0	197·0	204·0
Suspended matter	14·0	2·0	24·6	2·6	2·7	5·1	3·6	4·9	4·2	2·2	5·0	4·2	3·0	47·3	35·7	62·9	52·6
Residue on evaporation dried at 110° C	100·0	124·1	78·3	106·1	64·8	58·3	64·0	103·3	108·2	83·8	98·0	108·2	101·6	864·3	644·1	610·0	502·6
Silica (SiO_2)	5·4	7·7	3·3	6·1	4·8	4·7	4·2	3·9	12·1	1·2	4·4	12·1	6·6	14·8	8·1	17·5	24·0
Iron (Fe)	0·20	0·12	0·20	0·04	0·10	0·15	0·03	0·05	0·88	0·20	0·12	0·28	0·02	0·34	0·05	0·12	0·01
Calcium (Ca)	18·0	24·3	10·7	23·0	9·2	7·5	7·4	28·0	20·0	14·5	17·9	20·0	16·9	98·0	113·6	92·9	65·2
Magnesium (Mg)	4·5	8·1	3·1	5·2	3·2	3·1	2·5	3·7	5·5	4·5	6·3	5·5	5·5	40·0	42·5	38·3	32·8
Alkalis as sodium (Na)	3·1	3·4	2·5	5·0	·7·2	3·9	3·8	4·6	3·1	3·0	4·1	3·1	4·7	134·3	29·7	51·6	50·6
Hydrocarbonate (HCO_3)	64·5	75·6	32·3	78·7	28·7	18·3	20·7	78·7	53·1	57·3	53·7	53·1	57·5	222·7	256·2	240·3	248·9
Sulphate (SO_4)	5·7	5·2	6·0	5·8	8·2	7·4	5·6	10·7	10·9	5·4	11·3	10·9	7·7	202·0	221·7	185·5	111·2
Chloride (Cl)	1·5	1·2	0·5	1·0	1·2	1·5	0·7	1·2	1·5	1·0	1·2	1·5	0·4	211·5	18·6	49·0	49·5
Nitrate (NO_3)	0·20	0·90	0·44	1·10	0·50	1·33	0·09	1·80	1·33	0·70	0·80	1·33	1·95	0·90	1·33	2·21	0·62
Hardness as $CaCO_3$ calculated:																	
Total hardness	63·5	94·0	39·5	78·8	36·1	31·5	28·8	85·2	72·6	54·8	70·6	72·6	64·9	409·0	458·3	389·3	297·5
Carbonate hardness	53·0	62·0	26·5	64·5	23·5	15·0	17·0	64·5	43·5	47·0	44·0	43·5	47·1	182·5	210·0	197·0	204·0
Noncarbonate hardness	10·5	32·0	13·0	14·3	12·6	16·5	11·8	20·7	29·1	7·8	26·6	29·1	17·8	226·5	248·3	192·3	93·5
Calcium hardness	45·0	60·8	26·8	57·5	23·0	18·8	18·5	70·0	50·0	36·3	44·8	50·0	42·3	245·0	284·0	232·3	163·0
Magnesium hardness	18·5	33·2	12·7	21·3	13·1	12·7	10·3	15·2	22·6	18·5	25·8	22·6	22·6	164·0	174·3	157·0	134·5

Sample No.	379	571	895	945	942	380	382	565	893	939	381	566	564
Date of sampling	28/6/37	14/8/38	3/9/42	8/9/43	3/8/43	27/7/37	27/7/37	29/5/38	30/7/42	3/8/43	5/7/37	8/8/39	7/8/38
Source	Assiniboine River					Lake Winnipeg	South Saskatchewan River						Oldman River
Locality	Brandon, Man.				Portage la Prairie	Gimli, Man.	Saskatoon, Sask.				Medicine Hat, Alta.		Lethbridge, Alta.
Sample collected	Depth sample, 6-foot, midstream at waterworks				Intake pipe, city waterworks	Depth sample, 2 miles off shore	Depth sample, midstream at waterworks				Depth sample, midstream at waterworks		Depth sample, 10-foot, midstream
Gauge	Mean	High	High	High	High	Mean	Low	Above mean, 4 feet.	Mean	Low	Mean	Low	Mean
Temperature, °C	23·0	20·0	18·0	17·0	20·0	20·0	24·0	20·0	18·0	20·0	23·0	23·0	18·0
pH	8·3	8·3	8·0	8·0	8·0	7·7	8·4	8·2	8·2	8·2	8·4	8·2	8·2
Dissolved oxygen.............ml./l.	6·3	6·1	6·0	....	....	6·2	6·5	6·7	6·2	....	6·8	6·0	6·2
Free carbon dioxide (CO_2)...........p.p.m.	None	None	None	....	....	None	None	None	None	....	None	None	None
Turbidity	18·0	25·0	70·0	10·0	40·0	43·0	50·0	250·0	85·0	350·0	70·5	20·0	12·0
Colour	40·0	25·0	40·0	35·0	40·0	40·0	10·0	10·0	20·0	35·0	10·0	10·0	None
Alkalinity as $CaCO_3$	225·0	213·5	215·0	280·0	261·0	76·5	114·5	106·5	128·5	121·0	107·0	109·5	124·0
Suspended matter	19·8	27·0	101·4	15·0	50·0	61·8	66·0	261·0	129·8	431·6	77·2	28·2	4·8
Residue on evaporation dried at 110°C.	585·0	631·6	578·4	603·4	550·0	150·3	175·1	160·0	192·2	198·6	150·8	161·3	163·2
Silica (SiO_2)	18·3	18·9	22·0	15·6	24·6	19·2	3·2	6·9	12·0	3·2	6·9	3·2	2·0
Iron (Fe)	0·04	0·06	0·04	0·02	0·02	0·40	0·08	0·36	0·10	0·03	0·05	0·05	0·54
Calcium (Ca)	83·0	86·1	75·6	80·0	78·6	25·0	37·5	36·8	39·2	39·2	34·0	37·5	37·2
Magnesium (Mg)	38·0	44·0	37·2	39·3	35·3	9·2	13·0	11·1	12·8	12·2	10·0	12·9	13·4
Alkalis as sodium (Na)	43·9	48·2	59·2	60·0	59·4	9·8	10·0	8·0	8·4	8·3	7·5	7·7	9·6
Hydrocarbonate (HCO_3)	274·5	260·5	262·3	341·6	318·4	93·3	139·7	129·9	156·8	147·6	130·5	133·6	151·3
Sulphate (SO_4)	192·1	228·5	195·2	200·8	152·4	21·2	36·0	33·9	33·6	31·8	25·5	30·5	22·2
Chloride (Cl)	10·0	11·3	18·5	18·7	15·9	6·0	1·2	1·5	1·5	0·8	1·5	1·0	1·0
Nitrate (NO_3)	1·20	0·62	0·89	0·27	0·27	1·0	0·20	1·06	0·26	0·35	0·50	0·44	0·27
Hardness as $CaCO_3$ calculated:													
Total hardness	363·3	395·7	341·5	361·1	341·2	100·2	147·1	137·5	150·5	148·0	126·0	146·7	147·9
Carbonate hardness	225·0	213·5	215·0	280·0	261·0	76·5	114·5	106·5	128·5	121·0	107·0	109·5	124·0
Noncarbonate hardness	138·3	182·2	126·5	81·1	80·2	23·7	32·6	31·0	22·0	27·0	19·0	37·2	23·9
Calcium hardness	207·5	215·3	189·0	200·0	196·5	62·5	93·8	92·0	98·0	98·0	85·0	93·8	93·0
Magnesium hardness	155·8	180·4	152·5	161·1	144·7	37·7	53·3	45·5	52·5	50·0	41·0	52·9	54·9

¹ After two day's heavy rainfall.

	384	567	938	383	568	894	941	385	572	944	386	574	896	387	573
Sample No.	384	567	938	383	568	894	941	385	572	944	386	574	896	387	573
Date of sampling	22/7/37	27/6/38	4/8/43	17/7/37	2/7/38	3/8/42	30/7/43	14/7/37	4/7/38	3/8/43	13/7/37	6/7/38	27/8/42	13/7/37	6/7/38
Source	North Saskatchewan River							Red Deer River			Bow River			Elbow River	
Locality	Prince Albert, Sask.			Edmonton, Alta.				Red Deer, Alta.			Calgary, Alta.				
Sample collected	Intake pipe at waterworks			Intake pipe at waterworks				Intake pipe at waterworks			Intake pipe, No. 2 pumping station		Glenmore dam	Old pumping station, midstream, depth 8 feet	
Gauge	High	High	High	High	High	Mean	Mean	Mean	Above mean 2 feet	High	Mean	High	Mean	Mean	High
Temperature, °C	21·0	19·0	20·0	13·0	18·0	14·5	19·0	18·0	21·0	20·0	18·0	15·0	16·0	17·0	15·8
pH	8·4	8·3	8·0	7·8	8·2	8·1	7·6	8·4	8·0	8·1	8·2	8·3	8·2	8·2	8·4
Dissolved oxygen .... ml./l.	6·5	6·8	....	6·0	6·0	6·0	....	7·2	6·2	....	7·0	6·4	6·8	7·1	6·3
Free carbon dioxide (CO_2) .... p.p.m.	None	None	....	None	None	None	....	None	None	....	None	None	None	None	None
Turbidity	200·0	250·0	4·0	3,000·0[1]	200·0	140·0	95·0	5·8	400·0	None	10·0	26·0	10·0	5·8	63·0
Colour	10·0	10·0	25·0	15·0	5·0	25·0	15·0	None	25·0	10·0	5·0	5·0	10·0	5·0	5·0
Alkalinity as $CaCO_3$	94·0	103·5	103·6	109·0	91·0	113·5	94·8	123·0	118·0	143·5	97·0	97·0	145·5	127·0	118·0
Suspended matter	199·5	384·4	9·0	3,000·0[1]	165·0	160·0	122·8	9·3	372·0	1·6	12·9	35·0	14·2	7·2	56·0
Residue on evaporation dried at 110°C	132·8	172·7	207·4	172·8	137·1	169·0	156·6	180·3	174·4	204·8	145·6	137·0	212·0	207·7	174·0
Silica (SiO_2)	10·9	9·8	3·4	11·8	4·3	6·4	3·8	6·1	10·2	5·4	9·4	4·2	5·6	11·8	4·9
Iron (Fe)	0·06	0·12	0·06	0·03	0·07	0·05	0·06	0·06	0·34	0·04	0·01	0·06	0·04	0·04	0·10
Calcium (Ca)	33·0	37·9	39·4	35·5	35·5	38·4	37·2	35·0	38·5	46·6	35·0	36·5	50·0	48·5	45·0
Magnesium (Mg)	11·5	12·6	11·1	10·5	10·3	14·4	10·6	12·3	11·9	14·4	10·9	11·1	8·8	13·3	12·3
Alkalis as sodium (Na)	6·5	8·2	8·5	9·2	6·4	5·6	4·6	4·9	8·9	8·7	3·1	5·1	6·0	3·7	5·5
Hydrocarbonate (HCO_3)	114·7	126·3	126·4	133·0	111·0	138·5	115·7	150·1	144·0	175·1	118·3	118·3	177·5	154·9	144·0
Sulphate (SO_4)	31·3	29·4	44·8	30·5	25·7	31·6	35·2	35·6	21·6	32·1	26·0	20·4	36·8	23·1	30·7
Chloride (Cl)	1·2	1·5	1·2	1·2	1·5	1·8	0·7	1·5	1·2	0·8	1·2	1·5	1·5	1·2	1·5
Nitrate (NO_3)	1·20	0·44	0·18	0·20	0·53	0·26	0·62	None	1·06	0·27	0·20	0·44	0·09	0·20	0·53
Hardness as $CaCO_3$ calculated: Total hardness	129·7	146·5	144·0	131·9	131·0	155·0	136·5	137·9	145·1	175·5	132·2	136·8	161·1	175·8	162·9
Carbonate hardness	94·0	103·5	103·6	109·0	91·0	113·5	94·8	123·0	118·0	143·5	97·0	97·0	145·5	127·0	118·0
Noncarbonate hardness	35·7	43·0	40·4	22·9	40·0	41·5	41·7	14·9	27·1	32·0	35·2	39·8	15·6	48·8	44·9
Calcium hardness	82·5	94·8	98·5	88·8	88·8	96·0	93·0	87·5	96·3	116·5	87·5	91·3	125·0	121·3	112·5
Magnesium hardness	47·2	51·7	45·5	43·1	42·2	59·0	43·5	50·4	48·8	59·0	44·7	45·5	36·1	54·5	50·4

[1] After two days' heavy rainfall.

TABLE V—Continued

Analyses of Surface Waters—Continued

PACIFIC WATERSHED

	388	575	576	462	580	577	898	578	586	587	899	579
Sample No.	388	575	576	462	580	577	898	578	586	587	899	579
Date of sampling	10/7/37	10/7/38	29/7/38	9/7/37	4/8/38	12/7/38	24/8/42	26/7/38	4/12/38	26/7/38	19/8/42	27/7/38
Source	Columbia River		Trail,	Mark Creek		Okanagan Lake		Fraser River				Thompson River
Locality	Golden, B.C.		Trail, B.C.	Kimberley, B.C.		Kelowna, B.C.		Hope, B.C.		Mission, B.C.	New Westminster, B.C.	Kamloops, B.C.
Sample collected	Midstream, 6-foot depth		Mid-stream, 12-foot depth	Intake pipe, C.M.S. Company plant		Midlake, 25-foot depth		Midstream, 15-foot depth		Mid-stream, 15-foot depth	Midstream, at bridge	Bridge near outlet of lake
Gauge	Mean	High	High	Mean	Mean	Mean	High	Mean	Low	Mean	Mean	Mean
Temperature, °C	19·0	19·0	19·0	13·0	13·0	18·0	17·0	17·0	4·0	16·5	16·0	22·0
pH	7·3	7·6	7·4	7·0	7·1	8·0	8·0	7·7	7·1	7·5	7·0	7·4
Dissolved oxygen ml./l.	6·7	6·4	6·7	7·0	7·0	6·7	6·8	7·8	....	6·8	6·5	6·7
Free carbon dioxide (CO_2) p.p.m.	None	None	None	None	None	None	None	None	None	None	None	None
Turbidity "	90·0	15·0	11·0	5·0	7·0	14·0	None	100·0	5·0	80·0	45·0	16
Colour "	5·0	5·0	5·0	5·0	10·0	None	None	5·0	15·0	5·0	50·0	None
Alkalinity as $CaCO_3$ "	55·5	60·7	52·0	8·9	13·3	95·5	100·0	43·0	50·0	40·0	36·0	29·5
Suspended matter "	92·0	21·5	4·8	0·5	1·2	10·6	6·0	84·1	5·4	100·0	107·0	15·3
Residue on evaporation dried at 110°C. "	88·3	95·1	76·3	20·0	36·0	146·6	151·6	438·3[1]	83·1	71·3	70·6	63·9
Silica (SiO_2) "	3·8	5·0	5·3	2·5	6·4	10·6	8·2	3·8	7·3	4·5	3·2	5·6
Iron (Fe) "	0·07	0·06	0·05	0·04	0·06	0·05	0·04	0·03	0·07	0·08	0·21	0·03
Calcium (Ca) "	18·5	23·0	19·3	3·9	8·0	30·4	30·4	17·9	19·8	14·2	12·8	7·9
Magnesium (Mg) "	8·0	8·8	4·4	0·5	2·5	9·0	10·0	15·0	4·5	3·5	2·8	2·6
Alkalis as sodium (Na) "	2·2	3·9	4·2	2·0	4·2	12·2	7·6	110·2[1]	1·9	4·5	4·4	4·7
Hydrocarbonate (HCO_3) "	67·7	74·1	63·4	10·9	16·2	116·5	122·0	52·5	61·0	48·8	43·9	36·0
Sulphate (SO_4) "	18·0	16·1	8·9	4·0	5·2	19·2	22·4	33·4	10·0	14·8	12·8	6·4
Chloride (Cl) "	1·5	1·5	1·1	0·9	1·2	1·3	1·3	186·2[1]	1·5	3·5	1·2	5·5
Nitrate (NO_3) "	0·10	0·53	0·62	0·10	0·44	0·27	None	0·17	None	0·20	0·35	0·44
Hardness as $CaCO_3$ calculated:												
Total hardness "	79·1	93·6	66·3	11·9	30·3	112·9	117·0	106·3	68·0	49·9	43·5	30·5
Carbonate hardness "	55·5	60·7	52·0	8·9	13·3	95·5	100·0	43·0	50·0	40·0	36·0	29·5
Noncarbonate hardness "	23·6	32·9	14·3	3·0	17·0	17·4	17·0	63·3	18·0	9·9	7·5	1·0
Calcium hardness "	46·3	57·5	48·3	9·8	20·0	76·0	76·0	44·8	49·5	35·5	32·0	19·8
Magnesium hardness "	32·8	36·1	18·0	2·1	10·3	36·9	41·0	61·5	18·5	14·4	11·5	10·7

[1] Abnormal conditions as regards sodium chloride.

