**Dr. Theodore Thomson's report to the Local Government Board on an epidemic of enteric fever in the borough of Worthing and in the villages of Broadwater and West Tarring.**

PUBLIC HEALTH

DIVISION.

# Dr. Theodore Thomson's Report to the Local Government Board on an Epidemic of Enteric Fever in the Borough of Worthing and in the Villages of Broadwater and West Tarring.

R. Thorne Thorne,
Medical Officer,
June 11th, 1894.

On May 23rd, 1893, the Board was informed by the Medical Officer of Health of the Borough of Worthing that an outbreak of enteric fever was in progress there, and that measures were being taken by the Sanitary Authority to deal with the disease. This information was followed by a more detailed report from the Medical Officer of Health, received by the Board on June 2nd. In this report the epidemic was stated to be abating, and some particulars were given as to the measures that had been adopted by the Sanitary Authority, and as to the probable cause of the outbreak. In a further report, dated June 17th, the Medical Officer of Health gave statistical account of the fever, and stated that the epidemic was over. Early in July, however, the Board received from the Sanitary Authority, and from medical men and others resident in the place, representations setting forth that a further and more formidable outbreak of enteric fever was in progress, and urging the Board to make inquiry into the cause of this outbreak. I was accordingly instructed by the Board to make inquiry into the circumstances in which enteric fever had been prevailing in Worthing, and to this end I visited Worthing on July 12th and on several subsequent occasions. The facts which, as the result of my investigations, came to my knowledge I now proceed to set forth.

During 1893 only two cases of enteric fever had, prior to the month of May, been notified to the Worthing Urban Sanitary Authority as having occurred in their district. One of these cases occurred in January, the other in February. On May 3rd an additional case of enteric fever was notified to the Urban Sanitary Authority, to be followed five days later by the notification of a plurality of cases. Thenceforward the disease increased so rapidly that by June 9th notification of 284 cases had been received. From June 10th to July 1st there would appear to have been a lull in the extension of the disease, for the notifications received during these three weeks amounted to the relatively small number of 19 only. But, on July 2nd, the number of persons attacked began again to increase, and this so markedly that in the course of July alone no less than 678 fever cases were notified to the Urban Sanitary Authority as occurring in their district. Subsequent to July the epidemic continued to prevail, although with gradual abatement, through August, September, and October; but had by the end of November so far diminished, that during that month no more than nine cases of the disease were notified to the Urban Sanitary Authority. In all, during the period from May 3rd to the end of November, 1,315 attacks are known to have occurred in the borough of Worthing, with 168 deaths.

In addition to the town of Worthing, two neighbouring villages, Broadwater and West Tarring, participated in this epidemic. During the already-mentioned period of May 3rd to the end of November, 55 cases of enteric

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fever are known to have occurred in West Tarring and 41 in Broadwater, 9 proving fatal in each of these places. The total number, therefore, of persons known to have been attacked by enteric fever during this period in Worthing, Broadwater, and West Tarring amounts to 1,411.

These three places, Worthing Borough, Broadwater, and West Tarring, lie near together at the foot of the Sussex Downs. Worthing abuts on the sea, while the villages of Broadwater and West Tarring lie inland in a northerly direction from Worthing. Broadwater village lies rather less than a mile to the east of the village of West Tarring, and both are practically continuous with Worthing. All three are on the Chalk, which for the most part lies very near the surface. Across part of Broadwater runs a narrow alluvial strip; and this is the case in Worthing also, where, moreover, the Reading and Woolwich beds are sparingly represented.

The Borough of Worthing is 1,405 acres in extent, and at the census of 1891 contained 3,044 inhabited houses, with a population of 16,606 persons. The villages of Broadwater and West Tarring are both in the East Preston Rural Sanitary District, and contain the greater part of the population of the parishes of the same names. In view of the limitation of the epidemic to the village portions of these parishes I had a census made of these villages during the summer of 1893; and in this way ascertained that Broadwater village then contained 191 inhabited houses with a population of 787, and West Tarring 229 inhabited houses and 1,070 persons. The following tables (Tables I. and II.) show, from May to November inclusive, the incidence of enteric fever, as regards both sickness and mortality, on each of the areas invaded.

