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Some Features of Iowa Ground Waters

W. S. Hendrixson

SOME FEATURES OF IOWA GROUND WATERS.

BY W. S. HENDRIXSON.

About ten years ago the Iowa Geological Survey published an elaborate Report on Iowa Artesian Wells by Professor William H. Norton of Mt. Vernon. In this Report, which occupies most of Vol. VI of the Survey, are published the analyses of about fifty deep well waters. The geology of these wells and other deep borings was fully discussed, and illustrated.

About two years ago the United States Geological Survey extended its hydrographic work to this state. The Chief of the Department of Hydro-Economics, Mr. Marshall O. Leighton, visited the state and while here arranged with the writer for the further chemical examination of Iowa well waters, principally with regard to their fitness for economic uses. A year later a plan was made providing for the co-operation of the U. S. and Iowa Geological Surveys with a view to the preparation and publication of a more comprehensive statement of the geology and hydrography. The local work on the geology was to be in charge of Professor Norton and the chemistry of the water in charge of the writer. Last spring the scheme was still farther developed, and was extended to the important shallower wells, so as to make a more nearly complete statement of Iowa water resources. Professor Simpson of Colby College and three assistants were sent into the field to search out and investigate unrecorded or little known wells. During the summer they covered most of the state and collected a large amount of material, which will be used in the state and county reports.

The work in the state was taken up by the Department of Hydro-Economics and the object was primarily practical and economic. Later a combination in the work was effected with the Department of Geology with a view of covering the whole ground of the Iowa deep wells from both the practical and the scientific standpoint.

It is not the purpose of this paper to discuss the value of the work save at one point. Iowa is a state with a scanty supply of surface water, when compared with other states, especially our northern neighbors,. Wisconsin, Minnesota and Michigan, with their almost innumerable lakes and rivers of excellent and never-failing water. Probably Iowa has no lake or river water suitable for a municipal supply without treatment. The lakes are on the northern border of the state away from important centers of population. The important rivers that may be relied upon to supply large amounts of water, such as it is, are the Mississippi, the Missouri, the Des Moines and the Cedar. Apparently, it must always be that a very large proportion of the Iowa cities and towns must depend upon drilled wells for their water supplies, or at any rate upon wells of some sort; that is upon ground waters. Now the drilling of deep wells is very expensive. Well number 3 at Grinnell, cased and ready for the machinery for pumping, cost $8,000. Before city officers or even the isolated farmer in need of a better supply of water enters upon such an expensive and it may be, fruitless operation, he wants to know the probabilities, at least, that his efforts and outlay will be rewarded. To determine that matter is too large an undertaking for the individual or even the city. The government takes up the problem and by the correlation of data at hand and collectible it is able to chart the water probabilities of a distrct or a state, so that any individual or corporation may know in advance what to expect from a drilling,—how deep he will have to drill to get the desired supply of water, and what its quality will most probably be.

The analytical work on Iowa well waters during the past two years has been done in the chemical laboratory of Iowa College, mainly by the writer. There were shipped to this laboratory about thirty samples of water from Minnesota deep wells. To make the analyses of these waters and also to assist in the Iowa work as might be necessary, Mr. H. S. Spaulding of the national Survey was sent to Grinnell and remained about three months. About twenty-five analyses of Iowa waters are to be credited to him.

The waters that have been chemically investigated have been those of wells 500 feet deep or more; also, from wells as shallow as 100 feet when they supplied towns or represented large and important water-bearing sand areas. In general only a sufficient number of well waters from any given locality has been analyzed to determine with certainty the water bearing capabilities of the strata penetrated. In some cases spring waters have been investigated when the flows were large and when the waters were used or likely to serve important economic or other interests.

As a rule only mineral analyses have been made, though where evidence pointed to large amounts of nitrate this has also been determined. The usual determinations have been,—Cl, SO_4, HCO_3, SiO_2, Fe, Al, Ca, Mg, Na and K. Up to the present time the total number of analyses is about three hundred. About fifty have been transcribed and recalculated from Professor Norton's Report, a large number have been collected from the railroads and from other sources, but the larger portion have been made at Grinnell. The railroads to which the Survey is chiefly indebted are the Chicago & North-Western, the Chicago, Milwaukee & St. Paul and the Rock Island.