TABLE V—Concluded

Analyses of Surface Waters—Concluded

SEA WATERS PACIFIC OCEAN[1]

	581	582
Sample No.	581	582
Date of sampling.	27/7/38	19/6/38
Source.	Strait of Juan de Fuca	Barkley Sound
Locality.	Midway Victoria and Port Townsend	Port Alberni, B.C.
Sample collected.	Taken from steamer, 20-foot depth	At buoy seaward, 25-foot depth
Gauge.	Mean	Mean
Temperature, °C.	12·0	11·5
pH.	8·5	8·5
Dissolved oxygen.ml./l.	8·2	8·0
Free carbon dioxide (CO_2).p.p.m.	None	None
Turbidity. "	10·0	11·0
Colour. "	None	None
Alkalinity as $CaCO_3$. "	102·0	105·0
Suspended matter. "	1·6	4·4
Residue on evaporation dried at 110°C. "	30,964·0	31,108·0
Silica (SiO_2). "	17·0	8·0
Iron (Fe). "	0·04	0·03
Calcium (Ca). "	200·0	211·5
Magnesium (Mg). "	575·3	573·2
Alkalis as sodium (Na). "	10,936·5	10,979·8
Hydrocarbonate (HCO_3). "	124·4	128·1
Sulphate (SO_4). "	1,113·8	1,113·8
Chloride (Cl). "	18,000·3	18,068·0
Nitrate (NO_3). "		
Bromine. "	57·0	56·0
Hardness as $CaCO_3$ calculated:		
Total hardness. "	2,858·7	2,878·9
Carbonate hardness. "	102·0	105·0
Noncarbonate hardness. "	2,756·7	2,773·9
Calcium hardness. "	500·0	528·8
Magnesium hardness. "	2,358·7	2,350·1

[1] Analysed by R. A. Rogers.

TABLE VI

Analyses of Civic Water Supplies

NOVA SCOTIA

Sample No.	246	672	835	258	676	764	256	681	765	267	685	254	679	767	255	680	264	682
Date	29/6/36	2/8/39	16/7/41	16/6/36	8/8/39	30/7/40	18/6/36	4/8/39	1/8/40	23/6/36	16/8/39	18/6/36	10/8/39	31/7/40	18/6/36	11/8/39	20/6/36	16/8/39
Locality	Amherst			Bridgewater			Dartmouth			Glace Bay[1]		Halifax			Halifax		Inverness	
Source of supply	Nappan River			Hebb's Lake			Dartmouth water supply lakes			Sand Lake		Long Lake, lower service			Spruce Hill Lake, upper service		Mabou Reservoir, fed by springs	
Method of purification	Chlorination			No treatment			$CuSO_4$, inter-mittent	Chlorination		No treatment		Chlorination			Chlorination		No treat-ment	Inter-mittent chlor-ination

	246	672	835	258	676	764	256	681	765	267	685	254	679	767	255	680	264	682
Colour..........p.p.m.	....	25·0	25·0	....	15·0	30·0	....	None	5·0	....	10·0	....	10·0	30·0	....	5·0	....	10·0
Alkalinity as $CaCO_3$ "	17·0	27·5	17·0	None	None	None	None	None	3·5	None	None	None	0·5	None	None	None	3·5	13·0
Residue on evaporation dried at 110°C "	....	89·5	72·5	....	24·5	29·0	....	23·5	29·0	....	30·0	....	25·0	30·0	....	21·5	....	50·0
Silica (SiO_2) "	....	9·0	3·5	....	3·5	4·5	....	1·6	5·0	....	2·0	....	2·5	4·0	....	1·5	....	5·5
Iron (Fe) "	....	3·7	0·05	....	0·32	0·20	....	0·04	0·07	....	0·06	....	0·04	0·05	....	0·05	....	0·05
Calcium (Ca) "	10·0	11·4	10·0	4·3	1·4	9·0	5·0	1·4	5·0	6·4	2·1	2·0	2·1	5·7	4·3	2·1	6·4	4·3
Magnesium (Mg) "	3·1	2·4	2·0	2·6	1·5	1·2	3·0	1·3	2·8	3·5	1·3	2·3	1·7	1·1	2·7	1·3	3·9	2·8
Bicarbonate (HCO_3) "	20·7	33·6	20·7	None	None	None	None	None	4·3	None	None	None	0·6	None	None	None	4·3	15·9
Sulphate (SO_4) "	....	8·2	6·0	....	5·4	3·7	....	6·2	2·8	....	7·4	....	7·0	6·6	....	6·6	....	8·0
Chloride (Cl) "	....	8·0	4·4	....	3·5	3·0	....	5·0	4·5	....	10·0	....	6·5	2·5	....	5·5	....	10·0
Nitrate (NO_3) "	....	1·77	2·3	....	1·6	0·17	....	1·06	0·35	....	1·33	....	0·44	0·35	....	0·62	....	0·44
Total hardness as $CaCO_3$ "	37·7	38·3	33·2	21·5	9·7	27·4	24·8	8·8	24·0	30·4	10·6	14·4	12·3	18·8	21·9	10·6	32·0	20·2
Calcium hardness "	25·0	28·5	25·0	10·8	3·5	22·5	12·5	3·5	12·5	16·0	5·3	5·0	5·3	14·3	10·8	5·3	16·0	10·8
Magnesium hardness "	12·7	9·8	8·2	10·7	6·2	4·9	12·3	5·3	11·5	14·4	5·3	9·4	7·0	4·5	11·1	5·3	16·0	9.4

[1] Supplies Reserve Mines and Dominion.

Sample No.	260	766	832	259	677	768	769	268	688	770	265	686	315	690	771	673	772	829
Date	17/6/36	22/7/40	15/7/41	16/6/36	8/8/39	30/7/40	30/7/40	22/6/36	18/8/39	8/8/40	23/6/36	16/8/39	25/6/36	19/8/39	8/8/40	2/8/39	21/7/40	14/7/41
Locality	Kentville			Liverpool			Lunenburg	New Glasgow			New Waterford		Pictou			Springhill		
Source of supply	Magee Lake			Town Lakes			Canteloup Lake	Forbes Lake			Waterford Lake		Wells			Springs		
Method of purification	No treatment	Alum, lime, filtration, chlorination		No treatment			No treatment	No treatment			No treatment		No treatment			No treatment		
Colour ....p.p.m.	......	40·0	25·0	......	10·0	40·0	15·0	......	5·0	25·0	......	5·0	......	None	10·0	30·0	15·0	35·0
Alkalinity as CaCO3	15·0	8·0	None	None	None	None	None	7·5	10·0	10·0	19·5	0·5	73·0	83·5	96·5	None	8·5	2·0
Residue on evaporation dried at 110° C.	......	47·0	34·0	......	32·5	30·0	29·5	......	51·5	53·5	......	45·0	......	151·0	183·5	55·0	35·5	39·0
Silica (SiO2)	......	4·0	6·0	......	1·5	3·5	2·0	......	2·0	2·5	......	4·0	......	3·8	10·00	9·0	11·5	1·5
Iron (Fe)	......	0·07	0·04	......	0·32	0·15	0·07	......	0·05	0·07	......	0·05	......	0·42	0·23	0·05	0·01	0·05
Calcium (Ca)	2·1	6·4	6·4	4·3	1·4	5·7	5·0	12·1	10·0	12·9	3·6	2·9	35·7	33·6	32·2	3·5	6·3	5·7
Magnesium (Mg)	3·9	2·6	3·5	3·0	1·7	3·5	3·5	3·2	2·0	3·5	3·7	1·7	8·6	5·0	7·4	2·8	4·3	2·8
Bicarbonate (HCO3)	18·3	9·8	None	None	None	None	None	9·2	12·2	12·2	23·8	0·6	89·1	101·9	117·7			
Sulphate (SO4)	......	9·8	4·9	......	7·8	5·8	5·8	......	14·0	4·9	......	10·7	......	18·0	10·3	1·2	3·2	6·2
Chloride (Cl)	......	4·5	3·2	......	5·0	6·5	6·5	......	5·5	5·5	......	11·5	......	10·0	7·3	2·5	3·5	3·5
Nitrate (NO3)	......	0·17	0·9	......	1·77	0·7	0·44	......	3·54	0·35	......	0·80	......	1·33	0·17	0·17	0·17	1·7
Total hardness as CaCO3	21·3	26·7	30·4	23·1	10·5	28·7	26·9	43·4	33·2	46·7	24·2	14·3	124·6	104·5	110·8	20·3	33·4	25·8
Calcium hardness	5·3	16·0	16·0	10·8	3·5	14·3	12·5	30·3	25·0	32·3	9·0	7·3	89·3	84·0	80·5	8·8	15·8	14·3
Magnesium hardness	16·0	10·7	14·4	12·3	7·0	14·4	14·4	13·1	8·2	14·4	15·2	7·0	35·3	20·5	30·3	11·5	17·6	11·5

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

NOVA SCOTIA—Concluded

Sample No.	263	687	342	684	269	683	244	674	773	262	689	301	783	828	261	774	830
Date	20/6/36	18/8/39	23/6/36	16/8/39	22/6/36	15/8/39	19/6/36	3/8/39	31/7/40	20/6/36	19/8/39	17/6/36	21/7/40	24/7/41	6/6/36	29/7/40	17/7/41
Locality	Stellarton		Sydney		Sydney Mines[1]		Truro			Westville		Windsor			Yarmouth		
Source of supply	East River		Reservoir fed by springs and brooks		Powell Lake		Lepper Brook			Springs and Middle River		Mill Lake			Lake George		
Method of purification	Chlorination		No treatment		No treatment		No treatment			No treatment		No treatment			Chlorination		
Colour............p.p.m.	......	5·0	......	20·0	......	None	......	70·0	15·0	......	5·0	......	140·0	70·0	......	60·0	35·0
Alkalinity as CaCO3........"	15·5	18·0	None	1·5	3·5	1·0	9·0	16·5	15·0	18·0	11·0	None	None	None	None	None	None
Residue on evaporation dried at 110°C..... "	......	103·5	......	23·0	......	26·0	......	54·0	53·5	......	131·0	......	53·5	31·0	......	42·0	32·0
Silica (SiO2)............"	......	1·4	......	1·0	......	None	......	2·0	3·5	......	1·4	......	6·0	0·5	......	1·5	1·5
Iron (Fe)............."	......	0·06	......	0·17	......	0·05	......	3·2	4·5	......	0·8	......	0·02	0·09	......	0·05	0·09
Calcium (Ca)..........."	5·7	21·4	3·9	1·4	5·7	1·4	8·6	2·1	3·5	4·3	10·7	1·4	2·9	4·3	None	4·3	4·3
Magnesium (Mg)..........."	3·5	3·1	2·6	1·3	3·5	1·5	4·1	1·5	3·9	4·3	3·5	1·0	1·8	1·3	1·5	2·2	1·7
Bicarbonate (HCO3)........."	18·9	22·0	None	1·8	4·3	1·2	11·0	20·1	18·3	22·0	13·4	None	None	None	None	None	None
Sulphate (SO4)............"	......	32·4	......	5·4	......	7·4	......	7·0	5·3	......	11·1	......	2·1	5·8	......	6·2	5·3
Chloride (Cl)............"	......	9·4	......	6·5	......	6·5	......	4·0	4·5	......	52·5	......	3·0	2·5	......	11·0	6·0
Nitrate (NO3)............"	......	0·80	......	2·7	......	0·62	......	0·27	0·61	......	1·33	......	0·17	0·9	......	0·17	0·09
Total hardness as CaCO3........."	28·7	66·2	20·5	8·8	28·7	9·7	38·3	11·5	24·8	28·4	41·2	7·6	14·7	16·1	6·2	19·8	17·8
Calcium hardness........."	14·3	53·5	9·8	3·5	14·3	3·5	21·5	5·3	8·8	10·8	26·8	3·5	7·3	10·8	None	10·8	10·8
Magnesium hardness........."	14·4	12·7	10·7	5·3	14·4	6·2	16·8	6·2	16·0	17·6	14·4	4·1	7·4	5·3	6·2	9·0	7·0

[1] Supplies North Sydney.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

NEW BRUNSWICK

Sample No.	248	666	775	250	664	821	299	668	776	822	249	777	823	240	701	779	252	692	778
Date	3/7/36	27/7/39	24/6/40	4/7/36	26/7/39	6/9/41	4/7/36	30/7/39	23/6/40	3/9/41	3/7/36	23/6/40	6/9/41	5/6/36	27/8/39	16/8/40	6/6/36	23/8/39	1/7/40
Locality	Bathurst			Campbellton			Chatham				Dalhousie			Edmundston			Fredericton		
Source of supply	Springs and creek			Brook and spring			Creek, impounding dam				Well and creek		Well and creek, Mc-Neish dam	Madawaska River			St. John River		
Method of purification	No treatment			No treatment			No treatment				No treatment			Chlorination			Filtration, chlorination, alum, lime		
Colour.....p.p.m.	......	35·0	40·0	......	15·0	15·0	......	70·0	130·0	110·0	......	25·0	60·0	......	40·0	50·0	......	10·0	60·0
Alkalinity as CaCO₃..... "	69·5	73·0	62·5	14·5	47·0	38·0	15·5	25·0	37·5	21·5	35·0	27·1	46·0	66·5	41·5	48·5	19·0	14·5	7·5
Residue on evaporation dried at 110°C..... "	......	152·5	100·5	......	79·0	77·5	......	75·0	124·5	78·5	......	68·5	124·5	......	75·0	85·0	......	75·5	67·0
Silica (SiO)..... "	......	8·5	11·0	......	10·5	9·0	......	9·0	8·0	4·0	......	12·0	5·5	......	2·0	5·0	......	1·2	4·0
Iron (Fe)..... "	......	0·21	0·02	......	0·10	0·03	......	0·25	0·25	0·08	......	0·05	0·05	......	0·08	0·05	......	0·15	0·05
Calcium (Ca)..... "	29·3	29·3	28·6	15·7	16·4	17·2	5·7	8·6	14·3	8·6	14·3	18·6	24·3	26·8	19·3	19·3	16·4	15·0	15·7
Magnesium (Mg)..... "	5·2	4·8	5·2	4·5	4·8	3·1	1·4	3·7	5·5	2·8	3·4	4·5	3·5	7·2	4·4	3·9	3·9	2·0	4·1
Bicarbonate (HCO₃)..... "	84·8	89·1	76·3	17·7	57·3	46·4	18·9	30·5	45·8	26·2	42·7	33·1	56·1	81·1	50·6	59·2	23·2	17·7	9·2
Sulphate (SO₄)..... "	......	8·2	11·9	......	4·5	6·6	......	2·0	4·1	4·9	......	4·5	13·2	......	9·0	3·0	......	25·9	4·9
Chloride (Cl)..... "	......	3·0	1·5	......	1·5	1·0	......	1·0	1·5	1·0	......	4·0	7·5	......	2·0	1·0	......	2·3	2·5
Nitrate (NO₃)..... "	......	0·17	0·53	......	1·33	1·2	......	0·44	0·44	0·09	......	0·17	0·4	......	0·27	0·62	......	3·14	0·62
Total hardness as CaCO₃ "	94·6	93·0	92·8	57·8	60·7	55·7	20·0	36·7	58·4	33·0	49·7	65·0	75·2	96·5	66·3	64·3	57·0	45·7	56·1
Calcium hardness..... "	73·3	73·3	71·5	39·3	41·0	43·0	14·3	21·5	35·8	21·5	35·8	46·5	60·8	67·0	48·3	48·3	41·0	37·5	39·3
Magnesium hardness..... "	21·3	19·7	21·3	18·5	19·7	12·7	5·7	15·2	22·6	11·5	13·9	18·5	14·4	29·5	18·0	16·0	16·0	8·2	16·8

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

NEW BRUNSWICK—Concluded

	247	669	780	827	245	667	781	824	241	694	243	695	251	693	691	782	826	242	696	784
Sample No.	247	669	780	827	245	667	781	824	241	694	243	695	251	693	691	782	826	242	696	784
Date	2/7/36	30/7/39	6/7/40	13/8/41	1/7/36	29/7/39	29/7/40	2/9/41	6/6/36	8/25/39	6/6/36	25/8/39	6/6/36	8/23/39	21/8/39	2/7/40	12/8/42	6/6/36	27/8/39	16/8/40
Locality	Moncton				Newcastle				Saint John				St. Stephen[1]		Sussex			Woodstock		
Source of supply	Impounding reservoirs				Wells				Loch Lomond		Spruce Lake		Wells		Ward Creek			St. John River		
Method of purification	Chlorination				No treatment				Chlorination	Chlorination / Ammo. sulph.	Chlorination	Chlorination / Ammo. sulph.	No treatment		Black alum, lime, chlor., filtration			Chlorination, filtration, alum		
Colour .... p.p.m.	......	55·0	60·0	25·0	......	None	20·0	None	......	15·0	......	15·0	......	10·0	5·0	15·0	25·0	......·	30·0	25·0
Alkalinity as CaCO₃.... "	10·0	7·5	4·0	None	113·5	101·5	115·0	105·5	47·5	5·5	3·5	None	15·0	14·0	43·0	28·5	28·0	34·5	16·5	27·5
Residue on evaporation dried at 110°C......... "	......	50·0	45·0	42·5	......	165·5	173·0	185·5	......	27·5	......	22·5	......	37·5	84·0	77·5	92·5	......	75·0	89·5
Silica (SiO₂)............. "	......	2·0	5·5	2·0	......	15·5	18·0	14·5	......	1·0	......	0·5	......	3·5	3·2	11·0	4·5	......	3·0	4·5
Iron (Fe)............... "	......	0·37	0·12	0·06	......	0·06	0·12	0·05	......	0·06	......	0·06	......	0·05	0·04	0·07	0·04	......	0·06	0·08
Calcium (Ca)........... "	6·4	3·5	5·0	2·9	31·4	25·0	32·0	32·5	18·6	5·7	6·0	3·5	8·6	5·7	15·0	15·7	17·2	17·5	16·4	20·0
Magnesium (Mg)........ "	4·1	2·4	1·3	2·6	5·6	4·1	5·0	4·8	5·1	3·6	3·0	1·7	4·1	1·3	3·3	1·9	4·1	5·8	3·5	3·1
Bicarbonate (HCO₃)..... "	12·2	9·2	4·9	None	138·5	123·8	140·3	128·7	58·0	6·7	4·3	None	18·3	17·1	52·5	34·8	34·2	42·1	20·1	33·6
Sulphate (SO₄)........... "	......	5·7	2·8	5·8	......	22·5	19·8	21·8	......	2·4	......	6·6	......	5·3	12·8	12·6	14·8	......	26·8	16·5
Chloride (Cl)............ "	......	1·5	2·5	11·0	......	7·5	12·5	23·2	......	4·0	......	5·0	......	2·5	7·0	4·0	4·5	......	3·0	2·5
Nitrate (NO₃)........... "	......	0·27	0·35	None	......	None	0·08	0·3	......	1·33	......	1·06	......	1·77	3·14	0·08	None	......	0·17	0·53
Total hardness as CaCO₃ "	32·8	18·6	17·8	18·0	101·5	79·3	100·5	101·0	67·4	29·1	27·3	15·8	38·3	19·6	51·0	47·1	59·8	67·6	55·4	62·7
Calcium hardness........ "	16·0	8·8	12·5	7·3	78·5	62·5	80·0	81·3	46·5	14·3	15·0	8·8	21·5	14·3	37·5	39·3	43·0	43·8	41·0	50·0
Magnesium hardness..... "	16·8	9·8	5·3	10·7	23·0	16·8	20·5	19·7	20·9	14·8	12·3	7·0	16·8	5·3	13·5	7·8	16·8	23·8	14·4	12·7