In these Tables, and throughout the rest of this report, the Borough of Worthing is, for reasons which will presently appear, regarded as consisting of two parts, termed respectively "Worthing" and "West Worthing." Reference to the Urban Sanitary District of Worthing, which comprises "Worthing" and "West Worthing," will hereinafter be made only under the title "Borough of Worthing."

## TABLE I.

SHOWING severally for "WORTHING," "WEST WORTHING," WEST TARRING, and BROADWATER, the POPULATION, the NUMBER of ENTERIC FEVER CASES ascertained to have occurred in the seven months May to November 1893, and the rates of attacks per 1,000 of population.

| Sanitary District. | Area invaded by Enteric Fever. | Estimated Population in middle of 1893. | No. of Cases of Enteric Fever. | Attack rate per 1,000 population. |
|---|---|---|---|---|
| Borough of Worthing | "Worthing" | 15,317 | 1,257 | 82·0 |
| | "West Worthing" | 2,116 | 58 | 27·4 |
| East Preston Rural Sanitary District | Village of West Tarring | 1,070 | 55 | 51·4 |
| | Village of Broadwater | 787 | 41 | 53·4 |

## TABLE II.

SHOWING severally for "WORTHING," "WEST WORTHING," WEST TARRING, and BROADWATER, the POPULATION, the NUMBER of DEATHS referred to ENTERIC FEVER in the seven months May to November 1893, and the resulting death-rates per 1,000 inhabitants.

| Sanitary District. | Area invaded by Enteric Fever. | Estimated Population in the middle of 1893. | Enteric Fever. No. of Deaths. | Enteric Fever. Death-rate per 1,000 Inhabitants. |
|---|---|---|---|---|
| Borough of Worthing | "Worthing" | 15,317 | 153 | 10·0 |
| | "West Worthing" | 2,116 | 15 | 7·1 |
| East Preston Rural Sanitary District | Village of West Tarring | 1,070 | 9 | 8·4 |
| | Village of Broadwater | 787 | 9 | 11·4 |

From Table I. it appears that, taking the epidemic as a whole, the chief incidence of *attack* was on "Worthing"; that Broadwater and West Tarring were in this respect affected almost equally, but to a less degree than "Worthing"; and that the smallest incidence of attack was on "West Worthing." From Table II. it will be seen that relatively to population there were more *deaths* in Broadwater than in any of the other three districts; and that next in order comes "Worthing," followed by West Tarring and by "West Worthing,"—the area last named suffering least from deaths as from attacks. Table I., however, gives a more trustworthy indication of the relative prevalence of enteric fever in these four areas than does Table II., inasmuch as (save in the case of "Worthing"), the death figures being small, deductions therefrom are to a corresponding extent unsafe. No doubt the attack figures in certain of the areas are also small and to some extent the same objection applies to deductions based on them; they are, however, four or five times as large as the deaths, and therefore the more trustworthy.

These four places differ one from the other in several respects. Of the town area, the "Worthing" section contains in very large proportion persons earning their livelihood in one or other of the occupations common to seaside resorts, or employed in connection with fruit growing, which is a considerable industry in the district. "West Worthing," on the other hand, while containing a small proportion of the class that mainly composes the "Worthing" population, is largely a good class residential neighbourhood. The inhabitants of the villages of West Tarring and Broadwater are for the most part in poor circumstances, and are dependent on fruit growing and on agricultural pursuits. The inter-relations of the four places as regards sewerage and water supply are somewhat complicated. Thus "West Worthing" and about three-fourths of the village of West Tarring have a common water supply from the public service of "West Worthing"; "Worthing" and about one third of the village of Broadwater have a common water supply from the public service of "Worthing"; the parts of West Tarring and Broadwater not thus accounted for are supplied from local wells. Again, "West Worthing" has a system of sewers entirely confined to that district; "Worthing" and almost the whole of the village of West Tarring drain into the "Worthing" sewers; while Broadwater village drains entirely into cesspools and ditches. For the sake of clearness I append a table in which these facts are set forth.