All the analyses obtained from railroads and other sources have been calculated into modern terms used by the Geological Survey. The old system of grains per gallon and hypothetical compounds has been discarded and all results save SiO_2 are expressed in ions and parts per million as they probably exist in solution. When waters are acid to phenoltalein the carbonic acid ion is assumed to be HCO_3, or, all carbonates are regarded as acid carbonates.

At the present time by no means all the general results from the data at hand have been worked out or even attempted. However, certain definite general statements can be made with reasonable confidence.

It may be stated as most of us were already aware that Iowa ground waters are, even at the best, highly mineralized. No water coming from below the drift has been analyzed by the writer, which contained less than 250 parts of solids per million. From this minimum we find all grades of mineralization up to about 10,000 parts per million. As a rule the heavily mineralized waters contain large amounts of the sulfates of calcium and magnesium, and sometimes of sodium. In some cases, as in the 1,000-foot well at McGregor, the largest constituent of the solid matter is sodium chloride, more than sixty per cent. of the solids of this water being sodium and chloride ions. As a rule, however, simple salt waters are not found in Iowa. The waters containing large amounts of salt are also charged with large quantities of calcium or sodium sulfate or both. So far as known to me there are, properly speaking, no magnesium sulfate waters. Almost invariably the amount of the calcium ion is at least twice that of the magnesium ion, and usually the proportion of calcium is much larger. In a few shallow wells sulfates are practically absent, and in a few of the best deep well waters, as at Vinton and Dubuque, SO_4 is all but absent, the former of these waters, for example, containing less than 4 parts per million.

Except in two waters from shallow wells, both probably highly polluted, all Iowa waters examined have been found to be acid to phenoltalein; that is, they contain no normal carbonates. In many analyses by railroad chemists, however, considerable quantities of normal sodium carbonate are reported. In every case the waters analyzed have been found strongly alkaline to methyl-orange, which of course is not affected by carbonic acid. For these reasons, in practically all waters analyzed, the carbonates are regarded as acid carbonates and the acid ion is put down as HCO_3 when it is desired to represent the mineral matter as it actually exists in solution. Of course on evaporation approximately one-half of this ion is lost as CO_2 and H_2O.

There are in the state no highly carbonated waters such as those at Manitou and Saratoga. The ion HCO_2 rarely, if ever, exceeds 700 parts per million and usually falls rather below half of that amount. No waters have been found highly charged with free carbon dioxide, and 25 parts per million may be regarded as about the maximum. It should be stated, however, that in transit from the wells to the laboratory there is much opportunity for the loss of the dissolved gas.

When one attempts to formulate any general statements regarding the quality of deep well waters in different sections of the state and from different water-bearing strata, many complications are encountered. The difficulties are due to several causes which may be stated as follows:

1. There are not yet sufficient data available. For instance, in the southwestern section of the state very few deep wells have been drilled.

2. Except in the northeastern portion of the state deep wells receive water from more than one stratum, since the casings rarely go lower than about 1,000 feet.

3. Casings are difficult to make water-tight, and it is probable that in the majority of instances the casings have either been defective from the beginning or they have been rusted through by the highly mineralized waters of especially the carboniferous.

The problems of the relation of the quality of water to the geography and geology of the state have not yet been studied by the writer with any degree of thoroughness, and what is said below on this relationship is to be taken largely as tentative.

Whatever else may be uncertain, it is perfectly sure that the best waters obtained as yet from the deep wells have been obtained in the northeastern portion of the state. This section bounded on the west and south by a line from the Iowa lakes south to a little north of Des Moines, and then east to Muscatine, would contain all the deep wells which give abundant supplies of moderately good water. Outside of this area the deep well waters are scanty in amount or highly mineralized, and in fact, they are usually both.