[1] Supplies Milltown and Calais.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

PRINCE EDWARD ISLAND

Sample No.	253	671	785	834	257	670	786	831
Date	30/6/36	1/8/39	15/7/40	3/8/41	29/6/36	31/7/39	19/7/40	1/8/41
Locality	Charlottetown				Summerside			
Source of supply	Wells				Wells			
Method of purification	No treatment		Chlorination		No treatment			
Colour.................................p.p.m.		None	20·0	10·0		5·0	5·0	5·0
Alkalinity as CaCO3............................ "	86·5	87·5	85·0	95·0	111·5	107·0	109·5	124·0
Residue on evaporation dried at 110°C........ "		136·5	132·0	138·0		187·0	161·5	187·5
Silica (SiO2)................................... "		5·5	11·5	5·0		14·0	10·5	11·0
Iron (Fe)...................................... "		0·13	0·05	0·11		0·17	0·05	0·06
Calcium (Ca).................................. "	24·3	24·3	22·3	25·0	50·0	47·9	48·6	53·6
Magnesium (Mg).............................. "	12·5	14·0	13·8	12·7	3·0	3·7	4·3	3·0
Bicarbonate (HCO3)........................... "	105·5	106·8	103·7	115·9	136·0	130·5	133·6	151·3
Sulphate (SO4)................................ "		9·0	6·9	10·7		16·1	8·2	20·2
Chloride (Cl).................................. "		10·5	11·5	11·3		17·5	14·5	14·4
Nitrate (NO3)................................. "		3·54	0·44	2·8		3·54	0·17	3·9
Total hardness as CaCO3....................... "	112·1	118·2	112·4	114·6	137·3	135·0	139·1	146·3
Calcium hardness.............................. "	60·8	60·8	55·8	62·5	125·0	119·8	121·5	134·0
Magnesium hardness........................... "	51·3	57·4	56·6	52·1	12·3	15·2	17·6	12·3

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

QUEBEC

Sample No.	389	853	590	137	289	757	113	281	660	284	708	139	904	111	280	655	815	240	709	127	816
Date	12/9/37	27/6/42	16/6/38	24/7/35	20/7/36	21/8/40	29/6/35	11/7/36	23/7/39	9/7/36	18/5/39	25/7/35	18/10/42	27/6/35	11/7/36	20/7/39	13/9/41	10/7/35	11/7/39	17/7/35	18/9/41
Locality	Amos	Asbestos	Aylmer	Beauharnois			Beauport			Baie St. Paul	Bourlamaque	Buckingham[1]		Cap de la Madeleine				Chicoutimi[2]		Coaticook	Cowansville[3]
Source of supply	Harricanaw River	Spring	Ottawa River	St. Lawrence River			Wells			Reservoir fed by springs and creeks	Lac Bloin	Lièvre River		Springs				Chicoutimi River		Springs	Mountain lake fed by springs
Method of purification	Filtr. chlor.	Chlor.	Chlor.	Alum	Filtr.	Chlor.	No treatment			No treatment	No treatment	Chlor.		No treatment				Chlor.		No treatment	No treatment
Colour..........p.p.m.	......	20·0	80·0	......	......	20·0	......	......	5·0	170·0	......	......	35·0	......	......	15·0	10·0	......	50·0	......	10·0
Alkalinity as CaCO₃ "	14·5	57·6	4·5	84·4	97·0	92·0	91·5	86·5	106·0	59·5	9·0	10·5	15·0	2·0	11·5	4·5	1·5	7·0	6·0	107·5	11·5
Residue on evaporation dried at 110°C. "	......	105·5	50·0	......	......	161·0	......	......	132·0	68·0	2·0	......	51·5	......	......	34·0	34·3	......	40·0	......	42·0
Silica (SiO₂) "	......	6·5	2·5	......	......	2·5	......	......	5·1	2·0	0·6	......	3·0	......	......	2·0	9·0	......	4·5	......	0·5
Iron (Fe) "	0·80	0·10	0·07	......	......	0·3	......	......	0·45	0·6	......	......	0·20	......	......	1·5	0·04	......	0·09	......	0·04
Calcium (Ca) "	5·0	20·0	7·8	33·6	37·9	40·0	22·4	41·4	40·1	12·9	7·5	7·9	8·0	5·0	4·3	5·0	5·0	4·6	8·0	37·1	7·1
Magnesium (Mg) "	2·8	3·3	3·7	8·2	8·4	8·0	4·3	3·7	4·1	4·1	2·5	2·6	3·0	1·1	2·2	2·6	2·0	0·5	4·5	6·4	3·5
Bicarbonate (HCO₃) "	17·7	70·3	5·5	103·0	118·3	112·2	111·6	105·5	129·3	72·6	11·0	12·8	18·3	2·4	14·0	5·5	1·8	8·5	7·3	131·2	14·0
Sulphate (SO₄) "	......	12·3	4·9	......	......	15·0	......	......	8·6	7·0	......	......	9·5	......	......	4·9	3·7	......	6·5	......	9·1
Chloride (Cl) "	......	1·0	2·0	......	......	17·5	......	......	2·0	3·5	......	......	1·5	......	......	1·5	1·0	......	1·0	......	0·6
Nitrate (NO₃) "	......	0·9	2·0	......	......	None	......	......	1·33	1·77	......	......	0·3	......	......	None	1·7	......	0·7	......	2·2
Total hardness as CaCO₃ "	24·0	63·5	34·7	117·6	129·2	132·8	73·6	118·7	117·1	49·1	29·1	30·5	32·3	17·0	19·8	23·2	20·7	13·6	38·5	119·0	32·2
Calcium hardness "	12·5	50·0	19·5	84·0	94·8	100·0	56·0	103·5	100·3	32·3	18·8	19·8	20·0	12·5	10·8	12·5	12·5	11·5	20·0	92·8	17·8
Magnesium hardness "	11·5	13·5	15·2	33·6	34·4	32·8	17·6	15·2	16·8	16·8	10·3	10·7	12·3	4·5	9·0	10·7	8·2	2·1	18·5	26·2	14·4

¹ Supplies Masson.
² Supplies Rivière du Moulin.
³ Also supplies Sweetsburg.

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TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

QUEBEC—Continued

	656	758	133	279	858	125	288	703	130	812	129	271	706	108	276	654	837	919	140	605	711
Sample No.	656	758	133	279	858	125	288	703	130	812	129	271	706	108	276	654	837	919	140	605	711
Date	21/7/39	20/8/40	20/7/35	15/9/36	27/6/42	15/7/35	3/6/36	29/8/39	18/7/35	15/9/41	18/7/35	15/7/36	30/8/39	27/6/35	12/7/36	20/7/39	8/4/41	I/4/42	25/7/35	10/10/38	30/12/39
Locality	Donnacona		Drummondville			East Angus			Farnham		Granby			Grand-Mère					Hull		
Source of supply	Jacques Cartier River		St. Francis River			Hollow Brook, Willard Brook			Yamaska River		Shefford Mountain Lake			Lac de Pile			Spring, pulp-mill	St. Maurice River	Ottawa River		
Method of purification	Filtr.	Chlor.	Alum, filtration, chlorination			Chlorination			Alum, filtration, chlorination		Alum, soda, filtration, chlorination			Chlorination			No treatment	Mill water	Chlorination		
Colour............p.p.m.	60·0	40·0	......	......	25·0	......	......	10·0	......	10·0	......	......	10·0	......	......	30·0	None	40·0	......	60·0	60·0
Alkalinity as CaCO3....."	2·5	None	24·0	17·5	28·4	20·3	10·0	13·5	26·0	23·0	30·0	11·5	35·0	6·5	None	2·5	52·5	6·5	16·5	21·0	4·0
Residue on evaporation dried at 110°C.........."	44·0	49·5	......	......	119·5	......	......	43·0	......	90·0	......	......	60·0	......	......	39·5	186·5	41·5	......	75·0	40·0
Silica (SiO2)........."	4·0	4·0			3·0			6·0		4·0			1·2			9·0	21·5	3·5		7·0	2·0
Iron (Fe)........."	0·11	0·50			0·35			0·30		0·05			0·05			0·11	0·05	0·07		0·06	0·06
Calcium (Ca)........."	7·4	3·5	15·0	15·7	21·4	5·0	5·7	7·9	10·7	13·6	10·7	6·4	17·2	6·4	3·6	4·3	22·2	·5·0	7·9	11·0	6·5
Magnesium (Mg)........."	2·4	2·4	4·5	3·7	5·7	2·0	1·0	4·4	3·9	3·3	2·6	2·8	5·2	1·3	1·9	2·2	9·6	1·3	2·6	3·2	2·8
Bicarbonate (HCO3)........"	3·1	None	29·3	21·4	34·6	24·8	12·2	16·5	31·7	28·1	36·6	14·0	42·7	7·9	None	3·1	64·1	7·9	20·1	25·6	4·9
Sulphate (SO4)........."	5·4	1·6			30·5			8·2		17·3			16·8			0·8	40·7	5·8		26·0	4·6
Chloride (Cl)........."	2·0	None			2·3			1·0		13·5			0·5			1·5	13·0	0·7		7·5	1·8
Nitrate (NO3)........."	0·18	0·08			0·3			1·33		None			0·80			None	10·6	0·2		1·0	0·70
Total hardness as CaCO3."	28·3	18·6	56·0	54·5	76·9	20·7	18·4	37·8	42·8	47·5	37·5	27·5	64·3	21·3	16·8	19·8	94·9	17·8	30·5	40·6	27·8
Calcium hardness........"	18·5	8·8	37·5	39·3	53·5	12·5	14·3	19·8	26·8	34·0	26·8	16·0	43·0	16·0	9·0	10·8	55·5	12·5	19·8	27·5	16·3
Magnesium hardness......"	9·8	9·8	18·5	15·2	23·4	8·2	4·1	18·0	16·0	13·5	10·7	11·5	21·3	5·3	7·8	9·0	39·4	5·3	10·7	13·1	11·5

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

QUEBEC—Continued

Sample No.	858	106	277	119	661	118	659	141	101	314	588	282	663	818	107	699	759	114	702	136
Date	2/7/42	24/6/35	17/7/36	11/7/35	23/7/39	10/7/35	22/7/39	23/7/35	20/6/35	29/9/36	6/10/38	9/7/36	24/7/39	15/9/41	23/6/35	29/8/39	20/8/40	29/6/35	29/8/39	22/7/35
Locality	Iberville	Joliette		Jonquière[1]		Kenogami		Lachine[2]	Lachute			La Malbaie			La Tuque	Lauzon		Levis		Longueuil
Source of supply	Richelieu River	L'Assomption River		Rivière au Sable		Lac Long		Lake St.Louis	From stream, 2 miles below St. John Lake, by gravity			Mountain Lake			Lake Parker	St. Lawrence River		St. Lawrence River		St.Lawrence River
Method of purification	Alum, filtration, chlor.	Alum, filtration, chlorinatio		Chlorination		No treatment		Alum, filtr., chlor.	No treatment			Chlorination		No treatment	Filtr., chlor.	Alum, filtration, chlorination		Alum, filtration, chlorination		Rapid sand filters, alum, intermittent chlorination
Colour..............p.p.m.	20·0	......	......	......	65·0	......	50·0	......	......	......	50·0	......	30·0	15·0	......	10·0	10·0	......	20·0	......
Alkalinity as CaCO3.... "	23·5	2·0	16·5	3·8	None	10·0	9·0	57·3	8·0	65·0	9·5	33·5	50·5	39·5	1·0	46·5	53·0	60·5	56·6	92·2
Residue on evaporation dried at 110°C....... "	62·0	......	......	......	43·0	......	44·0	......	......	......	44·0	......	90·0	83·5	......	123·0	138·0	......	119·5	......
Silica (SiO2).......... "	0·5	......	......	......	2·0	......	5·1	......	......	......	3·0	......	15·0	7·5	......	1·0	3·0	......	1·0	......
Iron (Fe)............ "	0·10	......	......	......	0·06	......	0·09	......	......	......	0·25	......	0·53	0·04	......	0·08	0·50	......	0·11	......
Calcium (Ca)......... "	14·3	6·4	10·7	2·9	3·6	5·0	7·4	29·3	7·9	12·5	7·9	21·4	15·0	22·2	4·3	24·3	32·2	42·9	17·8	34·3
Magnesium (Mg)....... "	4·6	7·1	2·8	1·5	1·7	1·5	2·4	6·1	1·1	3·8	3·5	6·0	2·6	3·3	1·1	7·2	8·1	3·0	8·1	8·7
Bicarbonate (HCO3)... "	28·7	2·4	20·1	4·6	None	12·2	11·0	69·9	9·8	79·3	11·6	40·9	61·6	48·2	1·2	56·7	64·7	73·8	69·1	112·5
Sulphate (SO4)........ "	18·1	......	......	......	3·2	......	8·2	......	......	......	12·8	......	7·0	6·6	......	35·4	29·0	......	20·0	......
Chloride (Cl)......... "	6·0	......	......	......	3·0	......	1·5	......	......	......	2·0	......	1·5	0·7	......	11·5	10·0	......	13·0	......
Nitrate (NO3)......... "	0·6	......	......	......	0·44	......	0·80	......	......	......	3·0	......	1·06	3·4	......	0·27	None	......	2·7	......
Total hardness as CaCO3 "	54·7	45·1	38·3	13·5	16·0	18·7	28·3	98·3	24·3	46·9	34·2	78·1	48·2	69·0	15·3	90·3	113·7	119·6	77·7	121·5
Calcium hardness...... "	35·8	16·0	26·8	7·3	9·0	12·5	18·5	73·3	19·8	31·3	19·8	53·5	37·5	55·5	10·8	60·8	80·5	107·3	44·5	85·8
Magnesium hardness... "	18·9	29·1	11·5	6·2	7·0	6·2	9·8	25·0	4·5	15·6	14·4	24·6	10·7	13·5	4·5	29·5	33·2	12·3	33·2	35·7

[1]Supplies Arvida.
[2]Supplies La Salle

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

QUEBEC—Continued

	760	817	128	273	705	124	117	287	698	762	17	81	105	197	270	377
Sample No	760	817	128	273	705	124	117	287	698	762	17	81	105	197	270	377
Date	20/8/40	15/9/41	17/6/35	3/6/36	30/8/39	15/7/35	29/6/35	3/6/36	28/8/39	19/8/40	17/5/34	31/8/34	22/6/35	1/9/35	1/6/36	13/4/37
Locality	Louiseville[1]		Magog			Megantic	Montmagny				Montreal[2]					
Source of supply	Springs	Springs and river	Lake Memphremagog			Springs	Springs				St. Lawrence River					
Method of purification	No treatment	Filtration, chlorination	Chlorination			No treatment	No treatment				Filtration, chlorination					
Colour ....p.p.m.	15·0	5·0	....	....	15·0	....	....	....	35·0	30·0	....	....	....	....	....	....
Alkalinity as CaCO₃ "	15·0	17·5	34·9	72·0	33·0	29·5	20·6	26·5	23·5	24·0	58·0	....	84·5	78·5	74·0	57·0
Residue on evaporation dried at 110°C "	52·5	56·0	....	....	61·8	....	....	....	52·5	46·5	....	....	....	....	....	....
Silica (SiO₂) "	13·5	15·0	....	....	3·0	....	....	....	5·0	6·5	....	....	....	....	....	....
Iron (Fe) "	0·02	0·04	....	....	0·03	....	....	....	0·08	0·02	....	....	....	....	....	0·06
Calcium (Ca) "	6·4	5·7	15·0	28·6	16·4	8·6	7·1	11·4	10·7	11·4	22·5	37·5	35·0	28·5	32·9	24·8
Magnesium (Mg) "	3·7	2·8	3·3	4·8	5·7	2·8	1·3	1·5	2·0	3·5	4·4	8·0	1·6	6·9	8·2	6·5
Bicarbonate (HCO₃) "	18·3	21·4	42·6	87·8	46·4	36·0	25·1	32·3	28·7	29·3	70·8	....	103·1	95·8	90·3	69·5
Sulphate (SO₄) "	8·6	6·6	....	....	8·6	....	....	....	7·0	5·3	....	....	....	....	....	....
Chloride (Cl) "	None	0·5	....	....	2·5	....	....	....	1·5	1·0	....	....	....	....	....	....
Nitrate (NO₃) "	None	1·9	....	....	0·18	....	....	....	1·06	0·08	....	....	....	....	....	....
Total hardness as CaCO₃ "	31·2	25·8	51·0	91·2	64·4	33·0	23·1	34·7	35·0	42·9	74·3	126·6	94·1	99·6	115·9	88·7
Calcium hardness "	16·0	14·3	37·5	71·5	41·0	21·5	17·8	28·5	26·8	28·5	56·3	93·8	87·5	71·3	82·3	62·0
Magnesium hardness "	15·2	11·5	13·5	19·7	23·4	11·5	5·3	6·2	8·2	14·4	18·0	32·8	6·6	28·3	33·6	26·7