## TABLE III.

SHOWING in regard of WATER SUPPLY and DRAINAGE ARRANGEMENTS the inter-relations and the divergences of "WORTHING," "WEST WORTHING," WEST TARRING, and BROADWATER.

| Sanitary District. | Area invaded by Enteric Fever. | Water Supply. | Drainage. |
|---|---|---|---|
| Borough of Worthing - - | "Worthing" - | "WORTHING" WATERWORKS. | "WORTHING" SEWERAGE SYSTEM. |
| | "West Worthing" | "West Worthing" Waterworks. | "West Worthing" Sewerage System. |
| East Preston Rural Sanitary District - - | Village of West Tarring. | ¾ "West Worthing" Waterworks.<br>¼ *local wells.* | Almost entirely on the "WORTHING" SEWERAGE SYSTEM; the remainder drains into *cesspools.* |
| | Village of Broadwater. | ⅓ "WORTHING" WATERWORKS.<br>⅔ *local wells.* | Drains into *cesspools and ditches.* |

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## Enteric Fever in and about Worthing in previous Years.

The history of the above areas as regards enteric fever mortality during the past 11 years will be gathered from the annexed table (Table IV.), where I have dealt with "Worthing" and "West Worthing" together, under the title "Borough of Worthing." I make no attempt to supply death-rates per 1,000 living for any local area except the Borough; the small size of the villages of West Tarring and Broadwater rendering, as I have said, calculations based on the few figures for these areas of very doubtful value.

### TABLE IV.

Showing year by year for the 11 years 1883–1893, the Deaths from Enteric Fever in the Borough of Worthing, and in West Tarring and Broadwater Villages; and affording comparison of death-rates from this disease in the Borough, and in England and Wales.

| Year. | Borough of Worthing (comprising "Worthing" and "West Worthing"). | | | No. of Deaths from Enteric Fever in the | | England and Wales. |
|---|---|---|---|---|---|---|
| | Population. | No. of Deaths from Enteric Fever. | Enteric Fever Death-rate per 1,000 living | Village of Broadwater. | Village of West Tarring. | Enteric Fever Death-rate per 1,000 living. |
| 1883 | 12,180 | 2 | 0·16 | — | — | 0·23 |
| 1884 | 12,650 | 2 | 0·16 | — | — | 0·24 |
| 1885 | 13,040 | 3 | 0·23 | — | — | 0·17 |
| 1886 | 13,200 | 1 | 0·08 | — | — | 0·18 |
| 1887 | 13,350 | 1 | 0·08 | — | — | 0·18 |
| 1888 | 13,800 | — | 0·00 | — | — | 0·17 |
| 1889 | 14,200 | 2 | 0·14 | — | — | 0·18 |
| 1890 | 14,650 | 2 | 0·14 | — | — | 0·18 |
| 1891 | 16,722* | — | 0·00 | — | 1 | 0·17 |
| 1892 | 17,220 | 3 | 0·17 | — | 2 | 0·15† |
| 1893 (May to Nov.) | 17,433 | 168 | 9·64 | 9 | 9 | 0·16‡ |

* In September 1890, the limits of the borough were extended, and the additional population thus included accounts in part for the considerably increased population of 1891.

† The 1892 figures in this column are those given in the Registrar-General's quarterly returns as to "Fever;" they represent the death-rate from enteric, typhus, and simple or ill-defined forms of continued fever.

‡ "Fever" death-rate per 1,000 living in England and Wales during the second, third, and fourth quarters of 1893.

It will be seen, on comparison of the figures in Table IV. for the Borough of Worthing with those for England and Wales that, antecedent to 1893, this borough suffered less from enteric fever mortality than the country at large. Rarely did its death-rate from enteric fever equal the corresponding rate for England and Wales. So too with the villages of Tarring and Broadwater; in them no death was attributed to enteric fever during the first eight of the 11 years tabulated. In 1891 one death and in 1892 two deaths were referred to this cause in West Tarring village; but during these two years, as in the preceding eight, Broadwater remained entirely free from fatal enteric fever.

To what, then, is to be attributed the epidemic of enteric fever, that so suddenly, and with results so serious, invaded all these places in 1893?

With the view of finding a reply to this question it will be necessary to study in some detail the rise and progress of the outbreak; to note any differences that may be discernible as to distribution in time and in space of the fever in the several areas under examination; and to consider, for each area and for the four areas collectively, one and another condition reputedly causative of enteric fever, in its possible relation to the behaviour of the disease as witnessed in this epidemic.