It is certain also that the good waters from deep wells come from the lower sandstones. Downward or in the order in which they are penetrated by the drill they are, the St. Peter, the New Richmond, the Jordan and the Basal Sandstone. These strata outcrop to a small extent in the extreme northeastern corner of the state. In Wisconsin and Minnesota their surface areas serve as the collecting ground of water. These strata dip to the south and west and transmit through their porous structures the water which is to supply our wells in the northeastern portion of Iowa. As stated these strata outcrop or lie near the surface in the northeastern corner of the state. To the west they attain their greatest depth, along the northern border, at about the middle of the state then rise rather sharply to the west and apparently become obliterated as they near the northwestern corner of the state. In the northeastern portion of the state these rocks can be penetrated by drilling a few hundred feet and there is little or nothing to case out save the water from the drift. As we proceed to the south and west, however, these sandstones become deeply overlaid by the later geological formations, so deeply in fact that the effective shutting out of undesirable waters, especially from the carboniferous becomes more and more difficult and finally practically impossible. In this connection there is another consideration that merits attention. In the tabular statements of analytical results given below it may be observed that as we proceed to the south and west we find a sharp transition from comparatively soft waters to very hard waters. Now, if the statements of drillers and city officials are to be trusted there are some deep wells in the areas of hard waters that are cased to the bottom. It might reasonably be expected that some of them would have water only from the lower sandstones and that it would show as low mineral contents as the waters of the wells in Winneshiek County. In fact they never do. It seems, therefore, not impossible that there may be fissures sufficiently numerous and deep to allow a comparatively free mingling of the waters of these sandstones with those of the upper layers. These questions, however, demand farther study than I have been able to give them before they can be settled.

Whatever may be the character of the unmixed waters from diffrent strata there can be no doubt about the actual quality of water obtained by the driller when he has penetrated the deep lying sandstones in different localities. In the following tables no absolute accuracy can be claimed regarding the identity of the lowest strata penetrated in some of the drillings, though in most cases there can be no reasonable doubt, according to Dr. Norton, from whose report they are mostly taken. They show the increasing mineralization from north to south, and from east to west.

Table one shows the increase in mineralization of deep well waters as we go west through the second tier of counties from the northern boundary, from Waukon to Hull. As may be seen there is practical constancy till we pass Emmetsburg, but at Sanborn and Hull the solids increase about five times.

Table (2) represents waters from wells in the fourth tier of counties south, beginning at Dubuque and ending at Sioux City. At Dubuque the large number of wells show about the same amount of solids and a fair average is taken. There is an apparent irregularity in the solids at Webster City, which may be explained from the fact that the water was taken from a gas drilling, which was probably never properly cased.

Table (3) shows wells in the sixth tier of counties beginning at Clinton. It will be observed that the results are in general the same as in tables (1) and (2), save that the transition from light to heavy waters occurs farther east. The varying amounts of solids in the Grinnell wells will be referred to later. South of the sixth tier of counties deep wells are few and afford no series from east to west.

If we change the direction and pass from north to south the same general results are obtained. Table (4) begins at Lansing and follows along or near the Mississippi river. The transition may be assumed to occur at Davenport since Wilton is at a considerable distance from the river.

Table (5) represents a chain of wells beginning at Calmar, extending south and slightly west to Centerville. The transition, which is less sharp, though this may be accidental, occurs at Amanaon, about the same parallel as Davenport.

Table (6) represents wells from Mason City on the north to Des Moines. It is probable that the Nevada well is too shallow to be included in the series, but is the best available for the purpose.

In the southwestern portion of the state, the region outside the territory of the above tables, there are strictly speaking no deep wells save those at Council Bluffs and Glenwood, both of which furnish very hard waters.

The question is often asked whether the mineral content of a deep well changes with time and pumping. It would seem reasonable that the soluble mineral matter near the well might be dissolved out to a marked degree and that the water would in consequence gradually become softer. In the early stages of my work on Iowa waters this problem was taken up and several old wells were analyzed and these analyses compared with those contained in Professor Norton's Report. The effort in this direction was soon discontinued since it did not seem promising for several reasons. Some old analyses did not seem to be duly authenticated. Several wells had been deepened, partially filled, recased or abandoned, and in others the casings had very possibly become ineffective.

