

Well Water from the Trap

Area of Western India

by

H.H. Mann

Department of Agriculture, Bombay.

BULLETIN No. 74 OF 1915.

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WELL WATERS FROM THE TRAP AREA OF WESTERN INDIA.

I.

Introduction.

The examination of the well waters of Western India, and more particularly from the area covered by the Deccan trap is of very considerable interest from two points of view. In the first place the waters are interesting as resulting from the action of water on the Deccan trap itself, and hence give very important indications of the direction which the decomposition of the rock takes in the more or less deep-seated fissures. But they are of perhaps greater interest because of the agricultural importance of these waters. Except for a comparatively small area served by canals and tanks, and not until recently exceeding perhaps one hundred and fifty thousand acres in the Bombay Presidency (excluding Sind), almost the whole of the irrigation in Western India is conducted from wells, and the number of wells in the several districts is as follows * :—

		Poona	...	22,177
		Satara	...	26,946
		Sholapur	...	20,865
Deccan	...	Ahmednagar	...	29,904
		Nasik	...	21,679
		East Khandesh	...	19,705
		West Khandesh	...	7,326
		Belgaum	...	12,660
Karnatak	...	Bijapur	...	6,654
		Dharwar	...	4,835
		Kanara	...	18,205
		Ratnagiri	...	6,501
Konkan	...	Kolaba	...	1,555
		Thana	...	5,057
		Surat	...	7,147
		Brosch	...	1,153
British Gujarat	...	Kaira	...	10,986
		Ahmedabad	...	15,763
		Panch Mahals	...	2,582

* Statistical Atlas of the Bombay Presidency, 2nd edition, 1906.

Thus, in the various districts, there are wells as follows:—

Deccan	...	Poona	...	One well per 112 acres cultivated land.				
		Satara	...	" "	79	" "		
		Sholapur	...	" "	118	" "		
		Ahmednagar	...	" "	104	" "		
		Nasik	...	" "	110	" "		
		East Khandesh	...	" "	100	" "		
Karnatak	...	West Khandesh	...	" "	171	" "		
		Belgaum	...	" "	169	" "		
		Bijapur	...	" "	476	" "		
Konkan	...	Dharwar	...	" "	485	" "		
		Kanara	...	" "	19	" "		
		Ratnagiri	...	" "	55	" "		
		Kolaba	...	" "	482	" "		
...	...	Thana	...	" "	193	" "		
British Gujarat	}	Surat	...	" "	106	" "
		Broach	...	" "	540	" "
		Kaira	...	" "	67	" "
		Ahmedabad	...	" "	100	" "
		Panch Mahals	...	" "	281	" "

Not only, therefore, is the total number of wells enormous, amounting to the very large figure of 241,700, by far the greater number used for irrigation,—but also they are a very important factor in the agriculture of the country, their frequency varying from one well per nineteen acres of cultivation of all classes in Kanara, to one well per five hundred and forty acres of cultivation in Broach.

The cultivation on these wells, as I shall show, is vitally affected by the character of the water drawn up from them, and hence the study of the well waters and the variations in their composition is by no means a useless task.

The wells in the Deccan trap present several important features with regard to the depth at which water is found and the condition in which the water exists which must be indicated before the special character of the problem can be realised. In depth, the wells on the trap area proper like the Deccan varies from say ten feet or even less, up to fifty feet or perhaps a little more, but by far the greatest number are between twenty and forty feet deep.* Nearly all of them on the Deccan itself involve digging or

* The same appears to be the case in Madras, though the geological formation is very different.

blasting through at least one layer of hard trap rock, and the water when found is either actually flowing from fissures in the hard trap rock itself or contained in softer layers between layers of such trap rock. The water actually used has hitherto rarely been found under any great pressure. If water is not found at a depth of forty feet, the chance of meeting with it at a lower level has been usually considered to be comparatively slight, and though many wells are continued lower, the cost becomes so very great and the chance of water so remote, that they are rarely carried much below the higher depth I have indicated.

When found in the trap area, the water is almost always what may be termed 'fissure water' that is to say, it is not a generalised subsoil water which is tapped, but water flowing in definite fissures in a definite direction. If the well happens to meet a fissure containing water, well and good,—if it does not do so, then the well is a failure. The result of this is very marked. It means that the digging of a well is a risky business, as there is by no means a certainty of meeting water. The Deccan, the typical trap area, is full of wells which have been dug and been failures. There are no data to determine exactly the percentage of failures among wells dug by the people, but I do not think it can be less than forty per cent. The digging of wells in the Deccan is so expensive that this would probably deter anyone from digging wells at all, were it not that water is all that is required to convert an almost barren situation into a garden, and the presence of a successful well will often raise the value of land to five times its previous amount. The digging of a well is hence a speculation, exceedingly risky indeed, but the returns from which, if successful, are very large.

This fact of the water being almost entirely in fissures in a typical trap area has another effect. It makes any attempt at digging an ordinary well by tube boring or by any other means of digging a narrow trial hole, of very uncertain value, unless the presence of water has been made fairly certain beforehand. The chance of meeting a fissure in a hole sixteen feet in diameter is such that there are, as I have said, probably forty per cent. of failures: but the chance in meeting a fissure containing water in a narrow tube bore is very much smaller, and hence tube boring has not until recently been introduced. In recent years a modification has been used to deepen existing wells in the use of the 'jumper bar' which enables a bore to be easily made ten to twenty feet below the existing level of the well,—and a certain amount of success has been obtained. And still more recently boring up to two hundred feet has been undertaken by the agricultural department of Bombay, with a fair measure of success in tapping sub-artesian water, especially where some means have been taken beforehand to detect the actual site where the current is flowing.

So far I have described a typical situation on the trap area. In digging a well, a man has to take his chance of meeting a fissure containing flowing water. This is the general case. But there are a considerable number of enclosed valleys even in the typical trap area, where there is a generalised underground water supply over a limited area. This is what would be expected,—and numerous instances could be quoted. One for instance, is at Chikodi in the Belgaum District. Where this occurs, there is usually a smiling group of villages, often some special intense cultivation, and an air of well-being by no means found in most places.

Such are the conditions which are found on the Deccan. The areas in the South of the Presidency when the trap has been left behind to the North, and when the prevailing rocks are shales, sand-stones, hæmatitic quartzite,

and finally the granites and gneisses of Southern India, the conditions are quite different. In the last case, wells are not so frequent: in the sandstone they are very deep.

In the Konkan and Southern Gujarat, there is no doubt that the bulk of the supply which feeds the wells is derived ultimately from streams coming from the trap hills behind to the East. But water is much more generally found there than in the Deccan and the risk of failure in digging wells is usually much less. The difference between wells quite close to gether is so great, however, as to show that the sources are different.

In Northern Gujarat, on the alluvial plains lying North and East from the head of the Gulf of Cambay, the conditions again are quite different. The tract as I have said, is alluvial. Generalised subsoil water exists between every layer of fine alluvial clay,—and ultimately, if the boring goes deep enough, artesian or sub-artesian water is usually tapped. The position is, in fact, much more like that prevailing in the alluvial regions of Northern India. I do not intend in the present paper to refer again to the well waters of this region, but hope to deal with it in a later paper.

In spite of the interest of the question, there appear to be very few data on record as to the composition of the well and spring waters of the area with which we are dealing. The Bombay Gazetteer, the primary authority up to the early eighties of the last century, rarely notes more than that the water of a certain river or a certain village is bad, or salt, or unsuitable for irrigation. And since that time few investigations have been made. It is of course natural that the examples likely to come before a chemist are precisely those exceptional waters which contain a larger amount of salt than usual and are hence unfit for irrigation. And among my records there are several such which I will quote. But to get a general idea of the character of the well waters of the area, these must be considered merely as exceptional instances, and not as representative in any sense.

II.

Types of Well Waters in the Trap Area.

Before giving details of the actual analyses of any samples of water, I may state that in all cases only the more common mineral constituents were determined, and not even all of these. The determinations usually made were the alkalinity, where such existed, determined with potassium hydrogen sulphate, using phenol phthalein as indicator: the sulphuric acid as sulphate: the carbonates, the lime and magnesia, the chlorides, and, in addition, the total solid matter contained in the water. The potash was not determined, as for the primary purpose of these investigations it was not necessary to know its amount.

The analyses have always been calculated for the purposes of the present paper as follows:—The total salts have been given as parts per 100,000 of the water,—and then the percentage composition of the salts has been indicated, the calcium (Ca), magnesium (Mg), carbonic acid (CO_2), bicarbonic acid (HCO_3), sulphuric acid (SO_4), and chlorine (Cl), being separately indicated. No attempt has been made to combine these into salts in the general tables of analyses which have been given. Where such an artificial combination leads to the elucidation of any point, attention has been called to it in the text. One exception to this method has been admit-

ted: the alkalinity has been calculated to sodium carbonate (Na_2CO_3), and the figure for this has been introduced into the analytical figures given.

This being understood, I may go on to indicate the actual figures obtained for the analyses of a number of well waters from various parts of the trap area, before considering more in detail the figures obtained in a more special study of certain selected cases which I have conducted for nearly six years.

The first set of analyses is from one of the small enclosed valleys lying surrounded by trap hills which occasionally occur in the Deccan, and which at their best give a perennial supply of water to a small area. The case in question was the valley of Chikodi in the Belgaum district, a place where the intensive cultivation of betel vine has become a very important industry. The water in the wells stood at about twenty to twenty-five feet from the surface of the ground in February 12, 1910, when the samples were taken. They were all being used constantly and almost daily for irrigation and so the water in the wells was being constantly renewed. None of those wells, unlike the vast majority of wells on the Deccan, penetrated the rock. They passed through *murum*, that is to say, partly decomposed trap rock, and finally reached the so-called "*shedu*," another soft material of finer texture, probably produced by the carrying of the finer particles of *murum* to a lower level by aqueous action. It was in this material that the water was found.

The actual analyses of the water were as follows:—

	Well No. 1.	Well No. 2.	Well No. 3.	Well No. 4.	Well No. 5.
Total Salts (parts per 100,000)	34·0	30·0	28·0	30·0	30·0
Containing—	p. c.	p. c.	p. c.	p. c.	p. c.
Calcium	12·9	18·7	17·1	13·3	16·0
Magnesium	12·7	7·3	6·4	13·0	10·7
Chlorine	17·1	18·7	7·9	18·7	20·3
Sulphuric acid (SO_4)	3·5	4·0	4·3	2·7	4·0
Carbonic acid (CO_3)	34·1	29·3	32·9	34·7	29·0
Alkalinity (as sodium carbonate)	21·5	14·0	22·9	16·0	24·7

Although the amount of salt present in these waters is very small, yet they illustrate one or two points which are characteristic of the waters found all over the area. The first of these is the relatively large amount of soluble magnesium in these waters. This amounts to the following proportions of the total solids:—

No. 1—12·7 p. c.

No. 2— 7·3 „

No. 3— 6·4 „

No. 4—13·0 „

No. 5—10·7 „

The second point is the presence of definite alkalinity, which can best be represented as sodium-carbonate (Na_2CO_3). This is one of the most characteristic feature of Western India waters and we shall meet some very striking cases. In the present case it is very small, equivalent only to from 4.2 to 7.4 parts per 100,000 of the water, but forms a considerable part of the total salts present.

From this case of waters flowing from a relatively short distance into a closed area we may turn to a number of waters obtained under more ordinary Deccan trap conditions, where the water is obtained from trap fissures, is always flowing, and is often derived from a considerable distance. I will take as the first examples a series of four types of water all obtained from the immediate neighbourhood of the town of Malegaon in the Nasik District, and hence in a typical trap region.

Of these the first is an analysis of the water at the well at the *dak* bungalow taken in December 1909. It gave figures as follows:—

Total Salts (parts per 100,000)	... 50.0
Containing—	p. c.
Calcium	... 13.6
Magnesium	... 13.2
Chlorine	... 19.4
Sulphuric Acid (SO_4)	... 9.2
Carbonic acid (CO_3)	... 37.0

This represents about the best of irrigation waters in the trap area. The large proportion of magnesium is still obvious amounting to 13.2 per cent. of the total amount of salts. There is no alkalinity, however,—and the total salts only amount to fifty parts per 100,000.

The second set of analyses is of two wells, lying close to one another about one mile due East of Malegaon City.

They gave figures as follows:—

	Well No. 1.	Well No. 2.
Total Salts (parts per 100,000)	... 108.0	120.0
Containing—	p. c.	p. c.
Calcium	... 4.2	3.3
Magnesium	... 8.2	5.1
Chlorine	... 15.4	23.1
Sulphuric acid (SO_4)	... 3.7	5.8
Carbonic acid (CO_3)	... 25.3	17.5
Nitric acid (NO_3)	... 19.6	12.7

Here we get the new feature appearing of the presence of nitrates. This is not, however, usual; but often occurs near towns. It is also illustrated by the next analyses.

The third set of analyses was taken from wells between thirty and forty feet deep in Malegaon City or just outside the walls. They are exceptional from the very large amount of magnesium they contain (amounting to thirty-one and twenty-nine parts per 100,000) as well as from the presence of considerable quantities of nitric acid:—

	Well No. 1.	Well No. 2.
Total Salts (parts per 100,000) ...	324·0	260·0
Containing—	p. c.	p. c.
Calcium ...	14·5	14·1
Magnesium ...	9·6	11·1
Chlorine ...	30·5	39·5
Sulphuric acid (SO ₄) ...	8·5	14·8
Carbonic acid (CO ₂) ...	2·7	4·8
Nitric acid (NO ₃) ...	5·8	8·2

These contained so much of magnesium and other salts as to be undrinkable.

The last set of analyses from the neighbourhood of Malegaon was from a series of wells in a line North and South, about two miles to the East of the city. They were brought to my notice because of the effect of the water in making the soil very impervious to water, and hence very hard and difficult to wet. The water was evidently part of underground water from a similar source. The actual figures of the analyses were as follows:—

	Well No. 1.	Well No. 2.	Well No. 3.	Well No. 4.	Well No. 5.	Well No. 6.
Total Salts (parts per 100,000) ...	110·0	92·0	120·0	76·0	80·0	82·0
Containing—	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Calcium ...	2·2	2·6	2·3	3·2	4·0	3·4
Magnesium ...	3·6	5·4	4·2	6·6	5·6	5·7
Chlorine ...	16·4	16·5	9·2	16·8	20·7	20·2
Sulphuric acid (SO ₄) ...	2·2	1·7	2·0	3·2	3·0	2·9
Carbonic acid (CO ₂) ...	28·9	27·0	28·2	45·8	41·7	42·4
Nitric acid (NO ₃) ...	18·7	20·4	29·1	...	...	...
Alkalinity (as sodium carbonate) ...	...	4·6	2·7	...	...	...

Here the most striking point is the large quantity of alkaline bi-carbonates, and the small quantity of other sodium and potassium salts, except nitrate in certain cases. I have often noticed that these are the conditions which lead to soft irrigation water being injurious to a black cotton soil. If chlorides or sulphates in larger quantity accompany these alkaline bi-carbonates, they are relatively innocuous: if the bi-carbonates of the alkalies are present, as in the present case in quantity greater than the chlorides, then they are injurious and can only be used as irrigation waters with danger.