[1] Supplies Rivière du-Loup en Haut.
[2] Supplies Montreal North, Montreal South, Montreal East, and Montreal West, Mount Royal, Outremont, Pointe aux Trembles, St. Jean de Dieu, St. Michel, St. Pierre, Verdun, and Westmount.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

QUEBEC—Continued

		468	469	653	875	282	122	483	621	13	112²	239³	278	712	882	283	665	819	116	286	697
Sample No.		468	469	653	875	282	122	483	621	13	112²	239³	278	712	882	283	665	819	116	286	697
Date		5/6/37	29/9/37	19/7/39	3/7/42	9/7/36	13/7/35	29/12/37	18/5/39	26/5/34	28/6/35	28/6/35	11/7/36	22/7/39	27/6/42	5/7/36	27/7/39	6/19/41	8/7/35	6/7/36	28/8/39
Locality		Montreal—continued				Murray Bay	Nicolet	Noranda¹		Quebec City⁴					Richmond⁵	Rimouski			Rivière du Loup		
Source of supply		St. Lawrence River				Malbai River	Nicolet River	Dufault Lake		St. Charles River					Brompton Lake	Lake			Lac Municipal		
Method of purification		Filtration, chlorination				Filtration	Lime, alum, filtr., chlor.	Alum, lime, filtration		Chlorination					Filtr., chlor.	No treatment			No treatment		
Colour	p.p.m.			25.0	20.0	33.5	57.2		30.0					30.0	80.0		15.0	15.0			50.0
Alkalinity as CaCO3	"	73.0	87.6	77.5	73.5			9.8	3.0	16.0	3.0	9.5	None	7.5	22.9	46.5	44.5	25.0	11.3	17.5	9.5
Residue on evaporation dried at 110°C	"			149.5	140.0				86.0					42.0	58.5		81.0	81.0			44.0
Silica (SiO2)	"			None	2.0				4.5					None	2.0		5.0	8.0			2.0
Iron (Fe)	"	0.16	0.01	0.15	0.05			0.01	0.19					0.20	0.10		0.05	0.04			0.15
Calcium (Ca)	"	31.5	33.3	33.6	32.9	21.4	23.3	15.7	15.7	4.8	6.4	8.2	5.7	4.8	8.5	15.7	12.1	14.3	6.4	8.6	5.7
Magnesium (Mg)	"	7.0	8.5	8.0	8.9	6.0	4.7	2.7	2.6	0.8	0.9	1.5	2.2	3.7	5.7	3.7	3.9	3.5	0.7	2.3	2.2
Bicarbonate (HCO3)	"	89.1	106.9	94.6	89.7	40.9	69.8	12.0	3.7	19.5	3.7	11.6	None	9.2	26.8	56.7	54.3	30.5	13.8	21.4	11.6
Sulphate (SO4)	"			16.0	21.8				31.0					9.0	9.9		5.3	5.3			4.9
Chloride (Cl)	"			14.0	14.5				2.0					1.5	1.5		3.0	2.5			1.0
Nitrate (NO3)	"			0.80	0.6				1.2					0.17	1.2		2.7	2.2			0.62
Total hardness as CaCO3	"	107.5	118.2	116.8	118.8	78.1	77.6	50.4	50.0	15.3	19.7	26.7	23.3	27.2	44.7	54.5	46.3	50.2	18.9	30.9	23.3
Calcium hardness	"	78.8	83.3	84.0	82.3	53.5	58.3	39.3	39.3	12.0	16.0	20.5	14.3	12.0	21.3	39.3	30.3	35.8	16.0	21.5	14.3
Magnesium hardness	"	28.7	34.9	32.8	36.5	24.6	19.3	11.1	10.7	3.3	3.7	6.2	9.0	15.2	23.4	15.2	16.0	14.4	2.9	9.4	9.0

¹ Supplies Rouyn.
² Sample taken at Chateau d'Eau pumping station.
³ Sample taken at City Hall.
⁴ Supplies Quebec West.
⁵ Also supplies Melbourne.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

QUEBEC—Continued

Sample No.		761	102	132	884	103	12	131	813	885	120	662	134	104	10	109	657	126	274	704	887
Date		18/8/40	20/6/35	19/7/35	29/6/42	21/6/35	18/5/34	19/7/35	19/9/41	2/7/42	11/7/35	23/7/39	22/7/34	21/6/35	22/5/34	27/6/35	20/7/39	16/7/35	3/6/36	30/8/39	26/6/42
Locality		Riv. du Loup	Ste. Agathe des Monts	St. Hyacinthe	St. Hyacinthe	St. Jerome	St. Johns	St. Johns	St. Johns	St. Johns	St.Joseph d'Alma	St.Joseph d'Alma	St. Lambert¹	Ste. Thérèse	Shawinigan Falls²	Shawinigan Falls²	Shawinigan Falls²	Sherbrooke	Sherbrooke	Sherbrooke	Sherbrooke
Source of supply		—	Lac de Sable	Yamaska River	Yamaska River	Two springs	Richelieu River	Richelieu River	Richelieu River	Richelieu River	Saguenay River	Saguenay River	St. Lawrence River	One spring and two wells	Lac La Peche	Lac La Peche	Lac La Peche	Magog River	Magog River	Magog River	Magog River
Method of purification		—	No treatment	Alum, filtr., chlor.	Alum, lime, filtr., chlor.	Chlorination	Alum, filtr., chlor.	Alum, filtr., chlor.	Alum, filtr., chlor., lime	Alum, filtr., chlor.	Chlorination	Chlorination	Alum, filtr., chlor.	No treatment	Alum, lime, filtration, chlorination	Alum, lime, filtration, chlorination	Alum, lime, filtration, chlorination	Chlorination	Chlorination	Chlorination	Chlorination
Colour	p.p.m.	60.0			20.0				5.0	20.0		60.0					15.0			15.0	30.0
Alkalinity as CaCO₃.	"	15.5	None	21.5	18.0	24.0	39.0	27.3	29.7	34.0	1.0	10.0	77.0	206.0	6.0	3.5	13.0	31.0	35.0	34.0	35.0
Residue on evaporation dried at 110°C	"	52.5			105.0				80.5			32.5					47.0			74.0	66.0
Silica (SiO₂)	"	13.5			1.5				0.5	0.5		3.0					3.5			4.5	7.5
Iron (Fe)	"	0.02			0.10				0.04	0.15		0.20					0.11			0.03	0.05
Calcium (Ca)	"	7.0	5.7	16.0	10.7	7.8	15.6	16.0	17.2	13.8	3.6	5.0	30.7	52.9	4.8	8.6	13.6	13.2	17.1	17.8	14.3
Magnesium (Mg)	"	3.5	1.0	3.8	3.3	3.0	3.2	4.5	4.4	4.8	1.0	2.0	8.0	19.5	0.4	1.7	2.2	2.8	4.5	5.7	3.7
Bicarbonate (HCO₃)	"	18.9	None	26.2	22.0	29.3	47.6		36.2	41.5		12.2	93.9	251.3			15.9			41.5	42.7
Sulphate (SO₄)	"	3.7			34.6				17.3	19.3		4.5					9.9			9.5	10.3
Chloride (Cl)	"	0.5			4.5				3.2	3.5		0.5					0.5			1.0	1.2
Nitrate (NO₃)	"	0.17			0.7				None			0.44					0.18			1.33	0.6
Total hardness as (CaCO₃)	"	31.9	18.4	55.6	40.3	31.8	52.1	58.5	61.0	54.2	13.1	20.7	109.6	212.3	13.6	28.5	43.0	44.5	61.3	67.9	51.0
Calcium hardness	"	17.5	14.3	40.0	26.8	19.5	39.0	40.0	43.0	34.5	9.0	12.5	76.8	132.3	12.0	21.5	34.0	33.0	42.8	44.5	35.8
Magnesium hardness	"	14.4	4.1	15.6	13.5	12.3	13.1	18.5	18.0	19.7	4.1	8.2	32.8	90.0	1.6	7.0	9.0	11.5	18.5	23.4	15.2

¹ Supplies St. Antoine.
² Supplies Baie de Shawinigan.

TABLE VI—Continued

Analysis of Civic Water Supplies—Continued

QUEBEC—Concluded

Sample No.	135	123	272	700	9	110	275	658	820	409	622	110	290	763	121	285
Date	22/7/35	13/7/35	3/6/36	28/8/39	20/5/34	27/5/35	14/7/36	30/7/39	15/9/41	12/9/37	20/5/39	24/7/35	21/7/36	21/8/40	13/7/35	21/7/36
Locality	Sorel	Thetford Mines			Three Rivers					Val d'Or		Valleyfield			Victoriaville	
Source of supply	Richelieu	Springs			St. Maurice River					Spring		St. Lawrence River			Beaudette River	
Method of purification	Filtration, chlorination	No treatment			Alum, filtration, chlorination				Alum, soda, filtr., chlor.	Chlorination		Chlorination			Alum, filtration, chlorination	
Colour.....................p.p.m.	....	....	....	25·0	....	....	....	30·0	15·0	....	5·0	....	....	10·0	....	....
Alkalinity as CaCO₃........ "	24·5	33·0	15·0	28·5	16·5	11·5	10·5	16·0	24·5	12·6	49·0	80·0	88·0	86·0	45·8	50·0
Residue on evaporation dried at 110°C................ "	....	....	....	56·0	....	....	....	56·5	63·0	....	80·0	....	....	145·0	....	....
Silica (SiO₂)................ "	....	....	....	1·5	....	....	....	3·5	4·5	....	11·0	....	....	2·0	....	....
Iron (Fe)................... "	....	....	....	0·18	....	....	....	0·10	0·08	....	0·20	....	....	0·03	....	....
Calcium (Ca)............... "	15·0	11·0	11·4	11·4	6·6	3·6	4·3	5·0	5·7	8·9	10·0	34·6	37·9	34·0	25·7	23·6
Magnesium (Mg)........... "	4·3	3·0	3·2	3·5	0·8	1·5	2·8	2·4	1·5	2·4	2·4	8·2	8·5	7·5	2·0	3·2
Bicarbonate (HCO₃)........ "	30·0	40·3	18·3	34·8	20·1	14·0	12·8	19·5	29·9	15·4	59·8	97·6	107·4	104·9	55·9	61·0
Sulphate (SO₄)............. "	....	....	....	11·5	....	....	....	4·5	17·7	....	11·5	....	....	14·5	....	....
Chloride (Cl)............... "	....	....	....	1·5	....	....	....	1·0	17·5	....	....	....	....	18·0	....	....
Nitrate (NO₃)............. "	....	....	....	1·06	....	....	....	0·18	Trace	....	....	....	....	None	....	....
Total hardness as CaCO₃... "	55·1	39·8	41·6	42·9	19·8	15·2	22·2	22·3	20·5	32·1	34·8	120·1	129·7	115·8	72·5	72·1
Calcium hardness.......... "	37·5	27·5	28·5	28·5	16·5	9·0	10·7	12·5	14·3	22·3	25·0	86·5	94·8	85·0	64·3	59·0
Magnesium hardness........ "	17·6	12·3	13·1	14·4	3·3	6·2	11·5	9·8	6·2	9·8	9·8	33·6	34·9	30·8	8·2	13·1

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO

	198	49	163	199	389	551	738	39	148	839	74	189	411	854	412	71	184	391	739	841
Sample No.	198	49	163	199	389	551	738	39	148	839	74	189	411	854	412	71	184	391	739	841
Date	8/10/35	1/8/34	19/8/35	8/10/35	19/8/37	26/8/38	19/9/40	21/7/34	11/8/35	12/6/42	27/8/34	29/8/35	23/9/37	27/6/42	10/8/37	25/8/34	28/8/35	22/9/37	30/8/40	13/6/42
Locality	Almonte	Amherstburg	Arnprior				Aurora	Barrie			Belleville				Blind River	Bowmanville				Bracebridge
Source of supply	Two wells	Detroit River	Madawaska River				Wells	Artesian wells			Bay of Quinte				Wells	Springs				Springs
Method of purification	No treatment	Filtration	Chlorination, filtration				No treatment	No treatment			Chlorination, filtration			Alum, filtr., chlor.	No treatment	No treatment				No. treatment
Colour.....p.p.m.						40·0	20·0			10·0				25·0					5·0	5·0
Alkalinity as CaCO₃ "	247·0		80·0	26·3	33·8	37·0	247·5		192·0	190·0		82·0	75·4	77·0	194·5		183·8	171·8	170·5	6·7
Residue on evaporation dried at 110°C "						75·0	290·4			180·0				138·0					208·8	53·5
Silica (SiO₂) "						6·0	28·8			15·5				1·0					16·2	14·0
Iron (Fe) "					0·08	0·05	0·50			0·10				0·10					0·10	0·15
Calcium (Ca) "	73·6	31·5	29·7	11·4	15·4	15·0	76·8	59·0	71·4	35·0	38·5	33·6	33·9	39·3	60·4	59·5	57·1	52·5	46·5	7·0
Magnesium (Mg) "	28·8	8·0	8·9	3·8	4·0	5·4		17·0	17·8	18·3	4·0	5·3	4·6	5·9	16·2	14·0	14·7	14·7	16·7	4·3
Bicarbonate (HCO₃) "	301·3		97·6	32·1	41·2	45·1	302·0		234·2	231·8		100·0	92·0	93·9	237·3		224·2	209·6	208·0	8·2
Sulphate (SO₄) "						9·1	17·5			16·4				23·4					16·1	11·3
Chloride (Cl) "						4·0	1·0			·2·2				3·5					3·0	3·0
Nitrate (NO₃) "						2·0	0·62			0·4				3·2						0·53
Total hardness as CaCO₃ "	302·1	111·6	110·8	44·1	54·9	59·6	285·5	217·2	251·5	162·5	112·7	105·7	103·7	122·5	217·4	206·2	203·1	191·6	184·8	35·1
Calcium hardness "	184·0	78·8	74·3	28·5	38·5	37·5	192·0	147·5	178·5	87·5	96·3	84·0	84·8	98·3	151·0	148·8	142·8	131·3	116·3	17·5
Magnesium hardness "	118·1	32·8	36·5	15·6	16·4	22·1	93·5	69·7	73·0	75·0	16·4	21·7	18·9	24·2	66·4	57·4	60·3	60·3	68·5	17·6

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

Sample No	68	150	741	54	171	413	470	494	592	740	855	78	194	392	856	179	233	309
Date	22/8/34	13/8/35	21/9/40	6/8/34	20/8/35	14/6/37	23/12/37	24/3/38	21/12/38	5/9/40	7/6/42	24/8/34	30/8/35	22/9/37	27/5/42	26/8/35	4/10/35	1/8/36
Locality	Brampton			Brantford								Brockville				Burlington[1]		
Source of supply	Wells			Grand River								St. Lawrence River				Lake Ontario		
Method of purification	Drifting, sand filtration			Filtration, chlorination, alum, ammonium sulphate							Alum, activ. carb., ammon. sulph., filtr., chlor.	Chlorination				Filtration, alum, charcoal, chlorination		
Colour...............p.p.m.	......	......	5·0	......	......	......	......	10·0	20·0	10·0	15·0	......	......	......	10·0	......	......	......
Alkalinity as CaCO₃....."	......	242·3	245·4	......	165·5	221·0	253·5	177·0	250·0	203·0	179·5	......	90·5	85·5	81·0	131·5	171·5	94·5
Residue on evaporation dried at 110°C."	......	......	429·0	......	......	......	......	358·8	500·0	370·5	217·5	......	......	......	172·0	......	......	......
Silica (SiO₂)."	......	......	28·0	......	......	......	......	6·8	7·0	8·0	11·0	......	......	......	7·0	......	......	......
Iron (Fe)."	......	......	0·07	......	......	0·04	0·16	0·16	0·08	0·07	0·10	......	......	......	0·05	......	......	......
Calcium (Ca)."	86·0	95·0	109·3	96·0	91·4	83·6	122·0	82·9	108·1	89·3	46·4	39·3	36·8	35·7	37·2	46·4	63·7	44·3
Magnesium (Mg)."	21·0	22·5	26·0	24·0	25·6	21·6	28·2	21·8	30·0	26·7	20·1	9·0	8·9	9·2	10·5	11·7	16·9	10·2
Bicarbonate (HCO₃)."	......	295·6	299·4	......	201·9	269·6	309·3	215·9	305·0	247·7	219·0	......	110·4	104·3	98·8	160·4	209·2	115·3
Sulphate (SO₄)."	......	......	76·1	......	......	......	......	79·9	150·0	94·7	56·4	......	......	......	22·2	......	......	......
Chloride (Cl)."	......	......	6·0	......	......	......	......	10·0	18·0	16·5	9·5	......	......	......	16·8	......	......	......
Nitrate (NO₃)."	......	......	0·08	......	......	......	......	0·6	0·10	0·08	3·3	......	......	......	0·3	......	......	......
Total hardness as CaCO₃."	301·1	329·8	379·9	338·4	333·5	297·6	420·6	296·7	393·3	332·8	198·4	135·2	128·5	127·0	136·1	164·0	228·6	152·6
Calcium hardness."	215·0	237·5	273·3	240·0	228·5	209·0	305·0	207·3	270·3	223·3	116·0	98·3	92·0	89·3	93·0	116·0	159·3	110·8
Magnesium hardness."	86·1	92·3	106·6	98·4	105·0	88·6	115·6	89·4	123·0	109·5	82·4	36·9	36·5	37·7	43·1	48·0	69·3	41·8