Most of the analyses made agreed fairly well with the old analyses, though my analyses showed the mineral matter usually somewhat smaller. This may have been due to more nearly complete dehydration of the residues obtained on evaporation. Further, there is reason to believe that new wells show higher solids before thorough pumping has removed the water in the immediate vicinity of the bore, and washed out the well. There are two striking exceptions to the general result. The older analysis from the well at West Liberty, carried out by Mr. Floyd Davis, shows twice the solids that I obtained; that is, 2,224 parts per million against my result, 1,066. In the water from the well at Nevada Mr. Briggs found 4,209 parts, while the recent analysis showed 2,368.

The uncertainty of such comparisons and the difficulty also of arriving at a true estimate of the quality of water in any deep lying stratum are well illustrated in the history of the deep drillings at Grinnell. Well number (1) is 2,002 feet deep and was drilled in 1893. In Professor Norton's report are the results of four analyses, made at different stages of the drilling, the last having been made at the end of the work. It shows 2,054 parts per million, and the other results are very nearly the same as this one. Considered as they stand there appears no great reason why the well should have been cased at all. As a matter of fact the casing was never effective.

Some years later well number 2 was drilled to the same depth. From the beginning of its use it was pumped more hours per day than well (1) and there was noticed a marked decrease in the hardness of the city water supply. From time to time determinations of the total solids in the city supply were made and they showed 900 to 1,000 parts. On February 25, 1905, a sample of water was taken from well (2) alone and showed the total solids 865 parts, while well number (1) showed on the same day 2,107 parts per million, which is practically the same as the waters from the Carboniferous at this point are known to contain. The writer drew the inference that the lower half of the well was filled up, and the practical test by running down an iron pipe showed that the well was not open below about 800 feet. All efforts to clean it and recase it proved unavailing and it was, therefore, abandoned and well number 3 begun. Small pieces of casing were removed from well (1) and they were full of rust holes. Well (3) is 2,020 feet deep and was completed about six months ago. Soon after the completion of this well difficulties were experienced in pumping well number (2). Shortly after repairs on it the total solids were determined and gave 3,207; and again, after hard pumping during four hours, a determination of February 4th showed 1,211 parts of solids per million. Well number (3) which was cased with much care showed soon after completion 1,578 parts of solids per million, and on April 25, 1907, 1,329 parts. From these records it seems certain that the strata at Grinnell and lying below 900 feet are capable under the most favorable conditions of supplying water containing as low as 865 parts of solids, and possibly if the upper waters were entirely excluded they might be found to give water with as small a content of solids as the same strata give in the northeastern part of the state. The records make it equally clear that practically an ideal deep well in this locality is difficult to construct, and to keep in perfect condition, and those who seek water supplies from these sandstones, where they are deeply overlaid by later formations, should be prepared to get on with a water more or less contaminated with harder waters from the upper strata.

It is probable that the same conditions as at Grinnell have prevailed more or less in most of the localities where the highest strata belong to any system above the Silurian or at most the Devonian.

The further question might naturally arise as to whether there are in the state so-called "mineral waters." Yes, too many. Of course the term mineral water has no scientific meaning, as generally used. All natural waters are more or less mineralized and in this sense they are mineral waters. As commonly used, however, the term is applied to such waters as are supposed to have special medicinal value.

The writer firmly believes that in this sense "mineral waters" and the traffic in them are to be placed in the same class with patent medicines. He believes that the best waters are those which contain moderately small amounts of the usual mineral constituents, and are as free as possible from bacteria of disease and all forms of contamination. It is very probable that the beneficial effects derived from mineral waters are indirect. In some cases it must be admitted, that undue acidity of the stomach, and of the urine and a low alkalinity of the blood or the secretions may be corrected by alkaline waters. In a very few waters enough lithium has been found to give some medicinal benefit, perhaps, if the patient persistently drank the water to the full extent of his capacity. Of the indirect influences are, the faith element, the freedom from business and other worry and work when visiting mineral springs sanitariums, the early morning walk to the springs and the cleansing of the stomach by generous draughts of water before breakfast.