I have quoted these samples of water from Malegaon in detail, because they show the extent to which waters in the Deccan may vary in the course of two or three miles.

Waters very similar to some of those quoted can however be found in the same part of the Deccan. A set of samples very much like those described above as damaging to the texture of soil was obtained from the village of Bahmana in the Amalner Taluka of East Khandesh. They had the same reputation as those cited from Malegaon, and they were hence considered to be unfit for irrigation. Their analyses gave figures as follows:—

	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Well No. 5
Total Salts (parts per 100,000) ...	80.0	80.0	80.0	80.0	100.0
Containing—	p. c.	p. c.	p. c.	p. c.	p. c.
Calcium ...	1.0	1.0	1.0	1.0	1.2
Magnesium ...	3.0	2.4	4.0	6.2	2.2
Chlorine ...	12.9	12.9	12.9	17.2	27.3
Sulphuric acid (SO ₄) ...	.9	3.0	1.5	.5	1.2
Carbonic acid (CO ₃) ...	48.6	49.4	50.4	49.5	86.5
Alkalinity (as sodium carbonate) ...	1.4	5.2	2.6	2.0	2.1

Here we have the conditions in the previous case carried to a much more marked extent. The alkaline bi-carbonates become the prominent constituents of the water. Relatively speaking the chlorine is in small amount. The calcium almost disappears, and the magnesium, though only present in small amount, yet is in much greater quantity than the calcium.

The actual effect produced by these waters on the black cotton soil (*regur*) which covers all the neighbourhood is well described in the original letter reporting the matter to me. "When the crops on the land are irrigated for a year, it says, "the next year's rain water cannot be absorbed into it, and the cultivator has to discontinue drawing well water for irrigation purposes. Recently when I was encamped at Bahmana on the Pangra river, some of the cultivators came up to me with the same complaint . . . I found that the soil on which an irrigated crop was raised last year, was hardened and covered with a white matter."

The actual effect on the soil was to deflocculate the colloid clay material in the soil, so that, on mixing with water, the solid matter remains suspended

for practically an indefinite period. This seems always to happen (as already remarked) in black cotton soils when, in the water used for irrigation, even a small amount of alkaline carbonates or bi-carbonates are not accompanied by a larger quantity of chlorides or sulphates.

This condition of things which, though not usual, is by no means uncommon in the Deccan trap area, is found in an extreme form in a sample of water in a well, opened for irrigation, but of course useless for this purpose, at Kopargaon in the Ahmednagar district. The analysis is not complete as it was done when my investigation of Deccan well waters was only just commencing, but it contained—

Sodium carbonate ($\text{Na}_2 \text{CO}_3$)	...	137.0	parts per 100,000
Calcium carbonate	...	8.0	" " "
Magnesium carbonate	...	13.6	" " "
Sodium chloride	...	37.7	" " "

This is, of course, as already remarked, an extreme case.

These last cases, though not unusual, do not represent the character of the water in the bulk of the wells on the Deccan: if they did, then irrigation under present conditions would be impossible. A few samples typical of the general character of the well waters and taken from the various parts of the Deccan from the ordinary wells are as follows:—

No. 1.—Well on the Government farm, Dhulia, taken in February 1911.

No. 2.—Well at Pimpri, near Poona, taken in January 1909.

No. 3.—Well at Poona, taken in May 1911.

	Well No. 1.	Well No. 2.	Well No. 3.
Total Salts (parts per 100,000)	80.0	31.3	38.9
Containing—	p. c.	p. c.	p. c.
Calcium	3.0	24.3	4.1
Magnesium	7.0	5.7	3.3
Chlorine	21.4	6.7	26.7
Sulphuric acid (SO_4)	3.0	9.3	13.6
Carbonic acid (CO_2)	34.0	47.3	22.6
Alkalinity (as sodium carbonate)	...	...	6.7

These may be taken as normal, but on the Deccan trap we often meet with waters containing very much more salt than these. Some have already been given. So long as they do not contain a large excess of alkaline carbonates or bi-carbonates in excess of the amount of lime salts and of the chlorides and sulphates, they are useful for irrigation until the amount of salts reaches 200 parts per 100,000 (or 0.2 p. c.) or even a little more.

The analysis of two of these follows:—

No. 1 is from a well in the Kolhapur State, taken in March 1910. It is doubtful as an irrigation water.

No. 2 is from a well at Bijapur, taken in November 1910. It is too salt to be used for irrigation.

	Well No. 1	Well No. 2.
Total Salts (parts per 100,000) ...	204.0	297.0
Containing—	p. c.	p. c.
Calcium ...	15.9	6.2
Magnesium ...	10.4	4.8
Chlorine ...	19.0	21.6
Sulphuric acid (SO ₄) ...	42.8	27.7
Carbonic acid (CO ₃) ...	9.6	4.1
Alkalinity (as sodium carbonate) ...	1.8	1.1

Before passing to other classes of well waters in our area it may be well to collect together the percentage composition of the salts in a number of typical waters already cited. Thus we get—

	(1) Chitodi No. 1.	(2) Male- gaon Dak Bun- galow.	(3) Male- gaon East of City well No. 1	(4) Male- gaon well in city.	(5) Male- gaon al- kaline waters No. 2.	(6) Buh- mana No. 1.	(7) Dhulia Govt. Farm.	(8) Kolha- pur salt water.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Calcium ...	12.9	13.6	4.2	14.1	2.6	1.0	3.0	15.9
Magnesium ...	12.7	13.2	8.2	11.1	5.4	3.0	7.0	10.4
Chlorine ...	17.1	19.4	15.4	39.5	16.5	12.9	21.4	19.0
Sulphuric acid ...	9.5	9.2	3.7	14.8	1.7	.9	3.0	42.8
Carbonic acid ...	34.1	37.0	25.3	4.8	27.0	48.6	34.0	9.6
Nitric acid ...	...	...	19.6	8.2	20.4	...	...	...
Total Salts (parts per 100,000) ...	34.0	50.0	108.0	200.0	92.0	80.0	80.0	204.0

There is a general similarity about these typical analyses, different as are the waters from which they are derived, and we may tabulate their characters as follows:—

1. The amount of magnesium is about equal to that of lime, varying from some amount below to considerably above. Magnesium in the quantity present is a decided characteristic of the Deccan waters,

2. Chlorine is wonderfully constant varying from 15 to 21 per cent. of the total salts, if we exclude the city water, where chlorine is naturally present in large amount.

3. In nearly all cases sulphuric acid is only present in small proportion. The exceptions are from the South Deccan.

4. The alkalies and alkaline earths are present in largest proportion as carbonates or bi-carbonates in most cases, and, hence, so far as the hardness of these waters is caused by lime and magnesia, it is chiefly temporary hardness.

When we leave the Deccan and examine waters which, though still in the trap area, are found below the Western Ghats, between these mountains and the sea, there is not nearly such a striking difference in the character of the salts contained, as might have been expected. Often there is a much larger quantity of sodium chloride, as in the samples to be cited from Surat. But this is evidently more or less an accidental circumstance, and is by no means universally found. I will quote the analyses of four samples—

No. 1 is from a well within two or three miles of the sea near Alibag, in the Kolaba District. The water was within ten feet of the surface (November 1910).

No. 2 is from the village of Agashi, near Bassein, in the Thana District (November 1910) very near the coast.

No. 3 is from Tarapur, in the Thana District, also quite near the coast (September 1911).

No. 4 is from Athwa, near Surat, some five miles from the sea coast, and quite near to the tidal portion of the Tapti river.

	No. 1	No. 2.	No. 3.	No. 4.
Total Salts (parts per 100,000)	66.0	100.0	44.0	130.0
Containing—	p. c.	p. c.	p. c.	p. c.
Calcium	6.7	9.2	16.4	1.5
Magnesium	8.1	4.8	6.6	2.6
Chlorine	20.4	13.7	20.4	40.7
Sulphuric acid (SO ₄)	4.2	13.9	6.6	3.8
Carbonic acid (CO ₃)	38.1	34.3	34.1	15.1
Alkalinity (as sodium carbonate)	...	(Alkalinity not determined.)	5.4	8.3

These figures are strikingly similar to those obtained on the Deccan and previously discussed—if we exclude the large amount of common salt in some of the samples from consideration.

Such then, in the general lines, appears to be the composition of the well waters derived from the Deccan trap area, whether above or below the Western Ghats. The next question, and a very interesting and somewhat important one, is to ascertain to what extent the character and quantity of the salts vary at different times of the year in the same well. The water is nearly always shorter in amount in the months of May and early June

each year, and this should affect the amount of salt in the water, and also the proportion of the various salts. In order to ascertain to what extent this takes place, I have been conducting analyses monthly from wells from three centres for over six years and the results of the analyses from two of these may now be presented.

III.

Well Water from Dhulia.

The three centres chosen for this investigation were Dhulia, in Khandesh, situated on one of the most typical parts of the Deccan trap plateau area: Surat, near the Gujarat coast, and the tidal Tapti river, on an alluvium derived from the Deccan trap and fed so far as underground water is concerned, chiefly from the trap hills to the East: and Dharwar, which lies not on the Deccan trap at all, but on the shales and quartzites which lie to the South of it and separate the trap area from the gneisses and granites of South India. I will consider the results of my examination of the waters from the first two of these centres in succession.

The well at Dhulia, forty to forty-one feet deep, whose water has been examined, has a constant supply the whole year through, and the depth of the water in the well varies from eight feet to two feet at different periods. The water is in constant use, and so the analyses represent the water which is actually circulating in the rock at the time. The water is a pure fissure water, and arises directly from the hard rock.

Analyses have been made from January 1908 to April 1913, nearly every month, and the total amount of salts present is shown in the following table, in parts per 100,000 of the water:—

Total Solids.—Parts per 100,000 of water.

	1908.	1909.	1910.	1911.	1912.	1913.
January . . .	61.5*	...	64.0	...	70.0	77.0
February . . .	64.7*	72.8*	58.0	80.0	70.0	76.0
March . . .	46.9*	74.0*	56.0	70.0	77.0	75.0
April . . .	...	...	104.0	70.0	71.0	74.0
May . . .	52.0*	...	76.0	70.0	76.0	...
June . . .	53.4*	...	66.0	74.0	80.0	...
July . . .	52.6*	70.0	78.0	66.0	71.0	...
August . . .	...	86.0	92.0	80.0	74.0	...
September . . .	56.2*	60.0	88.0	68.0	74.0	...
October . . .	53.0*	64.0	80.0	65.0	68.0	...
November . . .	48.4*	60.0	120.0	60.0	75.0	...
December . . .	55.5*	64.0	70.0	69.0	76.0	...

* The figures with an asterisk are not directly determined, but are obtained by adding together the amount of the individual salts found in the water. Numerous actual determinations have shown that the error thus introduced is very small.

The first thing that strikes the observer about these results is their extraordinary constancy. They feel the effect of the changes in the season from the dryness of the early part of the year to the wet period between June and September much less than would have been expected. If we take all the years together it is curious to notice that the amount of salts in the water seems to reach a maximum in August, and the depth of the water in the well is as low then as at any time of the year. It is evident, therefore, and the result is important, that the water which is drawn up from rock fissures in wells like that at Dhulia is not surface water, but represents the tapping of a very considerable underground water reservoir. This might have been concluded from the fact that the supply though diminishing in the hot months never ceases. The constancy of the composition makes it, however, more certain. The sudden jump in November 1910 is quite unexplained.

The next point is the variation from year to year. This is not very marked here, but it seems clear that in 1908 the water did not contain so much salt as in the succeeding years. The rainfall for the years from 1907 to 1913 at Dhulia is shown in the following table, but it must be confessed that these figures do not explain the difference:—

	1907.	1908.	1909.	1910.	1911.	1912.	1913.
January ...	0.10	...	0.08	...	...	...	...
February ...	0.55	...	...	...	...	...	...
March ...	...	0.27	...	...	...	...	...
April ...	0.47	...	...	...	...	0.01	...
May ...	...	...	0.96	...	...	0.18	0.04
June ...	4.15	4.07	6.24	13.14	1.28	1.19	8.88
July ...	6.83	6.20	3.95	6.68	1.73	5.77	6.28
August ...	3.22	5.39	1.81	3.17	1.27	1.90	1.63
September ...	1.21	1.13	6.58	3.50	0.13	0.04	4.61
October ...	...	0.13	0.17	1.75	0.01	1.11	...
November ...	...	...	...	0.51	3.42	4.47	...
December ...	...	...	0.27	...	...	...	0.52
Total ...	16.53	17.19	20.06	28.76	7.84	14.67	21.91

The variation in the individual constituents affords some very interesting results.

The alkalinity, defined as already described in this paper, has a most marked seasonal variation, as is shown in the following table. As before all figures are in parts per 100,000 :—

*Alkalinity.—Parts per 100,000 of Sodium Carbonate
(Na₂CO₃) in water.*

	1908.	1909.	1910.	1911.	1912.	1913.
January ...	15·6	...	...	...	...	1·5
February ...	11·9	...	2·6	...	2·2	0·7
March ...	5·3	15·8	5·3	1·1	...	...
April ...	...	...	10·1	...	7·4	...
May ...	...	...	3·2	1·1	9·6	...
June ...	...	22·7	...	13·4	10·4	...
July ...	...	...	...	6·1	1·5	...
August ...	...	3·2	...	...	5·9	...
September ...	...	...	...	1·1	...	...
October ...	...	...	...	...	...	...
November ...	...	...	1·1	1·8	...	...
December ...	...	3·2	...	4·4	...	...

These figures can only mean one thing, that during the dry part of the year the alkalinity tends to accumulate, and that it is reduced during the rainy season to a negligible quantity. Each year the alkalinity reaches a maximum at a different period, but always between January and June and disappears during the rains.

I have already stated that the proportion of salts in the water is fairly constant throughout the year. The same may be said of the composition of these salts. I can only be astonished how close the composition is maintained to the average throughout the year. The average composition is shown in the following figures :—

Calcium	... 7·1	p. c.
Magnesium	... 9·9	
Chlorine	... 15·5	
Sulphuric acid (SO ₄)	... 7·9	
Carbonic acid (CO ₃)	... 37·5	
Nitric acid (NO ₃)	... 3·2	

Total Salts in water = 69·1, parts per 100,000.

The actual figures for each month are shown in the appendix to this paper, but there are several matters to which attention may be drawn.

The magnesium present is normally a little greater than the calcium, though they fluctuate *inter se* a good deal. The relative proportions do not appear in any way to depend on season. This excess of magnesium is, as I have already remarked, a special characteristic of the waters in the Deccan trap. Most of both the lime and magnesia seem to be present in the form of carbonates, the amount of sulphate being usually very small.

Occasionally, however, there is a sudden increase in the amount of sulphates in the waters. This increase is maintained for two or three months and then disappears. Thus, if the proportion of sulphuric acid (as sulphates) be tabulated, we have the following figures:—

Sulphuric acid.
(Percentage of Total Salts.)

	1908.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January ...	4.7	...	6.8	...	5.2	4.2
February ...	3.8	4.9	5.7	3.1	5.3	4.8
March ...	6.1	3.3	4.4	4.7	5.9	3.8
April ...	...	...	8.7	4.1	5.7	3.8
May ...	3.2	...	3.8	8.2	4.9	...
June ...	4.3	...	6.2	14.9	5.1	...
July ...	4.2	6.5	21.2	16.7	4.1	...
August ...	...	4.3	22.5	13.7	5.0	...
September ...	11.0	7.5	16.3	3.6	5.5	...
October ...	3.1	4.6	14.4	3.1	3.6	...
November ...	15.8	4.1	4.8	3.7	3.8	...
December ...	12.6	3.2	7.0	4.7	3.2	...