[1] Also supplies Nelson Tp.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	28	143	47	161	479	490	742	393	625	73	187	394	857	395	618	36	912	294	497	627	949
Sample No.	28	143	47	161	479	490	742	393	625	73	187	394	857	395	618	36	912	294	497	627	949
Date	14/7/34	9/8/35	28/7/34	17/8/35	15/6/37	21/3/38	22/8/40	28/8/37	23/5/39	26/8/34	29/8/35	23/9/37	28/5/42	3/9/37	8/5/39	20/7/34	12/6/42	9/8/36	24/8/38	26/5/39	14/9/43
Locality	Carleton Place		Chatham¹					Cobalt		Cobourg				Cochrane		Collingwood		Copper Cliff			
Source of supply	Mississippi River		Thames River					Lake Sasaganiga		Lake Ontario				Wells		Georgian Bay		Meat Bird Lake			
Method of purification	Chlorination		Filtration, alum, chlorination, ammonium sulphate					Chlorination		Pressure filters, chlorination			Filtr., chlor.	No treatment		Chlorination		Chlorination			
Colour......p.p.m.					15·0	30·0			10·0				10·0		5·0		10·0		5·0	10·0	10·0
Alkalinity as CaCO3 "		75·9		154·8	201·0	117·0	202·0	48·7	42·5		100·2	93·8	95·5	300·0	305·0		62·0	43·0	None	None	None
Residue on evaporation dried at 110°C "					294·5	247·5			85·0				178·0		368·0		100·0		51·0	77·5	76·0
Silica (SiO2) "					1·8	8·5			2·0				8·0		37·5		3·0		3·5	3·2	1·0
Iron (Fe) "				0·06	0·07	0·07			0·20				0·10		1·67		0·03		0·08	0·50	0·33
Calcium (Ca) "	27·5	29·3	58·5	66·8	76·8	80·0	80·0	18·9	9·3	39·5	37·1	36·4	37·9	94·0	95·0	35·5	22·0	8·6	12·0	8·6	11·4
Magnesium (Mg) "	6·0	7·3	23·0	21·6	18·4	23·3	19·7	5·7	2·8	9·0	9·0	9·0	10·5	19·3	20·0	7·0	6·0	4·8	4·1	2·6	4·2
Bicarbonate (HCO3) "		92·6		188·9	245·2	142·7	246·4	59·4	51·9		122·2	114·4	116·5	366·0	372·1		75·6	52·5	None	None	None
Sulphate (SO4) "					55·0	33·3			18·5				22·6		21·4		12·7		33·0	48·1	43·2
Chloride (Cl) "					5·0	16·0			1·5				17·3		7·0		3·5		1·5	1·0	1·7
Nitrate (NO3) "					4·0	0·17			0·62				1·9		0·27		0·6		0·10	0·62	Trace
Total hardness as CaCO3 "	93·4	103·2	240·6	255·6	267·4	295·5	280·8	70·7	34·8	135·7	129·7	127·9	137·9	314·1	319·5	117·5	79·6	41·2	46·8	32·2	45·7
Calcium hardness "	68·8	73·3	146·3	167·0	192·0	200·0	200·0	47·3	23·3	98·8	92·8	91·0	94·8	235·0	237·5	88·8	55·0	21·5	30·0	21·5	28·5
Magnesium hardness "	24·6	29·9	94·3	88·6	75·4	95·5	80·8	23·4	11·5	36·9	36·9	36·9	43·1	79·1	82·0	28·7	24·6	19·7	16·8	10·7	17·2

¹ Also supplies Chatham Tp.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	80	196	396	472	599	972	498	59	178	743	66	305	238	64	173	303
Sample No	80	196	396	472	599	972	498	59	178	743	66	305	238	64	173	303
Date	30/8/34	30/8/35	25/9/37	21/12/37	19/12/38	1/9/43	18/8/38	16/8/34	24/8/35	4/9/40	20/8/34	29/7/36	6/12/35	18/8/34	23/8/35	26/8/36
Locality	Cornwall					Craig-mont	Dryden	Dundas			Dunnville		Etobi-coke	Fort Erie		
Source of supply	St. Lawrence River[1]					Creek	Wabi-goon River	Spencer Creek and Hamilton Water Supply			Grand River		Wells	Lake Erie		
Method of purification	Chlorination					No treat-ment	Chlor-in-ation	Filtration, aeration, alum, ammonium sulphate, chlorination			Slow sand filtration, alum, ammonia		Zeolite treat-ment	Chlorination		
Colour........p.p.m.					None		65·0			20·0						
Alkalinity as CaCO3....."		89·5	90·2	92·5	92·0	54·8	38·5		145·0	165·5		112·0	308·0		96·0	97·0
Residue on evaporation dried at 110°C..."					160·0		72·0			322·0						
Silica (SiO2)..."					1·0		1·5			7·5						
Iron (Fe)..."			0·06	0·03	0·05	0·08	0·55			0·05						
Calcium (Ca)..."	36·1	35·4	37·5	36·4	38·0	22·2	16·0	59·0	58·6	74·3	100·0	125·0	27·1	33·5	34·6	37·1
Magnesium (Mg)..."	8·0	9·3	8·5	9·0	8·8	4·4	5·0	23·5	27·3	25·6	27·0	30·8	6·0	8·0	10·0	9·7
Bicarbonate (HCO3)..."		109·2	110·0	112·9	112·2	66·9	47·0		176·9	201·9		136·6	375·8		117·1	118·3
Sulphate (SO4)..."					20·5		6·2			92·6						
Chloride (Cl)..."					17·5		1·5			10·5						
Nitrate (NO3)..."					None	1·15	4·5			0·17						
Total hardness as CaCO3..."	123·1	126·6	128·7	127·9	131·1	73·5	60·5	243·9	258·4	290·8	360·7	438·8	92·4	116·6	127·5	132·6
Calcium hardness..."	90·3	88·5	93·8	91·0	95·0	55·5	40·0	147·5	146·5	185·8	250·0	312·5	67·8	83·8	86·5	92·8
Magnesium hardness..."	32·8	38·1	34·9	36·9	36·1	18·0	20·5	96·4	111·9	105·0	110·7	126·3	24·6	32·8	41·0	39·8

[1] Supplies Cornwall Tp.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	414	473	602	415	499	950	416	604	951	56	156	859	88	193	41	744	860	745	89	151
Sample No	414	473	602	415	499	950	416	604	951	56	156	859	88	193	41	744	860	745	89	151
Date	11/7/37	24/12/37	22/12/38	11/7/37	20/6/38	24/6/43	3/8/37	20/8/38	10/9/43	9/8/34	14/8/35	8/6/42	28/8/34	30/8/35	23/7/34	12/9/40	11/6/42	1/9/40	15/8/34	13/8/35
Locality	Fort Erie—Cont.			Fort Frances			Fort William			Galt			Gananoque		Goderich			Grimsby[1]	Guelph	
Source of supply	Lake Erie			Rainy River			Loch Lomond Lake			Wells			St. Lawrence River		Lake Huron			Lake Ontario	Metcalfe St. Well	
Method of purification	Chlorination			Filtration, chlorination			No treatment		Chlor.	No treatment			Chlorination		Settling basin, chlorination			Filtr., chlor.	No treatment	
Colour..........p.p.m.			None		80·0	50·0		30·0	35·0			10·0				10·0	5·0	10·0		
Alkalinity as CaCO3........... "	87·0	92·5	93·5	7·0	15·0	15·0	None	18·0	16·1		235·6	234·0		82·0		81·5	74·8	86·5		222·0
Residue on evaporation dried at 110°C.... "			165·0		58·3	62·5		40·8	65·5			475·0				138·5	132·0	162·5		
Silica (SiO2)............ "			4·2		4·7	1·0		4·2	2·0			15·5				4·0	7·5	1·5		
Iron (Fe)............ "	0·06	0·08	0·06		0·15	0·07	None	None	0·08			0·10				0·05	0·05	0·03		
Calcium (Ca)............ "	34·3	37·0	40·0	5·7	7·5	9·3	5·0	11·0	6·4	98·0	106·1	96·5	40·0	35·0	31·5	33·6	30·0	38·6	115·0	119·9
Magnesium (Mg)............ "	8·7	8·9	10·1	2·8	3·1	4·4	1·5	7·0	5·7	31·0	31·6	35·4	7·8	8·4	7·0	6·1	5·6	10·0	29·2	37·5
Bicarbonate (HCO3)............ "	106·1	112·9	114·1		18·3	18·3		22·0	19·6		287·4	285·5		100·0		99·4	91·3	105·5		270·8
Sulphate (SO4)............ "			23·2		7·4	8·6		6·6	13·2			110·3		11·3		18·0	19·8	19·0		
Chloride (Cl)............ "			16·5		1·5	2·0		8·5	3·7			11·3				9·0	6·3	17·0		
Nitrate (NO3)............ "			1·6		1·5	0·35		0·5	0·18			0·7				0·17	1·1	0·03		
Total hardness as CaCO3....... "	121·5	129·0	141·4	25·8	31·5	41·3	18·7	56·2	39·4	372·1	394·9	386·4	132·0	121·9	107·5	109·0	98·0	137·5	407·2	453·6
Calcium hardness............ "	85·8	92·5	100·0	14·3	18·8	23·3	12·5	27·5	16·0	245·0	265·3	241·3	100·0	87·5	78·8	84·0	75·0	96·5	287·2	299·8
Magnesium hardness.......... "	35·7	36·5	41·4	11·5	12·7	18·0	6·2	28·7	23·4	127·1	129·6	145·1	32·0	34·4	28·7	25·0	23·0	41·0	119·7	153·8

1 Also supplies Grimsby North Tp.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

		90	153	91	152	397	624	58	181	417	861	40	862	82	100	589	587	863	167	746	865
Sample No		90	153	91	152	397	624	58	181	417	861	40	862	82	100	589	587	863	167	746	865
Date		15/8/34	13/8/35	15/8/34	13/8/35	17/9/37	24/5/39	16/1/34	26/8/35	11/6/37	3/6/42	21/7/34	8/6/42	2/9/34	19/5/35	18/6/38	6/10/38	5/6/42	20/8/35	26/9/40	9/6/42
Locality		Guelph—Cont.				Haileybury		Hamilton				Hanover		Hawkesbury				Hespeler	Ingersoll		
Source of supply		Emma St. Well		Arkell Springs		Lake Timiskaming		Lake Ontario				Ruhl Lake		Ottawa River				Wells	Wells		
Method of purification		No treatment		Chlorination		Alum, chlorination, filtration		Rapid sand filters, ammonia, chlorination			Alum, amm., filtr., chlor.	Chlorination		Rapid sand filters, chlorination				Chlor.	Aeration		
Colour	p.p.m.						45·0				5·0		15·0			40·0	60·0	10·0		5·0	35·0
Alkalinity as CaCO3	"		234·4		228·0	11·3	3·5		93·5	117·3	83·5		195·5		16·5	18·0	22·0	243·0	225·8	224·0	209·0
Residue on evaporation dried at 110°C	"						67·5				170·0		251·5			50·0	63·0	556·0		544·0	594·0
Silica (SiO2)	"						4·5				3·0		8·5			6·5	5·1	14·0		10·0	18·5
Iron (Fe)	"					0·08	0·43				0·10		0·05			0·30	0·41	0·10		0·20	0·05
Calcium (Ca)	"	216·0	178·3	67·2	70·4	8·6	7·4	43·0	37·5	37·5	40·0	48·5	53·6	10·7	8·6	10·0	11·0	111·5	144·3	81·5	77·6
Magnesium (Mg)	"	58·0	49·4	22·2	24·9	2·6	3·1	8·0	9·5	8·6	11·1	24·8	24·0	1·7	2·7	3·4	3·5	40·6	43·9	41·5	40·4
Bicarbonate (HCO3)	"		286·0		278·2	13·8	4·3		114·1	143·1	101·9		238·5		20·1	22·0	26·8	296·5	275·5	273·3	255·0
Sulphate (SO4)	"						21·4				25·1		16·0			5·8	8·1	128·5		161·3	222·3
Chloride (Cl)	"						3·0				17·7		1·8			1·5	1·1	24·0		35·0	36·5
Nitrate (NO3)	"						1·06				1·4		3·3			0·30	0·60	3·1		0·27	2·2
Total hardness as CaCO3	"	777·8	648·3	259·0	278·1	32·2	31·2	140·3	132·8	129·1	145·5	223·0	232·4	33·8	32·6	38·9	41·9	445·3	540·8	374·0	359·6
Calcium hardness	"	540·0	445·8	168·0	176·0	21·5	18·5	107·5	93·8	93·8	100·0	121·3	134·0	26·8	21·5	25·0	27·5	278·8	360·8	203·8	194·0
Magnesium hardness	"	237·8	202·5	91·0	102·1	10·7	12·7	32·8	39·0	35·3	45·5	101·7	98·4	7·0	11·1	13·9	14·4	166·5	180·0	170·2	165·6

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

Sample No.	482	617	398	619	399	952	77	192	400	474	491	600	866	401	623	84	204	867
Date	29/8/37	17/5/39	31/8/37	12/5/39	29/7/37	22/8/43	28/8/34	30/8/35	24/9/37	21/12/37	21/3/38	19/12/38	27/5/42	8/8/37	23/5/39	14/8/34	14/8/35	6/6/42
Locality	Iroquois Falls[1]		Kapuskasing		Kenora		Kingston							Kirkland Lake		Kitchener		
Source of supply	Abitibi River		Kapuskasing River		Lake of the Woods		St. Lawrence River							Gull Lake		Shoemaker Well		
Method of purification	Alum, soda ash, filtration, chlorination		Alum, lime, filtration, chlorination		Chlorination		Chlorination							Chlorination		No treatment		
Colour..............p.p.m.	......	None	......	5·0	......	60·0	......	......	......	......	5·0	5·0	10·0	......	40·0	......	......	5·0
Alkalinity as CaCO3......... "	41·5	56·5	52·9	25·0	19·5	44·0	......	93·0	92·3	94·0	90·7	91·0	80·0	33·8	26·0	......	104·6	242·2
Residue on evaporation dried at 110°C............ "	......	143·0	......	174·0	......	97·0	......	......	......	......	186·2	162·0	162·5	......	84·0	......	......	324·0
Silica (SiO2).............. "	......	4·0	......	6·0	......	3·0	......	......	......	......	1·8	3·0	2·5	......	3·5	......	......	19·5
Iron (Fe)................. "	......	0·25	......	0·60	0·20	0·05	......	......	......	0·03	0·05	0·05	0·10	......	0·11	......	......	0·10
Calcium (Ca).............. "	17·5	13·9	37·2	28·9	16·4	17·2	39·3	37·5	36·4	37·0	42·3	38·6	37·2	14·3	15·7	68·4	63·1	51·5
Magnesium (Mg)........... "	7·4	3·7	4·7	8·2	6·7	6·3	9·0	7·6	8·5	8·0	10·5	8·8	10·0	3·5	3·7	25·8	22·0	32·7
Bicarbonate (HCO3)........ "	50·6	68·9	64·5	30·5	23·8	53·7	......	113·5	112·6	114·7	110·7	111·0	97·6	41·2	31·7	......	127·6	295·5
Sulphate (SO4)............. "	......	41·8	......	66·0	......	11·1	......	......	......	......	23·0	20·0	26·3	......	17·3	......	......	105·4
Chloride (Cl)............... "	......	0·5	......	2·0	......	0·7	......	......	......	......	17·0	17·0	16·8	......	2·5	......	......	4·0
Nitrate (NO3)............. "	......	0·44	......	0·44	......	None	......	......	......	......	0·20	None	0·9	......	1·33	......	......	0·6
Total hardness as CaCO3...... "	74·1	50·0	112·3	105·9	68·5	68·8	135·2	125·0	125·9	125·3	148·9	132·6	134·0	50·2	54·5	276·8	248·0	262·9
Calcium hardness............ "	43·8	34·8	93·0	72·3	41·0	43·0	98·3	93·8	91·0	92·5	105·8	96·5	93·0	35·8	39·3	171·0	157·8	128·8
Magnesium hardness......... "	30·3	15·2	19·3	33·6	27·5	25·8	36·9	31·2	34·9	32·8	43·1	36·1	41·0	14·4	15·2	105·8	90·2	134·1

[1] Supplies Ansonville.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	85	203	86	87	206	50	164	302	418	747	33	146	202	419	748	868	869
Sample No.	85	203	86	87	206	50	164	302	418	747	33	146	202	419	748	868	869
Date	14/8/34	14/8/35	14/8/34	14/8/34	14/8/35	1/8/34	19/8/35	20/8/36	14/6/37	9/9/40	16/7/34	10/8/35	20/10/35	10/8/37	20/9/40	29/5/42	29/5/42
Locality	Kitchener-*Cont.*					Leamington					Lindsay						
Source of supply	Strange Street reservoir	City Hall	C.N.R. Depot	Edwards Fire Hall		Four wells					Deep wells	Scugog River					No. 3 well, (new well)
Method of purification	No treatment		No treatment			No treatment					—	Chlorination, filtration				Alum, activ. carbon.; ammon. sulph., filtr., chlor.	No treatment
Colour.........p.p.m.										20·0					15·0	30·0	20·0
Alkalinity as CaCO₃......."		248·0			226·0		286·0	292·5	327·3	320·0		114·0	147·5	111·5	249·0	112·8	254·0
Residue on evaporation dried at 110°C......."										375·5					600·0	197·5	430·0
Silica (SiO₂)......."										33·0					16·0	3·0	22·5
Iron (Fe)......."										0·05					0·09	0·05	0·10
Calcium (Ca)......."	171·0	157·2	73·0	118·0	144·0	95·0	93·6	47·9	87·2	90·8	123·0	44·6	54·2	46·4	125·0	69·3	92·9
Magnesium (Mg)......."	86·8	55·8	23·4	26·4	40·0	29·0	29·5	29·6	28·8	32·6	14·5	8·7	10·6	8·1	44·8	8·1	16·6
Bicarbonate (HCO₃)......."		302·6			275·7		348·9	356·9	399·3	390·4		139·1	180·0	136·0	303·8	137·6	309·9
Sulphate (SO₄)......."										27·2					190·2	29·2	114·0
Chloride (Cl)......."										1·5					10·5	6·5	9·5
Nitrate (NO₃)......."										0·08					None	0·8	0·3
Total hardness as CaCO₃...."	783·4	621·8	278·4	403·2	524·0	356·4	355·0	241·2	336·1	360·0	367·0	147·2	179·0	149·2	496·2	206·5	300·4
Calcium hardness......."	427·5	393·0	182·5	295·0	360·0	237·5	234·0	119·8	218·0	227·0	307·5	111·5	135·5	116·0	312·5	173·3	232·3
Magnesium hardness......."	355·9	228·8	95·9	108·2	164·0	118·9	121·0	121·4	118·1	133·7	59·5	35·7	43·5	33·2	183·7	33·2	68·1