Recently the Department of Agriculture made analyses of about fifty of the best known commercial mineral waters and published the results in Bulletin 91 of the chemical series. It is interesting to compare some of these analyses with those of Iowa waters. With the exception of a few salt waters and a few highly carbonated waters to which there are no analogues in Iowa as already stated, also two or three waters with high lithium contents, all the other mineral waters can be paralleled in all essential respects over and over again, by Iowa waters. In order to show the compositions of a number of Iowa waters and also to compare them with the commercial mineral waters I have constructed three tabular statements. Table (7) shows light mineral waters in comparison with what may be considered normal waters of similar amounts of mineral constituents, taken from Lake Michigan and the drive wells at Atlantic, Iowa. So far as the mineral matter is concerned there is no evident reason why one should prefer one water rather than the other.

Table (8) shows moderately mineralized commercial waters and their Iowa parallels. It may be observed that the famous Buffalo Lithia water contains .04 part of lithium, which would require one to drink 800 liters to get the medicinal dose. Lithium occurs in some Iowa waters also but so far as known its amount has not been determined. It may be said that a large proportion of advertised lithia waters do not contain more than a trace of this element, and sometimes none at all.

Table (9) shows heavily mineralized waters, the kind we want to avoid and case out in Iowa well operations. In the best of them one would have to drink 350 liters of water and with it nearly a kilogram of other mineral matter to get a dose of lithium.

While Iowa has few rivers or lakes that are capable of affording good and abundant water supplies, and deep drillings are not markedly successful in a large portion of the state, there is a large compensation in the fact that the state is mostly covered by thick drift which in many localities may supply excellent water and abundant for smaller towns and for farm use. There are great numbers of drift wells from 50 to 300 feet deep. The quality of their water varies widely with locality. Table (10) shows the quality of the waters of a few such shallower wells taken at random. In several sections the wells are flowing.

The subject of the shallower and artesian wells will be discussed in a future communication.

TABLE I.

FROM WAUKON WEST, SECOND TIER OF COUNTIES.

	Stratum.	Depth.	Solids.
Waukon	Jordan (?)	600	282
McGregor	Basal S. S	520	484
Calmar	Jordan	1223	306
Charles City	Basal S. S	1588	282
Mason City	Basal S. S	1277	350
Algona	St. Peter	1050	540
Emmetsburg	St. Croix	965	410
Sanborn	St. Croix	1256	2189
Hull	Algonkian	1256	2364

TABLE II.

FROM DUBUQUE WEST, FOURTH TIER OF COUNTIES.

	Stratum.	Depth.	Solids.
Dubuque	Basal S. S	900-1300	270
Manchester	Basal S. S	1870	494
Waterloo	St. Peter	1170	459
Webster City	Trenton	1250	1023
Manson	Maquoketa (?)	1250	670
Holstein	St. Peter	2004	1491
Sioux City	Algonkian	2011	1986

TABLE III.

From Clinton West, Sixth Tier of Counties.

	Stratum.	Depth.	Solids.
Clinton	B. Sandstone	1065	400
Tipton	B. S.	2696	330
Amana	Jordan (?)	1640	1033
Homestead	Basal S. S.	2224	1239
Grinnell	New Richmond	2002	870 to 1500
Des Moines	Jordan	3000	2910
Dunlap	St. Peter (?)	1535	1385

TABLE IV.

Lansing to Keokuk, on or Near the Mississippi River.

	Stratum.	Depth.	Solids.
Lansing	Basal S. S.	668	451
McGregor	Basal S. S.	520	488
Monona	St. Peter	420	421
Manchester	Basal S. S.	1870	494
Dubuque	Basal Sand S.	900-1300	270
Monticello	Jordan	1198	408
Sabula	St. Croix	973	298
Clinton	Basal S. S.	1065	400
Wilton	New Richmond	1360	1146
Davenport	St. P. to B. S.	800-2100	1066
Burlington	Pre Cambrian	2430	1082
Ft. Madison	Kinderhook	680	1970
Keokuk	Maquoketa	767	3600

TABLE V.

South from Calmar, Winneshiek County, to Centerville.