During this period there have been three sudden increases in the amount of sulphuric acid. One of these was in the latter part of 1908, from September onward, and the others during the monsoon season of 1910 and 1911. There seems to be a suggestion in fact that the increase in sulphuric acid occurs (when it does occur) as a result of the rainy season, in other words of the percolation of an additional amount of water through the rock fissures. Sulphur exists to a not unimportant extent in trap rock, and it may well be that this is the case. I have found in the Nira Valley that on increasing the amount of drainage waters passing through a black soil, derived from trap, containing a rather large amount of alkaline salts, a considerable quantity of sulphur is removed by drainage water and actually deposited as such. The same may be the case in the rock fissures from which the Dhulia well water comes, under certain circumstances.

No such regularity can be observed in the amount of chlorine. This varies from 8.3 to 40.2 per cent. of the total salts. The latter figure is, how-

ever, abnormal, and the maximum apart from this is 22·8 per cent. The maxima and minima occur, however, at all parts of the year.

One of the curious features of these waters consists in the occasional presence of nitrates, and the variations in their amount. They occur and disappear with the most extraordinary irregularity as follows :—

Nitric Acid.
(Percentage of Total Salts.)

	1908.	1909.	1910.	1911.	1912.	1913.
January ...	...	...	7·6	...	5·7	6·3
February ...	7·5	5·7	...	...	5·7	5·8
March ...	...	4·9	...	...	6·1	5·3
April ...	...	...	16·9	...	5·6	6·2
May ...	...	...	13·4	...	6·7	...
June ...	...	...	...	...	5·7	...
July ...	...	...	...	...	5·1	...
August ...	...	25·2	...	...	6·7	...
September ...	...	...	...	...	6·6	...
October ...	7·3	10·5	...	...	5·9	...
November ...	6·7	7·8	...	...	6·1	...
December ...	...	7·2	...	5·8	5·3	...

There, thus seems to be no relationship to season or any other immediately visible factor in the amount recorded by my analyses.*

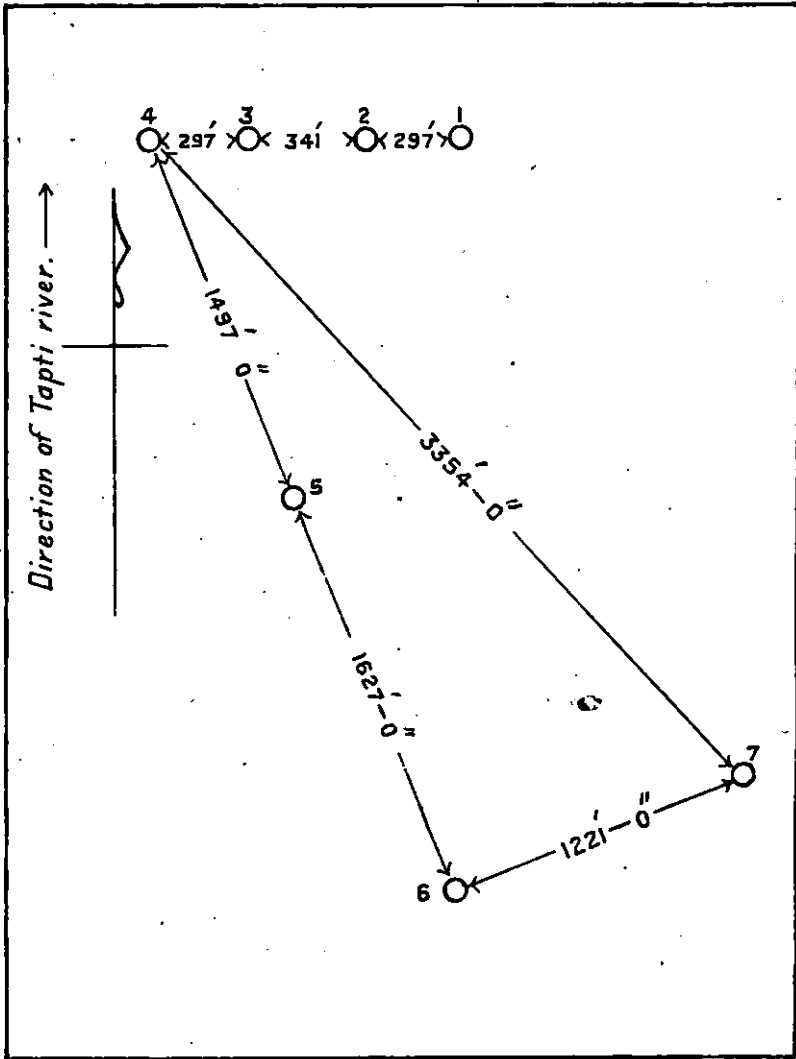
IV.

Well Waters from near Surat.

The second record, similar to that at Dhulia, has been made for a group of wells at Athva, about three miles away from Surat. These represent a condition of things quite dissimilar from that at Dhulia. The wells are below the Western Ghats,—a few feet only above the level of sea, and near the tidal portion of the river Tapti. They are not sunk into rock, but only into the alluvium, composed of *murum*, and *sheddu*-like elements which underlie the deep black cotton soil of which the surface is

* It was suggested at the meeting of the Bombay Presidency Science Association at which part of this paper was first presented that these figures are of exceeding interest in connection with the question of the occurrence and distribution of the nitrifying organism. I quite acknowledge this and hope I may have the opportunity of following up the matter.

SERIES OF WELLS AT ATHWA, SURAT



Scale 800 Feet = 1 Inch.

composed and which probably lie over trap rock. The water is much more generalised than usually is the case on the Deccan, and whenever a well is dug water of some sort is usually obtained. This is, evidently, however, not from a general reservoir of sub-soil water, as it differs in composition and depth in different wells within a short distance from one another. The fact that the supplies are from definite underground streams is also indicated from the fact that when a well is emptied the water usually flows into it chiefly, if not entirely, from the eastern side.

Nearly all the wells in this part of Gujarat are, however, somewhat salt, due either to the fact that the subsoil in which the water originates was originally washed by the sea, or else to a continual seepage from the sea. I think the latter is probably the source of the brackishness which is found almost everywhere, because of the series of results which followed the famines of 1896 and 1900. During these years the sources from which the wells in Gujarat are usually supplied dried up, and many of the wells gradually became salt. Many have remained so, and useless ever since: others have gradually after several years become sweet again. This can only be the result, it seems, of sea water coming in, when the fresh water current from the east, which usually kept it back, failed.

The variation of well waters within a few hundred yards is shown by the analyses of the water from this group of wells at Athwa. All the seven wells quoted are within about three quarters of a mile, and several are used either for irrigation or for drinking purposes. The following table indicates the enormous variation in the total salts and the chlorine contained in these waters for several typical months. All figures are given in parts per 100,000 of the water:—

I.—*Variation in Composition of Athwa Well Waters.*

(Parts per 100,000.)

Wells.	April 1908.		August 1909.		October 1910.		July 1911.	
	Total Salts.	Chlorine.	Total Salts.	Chlorine.	Total Salts.	Chlorine.	Total Salts.	Chlorine.
No. I ...	200.7	93.4	76.0	17.5	110.0	41.4	260.0	120.2
No. II ...	203.5	102.8	180.0	66.0	260.0	127.7	302.0	115.2
No. III ...	153.1	71.2	118.0	42.5	180.0	75.9	254.0	118.0
No. IV ...	131.2	52.7	104.0*	33.5*	150.0	61.6	154.0	52.8
No. V ...	135.0	61.6	150.0	50.0	150.0	53.6	182.0	48.8
No. VI ...	134.0	57.1	172.0	60.0	200.0	99.1	182.0	52.8
No. VII ...	...	...	70.0	16.3	130.0	41.4	70.0	16.5

These figures are merely a random selection from monthly determinations during six years, but they are sufficient to indicate the very different

* Refers to September 1909. The sample for August 1909 in this series was missing.

character of the underground sources from which these wells derive their supply. In the case of well No. I, the supply is evidently dependent on a stream of very variable character whose weakness admits salt water at many times of the year. On the other hand, well No. IV is very largely independent of the difference between the seasons, and only varies with the years. The difference between these wells is shown by the following table of the total salts in parts per 100,000, for the various quarters of the year:—

II.—*Variation in Composition of Athwa Well Waters.*

Total Solids (Parts per 100,000).

	Well No. II.	Well No. III.	Well No. IV.
1908—March ...	203·0	159·0	110·0
April and June ...	212·0	157·0	124·0
July and September ...	201·0	159·0	154·6
October and December ...	202·0	162·4	156·1
1909—February and March ...	231·0*	168·0	137·0
April and June ...	245·0	165·7	134·0
July and September ...	197·0	119·3	104·0†
October and December ...	200·0	129·0	113·0‡
1910—January and March ...	267·0	169·0	...
April and June ...	283·0	158·0	134·0§
July and September ...	271·0	187·0	136·0
October and December ...	274·0	195·0	147·0
1911—January and March ...	270·0	287·0	133·0
April and June ...	370·0†	...	120·0||
July and September ...	311·0	265·0	152·0
October and December ...	227·0	241·0	153·0
1912—January and March ...	303·0	273·0	164·0
April and June ...	306·0	267·5¶	157·0
July and September ...	306·0	188·6	146·0
October and December ...	304·0	194·6	167·0
1913—January and March ...	298·0	200·6	177·3
April and June ...	292·0	198·0	172·7
July and September ...	324·0	186·0	162·3
October ...	331·0	193·0	155·0

These figures show an extraordinary constancy for well No. III during the early part of the period and for IV throughout. In two out of these three cases the effect of the dry season of 1911 was most evident. In wells Nos. II and III, emphatically dependent as they are on several streams, the sources on which they usually depend were drying up in that year and the water, especially during the rains when it should be very fresh, contained more salt than at almost any time during the duration of my records.

This may cause serious thought in connection with one point,—the results of short rainfall in Gujarat on the character of the water in the

February only. † September only. ‡ October and November only. § May and June only.
 || April only. ¶ April and June only.

wells. I have already mentioned the effect of the drought of 1899 on many of the wells of Gujarat. An increase of salt occurred which has made many wells permanently useless, while many others are only just recovering from the effect. There may, from these figures, probably be a similar sequel to any year's serious drought. The following results from the other Athwa wells illustrate this point further :-

Total Salts.

	I.	II.	III.	IV.	V.	VI.	VII.
August 1908.	...	167·0	126·0	123·0	103·5	16·6	...
August 1909.	76·0	180·0	118·0	...	180·0	172·0	70·0
August 1910.	...	280·0	280·0	150·0	180·0	180·0	106·0
August 1911.	256·0	324·0	255·0	149·0	150·0	251·0	146·0
August 1912.	113·0	304·0	152·0	147·0	129·0	186·0	128·0
August 1913.	138·0	306·0	198·0	161·0	131·0	214·0	137·0

Some wells show the effect more than others. Well No. II in which the change has perhaps been greatest is perhaps hardly to be compared with the others, because an oil engine has been fixed on this well, which is, I fancy, drawing out more water than the fresh water supply can provide. But apart from this, the change in most cases is very evident and seems to indicate that the permanent effects of a long drought may not be limited to its action on cattle and men.

One thing is, however, quite evident. Where there is a very large difference between the quantity of salt in the water in different years, there the difference seems principally due to the presence of additional sodium chloride. - Where the content of salts in the water is constant, in different years, there the amount of sodium chloride is also constant, in other words, there is little seepage. The point is this. Where there is a *variable* fresh water supply, there the sea water takes advantage of the fact and soaks into the well. The only protection for a well against becoming salt is the vigour and size of the fresh water stream which keeps back the seepage of the sea water. This has one practical result in indicating the extreme danger of utilising too great a proportion of the water available in a well. This is illustrated by the figures already given for well No. II. There an oil-engine has been put into this well with the result that its water is now the most salt of the group.

Before proceeding to discuss the variations in the composition of the salts in the water from each well, as I have done in the case of the well at Dhulia, it will be well to indicate the rainfall for the years from 1907 to 1913 at Surat. This is shown in the following table, worked out for each month for the six years with which we are dealing. Although it is practically certain that these waters are not local waters, yet the distribution of the rainfall so far as the season of the year is concerned does not differ markedly from that in the area from which these waters are almost certainly derived.

Rainfall at Surat, 1907-1913.

	1907.	1908.	1909.	1910.	1911.	1912.	1913.
January ...	0·08	·82	...	...	0·08	...	...
February ...	...	...	0·02	...	...	...	...
March ...	...	...	...	...	0·18	...	...
April ...	0·05	...	0·04	...	...	...	...
May ...	...	...	...	...	...	...	0·01
June ...	4·83	2·83	11·91	14·27	5·43	7·04	20·14
July ...	18·44	33·85	27·84	8·69	2·65	36·81	8·06
August ...	15·28	6·48	6·22	10·92	8·37	6·30	5·44
September ...	0·20	3·96	6·95	1·10	2·92	2·25	3·82
October ...	...	0·01	0·06	1·28	...	1·20	0·18
November ...	...	...	...	0·22	...	3·59	...
December ...	...	...	0·42	...	...	...	...
Total ...	29·26	47·45	53·26	36·48	19·63	57·49	37·65

The distribution of the wells is shown in the attached sketch.

We will now consider each well in succession.

Well No. I.—(Rose Apple Tree Well) lies to the Eastern extremity of a line of four wells, nearly one thousand feet from one end to the other. The total depth of the well is 33½ feet. In this case, and only in this case in all the series, there is a chance of surface drainage running into the well during the rainy season. The figures for June, July, August and September are, hence, not very reliable in this case. The water stood six feet deep in the well just after the monsoon commenced in 1912. This water is only used occasionally.

The actual figures of the analysis of the water will be found in the appendix, but on account of the possibility of surface drainage into this well, I do not wish to discuss the figures in detail.

Well No. II.—(Oil-engine Well).—This lies 297 feet to the West of the last, and has a total depth of forty feet. In the early part of July 1912 there was a depth of water of thirteen feet in the well. On account of the excellent supply of water given in this well, as oil-engine was fitted some years ago, and the water which it has pumped has been constantly used since. From the change in composition, and increase in the amount of sodium chloride, I am inclined to think that the pump has been taking a little more water than the streams feeding the well have been able to supply, and the balance has been made up from the tidal Tapti river or other saline source.

The actual figures of the analysis of the water will be shown in the appendix.

The total amount of the solid matter has varied greatly, as is shown by the following figures :—

Total Solids.—Oil-Engine Well.

(Parts per 100,000.)