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	92	93	94	95	870	96	871	872	873	306	34	874	76	191	402	788	876	403	629
Sample No.	92	93	94	95	870	96	871	872	873	306	34	874	76	191	402	788	876	403	629
Date	26/7/34	26/7/34	26/7/34	26/7/34	10/6/42	26/7/34	10/6/42	10/6/42	12/6/42	27/8/36	18/8/34	12/6/42	26/8/34	29/8/35	23/9/37	29/8/40	27/5/42	16/9/37	6/5/39
Locality	London								Meaford	Merritton	Midland		Napanee					New Liskeard	
Source of supply	Spring bank	Adelaide St. well	Foster wells	Beck wells	Beck Well No. 6, Porter Well No. 4, Ridout pumping station	Well No. 1	East end reservoir. East and north end wells	Spring-bank and Lambeth Well No. 3	Wells; infiltration from bay	Welland canal	Spring creek, and artesian wells	Springs	Napanee River					Wells	
Method of purification	Chlorination									Ammon. sulph., filtr., chlor.	Chlor.	Intermittent chlor.	Filtration, chlorination, activated carbon				Black alum, ammon. sulph., filtr., chlor., intermittent activ. carb.	No treatment	
Colour .... p.p.m.	.....	.....	.....	.....	20·0	.....	10·0	20·0	10·0	.....	.....	70·0	.....	.....	.....	75·0	160·0	.....	10·0
Alkalinity as CaCO₃ ... "	.....	.....	.....	.....	260·5	.....	220·0	220·5	178·0	94·0	.....	120·0	.....	108·0	100·8	76·0	86·0	240·9	237·5
Residue on evaporation dried at 110°C "	.....	.....	.....	.....	458·5	.....	470·0	328·0	261·0	.....	.....	157·0	.....	.....	.....	198·0	196·0	.....	364·0
Silica (SiO₂) .... "	.....	.....	.....	.....	27·0	.....	13·5	11·0	11·0	.....	.....	10·0	.....	.....	.....	6·0	2·5	.....	12·5
Iron (Fe) .... "	.....	.....	.....	.....	0·10	.....	0·10	0·03	0·25	.....	.....	0·04	.....	.....	.....	Trace	0·90	.....	0·68
Calcium (Ca) .... "	74·2	81·0	141·0	143·0	88·6	189·0	76·5	88·6	55·7	37·9	54·0	37·2	34·3	40·1	38·6	39·3	40·0	70·7	50·0
Magnesium (Mg) ...... "	19·0	22·0	36·0	44·0	33·4	81·0	22·3	12·0	16·8	11·6	13·6	11·1	9·0	9·5	8·5	9·6	8·3	36·5	37·1
Bicarbonate (HCO₃) ... "	.....	.....	.....	.....	317·8	.....	268·4	269·0	217·2	114·7	.....	146·4	.....	131·8	123·0	92·7	104·9	293·9	289·8
Sulphate (SO₄) .... "	.....	.....	.....	.....	125·1	.....	44·0	196·7	20·6	.....	.....	9·8	.....	.....	.....	41·6	29·2	.....	104·5
Chloride (Cl) .... "	.....	.....	.....	.....	5·8	.....	9·0	4·3	12·0	.....	.....	1·1	.....	.....	.....	5·0	2·6	.....	2·0
Nitrate (NO₃) .... "	.....	.....	.....	.....	0·3	.....	0·3	0·6	3·9	.....	.....	1·9	.....	.....	.....	0·70	1·9	.....	3·54
Total hardness as CaCO₂ "	263·4	292·7	500·1	541·5	358·4	804·6	282·7	270·7	208·2	142·4	190·8	138·5	122·7	139·3	131·4	137·7	134·0	326·5	277·1
Calcium hardness ...... "	185·5	202·5	352·5	357·5	221·5	472·5	191·3	221·5	139·3	94·8	135·0	93·0	85·8	100·3	96·5	98·3	100·0	176·8	125·0
Magnesium hardness ... "	77·9	90·2	147·6	184·0	136·9	332·1	91·4	49·2	68·9	47·6	55·8	45·5	36·9	39·0	34·9	39·4	34·0	149·7	152·1

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	149	749	877	312	63	174	293	420	626	343	67	180	32	147	421	751	185	404
Sample No	149	749	877	312	63	174	293	420	626	343	67	180	32	147	421	751	185	404
Date	12/8/35	19/9/40	30/6/42	30/9/36	18/8/34	22/8/35	9/8/36	10/8/37	24/5/39	23/12/36	21/8/34	26/8/35	16/7/34	11/8/35	10/8/37	17/9/40	28/8/35	22/9/37
Locality	Newmarket			New[1] Toronto	Niagara Falls		North Bay			North York Tp.	Oakville		Orillia				Oshawa	
Source of supply	Artesian wells			Lake Ontario	Niagara River at Chippawa		Trout Lake			Don River	Lake Ontario		Lake Couchiching				Lake Ontario	
Method of purification	Aeration		No treatment	Activated carbon, filtr., chlor.	Chlorination		Chlorination			Filtr., alum, chlor., zeolite	Chlorination		Pressure filters, chlorination				Rapid sand filtration, chlorination	
Colour............p.p.m.	......	25·0	10·0	......	......	......	......	......	10·0	......	......	......	......	......	......	5·0	......	......
Alkalinity as CaCO₃...."	162·3	216·0	162·1	88·5	......	90·5	6·5	4·7	7·5	262·0	......	86·5	......	91·0	95·2	213·0	94·9	93·0
Residue on evaporation dried at 110°C.... "	......	353·5	348·5	......	......	......	......	......	39·0	......	......	......	......	......	......	279·0	......	......
Silica (SiO₂)......."	......	21·0	18·5	......	......	......	......	......	3·3	......	......	......	......	......	......	10·0	......	......
Iron (Fe)........."	......	0·20	0·15	......	......	......	......	......	0·20	......	......	......	......	......	......	0·57	......	......
Calcium (Ca)......."	40·0	47·2	37·2	37·9	41·0	37·1	8·6	4·3	5·7	89·3	36·0	36·2	44·0	36·4	36·1	77·2	37·1	37·5
Magnesium (Mg)......"	18·6	19·2	21·2	10·5	8·0	10·2	4·8	1·9	2·3	20·8	8·0	9·3	6·6	7·8	6·7	15·5	9·8	8·2
Bicarbonate (HCO₃)....."	198·0	263·5	197·8	103·0	......	110·4	7·9	5·7	9·2	319·6	......	105·5	......	111·0	116·1	259·9	115·8	113·5
Sulphate (SO₄)......."	......	3·7	24·7	......	......	......	......	......	18·5	......	......	......	......	......	......	28·0	......	......
Chloride (Cl)......."	......	74·5	98·5	......	......	......	......	......	2·5	......	......	......	......	......	......	0·5	......	......
Nitrate (NO₃)......."	......	3·1	2·2	......	......	......	......	......	1·33	......	......	......	......	......	......	1·68	......	......
Total hardness as CaCO₃."	176·3	196·7	179·9	137·9	135·3	134·6	41·2	18·6	23·7	308·6	122·8	128·6	137·1	123·0	117·5	256·6	133·0	127·4
Calcium hardness......."	100·0	118·0	93·0	94·8	102·5	92·8	21·5	10·8	14·3	223·3	90·0	90·5	110·0	91·0	90·3	193·0	92·8	93·8
Magnesium hardness....."	76·3	78·7	86·9	43·1	32·8	41·8	19·7	7·8	9·4	85·3	32·8	38·1	27·1	32·0	27·5	63·6	40·2	33·6

[1] Supplies Mimico, Long Branch.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

Sample No.	97[1]	98[2]	155	603	707[3]	37	38	878	55	170	235	236	291	201	405	500
Date	15/10/34	15/10/34	5/9/35	16/12/38	30/12/39	20/7/34	20/7/34	12/6/42	8/8/34	20/8/35	6/11/35	6/11/35	8/3/36	8/10/35	22/8/37	16/6/38
Locality	Ottawa[3]					Owen Sound			Paris				Parry Sound	Pembroke		
Source of supply	Ottawa River					Sydenham River	Spring	Springs and Sydenham River	Springs	Springs[4]	Old well	New[5] spring	Georgian Bay	Ottawa River		
Method of purification	Alum, filtration, lime, coagulation					Slow sand filtration. chlorination	Chlorination	Filtration. chlorination	No treatment	No treatment	No treatment	No treatment	Chlorination	Chlorination		
Colour..........p.p.m.				5·0	15·0											75·0
Alkalinity as CaCO3.... "			21·0	28·0	19·0			220·5		200·0	208·3	252·5	40·0	12·4	30·0	3·0
Residue on evaporation dried at 110°C... "				82·8	100·0			282·5								50·0
Silica (SiO2)......... "				4·5	1·6			7·5								2·5
Iron (Fe)........... "				0·04	0·10			0·03								0·0
Calcium (Ca)......... "	17·5	14·0	13·5	22·5	8·8	61·5	100·0	63·6	71·0	254·0	63·2	75·0	20·0	6·4	6·1	7·8
Magnesium (Mg)....... "	3·7	3·2	3·2	2·0	5·9	24·0	21·5	23·4	19·0	31·6	19·1	21·7	4·8	2·6	2·8	3·7
Bicarbonate (HCO3)... "			25·6	34·2	23·2			269·0		244·0	254·1	308·1				3·7
Sulphate (SO4)........ "				22·8	24·7			18·1								4·9
Chloride (Cl).......... "				2·0	1·0			3·2								2·0
Nitrate (NO3)......... "				0·40	0·35			3·9								0·7
Total hardness as CaCO3. "	59·0	48·1	46·9	64·5	46·2	252·2	338·2	254·9	255·4	764·6	236·3	276·5	69·7	26·7	26·3	34·7
Calcium hardness........ "	43·8	35·0	33·8	56·3	22·0	153·8	250·0	159·0	177·5	635·0	158·0	187·5	50·0	16·0	15·3	19·5
Magnesium hardness...... "	15·2	13·1	13·1	8·2	24·2	98·4	88·2	95·9	77·9	129·6	78·3	89·0	19·7	10·7	11·5	15·2

[1] Mines Branch laboratory tap.
[2] Glebe tap.
[3] Supplies Eastview, Nepean Tp. and Rockcliffe.
[4] Using reserve well, due to low supply.
[5] New supply developed since 1934.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

Sample No.	35	848	30	144	31	145	292	879	190	311	406	501	65	176	477	72	186	880
Date	18/7/34	12/6/42	14/7/34	9/8/35	15/7/34	10/8/35	6/8/36	28/5/42	29/8/35	4/9/36	3/8/37	20/8/38	20/8/34	23/8/35	11/6/37	26/8/34	28/8/35	28/5/42
Locality	Penetanguishene		Perth		Peterborough				Picton		Port Arthur		Port Colborne			Port Hope		
Source of supply	Wells		Tay River		Otonabee River				Bay of Quinte		Lake Superior		Lake Erie			Lake Ontario		
Method of purification	No treatment		Mechanical filtration, activated carbon, chlorination		Filtration, chlorination			Alum, intermittent soda to raise pH, filtr., chlor.	Filtration, chlorination		Chlorination		Chlorination			Settling basin, sand filters		Chlorination
Colour...........p.p.m.	....	None	....	....	....	....	....	30·0	....	....	....	5·0	....	....	....	....	....	10·0
Alkalinity as CaCO₃...... "	....	132·8	....	53·2	....	62·5	69·5	64·0	75·9	75·0	51·0	38·0	....	92·0	96·0	....	95·2	98·0
Residue on evaporation dried at 110°C................ "	....	151·5	....	....	....	....	....	115·5	....	....	....	85·0	....	....	....	....	....	168·0
Silica (SiO₂)............... "	....	21·5	....	....	....	....	....	1·5	....	....	....	6·5	....	....	....	....	....	1·8
Iron (Fe)................... "	....	0·05	....	....	....	....	....	0·04	....	....	0·04	0·12	....	....	0·05	....	....	0·05
Calcium (Ca)............. "	50·5	27·9	20·0	18·6	30·0	28·6	30·0	32·2	34·3	37·4	17·9	15·7	35·0	38·2	39·5	35·5	37·9	40·0
Magnesium (Mg).......... "	12·6	14·0	4·5	6·5	3·1	3·9	4·1	5·5	8·2	8·9	3·9	4·5	8·0	10·0	10·3	9·0	9·8	10·7
Bicarbonate (HCO₃)....... "	....	162·0	....	64·9	....	76·3	84·8	78·1	92·6	91·5	62·2	46·4	....	112·2	117·1	....	116·1	119·6
Sulphate (SO₄)............. "	....	12·3	....	....	....	....	....	26·8	....	....	....	4·1	....	....	....	....	....	31·7
Chloride (Cl).............. "	....	1·2	....	....	....	....	....	3·0	....	....	....	3·0	....	....	....	....	....	16·8
Nitrate (NO₃)............. "	....	2·6	....	....	....	....	....	0·9	....	....	....	1·0	....	....	....	....	....	0·9
Total hardness as CaCO₃... "	178·0	127·2	68·5	73·2	87·7	87·5	91·8	103·1	119·4	130·0	60·8	57·8	120·3	136·5	141·0	125·7	135·0	143·9
Calcium hardness.......... "	126·3	69·8	50·0	46·5	75·0	71·5	75·0	80·5	85·8	93·5	44·8	39·3	87·5	95·5	98·8	88·8	94·8	100·0
Magnesium hardness....... "	51·7	57·4	18·5	26·7	12·7	16·0	16·8	22·6	33·6	36·5	16·0	18·5	32·8	41·0	42·2	36·9	40·2	43·9

TABLE VI—Continued
Analyses of Civic Water Supplies—Continued
ONTARIO—Continued

	57	154	881	79	195	200	407	502	550	60	175	300	883	83	172	237	51	166	886
Sample No..............	57	154	881	79	195	200	407	502	550	60	175	300	883	83	172	237	51	166	886
Date...................	9/8/34	14/8/35	8/6/42	29/8/34	30/8/35	8/10/35	19/8/37	16/6/38	26/8/38	17/8/34	22/8/35	28/8/36	5/6/42	25/8/34	15/8/35	15/11/35	2/8/34	19/8/35	10/6/42
Locality...............	Preston			Prescott		Renfrew				St. Catharines[1]				St. Mary's			St. Thomas		
Source of supply.........	Wells		Three wells and two springs	St. Lawrence River		Bonnechère River				Welland Canal				Deep Wells[2]			Kettle Creek		
Method of purification....	No treatment		Chlor.	Chlorination		Chlorination				Filtration, chlorination			Alum, filtr., chlor.	No treatment			Chlorination, aeration filtration, second aeration and chlorination		Aeration, activated carbon, filtration, double chlorination
Colour..............p.p.m.			10·0																35·0
Alkalinity as CaCO₃ "		222·8	238·0		88·8	39·5	43·3	39·0	39·4		93·5	96·0	92·5		261·5	266·0		168·5	172·0
Residue on evaporation dried at 110°C. "			367·5					55·5	80·0				185·0						218·0
Silica (SiO₂)........ "			14·0					2·5	5·5				3·5						5·0
Iron (Fe)........... "			0·05					0·07	0·05				0·05						0·03
Calcium (Ca)......· "	250·0	245·7	79·3	39·3	31·8	11·0	15·0	15·0	14·3	36·5	35·7	39·3	40·0	154·0	132·2	135·7	51·0	54·3	63·6
Magnesium (Mg)..· "	51·0	50·9	24·0	8·0	9·5	5·3	3·9	2·2	10·0	9·0	9·8	9·2	10·3	96·0	60·6	54·2	17·5	18·0	16·6
Bicarbonate (HCO₃) "			271·8		108·3	48·2	52·8	47·6	48·1		114·1	117·1	112·9		319·0	324·5		205·5	209·8
Sulphate (SO₄)..... "			79·9					6·2	7·4				28·8						47·7
Chloride (Cl).....· "			8·5					2·5	3·5				16·5						8·0
Nitrate (NO₃)...... "			3·1					0·2	0·3				0·7						3·1
Total hardness as CaCO₃..........	834·1	823·0	296·7	131·1	118·5	49·2	53·5	46·5	76·8	128·2	129·4	136·0	142·2	778·6	579·0	561·5	199·3	209·6	227·1
Calcium hardness... "	625·0	614·3	198·3	98·3	79·5	27·5	37·5	37·5	35·8	91·3	89·3	98·3	100·0	385·0	330·5	339·3	127·5	135·8	159·0
Magnesium hardness "	209·1	208·7	98·4	32·8	39·0	21·7	16·0	9·0	41·0	36·9	40·1	37·7	42·2	393·6	248·5	222·2	71·8	73·8	68·1

[1] Also supplies Port Dalhousie.
[2] New supply developed since 1934.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