	Stratum.	Depth.	Solids.
Calmar	Jordan	1740	306
Oelwein		1000	395
Vinton	N. Richmond	1402	558
Amana	Jordan (?)	1640	1033
Homestead	Basal S. S.	2224	1239
Washington		1617	1630
Ottumwa	L. Oneota	2200	1155
Centerville	L. Oneota	2495	1746

TABLE VI.

From Mason City to Des Moines.

	Stratum.	Depth.	Solids.
Mason City	Basal S. S.	1277	350
Hampton	Jordan	1708	395
Ackley	Jordan	2032	604
Nevada	Above St. P.	980	2280
Des Moines	Jordan	3000	2910

TABLE No. VII.

LAKE MICHIGAN AND ATLANTIC, IOWA, WATERS AND LIGHTLY MINERALIZED COMMERCIAL WATERS.

	SiO_2	SO_4	HCO_3	Cl	Fe	Al	Ca	Mg	Na	K	Li	Solids
Lake Michigan. ..	5.2	6.8	144	2.2	.....	.2	32	11	3	....	.....	204
Atlantic, Iowa....	22	30	144	10	1.4	2.6	43	13	10	....	.....	276
Otterburn Lithia, Virginia...... ..	43	2.8	112	4.6	1.5		21	7	8	2	.03	201
Sublett Lithia Danville, Va....	31	6	166	10	1		37	12	15	3		288
Great Bear, Fulton, N. Y......	10	9	118	21	....		31	10	10	2	.....	299
Bear Lithia.......	15	3	115	2	1.4		18	10	5	2	.....	172
Thompson's Bromin, Va........	62	6	81	3	1		7	2	22	3	.....	191

Nitrates and ammonia omitted.

TABLE No. VIII.

MODERATELY MINERALIZED COMMERCIAL WATERS AND IOWA WATERS.

	SiO_2	SO_4	HCO_3	Cl	Fe	Al	Ca	Mg	Na	K	Li	Solids
Buffalo Lithia	35	405	85	11	.....	.5	166	6.4	31	4	.04	744
Rolfe, Iowa	28	145	261	7	2	2	176	9	34	....	....	664
Allouez, Wis.	21	59	360	31	.....	.8	87	43	20	2	....	623
Clinton, Iowa	9	63	306	54	.2	1	60	21	90	4	....	608
Pleasant Valley, Va.............	20	1.6	315	3	.....	1.5	53	28	7	2	....	431
Golindo Litha, Staunton, Va...	12	33	333	3	.....	.3	74	29	5	3	.1	492
Decorah, Iowa, Spring....... ...	13	19	333	4	.....	.5	78	27	4	1	....	476
Massenetta, Harrisburg, Pa.	12	3	342	2	.....	.3	63	28	4	3	....	457
Dubuque, Iowa...	8	20	310	8	.....	1.2	58	37	7	3	....	452

TABLE No. IX.

HEAVILY MINERALIZED COMMERCIAL WATERS AND IOWA WATERS.

	SiO_2	SO_3	HCO_3	Cl	Fe	Al	Ca	Mg	Na	K	Li	Solids
Geneva Lithia, N. Y...........	14	1520	245	204	.....	.....	521	116	131	4	.1	2755
Farmington, Iowa	13	1658	250	229	.....	1.6	340	112	442	14	....	3059
Berry Hill, Elkwood, Pa.......	27	1686	151	26	.....	1.5	524	59	164	4	....	2642
Bedford, Pa......	36	1727	192	10	.....	2.1	570	138	13	5	....	2694
Tate Springs, Tenn.	21	1460	260	9	.....	2.9	475	121	25	8	.1	2382
Chelsea, Iowa....	15	1923	240	7	5	2	489	204	38	....	....	2923

TABLE X.

A Few of the Many Good Shallow Wells.

	Depths.	Solids.
Atlantic	60	210
Newton	60	240
Brooklyn	180	509
Bageley	120	379
Boone	50	409
Browns	100	223
Carroll	120	422
Eagle Grove	400	462
Eldora	200	260
Iowa Falls	240	318
Sioux City	50 to 80	405
Perry	115	347