	1908.	1909.	1910.	1911.	1912.	1913.
January ...	...	231·0	260·0	180·0	307·0	307·0
February ...	...	...	260·0	320·0	301·0	303·0
March ...	294·0	...	280·0	310·0	300·0	285·0
April ...	203·5	244·0	274·0	370·0	305·0	280·0
May ...	...	250·0	280·0	...	307·0	300·0
June ...	220·0	240·0	294·0	...	307·0	294·0
July ...	228·0	220·0	312·0	302·0	309·0	338·0
August ...	167·5	180·0	280·0	324·0	307·0	306·0
September ...	207·0	190·0	220·0	306·0	303·0	338·0
October ...	229·0	...	260·0	276·0	309·0	331·0
November ...	179·3	242·0	261·0	132·0	307·0	...
December ...	197·0	300·0	300·0	274·0	303·0	...

I have already referred to the increase in the total solid matter which is going on in this well, partly I believe due to the fixing of the oil-engine, and partly due in 1911 to the abnormally dry character of the season.

Throughout the period under consideration, alkalinity, calculated as sodium carbonate (Na_2CO_3), is either absent or forms only a very small proportion of the total salts present. As a matter of fact, it occurs quite irregularly, and seems to have little relation to season. There is no such relationship to season as was found in the well water at Dhulia.

[For Statement see page 22.]

The actual figures are as follows:—

Alkalinity—Oil-Engine Wells.
(Percentage of Total Salts.)

	1908.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January	2·1	1·9	...
February	1·8	1·5	...
March	4·4	1·7	2·0	...
April ...	5·1	...	1·4	1·0	1·9	...
May	1·4	...
June	2·4	...	...	1·4	0·5
July	1·9	...	0·4
August	1·0	1·3	...	1·7	1·4
September	1·7	...	...	1·5	...
October	4·0	1·2	...
November	3·7	...	4·9	...	...
December	1·4	...	0·5	...	...

Nitrates are almost always absent from this water. They appeared, however, in small proportion on two occasions, in April 1909, and in August and September of the same year. I cannot, in any way, account for this appearance.

The variation in the chlorides is very remarkable. They go down very considerably in the rains in some cases and then gradually rise again. The extent to which they go down, and the time at which the fall occurs depends apparently as the amount and time of the heavy rainfall in the districts feeding these wells. The actual figures are as follows:—

[For Statement see page 23.]

Chlorine—Oil-Engine Well.

(Percentage of Total Salts.)

	1908.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January ...	...	...	50.0	49.8	50.9	52.7
February ...	...	51.4	50.0	52.4	51.2	50.6
March ...	45.4	...	47.7	53.1	52.7	51.4
April ...	50.5	50.5	51.2	55.3	51.1	55.6
May ...	...	51.8	53.6	...	51.9	49.6
June ...	50.7	55.7	47.6	...	52.0	49.4
July ...	50.5	49.4	43.1	36.0	51.3	51.2
August ...	54.1	36.6	50.5	44.8	51.8	55.5
September ...	54.5	23.9	51.5	37.7	51.0	50.8
October ...	52.5	...	49.1	53.0	51.8	51.5
November ...	51.1	32.5	53.2	37.2	51.7	...
December ...	47.1	50.1	52.9	53.1	51.1	...

The fall in the proportion of chlorine during the rains hardly appears in 1908, 1912 and 1913, but in 1909, 1910 and 1911 it is very marked indeed though the date on which it appears is different. In 1909 there was little effect shown in the July sample, while in 1910 and 1911 the effect of the rains is already markedly felt in that month. I cannot make out the connection between this and the rainfall.

Magnesium is almost always present in larger amount than Calcium. I have already referred in connection with the well at Dhulia to this almost universal characteristic of trap waters. The proportion between the two, however, varies considerably, and the presence of excess of magnesium (over lime) is by no means universal. Taking the amount of magnesium as the basis, the proportion of lime is as follows:—

[For Statement see page 24.]

Calcium
—*Oil-Engine Well.*
Magnesium

[Percentage of Calcium (Mg. = 100) .]

	1908.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January ...	...	...	71	61	70	58
February ...	...	72	36	61	65	60
March ...	14	...	30	66	57	64
April ...	106	71	75	193	75	82
May ...	...	74	86	...	72	78
June ...	86	88	61	...	67	74
July ...	56	73	54	50	72	33
August ...	136	136	91	112	48	78
September ...	77	85	65	146	64	81
October ...	104	...	50	17	60	61
November ...	104	98	11	70	66	...
December ...	74	66	77	64	68	...

The variations are, obviously exceedingly wide, and it is not possible to draw conclusions except with exceeding uncertainty. It would appear probable, however, that there is a tendency for the proportion of calcium to magnesium to be high in the dry weather of April and May, decrease with the first rains, and then increase in the later part of the rains. The proportion is high in April and in August of each year.

The sulphuric acid, and the carbonic acid are very constant in proportion, the former even more than the latter,—and on the whole they vary together,—increase in proportion when the chlorine diminishes in the rains, and also decreases when, as in the later records, the chlorine has increased in proportion.

Well No. III.—(Roofed Well)—This well lies almost due West of that last considered at a distance of 341 feet. It is thirty-eight feet deep, and in the early part of July 1912 there was a depth of eleven feet of water. This well is only used very occasionally, and the principal interest of my series of figures is to show how the depth of the water, the salts in the water vary in a well which is not used and into which no surface water whatever can drain.

The variation in the level of the water at different times of the various years is shown in the following table, and is very interesting as showing the effect of the season on the force of the streams feeding the well.

Distance of the water from the surface of the ground :—

	1908.	1909. A	1910.	1911.	1912.	1913.	Average.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.
January ...	...	...	29	29	29½	29	29
February ...	...	26	29½	28½	30½	29½	28½
March ...	...	26	29	28½	30	30½	28½
April ...	...	28	29½	...	30	30½	29½
May ...	...	27½	30½	29½	...	30½	29½
June ...	26	26½	28½	30½	32½	28	28½
July ...	25	26½	27½	29½	27	28	27½
August ...	23½	23½	22	30	24½	25½	24½
September ...	...	22	22½	25½	24	25½	24
October ...	28	26½	25½	26½	25	32½	27½
November ...	26	28	27½	30½	27	...	27½
December ...	25½	28½	27½	30½	29	...	28½

The water, as a matter of fact, hardly rises till July, and reaches its highest level in September, that is to say, nearly two months after the actual time of highest rainfall.

The variation in the composition of the water circulating and feeding this well is perhaps sufficiently shown by the figures for the total solid matter. Details of composition may be found in the figures in the appendix :—

Well No. III—Total Salts.

	1908.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January ...	...	...	170·0	260·0	272·0	198·0
February ...	...	165·5	168·0	300·0	273·0	197·0
March ...	159·0	170·5	170·0	300·0	274·0	207·0
April ...	153·0	167·0	160·0	...	263·0	205·0
May ...	...	168·0	150·0	...	...	193·0
June ...	160·5	162·0	164·0	...	272·0	197·0
July ...	173·0	132·0	134·0	254·0	241·0	182·0
August ...	126·4	118·0	280·0*	255·0	152·0	193·0
September ...	173·0	108·0	143·0	285·0	173·0	179·0
October ...	...	122·0	180·0	225·0	201·0	193·0
November ...	142·0	180·0	125·0	235·0	196·0	...
December ...	183·0	86·0	280·0	262·0	187·0	...

* Omitted from calculations below.

This well, representing the actual water circulating in the soil without constant removal, shows well the effect of the drought of 1911 on the amount of salt in the water. The average content, in parts per 100,000 for the years recorded is: 1908 (8 months)—159.9; 1909 (11 months)—144.0; 1910 (11 months)—166.0; 1911 (9 months)—264.0; 1912 (11 months)—228.0; 1913 (10 months)—195.0. The effect is apparently only passing off two years after.

Well No. IV (Village well).—This well will probably give a better indication than any of the others of the actual variation in the composition of these subsoil waters. It is not employed for irrigation, but is the well regularly used for drinking by the people of Athwa village. The use of it, therefore, very regular, but is not excessive. The well itself is closed in. It lies 297 feet due West from well No. III and 638 feet due West from well No. II. The total depth is twenty-seven feet, and it usually has a depth of five feet of water. The distance of the surface of the water from the surface of the ground is shown in the following figures:—

	1908.	1909.	1910.	1911.	1912.	1913.	Average.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.
January ...	...	...	...	25½	28½	26	26½
February ...	...	27	...	26½	27½	27	27
March ...	...	26	...	27½	27	27½	27
April ...	...	29½	...	27½	27	27½	27½
May ...	...	29	28	...	29	27½	28½
June ...	26	26	...	27½	30	27½	27½
July ...	26	...	26	28	22	24½	25½
August ...	28	...	24	27	24½	23	24½
September ...	24½	29½	24	27	24½	22½	24½
October ...	25½	24	23	25½	24½	30	25½
November ...	27	24½	24½	27½	23	...	25½
December ...	26½	...	27½	28	29	...	27½

This shows a nearly constant level from December to June, differing a little on one side or other of the mean owing to more or less water being used on any day. Then in July there is a rise of two feet or so, a further foot in August, and this level is maintained through September. Then the water gradually drops to the dry season level, reaching it by December. The rise is about a month later than the coming of the rain; the fall is about a month later than its ceasing.

This well has been throughout the least saline of any of this series, and by far the most constant in composition. The following table shows the total amount of solid matter in the water :—

Total Solids—Village Well.

Parts per 100,000.

	1908.	1909.	1910.	1911.	1912.	1913.
January ...	...	...	...	150·0	181·0	169·0
February ...	...	138·1	...	120·0	155·0	180·0
March ...	110·0	136·5	...	130·0	155·0	189·0
April ...	131·0	153·0	...	120·0	170·0	159·0
May ...	...	133·3	140·0	...	147·0	152·0
June ...	117·6	116·0	128·0	...	153·0	207·0
July ...	126·6	...	118·0	154·0	147·0	161·0
August ...	122·7	...	150·0	149·0	147·0	161·0
September ...	214·5	104·0	140·0	159·0	145·0	165·0
October ...	215·7	106·0	150·0	172·0	163·0	155·0
November ...	116·7	120·0	130·0	159·0	163·0	...
December ...	135·9	...	160·0	130·0	175·0	....

The first point about these figures is the very great difference between them and those given already for well No. II, although the latter is only 638 feet away, and the large difference even between this and well No. III. These alone would prove that we are dealing not with any generalised sub-soil water, but with a number of streams which cross the line of these wells,—streams which are distinct in origin and in character. The second point to notice is the relatively very great constancy of the amount of salt carried by the water of this well. With the exception of a sudden increase in September and October 1908, and a slight fall (not moreover always present) usually in the rainy season, the figures vary very little, in spite of the constant and daily use of the water. This indicates a distant source and a fair underground reservoir from which this particular well is fed. This is confirmed by the fact that in the long drought of 1900-01, when nearly all other wells dried up, this one still gave a supply sufficient for drinking for the village. It is also confirmed by the fact that the drought of 1911 made very little difference to the amount of salts contained in the water of this well. While there has been a slight gradual increase in the amount of salts, it is evidently independent of the drought in that year. The actual figures of the average salt content for each year are as follows :—

1908 (9 months) ...143 parts per 100,000.

1909 (8 months) ...126 „ „

1910 (8 months)	...139	parts per 100,000.
1911 (10 months)	...144	„ „
1912 (12 months)	...158	„ „
1913 (10 months)	...169	„ „

The fact that we have a very constant supply of water of very constant composition gives a special interest to the water of this well, and we may consider the amounts of the constituents present in some detail.

In the first place this water is never alkaline. This is in marked contrast with the previous waters we have considered. The carbon dioxide has always been present in quantity enough to form, at least, bi-carbonates. Secondly, the water is, in all cases except one, free from nitrates. This is what might have been expected in a water originating in a deep seated fissure.

The proportion of chlorides in the salts is much less than in the last well considered, and varies much less. The actual figures are as follows:—

Chlorine—Village Well.

(Percentage of Total Salts.)

	1908.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January	...	...	...	45.3	30.3	38.5
February	...	37.5	...	41.6	36.2	38.3
March	...	37.8	...	40.5	36.2	38.7
April	40.2	39.5	...	37.5	33.8	40.1
May	...	38.6	40.0	...	38.2	36.1
June	36.0	35.4	38.3	...	36.7	46.4
July	36.6	...	36.5	34.3	40.9	34.9
August	40.5	...	40.7	35.4	39.5	40.9
September	51.6	32.2	37.0	36.9	42.0	38.9
October	49.1	31.8	41.1	39.0	38.3	42.3
November	36.4	31.2	41.2	37.1	38.3	...
December	35.0	...	43.1	45.2	35.6	...

Here with the exception of a sudden increase in the proportion of chlorine in September and October 1908, a less marked one at the end of 1910, and perhaps one in June 1913, there is very little variation. The effect of the rains is negligible, either one way or the other.

The results of the determination of the sulphuric acid (as sulphates) presents one point of interest. During the monsoon season of 1911 (the year of drought) occurred the only large increase in the amount of this constituent which lasted for any length of time. In that year there was a rise in the amount of sulphates which lasted from July to September. It is interesting to compare this result with that already noted from the well at Dhulia (see page 15). As in the water from Dhulia, the sulphates only form a relatively minor constituent in these deep-seated trap well waters.

The proportion of calcium to magnesium is indicated in the following table :—

Calcium
Magnesium . Village Well.

(Percentage of Calcium to Magnesium.)
(Mg=100.)

	1908.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January ...	...	...	...	202	70	49
February ...	...	70	...	85	62	64
March ...	...	74	...	221	55	54
April ...	36	68	...	61	62	80
May ...	...	77	71	...	2 (?)	59
June ...	73	146	45	...	68	107
July ...	68	...	111	123	70	91
August ...	135	...	119	53	87	70
September ...	46	96	43	77	46	82
October ...	129	92	55	35	64	58
November ...	89	49	56	60	96	...
December ...	91	...	97	39	75	...

It is difficult to interpret these figures in the light of any seasonal changes at Surat itself, as would probably be expected in what is evidently a deep fissure water, but the proportion of calcium while generally less than the magnesium in each year takes a rise, followed by a fall, and this again by a second rise. The period is not the same each year, but so far as they show anything, they are not inconsistent with what has been already pointed out for well No. II.

The three remaining wells at Athwa are interesting, because each of them, during the continuance of this experiment were deepened by one or more borings in the bottom of the well as follows :—

	Original depth of well.	Date of Boring.	Depth of Borings.
Well No. V (Stepped well) ...	31 feet	March 1909	25 feet (2 borings)
Well No. VI (Panas well) ...	45 feet	May 1909	43 feet
Well No. VII (Bhatar New Well) ...	43 feet	December 1909	46 feet

The bores, in each case, only penetrated through soft material, and did not in any case reach the trap rock which probably underlies this area. There was no material rise of the water in the wells as a result of these borings, and it is evident that artesian or sub-artesian water was not tapped in any case.

Well No. V (Stepped well) lies 1,497 feet almost due South from the line of four wells already discussed. It is a large stepped well in fairly constant use for human consumption chiefly, and little for irrigation. In July 1912 it contained seven feet of water. The total solids in the water, before and after boring, is shown in the following table :—

Total Solids—Stepped Well.

Parts per 100,000.