Sample No.	44	159	422	296	424	503	953	297	423	504	313	53	752	29	142	630	714
Date	24/7/34	16/8/35	15/6/37	10/8/36	18/6/37	3/8/38	13/9/43	10/8/36	18/6/37	3/8/38	23/12/36	4/8/34	5/9/40	14/7/34	9/8/35	30/6/39	5/10/39
Locality	Sarnia[1]			Sault Ste. Marie							Scarborough Tp.[2]	Simcoe		Smiths Falls			
Source of supply	Lake Huron			St. Mary's River				Wells at Steelton			Lake Ontario	Two wells		Rideau River			
Method of purification	Chlorination			Chlorination			Di-chlora-mine	Chlorination			Coagulation, rapid sand filtration, chlorination	No treatment, intermittent zeolite		Filtration, chlorination			
Colour..........p.p.m.	......	......	......	......	......	None	10·0	......	......	5·0	......	......	10·0	......	......	20·0	25·0
Alkalinity as CaCO3 "	......	82·5	77·8	30·0	34·5	38·6	38·2	82·0	34·0	44·0	91·5	......	171·5	......	78·3	75·0	65·0
Residue on evaporation dried at 110°C "	......	......	......	......	......	62·5	67·5	......	......	76·5	......	......	228·5	......	......	133·0	106·3
Silica (SiO2) "	......	......	......	......	......	4·6	None	......	......	10·0	......	......	15·0	......	......	0·5	1·0
Iron (Fe) "	......	......	0·05	......	Trace	0·05	1·00	......	Trace	0·05	......	......	0·05	......	......	0·04	0·06
Calcium (Ca) "	24·5	30·4	24·3	14·3	12·2	13·0	15·0	28·6	14·3	14·3	40·7	71·0	57·2	26·0	23·7	28·3	25·0
Magnesium (Mg) "	8·0	9·3	7·0	4·9	3·6	3·0	3·9	4·4	5·3	5·5	11·0	13·0	15·9	5·4	7·4	7·5	9·1
Bicarbonate (HCO3) "	......	100·7	94·9	36·6	42·1	47·1	46·6	100·0	41·5	53·7	111·6	......	209·2	......	95·5	91·5	79·3
Sulphate (SO4) "	......	......	......	......	......	2·0	6·6	......	......	8·2	......	......	18·1	......	......	18·0	15·0
Chloride (Cl) "	......	......	......	......	......	3·5	1·3	......	......	3·0	......	......	2·5	......	......	1·0	1·0
Nitrate (NO3) "	......	......	......	......	......	1·0	None	......	......	3·5	......	......	None	......	......	0·75	0·80
Total hardness as CaCO3 "	94·1	114·1	89·5	55·9	45·3	44·8	53·5	89·5	57·5	58·4	146·9	230·8	208·2	87·1	89·6	101·6	99·8
Calcium hardness "	61·3	76·0	60·8	35·8	30·5	32·5	37·5	71·5	35·8	35·8	101·8	177·5	143·0	60·0	59·3	70·8	62·5
Magnesium hardness "	32·8	38·1	28·7	20·1	14·8	12·3	16·0	18·0	21·7	22·6	45·1	53·3	65·2	22·1	30·3	30·8	37·3

[1] Also supplies Point Edward.
[2] Also supplies East York Tp.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	45	158	753	298	425	295	426	505	62	308	52	165	304	754	888	408	620
Sample No	45	158	753	298	425	295	426	505	62	308	52	165	304	754	888	408	620
Date	25/7/34	15/8/35	6/9/40	9/8/36	3/8/37	9/8/36	9/8/37	25/8/38	17/8/34	28/8/36	3/8/34	19/8/35	20/8/36	6/9/40	9/6/42	4/9/37	15/5/39
Locality	Stratford			Sturgeon Falls		Sudbury			Thorold		Tillsonburg					Timmins[1]	
Source of supply	Wells			Sturgeon River		Ramsay Lake			Welland Canal		Wells and spring				Wells	Mattagami River	
Method of purification	No treatment			Filtration, chlorination		Chlorination			Rapid sand filtration, chlorination		Wells—No treatment Spring—Chlorination				No treatment	Chlorination	
Colour............p.p.m.			25·0					15·0						15·0	5·0		70·0
Alkalinity as CaCO3... "		225·0	212·0	12·1	13·6	9·0	11·1	7·0		94·5		184·9	164·5	164·5	153·0	30·5	15·0
Residue on evaporation dried at 110°C..... "			702·0					56·0						213·5	226·0		74·0
Silica (SiO2)........... "			15·0					3·5						15·0	14·0		5·0
Iron (Fe)............ "			0·20		Trace			0·02						0·10	0·05	0·22	0·12
Calcium (Ca)......... "	135·5	141·4	155·7	7·9	5·7	7·9	8·9	9·2	42·5	35·7	72·5	70·4	55·7	55·7	55·7	13·6	7·9
Magnesium (Mg)...... "	31·0	29·2	39·7	3·9	3·1	4·3	3·9	4·8	9·0	11·3	14·5	13·9	15·9	15·3	15·5	4·5	2·2
Bicarbonate (HCO3)... "		274·5	258·6	14·8	16·6	11·0	13·5	8·5		115·3		225·6	200·7	200·7	185·4	37·2	18·3
Sulphate (SO4)......... "			257·7					21·4						20·0	37·0		21·4
Chloride (Cl)......... "			1·5					2·5						1·5	3·0		5·0
Nitrate (NO3)......... "			None					0·1						None	0·3		1·5
Total hardness as CaCO3 "	465·9	473·2	552·1	35·8	27·0	37·4	38·3	42·7	143·2	135·6	240·8	233·0	204·5	202·0	202·9	52·5	28·8
Calcium hardness...... "	338·8	353·5	389·3	19·8	14·3	19·8	22·3	23·0	106·3	89·3	181·3	176·0	139·3	139·3	139·3	34·0	19·8
Magnesium hardness... "	127·1	119·7	162·8	16·0	12·7	17·6	16·0	19·7	36·9	46·3	59·5	57·0	65·2	62·7	63·6	18·5	9·0

[1] Also supplies Schumacher and Tisdale Tp.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Continued

	69	182	480	481	492	601	75	188	310	427	755	889	973	890	46	162	157	61	177	891
Sample No	69	182	480	481	492	601	75	188	310	427	755	889	973	890	46	162	157	61	177	891
Date	24/8/34	27/8/35	12/6/37	25/12/37	22/3/38	20/12/38	27/8/34	29/8/35	5/9/36	23/9/37	29/8/40	27/5/42	1/9/43	11/6/42	27/7/34	17/8/35	14/8/35	18/3/34	24/8/35	5/6/42
Locality	Toronto[1]						Trenton						Twin Province	Walkerton	Wallaceburg		Waterloo	Welland[2]		
Source of supply	Lake Ontario						Wells						Mine	Springs	Chenal Ecarté River		Wells	Welland Canal		
Method of purification	Filtration, chlorination						No treatment						No treatment	Chlorination	Ammonia treatment, chlorination, filtration		No treatment	Sand filtra., chlorination		Alum, filtra. chlor.
Colour.......p.p.m.					None	None					10·0	55·0		None						25·0
Alkalinity as CaCO3 "		93·5	90·6	95·2	89·3	93·5		211·7	206·5	203·6	205·5	214·0	2,160·0	196·0		81·0	248·1		89·0	80·5
Residue on evaporation dried at 110°C "					180·5	164·0					272·5	291·0	5,964·5	2,111·5						189·0
Silica (SiO) "					1·6	3·0					13·0	20·5	23·0	12·0						2·0
Iron (Fe) "			0·05	0·06	0·05	0·04					0·02	0·03	0·70	0·15						0·10
Calcium (Ca) "	36·0	35·7	38·3	37·5	41·3	41·0	80·5	78·6	78·2	80·0	77·9	76·5	66·5	523·8	31·6	28·6	130·0	41·5	37·9	42·9
Magnesium (Mg) "	8·0	9·5	9·3	8·5	10·0	9·2	11·0	12·4	14·1	11·5	14·9	12·5	31·9	55·7	8·0	9·3	37·3	9·0	10·0	10·0
Bicarbonate (HCO3) "		114·1	110·5	116·1	108·9	114·1		258·3	251·9	248·4	250·7	261·1	2,635·2	239·1		98·8	302·7		108·6	98·2
Sulphate (SO4) "					23·9	22·1					25·9	28·8	1,523·0	1,212·6						40·3
Chloride (Cl) "					16·0	17·5					4·5	3·0	678·0	3·0						18·5
Nitrate (NO3) "					0·5	0·2					None	3·9	None	1·1						3·3
Total hardness as CaCO3 "	122·8	128·3	133·9	128·7	144·3	140·2	246·4	247·3	253·3	247·2	255·9	242·6	297·1	1,537·9	111·8	109·6	477·9	140·7	135·8	148·3
Calcium hardness "	90·0	89·3	95·8	93·8	103·3	102·5	201·3	196·5	195·5	200·0	194·8	191·3	166·3	1,309·5	79·0	71·5	325·0	103·8	94·8	107·3
Magnesium hardness "	32·8	39·0	38·1	34·9	41·0	37·7	45·1	50·8	57·8	47·2	61·1	51·3	130·8	228·4	32·8	38·1	152·9	36·9	41·0	41·0

[1] Also supplies Forest Hill, Leaside, Swansea, York Tp.
[2] Supplies Crowland Tp.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ONTARIO—Concluded

		344	70	183	410	48	160	428	493	42	168	756	43	169
Sample No.		344	70	183	410	48	160	428	493	42	168	756	43	169
Date		23/12/36	25/8/34	28/8/35	22/9/37	28/7/34	17/8/35	15/6/37	24/3/38	24/7/34	20/8/35	6/9/40	24/7/34	20/8/35
Locality		Weston	Whitby			Windsor¹				Woodstock				
Source of supply		Two wells	Lake Ontario			Detroit River				Spring (main supply)			Well	
Method of purification		No treatment	Chlorination			Coagulation, filtration, chlorination				Chlorination			Chlorination	
Colour	p.p.m.								None			25·0		
Alkalinity as CaCO3	"	326·0		99·0	98·1		81·0	85·9	66·5		252·5	248·5		247·0
Residue on evaporation dried at 110°C	"								148·0			288·0		
Silica (SiO2)	"								2·8			14·0		
Iron (Fe)	"								0·12			0·10		
Calcium (Ca)	"	100·0	37·5	34·7	39·7	27·5	28·6	26·8	40·0	81·0	76·7	79·3	120·5	151·4
Magnesium (Mg)	"	16·0	9·0	9·8	9·0	8·0	9·3	8·0	9·0	22·0	24·5	26·8	47·0	61·3
Bicarbonate (HCO3)	"	397·7		120·8	119·7		98·8	104·8	81·1		308·1	303·2		301·3
Sulphate (SO4)	"								16·0			18·9		
Chloride (Cl)	"								4·5			4·0		
Nitrate (NO3)	"								0·3			None		
Total hardness as CaCO3	"	315·6	130·7	127·0	136·2	101·6	109·6	99·8	136·9	292·7	292·3	308·2	494·0	629·8
Calcium hardness	"	250·0	93·8	86·8	99·3	68·8	71·5	67·0	100·0	202·5	191·8	198·3	301·3	378·5
Magnesium hardness	"	65·6	36·9	40·2	36·9	32·8	38·1	32·8	36·9	90·2	100·5	109·9	192·7	251·3

¹ Also supplies Riverside.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

MANITOBA

Sample No.	429	506	913	430	507	954	431	508	956	432	509	914	957	433	510	434	511	915	959
Date	28/6/37	15/8/38	3/9/42	26/7/37	20/6/38	3/9/43	25/7/37	25/6/38	31/8/43	27/6/37	25/6/38	13/9/42	31/8/43	28/7/37	11/8/38	26/6/37	16/8/38	6/9/42	8/9/43
Locality	Brandon			Dauphin			Neepawa			Portage la Prairie				Selkirk		Winnipeg[1]			
Source of supply	Assiniboine River			Edwards Lake			Whitemud River			Assiniboine River				Wells		Shoal Lake			
Method of purification	Filtration, coagulation, lime, alum, chlorination	Sed., filtr., chlor.		No treatment		Chlorination	Alum, filtration, chlorination		Chlor., alum, act. carbon filtr.	Sand filtration, chlorination			Alum, black char, filtr.	No treatment		Chlorination		Ammonia, chlorination	Chlorination
Colour.................p.p.m.	....	20·0	15·0	....	65·0	20·0	....	40·0	30·0	....	10·0	10·0	35·0	....	None	....	5·0	5·0	20·0
Alkalinity as CaCO3 "	230·0	204·0	210·0	247·9	174·5	235·5	322·4	241·5	278·5	262·3	196·5	200·0	252·0	585·0	462·0	79·5	78·0	79·0	80·0
Residue on evaporation dried at 110°C "	....	609·0	550·0	....	293·0	375·5	....	354·0	336·5	....	545·0	500·0	548·5	....	1620·0	....	116·5	110·0	120·5
Silica (SiO2) "	....	11·0	11·0	....	13·0	22·0	....	21·5	16·5	....	17·5	15·0	13·0	20·24	3·5	....	None	6·8	6·5
Iron (Fe) "	0·03	0·28	0·03	0·07	0·43	0·07	....	0·29	0·11	....	0·03	0·03	0·10	23·60	0·05	0·04	0·22	0·05	0·09
Calcium (Ca) "	83·6	86·3	75·5	58·2	57·2	72·2	79·3	80·0	74·5	77·9	71·5	73·2	77·9	98·3	95·8	23·6	26·4	25·8	25·0
Magnesium (Mg) "	39·0	45·9	34·8	18·3	22·3	27·5	24·5	25·1	23·6	33·4	42·1	34·7	36·0	101·6	96·1	6·6	7·9	7·1	7·9
Bicarbonate (HCO3) "	280·6	248·9	256·2	302·4	212·9	287·3	393·3	294·6	339·8	320·0	239·7	244·0	307·4	713·7	563·6	97·0	95·2	96·4	97·6
Sulphate (SO4) "	....	244·1	195·2	....	42·0	72·8	....	43·6	18·1	....	199·6	190·5	160·0	....	232·1	....	8·2	8·0	12·8
Chloride (Cl) "	....	13·0	18·8	....	1·5	5·2	....	1·0	2·4	....	15·0	18·0	18·3	....	49·2	....	3·0	3·0	2·2
Nitrate (NO3) "	....	0·40	0·9	....	4·0	1·15	....	3·0	Trace	....	1·5	1·5	None	....	0·5	....	1·5	1·0	1·42
Total hardness as CaCO3 "	368·9	404·0	331·5	220·5	234·4	293·3	298·8	302·9	283·5	331·7	351·4	325·3	342·4	662·4	633·5	86·1	98·4	93·6	94·9
Calcium hardness "	209·0	215·8	188·8	145·5	143·0	180·5	198·3	200·0	186·3	194·8	178·8	183·0	194·8	245·8	239·5	59·0	66·0	64·5	62·5
Magnesium hardness "	159·9	188·2	142·7	75·0	91·4	112·8	100·5	102·9	96·8	136·9	172·6	142·3	147·6	416·6	394·0	27·1	32·4	29·1	32·4

[1] Also supplies East Kildonan, St. Boniface, St. James, St. Vital, Transcona, and Tuxedo.

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

SASKATCHEWAN

Sample No	435	436	437	961	438	439	512	916	962	440	963	441	513	444	514	964
Date	20/7/37	29/6/37	24/7/37	10/8/43	5/7/37	22/7/37	24/6/38	28/7/42	7/8/43	23/7/37	16/8/43	3/7/37	12/8/38	20/7/37	3/6/38	1/8/43
Locality	Biggar	Estevan	Kamsack		Maple Creek		Melfort			Melville		Moose Jaw		North Battleford		
Source of supply	Wells	Long Creek	Assiniboine River	Spring	Springs	Melfort Creek			Eagle Lake and Stony Creek	C.N.R. dam	Wells	Three wells		Wells on bank of North Saskatchewan River		
Method of purification	Alum, filtration, aeration	Sand filtration, alum, aeration, chlor., soda	Sand filtration, alum, chlorination	Filtra., alum, chlor.	No treatment	Alum, filtration, chlorination, intermittent copper sulphate			Filtr., alum, chlor., act. carb., copper sulph. intermittently	Alum, filtr., activ. carbon, chlor.	Chlor.	Chlorination		No treatment		
Colour........................p.p.m.				10·0			55·0	40·0	45·0		25·0		5·0		15·0	20·0
Alkalinity as CaCO₃............ "	411·5	275·8	316·8	251·0	270·5	288·0	180·0	200·0	192·0	289·4	198·9	321·5	291·2	216·1	237·5	230·0
Residue on evaporation dried at 110°C.................... "				593·0			596·0	550·0	958·5		452·0		1,002·0		530·5	377·0
Silica (SiO)..................... "				15·0			1·0	7·0	14·0		12·0		13·0		6·0	12·0
Iron (Fe)...................... "	0·20	0·12	Trace	0·15	Trace	0·07	0·13	0·09	0·05	0·07	0·07	0·45	0·11	0·60	3·16	0·28
Calcium (Ca)................... "	120·1	46·4	98·6	94·3	66·5	49·3	91·5	85·0	115·1	48·2	80·7	124·7	63·6	61·1	57·2	74·5
Magnesium (Mg)................. "	29·2	28·4	44·2	38·0	27·5	37·3	45·9	44·5	61·6	38·3	37·1	37·9	43·9	20·1	21·4	21·8
Bicarbonate (HCO₃)............. "	502·0	336·5	386·5	306·2	330·0	351·4	219·6	244·0	234·2	353·1	242·7	392·2	355·3	263·6	289·8	280·6
Sulphate (SO₄)................. "				195·4			237·1	220·0	350·9		116·4		426·0		71·6	84·3
Chloride (Cl).................. "				7·5			9·0	8·5	10·2		10·2		12·0		4·0	7·0
Nitrate (NO₃)................. "				0·44			1·2	1·0	2·21		22·14		1·5		2·0	1·68
Total hardness as CaCO₃....... "	420·0	232·4	427·7	391·6	279·1	276·2	417·0	395·0	540·4	277·5	353·9	467·2	339·0	235·2	230·7	275·7
Calcium hardness.............. "	300·3	116·0	246·5	235·8	166·3	123·3	228·8	212·5	287·8	120·5	201·8	311·8	159·0	152·8	143·0	186·3
Magnesium hardness........... "	119·7	116·4	181·2	155·8	112·8	152·9	188·2	182·5	252·6	157·0	152·1	155·4	180·0	82·4	87·7	89·4