	1908.	1909.	1910.	1911.	1912.	1913.
January ...	...	...	160·0	180·0	144·0	140·0
February ...	...	128·1	140·0	150·0	133·0	137·0
March ...	131·0	160·2	188·0	...	111·0	133·0
April ...	135·0	140·7	160·0	120·0	135·0	124·0
May ...	...	163·0	144·0	...	130·0	130·0
June ...	121·0	160·0	126·0	...	144·0	131·0
July ...	119·0	148·0	108·0	132·0	127·0	111·0
August ...	103·5	150·0	130·0	150·0	129·0	131·0
September ...	155·0	100·0 (?)	130·0	132·0	126·0	119·0
October ...	215·0	118·0	150·0	59·0	136·0	126·0
November ...	109·0	120·0	?	101·0	137·0	...
December ...	118·0	140·0	150·0	136·0	131·0	...

In the first place, the boring seems to have made no difference to the amount of the total solids present in the water. This is perhaps what would be expected unless water under pressure were found in the boring which is not the case. In the second place, the water here feeding this well is affected very quickly by the rainfall, as the reduction in the total solids in the water follows, in each year, shortly after the heavy rainfall has been received. This well represents in fact the exact opposite of the 'Village well' last described. There the water seemed independent of the local rainfall: here it is extremely sensitive to it. It is, therefore, essentially a local water.

The next point of interest is that this very largely local water is very often alkaline. The following table indicates the results:—

Alkalinity—Sodium Carbonate (Na_2CO_3) in Water.

Parts per 100,000

	1908.	1909.	1910.	1911.	1912.	1913.
January ...	...	...	...	3·7	7·4	0·7
February ...	...	...	...	4·8	8·1	0·7
March ...	8·7	...	10·1	...	8·1	0·7
April ...	8·8	...	5·8	12·2	12·6	10·4
May ...	...	...	...	...	6·7	...
June ...	2·4	3·7	...	...	0·7	...
July ...	...	...	...	6·1	2·2	...
August ...	...	1·8	4·2	4·9	3·7	4·4
September ...	...	4·8	...	9·8	9·6	3·0
October ...	2·1	...	...	16·6	4·4	5·9
November ...	...	3·7	10·8	9·2	...	...
December ...	...	4·8	1·1	7·4	2·2	...

These results are peculiar, but are fairly regular. The maximum is reached as a rule in April. The amount of alkalinity falls in May, and remains low till August after which it gradually rises till October and November, falls a little in December to February and then rises again to the maximum. At present, I do not understand the distribution.

The following table shows the variation in the proportion of chlorine to the other constituents in the water :—

Chlorine—Stepped Well.
(Percentage of Total Salts.)

	1008.	1909.	1910.	1911.	1912.	1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
January ...	...	...	42·6	43·1	39·2	38·6
February ...	...	33·7	42·6	39·5	39·5	36·6
March ...	46·4	45·0	50·3	...	46·1	38·5
April ...	45·6	48·6	41·5	45·9	43·6	43·0
May ...	...	46·3	44·9	...	38·7	37·0
June ...	44·0	22·2	45·9	...	37·4	34·9
July ...	41·5	44·0	47·9	36·9	37·3	35·3
August ...	41·3	33·3	39·0	32·5	38·8	35·1
September ...	49·8	33·9	40·1	35·7	38·7	39·6
October ...	51·1	36·0	39·1	7·6)	35·7	40·9
November ...	42·0	41·6	(12·9)	48·5	36·4	...
December ...	43·9	42·0	41·2	41·9	40·5	...

These figures show that although the water in the well is largely of relatively local origin, yet there is no sea water seepage. It lies 1,500 feet further from the tidal river Tapti than the last series, and is evidently not influenced by it to any appreciable extent. The figures show the reduction in the proportion of chlorides which would be expected in the rains, when the less soluble decomposition products would naturally be present in larger proportion than at other times. On the other hand, the proportion of chlorides is always higher than in a pure rock fissure water like that of Dhulia.

The variation in the amount of sulphates and carbonates presents no special features for remark. It certainly cannot be said that their proportion regularly increases or decreases with the season. The proportion of calcium to magnesium on the whole becomes greater after heavy rain, though the results are somewhat irregular.

Well No. VI (Panas Well) lies 1,627 feet almost due South of the last, and is thus still further away from the tidal river Tapti to which I am inclined to attribute most of the sea water seepage into the series of wells I am discussing. It is a good well, however, constantly used for irrigation rather deeper than the others (forty-five feet) and containing in July 1912, water eighteen feet deep. A boring was made forty-three feet deep, in the bottom of the well in May 1909, but the water did not rise, and it has produced

very little change in its composition. The content of solid matter in this well throughout the duration of my records is as follows:—

Total Solids—Panas Well.

Parts per 100,000.

	1908.	1909.	1910.	1911.	1912.	1913.
January ....	..	...	270·0	220·0	294·0	185·0
February ...	...e	130·0	170·0	222·0	280·0	215·0
March ...	...	124·0	190·0	350·0	241·0	190·0
April ...	134·0	132·0	230·0	140·0	268·0	218·0
May ...	...	...	300·0	...	298·0	168·0
June ...	126·0	108·0	278·0	...	...	174·0
July ...	152·0	180·0	254·0	132·0	261·0	148·0
August ...	117·0	172·0	190·0	251·0	186·0	214·0
September ...	265·0	126·0	180·0	229·0	181·0	203·0
October ...	200·0	136·0	200·0	180·0	195·0	209·0
November ...	111·0	180·0	203·0	235·0	227·0	...
December ...	131·4	250·0	230·0	296·0	227·0	...

Here we have a case in which the amount of solids in the water seems totally independent of the rainfall. Sometimes in the rainy season the solids decrease: sometimes it is the opposite. It looks rather as if the rainy season awakened new and additional supplies, which have a quite different composition from that which normally supplies the well. For this reason,—that we do not appear to be dealing with a single supply or a single series of supplies, I refrain from discussing these figures in detail. The actual figures of analysis will be found in the appendix.

Well No VII (Bhattar Well).—This well which is the newest of the series, lies 1,221 feet to the south of that last discussed. It was forty-three feet deep, entirely in soft material, and in July 1912 it contained water fourteen feet deep. The amount of water in the well followed very closely (a month later) the coming and passing of the rainy season. The well was deepened by boring in December 1909, and this rather tended to lower the height of the water and to increase the amount of salts in it.

The amount of solids in the water during the course of these tests shown by the following table :—

Total Solids—Bhattar Well.

Parts per 100,000.

	1909.	1910.	1911.	1912.	1913.
January ...	...	92	160	153	126
February ...	...	120	140	139	139
March ...	...	120	134	139	132
April ...	...	164	130	140	137
May ...	124	148	...	151	128
June ...	...	144	...	139	124
July ...	80	190	78	133	125
August ...	70	106	146	128	137
September ...	...	190	129	123	123
October ...	60	130	129	143	121
November ...	76	128	142	130	...
December ...	100	164	138	145	...

Though so near to the other wells this one nearly always is distinctly alkaline and has been getting more constantly so. It is a standing illustration of the impossibility in this part of Gujarat of calculating what will be the value of the new supply, although water be found at the same level as in wells near by, without actual test. As a matter of fact this is a distinctly questionable water from an irrigation point of view.

Alkalinity.—Bhattar Well.(CALCULATED AS Na^2CO^3 .)

Parts per 100,000.

	1909	1910	1911	1912	1913
	p. c.	p. c.	p. c.	p. c.	p. c.
January ...	...	3·7	3·7	26·6	2·9
February ...	...	...	6·4	7·4	1·5
March ...	...	10·1	5·8	5·9	None.
April ...	...	12·2	9·0	5·9	28·1
May ...	...	None.	...	18·8	4·4
June ...	...	None.	...	10·4	11·1
July ...	4·2	None.	12·2	10·4	5·2
August ...	0·8	None.	4·8	6·7	14·8
September ...	...	None.	4·9	5·2	4·4
October ...	24·9	None.	25·9	8·1	8·9
November ...	18·8	16·2	11·1	0·7	...
December ...	None.	None.	20·7	2·2	...

The difference of this well from the others, which nevertheless lie so close, is indicated by the comparatively small proportion which chlorine forms of the total salts contents, while the carbonic acid forms a much larger relative amount than is found in the other wells. This perhaps can best be illustrated by taking the average figures for these constituents in each year for the four most typical wells in this Athwa series :—

	1908.		1909.		1910.		1911.		1912.		1913.	
	CL.	CO ₂ .	CL.	CO ₂ .	CL.	CO ₂ .	CL.	CO ₂ .	CL.	CO ₂ .	CL.	CO ₂ .
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Well No. II ...	50·7	8·7	44·7	9·3	50·4	7·2	47·1	7·0	51·5	6·5	51·8	6·2
.. .. III ...	45·1	13·0	39·3	17·3	43·3	13·5	49·1	6·0	49·2	6·6	47·2	7·9
.. .. IV ...	40·7	15·2	35·5	20·2	39·7	18·7	39·1	14·5	37·2	15·8	39·5	14·6
.. .. VII ...	...	...	19·1	35·2	39·9	27·5	30·9	23·1	29·1	29·1	27·2	29·1

* 9 months only. † 7 months only. ‡ 8 months only. § 11 months only. ¶ 7 months only.

While therefore the chlorine is usually in each year at least twice and usually three times the amount of the carbonic acid in the salts in the waters of other wells, in the one which we are discussing the chlorine is only just equal to the carbonic acid and often below it in amount. In fact, while it is not a typical trap water such as those cited on page 10 and as those previously discussed from the Dhulia well, it is much more near to these pure trap waters than any of those we have considered at Surat.

The other constituents of this water do not require further special discussion. The actual figures will be found in the appendix.

Conclusions drawn from the examination of the Surat (Athwa) Well Waters.—It remains to summarise the conclusions which may be drawn from the long series of analyses of the well waters from Athwa (Surat). In doing so it must be remembered that they occur in a soil evidently derived from trap rock, from wells which do not penetrate the rock, and are waters which as they enter the wells from the East may be considered as being at any rate in large measure derived from the trap ranges to the East. Keeping this in mind, I think the following conclusions may be drawn.

(1) The sources supplying these wells do not represent a generalised subsoil water, but rather a series of separate streams which are running from East to West, and which are tapped by the wells.

(2) When not altered by infiltration from saline sources, chiefly in this case the tidal river Tapti, they approach the composition of the normal trap waters previously presented, except that in every case the chlorine is considerably higher than in a trap fissure water on the Deccan. This is particularly seen in the relationship between the lime and magnesia, and in the sulphates. It is best shown by Well No. VII, which is most remote from sea water contamination.

(3) All these waters contain much more solid matter than is usual in most of the true trap waters on the Deccan, but leaving aside the sea water infiltration, this is what would be expected as they must have had a much longer course in trap rock and trap rock residues than the Deccan waters.

(4) Other things being equal, the amount of salt in the water depends on the strength of the fresh water stream through the well. If this becomes feebler, then infiltration increases, and the evident sea water contamination is high. This is illustrated Well by Well No. II, and by general rise in the proportion of chlorine in the very dry year 1911.

(5) Though the conclusion under (4) seems to apply to nearly all these wells yet there are wells which are fed from such constant sources that there seems to be no infiltration at any time, even during a very dry year, and the composition does not seem to vary much at any time. It is evident that such wells (as Well No. IV in the present series) draws its water from a large supply which is not immediately and largely dependent on the rainfall in the near vicinity or even in the same season. In the case of Well No. IV any effect of the drought of 1911 appears gradually in 1912 and 1913.

(6) The variation in the alkalinity of the waters of these seven adjacent wells is remarkable. So far as most of them are concerned, the alkalinity is extremely small. Even the apparently deep seated supply in

Well No. IV is never alkaline. On the other hand, Well No. VII is generally alkaline and so distinctly so as to make it a dangerous water for use in irrigation. Even here it varies enormously. In 1910 it was not alkaline for the greater part of the year, in the next season (a very dry one) the alkalinity rose to a maximum, and has, on the whole, tended to decrease during the more normal years which have followed. A similar cause of events can perhaps be traced in some of the other cases.

(7) The rise and fall of the relative quantities of calcium and magnesium in these waters is curious. So far as one can see, there seems to be a tendency for the proportion of calcium to magnesium to take a rise in each year followed by a fall (generally in the beginning of the rains), this being again followed by a second rise. The period is not the same each year.

(8) The proportion of the total salts formed by sulphates is small. But just as was pointed out in the case of the well at Dhulia, it seems subject to curious sudden rises, often at the beginning of the rains, but by no means always so, which last for three or four months, when the proportion becomes normal again.

APPENDIX.

ANALYSES OF WATER FROM WELL AT DEULIA.

Composition of Salts in Well-water.

	January 1908.	Feb. 1908.	March 1908.	May 1908.	June 1908.	July 1908.	Sept. 1908.	October 1908.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	61.5	64.7	46.9	51.9	58.4	52.6	56.2	53.0
Containing—								
Calcium	7.1	6.2	12.4	8.7	10.9	13.5	15.0	9.8
Magnesium	6.0	8.0	15.1	16.0	14.9	15.9	7.5	15.8
Chlorine	14.4	11.6	22.8	17.5	17.9	22.5	19.0	16.2
Sulphuric acid (SO ₄)	4.7	3.8	6.1	3.2	4.3	4.2	11.0	3.1
Carbonic acid (CO ₂)	39.8	39.4	38.6	43.3	44.0	41.6	33.8	41.7
Nitric acid (NO ₃)	...	7.5	...	...	...	...	...	7.8
Alkalinity (as sodium car- bonate).	25.4	18.4	11.2	...	...	...	...	...

	Nov. 1908.	Dec. 1908.	Feb. 1909.	March 1909.	July 1909.	Aug. 1909.	Sept. 1909.	October 1909.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	48.4	55.5	72.8	74.0	70.0	86.0	60.0	64.0
Containing—								
Calcium	11.6	8.6	7.1	4.8	5.7	4.6	6.7	3.7
Magnesium	11.4	17.6	10.5	7.3	10.3	8.6	12.4	8.8
Chlorine	22.3	12.0	18.5	18.5	19.6	5.8	12.5	10.1
Sulphuric acid (SO ₄)	15.8	12.6	4.9	3.3	6.5	4.3	7.5	4.6
Carbonic acid (CO ₂)	23.1	44.7	36.1	36.5	38.3	33.8	44.8	40.6
Nitric acid (NO ₃)	6.7	....	5.7	4.9	...	25.2	...	10.5
Alkalinity (as sodium car- bonate).	...	...	...	21.4	...	3.4	...	...

	Nov. 1909.	Dec. 1909.	January 1910.	Feb. 1910.	March 1910.	April 1910.	May 1910.	June 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	60.0	64.0	64.0	58.0	56.0	104.0	76.0	66.0
Containing—								
Calcium	5.8	6.9	5.6	5.5	8.6	11.9	5.3	4.2
Magnesium	11.6	11.4	12.3	9.8	10.1	4.8	8.3	7.9
Chlorine	8.3	15.6	12.0	16.9	2.2	8.1	11.0	20.8
Sulphuric acid (SO ₄)	4.1	3.2	6.3	5.7	4.4	8.7	3.8	6.2
Carbonic acid (CO ₂)	44.2	39.4	41.7	41.0	44.6	29.6	36.7	37.1
Nitric acid (NO ₃)	7.8	7.2	7.6	...	...	16.9	18.4	...
Alkalinity (as sodium car- bonate).	...	5.0	...	4.5	9.4	10.6	4.1	...