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

SASKATCHEWAN—Concluded

Sample No.	445	515	920	965	446	516	966	447	517	917	448	518	918	449	443	519
Date	21/7/37	28/6/38	30/7/42	4/8/43	3/7/37	13/8/38	12/8/43	21/7/37	28/6/38	30/7/42	4/7/37	11/8/38	28/8/42	29/6/37	24/7/37	26/6/38
Locality	Prince Albert				Regina			Saskatoon			Swift Current			Weyburn	Yorkton	
Source of supply	North Saskatchewan River				Wells		Springs and wells	South Saskatchewan River			Swift Current Creek			Wells	Wells	
Method of purification	Alum, filtration, chlorination				No treatment. Chlorination when necessary		No treatment	Alum, filtration, chlorination			Alum, filtration, chlorination			No treatment	No treatment	
Colour........p.p.m.	....	10·0	10·0	None	....	5·0	5·0	....	25·0	20·0	....	20·0	15·0	....	....	10·0
Alkalinity as CaCO3 "	122·5	108·5	115·0	101·0	412·5	445·0	422·2	152·3	97·5	125·0	171·3	135·0	130·0	335·3	498·3	502·0
Residue on evaporation dried at 110°C. "	....	175·0	170·4	194·5	....	1,128·0	1,027·0	....	168·0	180·6	....	416·0	390·5	....	....	776·5
Silica (SiO2) "	....	11·0	5·0	3·0	....	27·0	26·0	....	4·0	6·9	....	4·0	3·5	....	....	27·0
Iron (Fe) "	0·05	0·12	0·03	0·09	0·04	0·13	0·10	Trace	0·40	0·08	Trace	0·10	0·07	12·30	0·26	8·71
Calcium (Ca) "	33·6	38·6	38·2	42·2	150·1	163·6	56·5	35·0	32·2	39·0	22·5	25·7	25·0	116·1	120·1	125·8
Magnesium (Mg) "	10·0	12·2	14·0	15·1	72·7	86·5	21·0	12·1	10·0	12·5	42·5	34·7	28·2	44·7	65·6	66·0
Bicarbonate (HCO3) "	149·5	132·4	140·3	123·2	503·3	542·9	515·1	185·8	119·0	152·5	209·0	164·7	158·6	409·1	607·9	612·4
Sulphate (SO4) "	....	39·5	33·3	44·4	....	423·9	386·7	....	32·0	35·0	....	171·6	166·8	....	....	220·2
Chloride (Cl) "	....	1·0	1·9	1·4	....	9·0	6·3	....	1·0	1·5	....	4·0	3·5	....	....	11·0
Nitrate (NO3) "	....	0·7	0·3	0·08	....	0·50	0·89	....	0·2	0·3	....	2·0	1·5	....	....	1·5
Total hardness as CaCO3 "	125·0	146·5	152·9	167·4	673·4	763·7	227·4	137·1	121·5	148·8	230·6	206·6	178·1	473·6	569·3	585·1
Calcium hardness "	84·0	96·5	95·5	105·5	375·3	409·0	141·3	87·5	80·5	97·5	56·3	64·3	62·5	290·3	300·3	314·5
Magnesium hardness "	41·0	50·0	57·4	61·9	298·1	354·7	86·1	49·6	41·0	51·3	174·3	142·3	115·6	183·3	269·0	270·6

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ALBERTA

Sample No.	450	520	452	521	921	940	522	451	523	453	454	524	955	455	525
Date	10/7/37	8/7/38	13/7/37	6/7/38	27/8/42	29/7/43	6/8/38	7/7/37	4/8/38	13/7/37	17/7/37	4/7/38	31/7/43	16/7/37	8/8/38
Locality	Banff		Calgary				Cardston	Coleman		Drumheller	Edmonton			Lethbridge	
Source of supply	Mountain Stream		Elbow River		Glenmore reservoir	Glenmore dam	Lee's Creek	Wells		Red Deer River	North Saskatchewan River			Oldman River	
Method of purification	No treatment		Alum, filtration, chlorination, activated carbon		Alum, filtration, activated carbon, chlorination	Filtration, alum, chlorination	No treatment	No treatment		Filtration, chlorination	Alum, filtration, intermittent chlorination		Filtr., water softening, alum, chlorination, soda ash, lime, phosphate, CO2	Alum, filtration, chlorination	
Colour...............p.p.m.	....	15·0	....	5·0	5·0	5·0	5·0	....	10·0	....	....	5·0	10·0	....	20·0
Alkalinity as CaCO3....... "	135·4	132·0	124·0	140·0	145·0	131·0	193·2	133·5	155·5	240·8	64·8	99·0	25·0	106·5	116·0
Residue on evaporation dried at 110°C............. "	....	179·5	....	180·0	190·7	230·5	247·0	....	195·0	....	....	171·0	81·0	....	163·5
Silica (SiO2)........... "	....	6·0	....	6·0	4·8	3·5	6·0	....	2·0	....	....	None	1·5	....	None
Iron (Fe)............... "	Trace	0·08	Trace	0·10	0·04	0·13	0·51	Trace	0·02	0·39	Trace	0·08	0·13	Trace	0·08
Calcium (Ca)........... "	41·8	40·0	47·9	41·0	50·0	50·0	47·2	41·4	52·9	66·8	38·6	41·7	14·3	30·0	37·2
Magnesium (Mg)......... "	12·7	13·0	13·7	12·0	8·7	14·2	27·7	10·3	12·2	20·3	10·8	9·8	7·6	10·4	13·5
Bicarbonate (HCO3)..... "	165·2	161·0	151·3	170·8	176·9	159·8	235·7	162·9	189·7	293·8	79·1	120·8	30·5	129·9	141·5
Sulphate (SO4).......... "	....	39·0	....	42·0	40·0	36·2	23·0	....	15·2	....	....	44·0	38·3	....	26·8
Chloride (Cl)........... "	....	1·0	....	1·0	1·6	0·7	1·5	....	1·0	....	....	1·0	0·9	....	1·0
Nitrate (NO3).......... "	....	0·2	....	0·10	0·07	0·35	1·2	....	2·2	....	....	1·0	0·09	....	None
Total hardness as CaCO3.... "	156·6	153·3	176·0	151·7	160·7	183·2	231·6	145·7	182·3	250·2	140·8	144·5	81·0	117·6	148·4
Calcium hardness........... "	104·5	100·0	119·8	102·5	125·0	125·0	118·0	103·5	132·3	167·0	96·5	104·3	35·8	75·0	93·0
Magnesium hardness........ "	52·1	53·3	56·2	49·2	35·7	58·2	113·6	42·2	50·0	83·2	44·3	40·2	31·2	42·6	55·4

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

ALBERTA—Concluded

	456	527	457	526	528	458	588	442	529	958	459	554
Sample No	456	527	457	526	528	458	588	442	529	958	459	554
Date	6/7/37	7/8/38	5/7/37	8/8/38	7/8/38	14/7/37	4/7/38	18/7/37	1/7/38	31/7/43	15/7/37	5/7/38
Locality	Macleod		Medicine Hat		Raymond	Red Deer		Vegreville			Wetaskiwin	
Source of supply	Oldman River		South Saskatchewan River		Impounding reservoir	Red Deer River		Wells			Wells	
Method of purification	Alum, filtration, chlorination		Alum, filtration, chlorination		Chlorination	Filtration, chlorination		No treatment		Aeration	No treatment	
Colour....................p.p.m.	....	5·0	....	10·0	35·0	....	20·0	....	40·0	20·0	....	60·0
Alkalinity as CaCO₃................"	125·3	143·6	102·4	108·0	245·5	139·1	118·0	525·5	533·0	522·0	491·5	472·0
Residue on evaporation dried at 110°C........."	....	200·0	....	191·0	205·0	....	168·0	....	897·0	1,231·0	....	857·5
Silica (SiO₂)................."	....	2·0	....	2·0	12·0	....	2·0	....	11·0	12·0	....	2·0
Iron (Fe)................."	0·04	0·3	0·27	0·40	0·40	0·06	0·18	0·08	0·20	0·08	0·05	0·17
Calcium (Ca)................."	37·2	35·7	33·9	37·1	28·6	41·8	37·5	23·6	55·0	25·0	2·1	7·9
Magnesium (Mg)................."	10·7	15·7	11·0	15·0	10·9	14·1	11·2	7·2	41·7	7·4	0·4	3·7
Bicarbonate (HCO₃)................."	152·9	175·2	124·9	131·8	299·5	169·7	144·0	641·1	650·3	636·8	599·6	575·8
Sulphate (SO₄)................."	....	25·9	....	27·0	....	....	20·8	....	398·8	423·7	....	21·8
Chloride (Cl)................."	....	1·5	....	1·5	1·4	....	1·5	....	7·5	6·3	....	168·0
Nitrate (NO₃)................."	....	1·3	....	0·05	4·0	....	1·3	....	4·0	3·37	....	0·1
Total hardness as CaCO₃................."	136·9	153·7	129·9	154·3	116·2	162·3	139·7	88·5	308·5	92·8	6·9	35·0
Calcium hardness................."	93·0	89·3	84·8	92·8	71·5	104·5	93·8	59·0	137·5	62·5	5·3	19·8
Magnesium................."	43·9	64·4	45·1	61·5	44·7	57·8	45·9	29·5	171·0	30·3	1·6	15·2

TABLE VI—Continued

Analyses of Civic Water Supplies—Continued

BRITISH COLUMBIA

Sample No.	530	460	531	532	461	533	534	543	535	922	462	589	536	537	553
Date	15/7/38	8/7/37	4/8/38	21/4/38	7/7/37	4/8/38	1/8/38	27/7/38	12/7/38	25/8/42	9/7/37	4/8/38	27/7/38	14/7/38	6/9/38
Locality	Chilliwack	Cranbrook		Duncan	Fernie		Grand Forks	Kamloops	Kelowna[1]		Kimberley		Ladysmith	Merritt	Nanaimo
Source of supply	Elk Creek	St.Joseph'sCreek and Gold Creek		Lone Chain River	Fairy Creek		Kettle River	Thompson River	Okanagan Lake		Mark Creek		Stocking Lake	Wells	Dam 3 miles from city
Method of purification	No treatment	No treatment		No treatment	No treatment		Intermittent chlor.	Intermittent chlor.	Intermittent chlorination		No treatment		No treatment	No treatment	No treatment
Colour................p.p.m.	10·0	....	10·0	40·0	....	5·0	10·0	None	None	None	....	5·0	25·0	10·0	15·0
Alkalinity as CaCO$_3$	89·0	90·0	104·0	16·9	84·0	95·3	98·5	26·0	97·0	100·0	8·9	13·5	5·4	36·5	13·0
Residue on evaporation dried at 110°C	150·0	....	118·0	81·0	....	129·0	147·5	60·0	150·2	151·0	....	36·2	25·0	77·5	31·0
Silica (SiO$_2$)	8·0	....	9·5	8·5	....	5·0	11·5	5·0	10·0	7·8	....	6·3	2·0	7·0	1·5
Iron (Fe)	0·17	0·05	0·9	0·7	0·04	0·70	0·07	0·03	0·06	0·04	0·04	0·05	0·07	0·05	0·12
Calcium (Ca)	44·0	25·7	35·7	17·0	28·6	35·7	31·4	7·6	31·3	30·4	3·9	8·0	5·7	20·7	9·2
Magnesium (Mg)	3·7	7·1	9·6	5·2	6·1	12·7	9·8	2·6	9·2	10·0	0·5	2·5	3·8	5·9	10·2
Bicarbonate (HCO$_3$)	108·6	109·8	126·9	20·6	102·5	116·3	120·2	31·7	118·3	122·0	10·9	16·5	6·6	44·5	15·9
Sulphate (SO$_4$)	34·1	....	5·8	7·0	....	11·9	20·6	6·5	20·0	22·4	....	5·2	2·0	8·2	6·6
Chloride (Cl)	1·5	....	1·0	3·0	....	1·0	1·0	1·0	1·0	1·3	....	1·0	1·0	1·0	5·0
Nitrate (NO$_3$)	0·9	....	1·2	0·3	....	1·7	1·6	1·5	0·1	None	....	0·4	0·1	0·3	1·0
Total hardness as CaCO$_3$	125·2	93·4	128·7	63·8	96·5	141·4	118·7	29·7	116·0	117·0	11·9	30·3	29·9	76·0	64·8
Calcium hardness	110·0	64·3	89·3	42·5	71·5	89·3	78·5	19·0	78·3	76·0	9·8	20·0	14·3	51·8	23·0
Magnesium hardness	15·2	29·1	39·4	21·3	25·0	52·1	40·2	10·7	37·7	41·0	2·1	10·3	15·6	24·2	41·8

Supplies municipality of Glenmore and district of Woodlawn.

TABLE VI—Concluded

Analyses of Civic Water Supplies—Concluded

BRITISH COLUMBIA—Concluded

	538	539	923	967	540	892	542	541	968	544	545	546	547	970	969	548	549	924	971
Sample No	538	539	923	967	540	892	542	541	968	544	545	546	547	970	969	548	549	924	971
Date	1/8/38	25/7/38	18/8/42	4/7/43	13/7/38	23/8/42	20/7/38	14/7/38	16/7/43	11/7/38	29/7/38	30/7/38	25/7/38	4/7/43	23/7/43	12/7/38	23/7/38	10/8/42	7/6/43
Locality	Nelson	New Westminster		North Vancouver	Penticton		Port Alberni	Princeton	Prince Rupert	Revelstoke	Rossland	Trail	Vancouver¹			Vernon	Victoria²		
Source of supply	Mountain Lake	Coquitlam Lake and Creek		Creek	Mountain Spring	Penticton Creek	China Creek	Tulameen River	Lake, 7 miles distant	Bridge and Hamilton Creeks	Mountain stream	Mountain stream	Capilano Lake			B.X. Creek, main source, Kalamalka Lake auxiliary	Sooke Lake		
Method of purification	No treatment	No treatment		No treatment	Sand gravel filters	No treatment	No treatment	Gravel filters, no chemicals	No treatment	No treatment	No treatment	No treatment	No treatment			No treatment	No treatment	No treatment	Chlorination
Colour p.p.m.	15·0	40·0	35·0	5·0	35·0	35·0	10·0	20·0	40·0	25·0	15·0	15·0	5·0	30·0	5·0	20·0	15·0	10·0	25·0
Alkalinity as CaCO₃ "	5·5	None	None	None	2·6	14·5	51·5	66·0	6·5	3·5	13·6	50·0	4·0	3·3	3·5	122·0	1·2	1·5	None
Residue on evaporation dried at 110°C. "	39·5	19·0	20·0	21·0	52·0	53·0	75·0	104·0	32·5	27·0	55·0	77·0	17·0	21·0	15·0	186·5	26·5	30·0	49·0
Silica (SiO₂) "	8·5	1·0	1·2	3·5	12·5	14·0	4·0	8·0	0·5	4·0	2·0	3·0	4·0	3·0	4·0	11·5	3·5	3·5	2·0
Iron (Fe) "	0·02	0·16	0·10	0·08	0·12	0·07	None	0·02	0·05	0·02	0·07	Trace	0·07	0·05	0·06	Trace	Trace	Trace	0·13
Calcium (Ca) "	10·0	3·5	3·5	1·4	7·1	5·7	23·6	22·9	6·4	5·7	10·7	20·0	4·3	2·1	2·1	32·9	5·7	6·0	4·3
Magnesium (Mg) "	3·8	4·4	4·0	1·5	5·0	1·5	8·5	6·6	2·4	3·2	2·6	4·8	1·6	1·1	1·7	10·2	2·8	3·1	2·2
Bicarbonate (HCO₃) "	6·7	None	None	None	3·2	17·7	62·8	80·5	7·9	4·3	16·6	61·0	4·9	4·0	4·3	148·5	1·5	1·8	None
Sulphate (SO₄) "	6·2	6·2	5·8	5·3	5·8	4·1	5·3	12·5	7·4	7·0	21·0	10·7	4·1	6·2	4·9	34·2	2·9	3·2	4·9
Chloride (Cl) "	1·0	1·0	1·0	0·2	1·0	1·0	4·0	1·0	1·0	1·1	1·0	1·0	1·0	0·8	0·7	1·0	3·5	4·0	2·5
Nitrate (NO₃) "	0·3	0·2	0·2	None	0·5	0·3	0·4	3·5	None	0·7	0·2	0·5	0·7	Trace	0·27	0·3	0·1	0·1	None
Total hardness as CaCO₃ "	40·0	26·8	25·2	9·7	38·3	20·5	93·9	84·4	25·8	27·4	37·8	69·7	17·4	9·8	12·3	124·1	25·8	27·7	19·8
Calcium hardness "	25·0	8·8	8·8	3·5	17·8	14·3	59·0	57·3	16·0	14·3	26·8	50·0	10·8	5·3	5·3	82·3	14·3	15·0	10·8
Magnesium hardness "	15·6	18·0	16·4	6·2	20·5	6·2	34·9	27·1	9·8	13·1	11·0	19·7	6·6	4·5	7·0	41·8	11·5	12·7	9·0

¹ Also supplies Burnaby, Coquitlam district, Port Coquitlam, Richmond. and West Vancouver.
² Also supplies Esquimalt, Oak Bay, Saanich.

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