	July 1910.	Aug. 1910.	Sept. 1910.	October 1910.	Nov. 1910.	Dec. 1910.	Feb. 1911.	March 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	78.0	92.0	88.0	80.0	120.0	70.0	80.0	70.0
Containing—								
Calcium	4.1	3.9	12.3	7.5	3.7	5.7	3.0	4.6
Magnesium	8.0	6.0	5.7	9.8	5.4	8.4	7.1	9.2
Chlorine	13.5	13.3	12.7	12.3	40.2	19.7	21.5	19.7
Sulphuric acid (SO ₄)	21.2	22.5	16.3	14.4	4.8	7.0	3.1	4.7
Carbonic acid (CO ₂)	34.7	29.8	31.1	36.4	20.7	33.0	36.9	38.9
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium car- bonate).	...	...	...	...	0.9	...	...	1.5

	April 1911.	May 1911.	June 1911.	July 1911.	Aug. 1911.	Sept. 1911.	October 1911.	Nov. 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	70.0	70.0	74.0	66.0	80.0	68.0	65.0	66.0
Containing—								
Calcium ...	5.1	6.3	6.5	3.8	6.4	6.4	7.3	7.2
Magnesium ...	8.4	8.4	8.2	10.8	8.4	7.2	7.2	8.4
Chlorine ...	15.0	15.0	12.5	16.0	13.2	13.1	12.5	12.3
Sulphuric acid (SO ₄) ...	4.1	3.2	14.9	16.7	13.7	3.6	3.1	3.7
Carbonic acid (CO ₃) ...	41.0	40.0	32.8	40.0	34.4	39.2	40.4	39.1
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate) ...	...	1.5	19.1	9.0	...	1.6	...	2.8

	Dec. 1911.	January 1912.	Feb. 1912.	March 1912.	April 1912.	May 1912.	June 1912.	July 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	69.0	70.0	70.0	77.0	71.0	76.0	80.0	71.0
Containing—								
Calcium ...	6.0	5.1	6.2	5.1	4.5	5.7	5.5	5.6
Magnesium ...	11.1	11.1	12.6	7.0	5.4	7.0	6.9	8.6
Chlorine ...	11.3	13.1	11.5	11.0	14.5	16.8	13.0	12.2
Sulphuric acid (SO ₄) ...	4.7	5.2	5.3	5.8	5.7	4.8	5.0	4.0
Carbonic acid (CO ₃) ...	36.6	38.2	37.1	37.4	35.5	31.7	33.1	33.9
Nitric acid (NO ₃) ...	5.8	5.7	5.7	6.1	5.6	6.7	5.6	5.0
Alkalinity (as sodium carbonate) ...	6.4	...	3.1	...	10.4	12.6	12.9	2.0

	Aug. 1912.	Sept. 1912.	October 1912.	Nov. 1912.	Dec. 1912.	January 1913.	Feb. 1913.	March 1913.	April 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	74.0	74.0	68.0	75.0	76.0	77.0	76.0	75.0	74.0
Containing—									
Calcium ...	5.9	4.8	4.7	5.8	5.7	5.1	5.7	5.8	4.8
Magnesium ...	4.4	10.1	8.1	7.8	7.2	9.0	9.2	5.4	7.7
Chlorine ...	12.9	12.9	14.2	12.9	12.7	13.6	12.7	12.9	13.1
Sulphuric acid (SO ₄) ...	4.9	5.5	3.5	3.8	3.2	4.2	4.8	3.8	3.8
Carbonic acid (CO ₃)..	38.8	32.2	33.4	36.3	37.1	36.4	37.1	40.3	39.8
Nitric acid (NO ₃) ...	6.5	6.5	5.8	6.0	5.2	6.3	5.2	5.3	6.1
Alkalinity (as sodium carbonate)	3.0	...	...	...	...	1.9	0.9	...	...

Analysis of Water from Wells at Surat.

WELL NO. I.

Composition of salts in Well water.

	March 1908.	April 1908.	June 1908.	May 1909.	June 1909.	July 1909.	August 1909.	Sept. 1909.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	192.4	200.7	220.8	165.4	134.0	118.0	76.0	44.0
Containing—								
Calcium	2.2	7.1	7.6	1.5	5.4	5.4	17.5	10.9
Magnesium	8.6	4.9	5.6	2.6	4.6	4.4	8.6	5.9
Chlorine	45.4	46.7	43.5	48.8	47.2	44.4	23.0	15.9
Sulphuric acid (SO ₄)	4.3	...	2.3	2.0	5.8	6.9	27.1	4.7
Carbonic acid (CO ₂)	20.6	18.2	17.2	12.1	15.5	13.6	24.6	40.9
Nitric acid (NO ₃)	...	...	...	...	...	...	...	3.2
Alkalinity (as sodium carbonate).	...	4.2	3.6	4.4	4.7	...	1.7	8.4

	Oct. 1909.	Nov. 1909.	Dec. 1909.	Jan. 1910.	Feb. 1910.	March 1910.	April 1910.	May 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	58.0	46.0	120.0	166.0	160.0	186.0	180.0	160.0
Containing—								
Calcium	1.9	8.7	5.0	0.7	4.0	1.3	3.8	3.5
Magnesium	3.4	6.1	5.9	5.5	4.4	4.3	7	3.7
Chlorine	12.9	14.1	42.7	41.3	46.8	47.0	46.7	50.3
Sulphuric acid (SO ₄)	16.3	6.2	3.8	8.7	4.9	5.8	4.1	10.2
Carbonic acid (CO ₂)	32.6	40.4	16.3	13.2	13.8	9.8	12.5	11.3
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	...	6.9	...	...	2.0	6.0	2.6	...

	June 1910.	July 1910.	October 1910.	March 1911.	April 1911.	July 1911.	August 1911.	Sept. 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000.)	194.0	76.0	110.0	122.0	260.0	260.0	256.0	93.0
Containing—								
Calcium	1.9	6.3	4.7	9.0	4.6	3.2	4.8	12.1
Magnesium	4.8	1.1	4.8	2.0	3.4	6.2	8.0	7.8
Chlorine	42.0	27.2	37.6	54.7	50.8	46.2	46.4	34.1
Sulphuric acid (SO ₄)	4.2	4.3	3.3	7.4	3.1	6.8	9.0	9.5
Carbonic acid (CO ₃)	11.2	17.1	19.2	15.5	8.3	10.2	7.9	17.7
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	...	...	...	4.3	1.0	3.7	1.0	9.1

	July 1912.	August 1912.	Sept. 1912.	July 1913.	August 1913.	Sept. 1913.	Oct. 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	234.0	118.0	134.0	106.0	138.0	339.0	193.0
Containing—							
Calcium	6.4	12.3	9.8	13.2	6.3	6.9	5.7
Magnesium	3.0	6.6	6.3	4.0	2.0	4.6	1.6
Chlorine	31.9	35.8	35.4	33.0	36.1	32.0	32.5
Sulphuric acid (SO ₄)	4.0	10.0	7.4	4.8	4.4	4.7	2.5
Carbonic acid (CO ₃)	9.7	17.7	16.1	17.5	15.0	15.8	11.1
Nitric acid (NO ₃)	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	0.3	1.3	1.6	...	5.3	3.6	5.3

WELL NO. II.

Composition of Salts in Well water.

	March 1908.	April 1908.	June 1908.	July 1908.	August 1908.	Sept. 1908.	Oct. 1908.	Nov. 1908.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	203.8	203.5	220.3	227.6	167.4	206.9	228.8	179.5
Containing—								
Calcium ...	1.2	5.5	5.6	4.3	9.0	5.1	7.2	8.8
Magnesium ...	8.6	5.2	6.5	7.7	6.5	6.8	6.9	8.5
Chlorine ...	45.4	50.5	50.7	50.5	54.1	54.5	52.5	51.1
Sulphuric acid (SO ₄) ...	6.0	1.2	5.0	6.9	2.4	4.4	4.7	4.8
Carbonic acid (CO ₂) ...	2.5	11.2	8.8	8.0	8.1	7.1	7.8	9.9
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate). ...	...	.1	...	...	...	...	...	...

	Dec. 1908.	Feb. 1909.	April 1909.	May 1909.	June 1909.	July 1909.	August 1909.	Sept. 1909.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	197.0	231.0	244.1	250.2	240.0	220.0	180.0	190.0
Containing—								
Calcium ...	5.8	5.4	4.9	4.9	5.7	6.0	7.1	7.8
Magnesium ...	7.8	7.5	6.9	6.6	6.5	8.2	5.2	9.2
Chlorine ...	47.1	51.4	50.5	51.8	55.7	49.4	36.6	28.9
Sulphuric acid (SO ₄) ...	4.5	5.3	4.7	4.1	5.5	6.5	10.5	6.4
Carbonic acid (CO ₂) ...	14.7	9.8	9.0	8.6	8.4	9.4	19.2	11.0
Nitric acid (NO ₃) ...	...	...	0.6	...	...	...	1.7	0.7
Alkalinity (as sodium carbonate). ...	...	...	...	...	2.4	...	1.0	1.7

	Nov. 1909.	Dec. 1909.	Jan. 1910.	Feb. 1910.	March 1910.	April 1910.	May 1910.	June 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	242.0	300.0	260.0	260.0	280.0	274.0	260.0	294.0
Containing—								
Calcium ...	4.4	4.8	4.9	4.0	2.1	4.4	4.2	4.5
Magnesium ...	4.5	6.5	6.9	11.1	7.0	5.9	4.9	7.4
Chlorine ...	32.5	50.1	50.0	50.0	47.7	51.2	53.6	47.6
Sulphuric acid (SO ₄) ...	7.3	4.4	5.5	9.3	6.0	5.2	5.7	not de- termin- ed.
Carbonic acid (CO ₃) ...	8.1	7.0	8.5	7.0	6.6	7.7	8.7	11.6
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate.)	3.7	1.4	...	..	4.4	1.4	...	...

	July 1910.	August 1910.	Sept. 1910.	Oct. 1910.	Nov. 1910.	Dec. 1910.	Jan. 1911.	Feb. 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	312.0	280.0	220.0	260.0	261.0	300.0	180.0	320.0
Containing—								
Calcium ...	3.1	4.0	5.4	3.7	0.5	1.7	2.7	1.9
Magnesium ...	5.7	4.4	8.8	7.5	4.5	2.2	4.4	3.1
Chlorine ...	43.1	50.5	51.5	49.1	58.2	52.9	48.8	52.4
Sulphuric acid (SO ₄) ...	4.0	7.3	6.4	4.3	1.1	2.6	4.3	2.6
Carbonic acid (CO ₃) ...	6.0	4.9	6.7	8.1	2.8	7.4	18.1	6.0
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate.)	...	1.3	...	...	...	...	2.1	1.8

	March 1911.	April 1911.	July 1911.	August 1911.	Sept. 1911.	Oct. 1911.	Nov. 1911.	Dec. 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	310·0	370·0	320·0	320·0	366·0	276·0	132·0	274·0
Containing—								
Calcium ...	2·1	2·9	3·4	4·7	7·3	1·3	5·1	4·1
Magnesium ...	3·2	1·5	6·8	4·1	5·0	7·5	7·3	6·3
Chlorine ...	53·1	55·3	36·0	44·8	37·7	53·0	37·2	58·1
Sulphuric acid (SO ₄) ...	2·7	2·2	9·7	9·9	8·6	5·0	3·7	5·4
Carbonic acid (CO ₂) ...	6·1	2·6	4·3	6·1	...	5·0	13·1	0·7
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate). ...	1·7	1·0	1·9	...	...	4·0	4·9	0·5

	Jan. 1912.	Feb. 1912.	March 1912.	April 1912.	May 1912.	June 1912.	July 1912.	August 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	307·0	301·0	300·0	305·0	307·0	307·0	309·0	307·0
Containing—								
Calcium ...	5·1	4·9	4·3	5·2	5·1	4·7	5·2	3·5
Magnesium ...	7·3	7·5	7·5	6·9	7·2	7·2	7·2	7·3
Chlorine ...	50·9	51·1	52·6	51·1	51·8	51·9	51·3	51·8
Sulphuric acid (SO ₄) ...	4·7	5·2	5·2	4·7	4·9	5·3	4·9	5·5
Carbonic acid (CO ₂) ...	6·7	7·0	5·2	7·1	6·6	5·1	6·7	6·2
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate). ...	1·9	1·4	1·9	1·9	1·4	1·4	...	1·6

	Sept. 1912.	Oct. 1912.	Nov. 1912.	Dec. 1912.	Jan. 1913.	Feb. 1913.	March 1913.	April 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	303.0	303.0	307.0	303.0	307.0	308.0	285.0	281.0
Containing—								
Calcium ...	3.9	4.2	4.8	5.6	4.8	4.8	4.9	5.5
Magnesium ...	6.2	6.9	7.3	8.2	7.3	7.2	7.7	6.8
Chlorine ...	51.0	51.2	51.6	51.1	52.7	50.6	51.4	55.7
Sulphuric acid (SO ₄) ...	5.4	5.9	5.1	5.7	4.6	4.7	3.6	5.0
Carbonic acid (CO ₂) ...	6.7	6.6	7.0	7.1	7.0	7.4	7.6	1.2
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	1.4	1.2	...	...	...	...	...	...

	May 1913.	June 1913.	July 1913.	August 1913.	Sept. 1913.	Oct. 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	300.0	294.0	333.0	306.0	333.0	331.0
Containing—						
Calcium ...	5.3	5.1	2.1	5.8	4.4	4.2
Magnesium ...	6.8	7.0	6.5	7.5	5.4	6.8
Chlorine ...	49.5	49.3	51.1	55.4	50.7	51.5
Sulphuric acid (SO ₄) ...	5.1	5.3	4.9	6.1	2.2	5.1
Carbonic acid (CO ₂) ...	8.9	7.2	6.1	2.9	6.9	6.3
Nitric acid (NO ₃) ...	...	...	...	...	...	...
Alkalinity (as sodium carbonate) ...	...	0.5	0.4	1.4	...	...

WELL NO. III.

	April 1908.	June 1908.	July 1908.	August 1908.	Sept. 1908.	October 1908.	Nov. 1908.	Dec. 1908.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	153.0	160.5	173.0	126.0	178.0	279.0	142.0	183.0
Containing—								
Calcium ...	7.4	2.0	4.1	7.2	4.4	3.5	7.7	3.5
Magnesium ...	4.0	6.4	5.3	5.1	4.1	2.9	6.8	4.6
Chlorine ...	46.5	43.3	44.5	43.7	44.7	51.6	43.0	38.2
Sulphuric acid (SO ₄) ...	Not deter- mined	6.4	7.1	2.3	4.3	3.5	7.0	7.9
Carbonic acid (CO ₂) ...	15.5	14.3	12.1	12.6	9.2	7.2	14.4	18.4
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate). ...	7.7	3.9	...	...	...	...	...	...

	Feb. 1909.	March 1909.	April 1909.	May 1909.	June 1909.	July 1909.	August 1909.	Sept. 1909.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	165.4	170.5	167.2	168.0	162.0	132.0	118.0	108.0
Containing—								
Calcium ...	3.9	9.5	3.6	2.1	4.4	4.2	10.8	6.7
Magnesium ...	6.4	5.3	5.2	5.6	4.0	6.6	5.2	6.8
Chlorine ...	39.8	42.2	43.1	45.1	46.9	39.6	36.0	37.5
Sulphuric acid (SO ₄) ...	2.1	6.0	5.5	4.2	6.9	8.4	12.9	4.7
Carbonic acid (CO ₂) ...	15.1	14.3	14.3	14.0	15.0	16.9	17.3	19.4
Nitric acid (NO ₃) ...	...	0.7	...	...	1.0	...	4.2	1.3
Alkalinity (as sodium carbo- nate). ...	...	...	...	...	2.3	...	1.9	7.8

	October 1909.	Nov. 1909.	Dec. 1909.	January 1910.	Feb. 1910.	March 1910.	April 1910.	May 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	122.0	180.0	86.0	170.0	168.0	170.0	160.0	150.0
Containing—								
Calcium	5.9	4.0	7.9	5.9	3.3	2.4	3.0	2.9
Magnesium	6.4	4.7	10.9	1.6	4.5	4.7	4.6	4.9
Chlorine	37.9	41.5	22.8	40.4	40.0	41.8	49.6	39.7
Sulphuric acid (SO ₄)	4.8	7.6	12.9	7.0	5.9	7.7	1.0	19.1
Carbonic acid (CO ₂)	20.7	13.5	29.8	8.9	16.1	18.8	15.4	13.7
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate).	...	5.0	4.9	...	...	5.0	4.8	...

	June 1910.	July 1910.	August 1910.	Sept. 1910.	October 1910.	Nov. 1910.	Dec. 1910.	January 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	164.0	134.0	280.0	148.0	180.0	125.0	280.0	260.0
Containing—								
Calcium	5.6	2.1	1.6	1.9	3.1	1.6	3.6	2.8
Magnesium	5.3	4.4	2.4	4.6	4.6	3.7	7.6	2.1
Chlorine	36.7	42.5	49.6	44.3	42.1	42.8	56.7	55.7
Sulphuric acid (SO ₄)	7.5	6.1	4.0	5.5	4.0	Not deter- mined	1.4	3.6
Carbonic acid (CO ₂)	16.0	14.8	7.7	12.4	14.7	23.0	5.1	3.0
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate).	...	...	1.9	...	...	13.4	...	2.0

	Feb. 1911.	March 1911.	July 1911.	August 1911.	Sept. 1911.	October 1911.	Nov. 1911.	Dec. 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	300.0	300.0	254.0	255.0	285.0	225.0	235.0	262.0
Containing—								
Calcium	3.1	3.2	2.8	4.1	3.9	5.1	4.9	3.3
Magnesium	1.6	1.8	6.8	5.6	5.5	6.4	7.1	5.8
Chlorine	52.5	47.7	46.5	46.1	44.1	50.5	49.6	49.0
Sulphuric acid (SO ₄)	1.9	2.1	12.8	9.4	10.8	3.8	5.9	8.8
Carbonic acid (CO ₃)	6.6	6.6	4.8	7.6	7.4	7.4	6.4	4.1
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	3.0	2.8	2.9	1.4	3.8	4.9	2.7	1.4

	January 1912.	Feb. 1912.	March 1912.	April 1912.	June 1912.	July 1912.	August 1912.	Sept. 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	272.0	273.0	274.0	263.0	272.0	241.0	152.0	173.0
Containing—								
Calcium	4.6	4.9	4.5	5.1	5.2	4.3	6.0	5.0
Magnesium	5.5	5.8	6.2	6.0	5.8	5.0	7.5	8.6
Chlorine	48.8	51.0	50.4	51.2	48.8	49.5	47.8	48.4
Sulphuric acid (SO ₄)	4.7	4.6	5.0	4.9	5.8	4.9	8.1	7.8
Carbonic acid (CO ₃)	6.1	6.1	6.0	6.8	6.4	7.1	6.1	7.0
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	2.4	1.0	1.8	0.8	2.7	1.5	0.9	1.7

	October 1913.	Nov. 1912.	Dec. 1912.	January 1913.	Feb. 1913.	March 1913.	April 1913.	May 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	201.0	196.0	187.0	198.0	197.0	207.0	205.0	195.0
Containing—								
Calcium ...	3.5	4.2	3.2	4.4	5.8	6.4	5.0	4.2
Magnesium ...	5.2	4.6	5.5	4.5	7.1	4.9	4.1	4.7
Chlorine ...	47.0	48.2	49.8	47.7	42.4	45.8	49.5	41.9
Sulphuric acid (SO ₄) ...	6.1	4.6	6.1	4.1	6.4	5.3	4.2	4.8
Carbonic acid (CO ₂) ...	7.0	6.7	7.3	7.4	7.9	5.8	8.0	5.9
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate). ...	...	...	0.3	0.3	...	...	2.8	...

	June 1913.	July 1913.	August 1913.	September 1913.	October 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	197.0	182.0	198.0	179.0	193.0
Containing—					
Calcium ...	5.1	4.4	5.0	4.9	3.9
Magnesium ...	4.9	3.5	3.8	4.6	2.0
Chlorine ...	47.3	43.1	46.8	48.2	39.1
Sulphuric acid (SO ₄) ...	4.6	4.2	4.6	4.6	5.9
Carbonic acid (CO ₂) ...	8.0	7.3	7.5	8.3	12.2
Nitric acid (NO ₃) ...	...	...	...	...	...
Alkalinity (as sodium carbo- nate). ...	...	1.2	3.0	1.6	3.8

WELL No. IV.

	April 1908.	June 1908.	July 1908.	August 1908.	Sept. 1908.	October 1908.	Nov. 1908.	Dec. 1908.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	131.0	117.6	126.6	122.7	214.5	215.7	116.7	135.9
Containing—								
Calcium	6.9	4.4	6.6	7.4	8.3	3.6	5.5	3.2
Magnesium	1.9	6.0	9.7	5.5	7.2	2.8	6.2	3.5
Chlorine	40.2	36.0	36.6	40.5	51.6	49.1	36.4	35.0
Sulphuric acid (SO ₄)	4.0	7.5	3.2	6.0	3.6	2.8	8.8	8.5
Carbonic acid (CO ₂)	14.0	20.5	16.2	16.7	9.3	9.6	18.6	16.7
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	1.7	4.5	...	...	...	0.7	...	5.5

	Feb. 1909.	March 1909.	April 1909.	May 1909.	June 1909.	Sept. 1909.	October 1909.	Nov. 1909.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	138.1	136.5	153.0	133.3	116.0	104.0	106.0	120.0
Containing—								
Calcium	3.2	2.6	2.1	3.0	4.1	5.0	4.5	2.7
Magnesium	4.6	3.5	3.1	3.9	2.3	5.2	4.9	5.5
Chlorine	37.5	37.8	39.5	38.6	35.4	32.2	31.8	31.2
Sulphuric acid (SO ₄)	5.7	5.4	4.8	4.6	6.4	7.0	6.2	7.9
Carbonic acid (CO ₂)	19.3	18.8	17.3	17.5	22.1	20.0	24.0	22.9
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	5.8	10.9	11.5	7.5	...	6.6	...	...

	May 1910.	June 1910.	July 1910.	August 1910.	Sept- 1910.	October 1910.	Nov. 1910.	Dec. 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	140.0	128.0	118.0	150.0	140.0	150.0	180.0	160.0
Containing—								
Calcium	2.9	2.2	8.1	4.8	2.9	2.1	1.5	8.5
Magnesium	4.1	4.9	4.6	8.6	6.7	8.8	2.7	8.6
Chlorine	40.0	38.3	36.5	40.7	37.0	41.1	41.2	48.1
Sulphuric acid (SO ₄)	18.8	4.8	5.2	5.2	5.7	1.1	8.7	8.9
Carbonic acid (CO ₃)	19.5	21.0	20.6	14.7	18.9	21.6	15.2	18.1
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium car- bonate).	...	...	...	5.3	...	...	8.8	0.7

	January 1911.	Feb. 1911.	March 1911.	April 1911.	July 1911.	August 1911.	Sept. 1911.	October 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	150.0	120.0	130.0	120.0	154.0	149.0	159.0	172.0
Containing—								
Calcium	9.9	6.8	6.2	8.8	8.2	2.6	2.7	1.8
Magnesium	4.9	7.4	2.8	5.4	2.6	4.9	8.5	5.2
Chlorine	45.8	41.6	40.5	37.5	34.8	35.4	36.9	33.0
Sulphuric acid (SO ₄)	5.5	6.5	6.8	4.1	13.0	12.9	12.8	7.4
Carbonic acid (CO ₃)	10.5	14.0	13.4	13.0	19.4	14.6	12.2	18.6
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium car- bonate).	7.7	4.4	3.6	10.1	8.0	6.5	6.1	8.6

	Nov. 1911.	Dec. 1911.	January 1912.	Feb. 1912.	March 1912.	April 1912.	May 1912.	June 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	153.0	130.0	161.0	155.0	155.0	170.0	147.0	153.9
Containing—								
Calcium ...	4.1	1.8	2.4	2.8	3.0	2.8	0.1	3.6
Magnesium ...	7.0	4.5	8.5	4.5	5.6	8.7	4.3	5.4
Chlorine ...	37.0	43.2	30.8	36.2	36.2	33.8	33.0	36.6
Sulphuric acid (SO ₄) ...	5.9	6.2	9.9	5.0	5.0	10.5	7.0	7.3
Carbonic acid (CO ₂) ...	18.8	18.3	15.5	13.1	17.4	16.5	13.6	15.8
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	7.2	3.4	0.8	2.8	2.8	4.3	10.0	3.8

	July 1912.	August 1912.	Sept. 1912.	October 1912.	Nov. 1912.	Dec. 1912.	January 1913.	Feb. 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	147.0	147.0	145.0	143.0	163.0	175.0	169.0	180.0
Containing—								
Calcium ...	3.0	4.0	1.9	2.7	1.7	3.2	1.3	2.6
Magnesium ...	4.2	4.7	4.1	4.1	4.6	4.3	3.8	4.2
Chlorine ...	40.8	39.5	42.0	33.2	33.2	35.6	33.5	33.3
Sulphuric acid (SO ₄) ...	4.7	3.3	5.6	7.1	7.8	7.3	5.3	4.9
Carbonic acid (CO ₂) ...	17.1	15.6	16.0	15.7	16.8	15.6	16.5	15.9
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	1.5	3.0	5.1	...	0.9	0.8	0.8	1.2

	March 1913.	April 1913.	May 1913.	June 1913.	July 1913.	August 1913.	Sept. 1913.	October 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	188.0	159.0	152.0	207.0	161.0	161.0	165.0	155.0
Containing—								
Calcium	2.1	3.2	2.3	4.8	2.9	3.7	3.1	1.8
Magnesium	4.0	0	4.0	4.4	3.2	5.3	3.8	3.0
Chlorine	38.7	40.1	36.1	46.4	34.9	40.9	38.8	42.3
Sulphuric acid (SO ₄)	4.4	5.7	6.4	4.7	6.8	8.5	8.2	0.8
Carbonic acid (CO ₂)	16.1	14.9	17.5	7.6	16.2	10.5	12.5	18.8
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	0.4	3.3	...	...	1.8	10.1	2.2	...

WELL NO. V.

	March 1908.	April 1908.	June 1908.	July 1908.	Aug. 1908.	Sept. 1908.	Oct. 1908.	Nov. 1908.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	131.0	135.0	121.0	119.0	103.5	155.0	215.0	109.0
Containing—								
Calcium	...	4.8	8.7	7.6	11.8	8.0	5.3	10.6
Magnesium	6.2	4.0	5.0	7.2	5.6	8.5	3.2	6.8
Chlorine	46.4	45.6	44.0	41.5	41.3	49.8	51.1	42.0
Sulphuric acid (SO ₄)	3.4	...	4.0	7.2	7.3	4.2	2.6	5.2
Carbonic acid (CO ₂)	13.0	16.1	16.5	16.7	15.5	11.3	8.5	17.0
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	6.6	6.4	1.9	...	...	...	0.0	...

	Dec. 1908.	Feb. 1909.	Mach 1909.	April 1909.	May 1909.	June 1909.	July 1909.	Aug. 1909.
	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.
Total Salts (Parts per 100,000)	118.0	128.0	160.0	141.0	163.0	124.0	148.0	150.0
Containing—								
Calcium	6.4	0.6	6.2	5.9	4.1	3.8	5.5	8.2
Magnesium	5.5	6.4	5.3	3.9	6.3	2.1	6.4	4.4
Chlorine	43.9	33.7	45.0	48.6	46.3	22.2	44.0	33.3
Sulphuric acid (SO ₄)	5.9	4.8	4.7	5.5	3.5	2.7	6.3	4.5
Carbonic acid (CO ₂)	14.6	17.6	14.0	8.9	14.0	6.9	14.0	13.0
Nitric acid (NO ₃)	...	...	...	...	...	...	...	5.8
Alkalinity (as sodium carbonate).	...	...	...	...	...	1.1	...	1.1

	Sept. 1909.	Oct. 1909.	Nov. 1909.	Dec. 1909.	Jan. 1910.	Feb. 1910.	March 1910.	April 1910.
	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.
Total Salts (Parts per 100,000)	100.0	118.0	120.0	140.0	160.0	140.0	188.0	160.0
Containing—								
Calcium	6.4	6.4	6.6	4.2	5.7	4.2	3.8	5.0
Magnesium	8.0	4.7	6.9	7.3	7.0	6.8	4.9	5.4
Chlorine	33.9	36.0	41.6	42.0	42.6	42.6	50.3	41.5
Sulphuric acid (SO ₄)	10.3	5.2	6.1	5.5	4.8	2.9	6.9	4.1
Carbonic acid (CO ₂)	18.0	22.2	16.2	14.3	15.6	17.6	12.3	17.1
Nitric acid (NO ₃)	1.4	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	4.8	...	3.0	3.4	...	...	5.3	3.3

	May 1910.	June 1910.	July 1910.	Aug. 1910.	Sept. 1910.	Oct. 1910.	Nov. 1910.	Dec. 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	144.0	126.0	108.0	180.0	180.0	150.0	40.0	150.0
Containing—								
Calcium	4.1	4.7	1.8	5.8	2.4	3.7	5.0	4.5
Magnesium	5.7	6.7	1.0	2.5	5.4	5.2	11.5	2.8
Chlorine	44.9	45.9	47.9	39.0	40.1	39.1	12.9	41.2
Sulphuric acid (SO ₄)	8.3	9.7	5.0	7.5	6.9	6.0	5.1	2.1
Carbonic acid (CO ₃)	15.2	16.3	13.4	15.2	15.2	16.4	52.7	16.5
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	...	...	...	3.2	...	...	26.9	0.7

	Jan. 1911.	Feb. 1911.	April 1911.	July 1911.	Aug. 1911.	Sept. 1911.	Oct. 1911.	Nov. 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts Parts per (100,000)	180.0	150.0	120.0	132.0	150.0	132.0	59.0	101.0
Containing—								
Calcium	2.6	6.6	3.3	5.5	3.5	4.5	4.0	1.9
Magnesium	3.8	2.0	4.6	5.3	5.2	4.6	5.0	6.1
Chlorine	43.1	39.5	45.9	36.9	32.5	35.7	7.6	48.6
Sulphuric acid (SO ₄)	4.3	6.5	4.1	7.5	19.0	3.0	7.7	0.4
Carbonic acid (CO ₃)	11.7	12.8	13.0	20.2	13.4	20.7	38.1	18.0
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	2.0	3.1	10.1	4.6	3.2	7.4	28.2	9.1

	Dec. 1911.	Jan. 1912.	Feb. 1912.	March 1912.	April 1912.	May 1912.	June 1912.	July 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	136.0	144.0	133.0	111.0	135.0	130.0	144.0	127.0
Containing—								
Calcium	2.3	1.9	3.9	5.7	2.0	4.0	4.7	4.7
Magnesium	7.1	4.1	6.2	7.5	4.4	6.2	4.3	5.3
Chlorine	41.9	39.2	39.4	46.0	43.6	38.7	37.4	37.3
Sulphuric acid (SO ₄)	4.8	19.0	4.7	5.2	7.9	7.1	4.0	4.0
Carbonic acid (CO ₂)	12.7	6.1	14.9	21.8	12.1	17.2	18.0	17.8
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	5.4	5.1	6.1	7.3	9.3	5.1	0.5	1.7

	Aug. 1912.	Sept. 1912.	Oct. 1912.	Nov. 1912.	Dec. 1912.	Jan. 1913.	Feb. 1913.	March 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	129.0	126.0	136.0	137.0	131.0	140.0	137.0	133.0
Containing—								
Calcium	4.6	3.1	2.9	4.9	5.5	5.1	4.7	4.8
Magnesium	4.9	8.5	5.8	4.9	5.9	5.0	5.2	5.9
Chlorine	38.7	38.7	35.6	36.4	40.5	38.6	36.6	38.5
Sulphuric acid (SO ₄)	3.8	4.8	7.0	4.2	6.0	4.4	4.2	4.3
Carbonic acid (CO ₂)	14.7	18.1	16.8	18.5	20.6	19.1	19.2	18.4
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	2.8	7.6	3.2	...	1.6	0.5	0.5	0.5

	April 1913.	May 1913.	June 1913.	July 1913.	Aug. 1913.	Sept. 1913.	Oct. 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	124.0	130.0	131.0	111.0	131.0	119.0	126.0
Containing—							
Calcium	5.8	4.9	5.5	4.6	3.8	5.3	5.7
Magnesium	6.5	6.7	5.7	4.3	5.3	3.7	4.6
Chlorine	43.0	37.0	34.9	35.3	35.1	39.5	40.8
Sulphuric acid (SO ₄)	3.5	5.7	4.7	4.7	6.3	4.1	4.9
Carbonic acid (CO ₃)	14.8	19.4	18.7	21.0	17.5	15.1	15.3
Nitric acid (NO ₃)	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate)...	8.3	...	...	...	3.3	2.4	4.7

WELL No. VI.

	June 1907.	Oct. 1907.	April 1908.	June 1908.	July 1908.	August 1908.	Sept. 1908.	October 1908.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	129.0	119.0	134.3	126.2	152.4	116.6	264.9	200.0
Containing—								
Calcium	0.6	4.0	7.2	8.2	3.4	9.1	2.9	3.5
Magnesium	5.6	4.7	4.4	6.3	7.8	5.1	1.9	2.9
Chlorine	36.5	38.4	42.6	40.8	42.0	44.8	54.7	51.8
Sulphuric acid (SO ₄)	7.1	3.1	7.0	5.7	10.8	7.0	3.1	2.4
Carbonic acid (CO ₃)	19.5	21.0	16.6	18.2	12.7	12.4	5.8	7.8
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate).	15.6	4.9	8.2	5.4	...	...	...	1.3

	Nov. 1908.	Dec. 1908.	Feb. 1909.	March 1909.	April 1909.	June 1909.	July 1909.	August 1909.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	111.0	131.4	130.0	124.9	132.5	108.0	180.0	192.0
Containing—								
Calcium	8.7	4.2	4.6	4.4	0.9	3.3	7.3	8.1
Magnesium	8.1	4.8	7.7	6.6	5.0	3.2	7.0	2.2
Chlorine	41.2	40.8	40.9	41.2	41.4	44.9	47.5	34.8
Sulphuric acid (SO ₄)	5.5	5.3	5.8	3.9	3.6	4.9	6.4	5.6
Carbonic acid (CO ₂)	18.3	14.7	19.5	15.7	18.1	20.0	11.3	9.1
Nitric acid (NO ₃)	...	...	...	1.0	1.2	...	...	4.7
Alkalinity (as sodium carbo- nate).	...	...	...	...	...	6.8	...	0.7

	Sept. 1909.	October 1909.	Nov. 1909.	Dec. 1909.	Jan. 1910.	Feb. 1910.	March 1910.	April 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	126.0	136.0	180.0	250.0	270.0	170.0	190.0	230.0
Containing—								
Calcium	9.5	7.9	7.8	6.5	7.4	5.1	4.8	6.6
Magnesium	7.4	6.4	10.7	6.4	5.6	5.8	6.3	6.5
Chlorine	38.8	38.6	51.6	40.2	49.3	46.5	44.4	47.4
Sulphuric acid (SO ₄)	7.5	11.6	7.3	9.1	6.2	4.3	8.4	4.4
Carbonic acid (CO ₂)	15.7	15.0	8.0	7.4	8.1	13.1	8.3	8.2
Nitric acid (NO ₃)	1.0	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate).	4.6	...	...	...	...	...	5.3	2.7

	May 1910.	June 1910.	July 1910.	August 1910.	Sept. 1910.	October 1910.	Nov. 1910.	Dec. 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Al Salts (Parts per 100,000)	300.0	298.0	254.0	130.0	180.0	200.0	209.0	230.0
Containing—								
Calcium	4.0	5.0	5.0	10.9	5.7	6.2	2.9	1.9
Magnesium	4.5	1.8	5.0	13.2	6.1	7.3	1.4	2.9
Chlorine	31.8	42.8	36.4	...	51.8	49.5	55.5	51.1
Sulphuric acid (SO ₄)	5.9	4.8	3.8	12.2	5.7	5.3	2.6	3.4
Carbonic acid (CO ₂)	7.5	7.0	7.7	11.0	7.0	10.2	5.1	7.8
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate).	...	...	...	1.2	...	...	2.6	1.5

	Jan. 1911.	Feb. 1911.	March 1911.	April 1911.	July 1911.	August 1911.	Sept. 1911.	Oct. 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	220.0	222.0	350.0	140.0	132.0	251.0	229.0	180.0
Containing—								
Calcium	4.3	3.7	2.1	2.8	3.3	4.5	5.4	5.1
Magnesium	0.9	2.1	1.4	6.3	5.5	6.8	6.2	11.5
Chlorine	45.0	50.1	52.3	45.3	40.0	44.7	44.6	58.2
Sulphuric acid (SO ₄)	4.6	5.6	4.8	4.1	6.9	8.8	8.4	8.1
Carbonic acid (CO ₂)	9.7	4.9	3.2	11.5	15.8	8.8	10.4	8.6
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate).	1.5	1.9	1.0	2.6	8.4	11.3	1.5	2.0

	Nov. 1911.	Dec. 1911.	Jan. 1912.	Feb. 1912.	March 1912.	April 1912.	May 1912.	July 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	235.0	296.0	294.0	280.0	241.0	288.0	293.0	265.0
Containing—								
Calcium ...	10.2	4.8	6.8	6.7	7.1	7.5	7.8	7.2
Magnesium ...	11.7	10.4	7.2	6.8	7.2	7.0	8.0	6.5
Chlorine ...	51.3	48.9	48.0	47.5	47.7	49.8	53.1	50.4
Sulphuric acid (SO ₄) ...	6.1	5.1	4.5	4.8	2.7	4.4	4.6	4.3
Carbonic acid (CO ₃) ...	3.0	10.1	6.3	7.3	9.8	7.9	6.9	6.6
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	1.1	1.0	2.2	1.3	2.1	1.0	0.7	1.9

	August 1912.	Sept. 1912.	October 1912.	Nov. 1912.	Dec. 1912.	Jan. 1913.	Feb. 1913.	March 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000) ...	186.0	181.0	195.0	227.0	227.0	185.0	215.0	190.0
Containing—								
Calcium ...	9.7	12.2	8.2	4.7	7.0	7.7	8.2	9.0
Magnesium ...	9.1	9.4	5.1	7.1	7.5	7.6	8.5	9.4
Chlorine ...	52.8	48.0	49.4	46.0	47.9	41.5	48.8	46.4
Sulphuric acid (SO ₄) ...	6.5	7.4	0.8	6.3	5.5	6.6	4.0	3.2
Carbonic acid (CO ₃) ...	10.2	9.5	9.2	9.0	9.0	12.6	9.5	12.0
Nitric acid (NO ₃) ...	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate).	3.1	3.2	2.6	...	...	1.2	...	...

	April 1913.	May 1913.	June 1913.	July 1913.	August 1913.	Sept. 1913.	October 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	213.0	168.0	174.0	143.0	214.0	203.0	209.0
Containing—							
Calcium	6.8	10.7	6.4	4.1	6.2	6.5	5.7
Magnesium	6.4	7.6	5.7	1.7	5.8	4.6	5.1
Chlorine	50.5	44.7	41.4	41.1	47.6	54.5	47.3
Sulphuric acid (SO ₄)	4.6	5.4	4.7	4.8	5.7	5.5	5.4
Carbonic acid (CO ₂)	6.1	11.5	10.5	14.8	8.0	4.5	7.7
Nitric acid (NO ₃)	...	...	...	...	...	...	...
Alkalinity (as sodium carbo- nate).	3.4	0.8	1.7	1.0	1.7	...	...

WELL NO. VII.

	May 1909.	July 1909.	August 1909.	Oct. 1909.	Nov. 1909.	Dec. 1909.	Jan. 1910.	Feb. 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	123.5	80.0	70.0	60.0	76.0	100.0	92.0	120.0
Containing—								
Calcium	1.6	4.0	13.5	15.6	2.6	2.8	5.6	2.6
Magnesium	1.4	3.8	7.9	2.5	12.3	4.7	5.0	4.5
Chlorine	19.3	21.4	23.2	20.8	13.1	16.7	17.5	23.0
Sulphuric acid (SO ₄)	1.9	7.7	23.7	17.1	7.0	4.9	...	4.4
Carbonic acid (CO ₂)	38.5	36.7	23.0	23.6	44.9	44.3	48.3	32.7
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium car- bonate)	50.5	5.2	1.2	41.5	18.1	...	4.0	...

	March 1910.	April 1910.	May 1910.	June 1910.	July 1910.	August 1910.	Sept. 1910.	Oct 1910.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	120.0	164.0	148.0	144.0	130.0	106.0	130.0	130.0
Containing—								
Calcium	3.0	4.6	3.2	4.1	2.7	2.6	2.7	2.1
Magnesium	2.7	4.1	3.2	6.3	3.3	4.3	3.3	4.3
Chlorine	35.0	36.2	29.5	27.9	30.5	25.6	31.1	31.8
Sulphuric acid (SO ₄)	7.1	9.5	3.8	7.1	5.0	9.7	5.6	5.3
Carbonic acid (CO ₃)	21.3	19.6	25.6	25.7	23.1	21.6	27.6	26.7
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate)	8.4	7.4	...	...	...	...	...	...

	Nov. 1910.	Dec. 1910.	Jan. 1911.	Feb. 1911.	March 1911.	April 1911.	July 1911.	August 1911.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	128.0	164.0	160.0	140.0	134.0	130.0	70.0	146.0
Containing—								
Calcium	1.0	2.1	3.0	4.0	4.4	2.4	4.2	0.8
Magnesium	2.7	3.5	2.3	4.0	4.8	7.2	5.6	3.5
Chlorine	29.6	35.7	36.6	35.0	39.1	30.4	23.5	23.3
Sulphuric acid (SO ₄)	2.2	6.0	4.1	4.9	6.0	4.1	13.4	10.5
Carbonic acid (CO ₃)	31.1	21.7	17.0	21.5	15.9	29.6	28.7	24.6
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate)	12.6	...	2.3	4.5	4.3	6.9	17.4	3.3

	Sept. 1911.	Oct. 1911.	Nov. 1911.	Dec. 1911.	Jan. 1912.	Feb. 1912.	March 1912.	April 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	129.0	129.0	142.0	138.0	153.0	139.0	139.0	140.0
Containing—								
Calcium	1.8	1.5	4.4	1.1	3.1	3.1	3.4	3.4
Magnesium	0.8	4.5	8.8	5.2	5.1	4.4	3.6	3.6
Chlorine	25.3	24.1	32.3	39.1	31.6	30.0	31.0	27.0
Sulphuric acid (SO ₄)	7.7	9.9	4.9	4.2	3.1	2.6	3.2	3.2
Carbonic acid (CO ₃)	29.4	26.5	23.8	14.0	21.9	28.9	30.0	29.7
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate)	3.7	20.0	7.8	15.0	17.4	5.3	4.2	4.2

	May 1912.	June 1912.	July 1912.	August 1912.	Sept. 1912.	Oct. 1912.	Nov. 1912.	Dec. 1912.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total Salts (Parts per 100,000)	151.0	139.0	133.0	128.0	123.0	143.0	130.0	145.0
Containing—								
Calcium	2.3	1.4	2.1	3.1	4.2	1.4	2.1	3.3
Magnesium	2.7	2.9	3.5	5.0	4.2	3.6	2.6	4.1
Chlorine	28.5	25.3	25.6	28.1	27.0	45.2	23.4	27.7
Sulphuric acid (SO ₄)	3.8	3.2	2.7	3.2	3.9	3.4	4.1	4.4
Carbonic acid (CO ₃)	29.4	31.2	32.3	28.4	30.7	26.4	33.1	26.5
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium carbonate)	8.8	7.4	7.3	5.2	5.4	5.6	0.5	1.5

	Jan. 1913.	Feb. 1913.	March 1913.	April 1913.	May 1913.	June 1913.	July 1913.	August 1913.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Total salts (Parts per 100,000)	126.0	139.0	132.0	137.0	128.0	124.0	125.0	137.0
Containing—								
Calcium	2.5	2.8	3.9	3.2	3.1	2.2	2.5	2.9
Magnesium	2.7	3.8	4.0	3.4	3.0	3.5	2.1	3.0
Chlorine	25.3	31.9	30.4	29.3	23.4	22.1	23.0	25.0
Sulphuric acid (SO ₄)	4.5	2.9	3.0	2.9	3.5	3.6	4.5	7.4
Carbonic acid (CO ₃)	31.7	26.4	30.0	28.9	34.3	33.5	33.8	26.4
Nitric acid (NO ₃)	...	...	...	...	...	...	...	...
Alkalinity (as sodium car- bonate)	2.3	1.0	...	20.5	3.4	8.9	4.1	10.8

	Sept. 1913.	Oct. 1913.
	p. c.	p. c.
Total Salts (Parts per 100,000)	123.0	121.0
Containing—		
Calcium	2.2	2.0
Magnesium	2.7	3.7
Chlorine	30.1	31.8
Sulphuric acid (SO ₄)	5.9	8.4
Carbonic acid (CO ₃)	24.9	20.5
Nitric acid (NO ₃)	...	...
Alkalinity (as sodium car- bonate)	3.5	7.3