## Rise and Progress of the Outbreak.

The commencement and the subsequent course of the outbreak are exhibited in detail in the subjoined tables, Table V. and VI., as also in the charts (I–IV.) opposite and the maps (3–15) appended to this report.

## TABLE V.

Showing fortnightly from March to December 1893, the number of Cases of Enteric Fever *notified* in "Worthing," "West Worthing," West Tarring, and Broadwater.

| Period. | "Worthing" (population, 15,317). | "West Worthing" (population, 2,116). | Village of West Tarring (population, 1,070). | Village of Broadwater (population, 787). |
|---|---|---|---|---|
| Month of January | 1 | — | — | — |
| „ February | 1 | — | — | — |
| „ March | — | — | — | — |
| April 1—14 | — | — | — | — |
| „ 15—28 | — | — | — | — |
| „ 29—May 12 | 40 | — | 1 | 1 |
| May 13—26 | 189 | — | — | 2 |
| „ 27—June 9 | 55 | — | — | — |
| June 10—23 | 12 | — | — | 2 |
| „ 24—July 7 | 146 | 1 | 3 | 4 |
| July 8—21 | 418 | 4 | 3 | 18 |
| „ 22—Aug. 4 | 151 | 7 | 8 | 1 |
| Aug. 5—18 | 120 | 27 | 25 | 8 |
| „ 19—Sept. 1 | 43 | 6 | 7 | 1 |
| Sept. 2—15 | 27 | 7 | 1 | — |
| „ 16—29 | 31 | 2 | 1 | — |
| „ 30—Oct. 13 | 8 | 1 | 3 | 1 |
| Oct. 14—27 | 9 | — | 1 | — |
| „ 28—Nov. 10 | 6 | — | 1 | — |
| Nov. 11—24 | 2 | 3 | 1 | 3 |
| „ 25—Dec. 8 | — | — | — | — |
| Total | 1,259 | 58 | 55 | 41 |

## TABLE VI.

Showing the Number of Enteric Fever Attacks *ascertained to have commenced* in each fortnight from March to December 1893 in "Worthing," "West Worthing," West Tarring, and Broadwater.

| Period. | "Worthing" (population, 15,317). | "West Worthing" (population, 2,116). | Village of West Tarring (population, 1,070). | Village of Broadwater (population, 787). |
|---|---|---|---|---|
| The month of January | 1 | — | — | — |
| „ February | 1 | — | — | — |
| „ March | — | — | — | — |
| April 1—14 | — | — | — | — |
| „ 15—28 | 9 | — | — | 1 |
| „ 29—May 12 | 153 | — | 1 | 2 |
| May 13—26 | 106 | — | — | — |
| „ 27—June 9 | 24 | — | — | 2 |
| June 10—23 | 59 | — | — | — |
| „ 24—July 7 | 391 | 4 | 6 | 12 |
| July 8—21 | 225 | 2 | 3 | 12 |
| „ 22—Aug. 4 | 110 | 24 | 21 | 4 |
| Aug. 5—18 | 78 | 11 | 14 | 4 |
| „ 19—Sept. 1 | 30 | 4 | 2 | — |
| Sept. 2—15 | 41 | 9 | 1 | — |
| „ 16—29 | 10 | — | 2 | — |
| „ 30—Oct. 13 | 6 | 1 | 5 | 1 |
| Oct. 14—27 | 9 | — | — | 2 |
| „ 28—Nov. 10 | 5 | 2 | — | 1 |
| Nov. 11—24 | 1 | 1 | — | — |
| „ 25—Dec. 8 | — | — | — | — |
| Total | 1,259 | 58 | 55 | 41 |

Table V. shows fortnight by fortnight the number of cases notified from March to December, 1893, in each of the four invaded areas, in all of which

compulsory notification of enteric fever (among other diseases) is in force. In the charts corresponding to this table (Charts I. and II.), the notifications received are shown day by day for a somewhat shorter period than that covered by the table. Table VI. and the charts corresponding to it (Charts III. and IV.) are based upon the *actual dates* on which persons attacked are stated to have first shown symptoms of illness, and are therefore to be preferred in comparisons as to time-incidence of the disease on one and another area.

Study of these data reveals the fact that the behaviour of the disease, in the matter of time-distribution, was not the same in all four invaded areas.

*Incidence in regard of Time.*—In "Worthing" the first case of the epidemic would appear (*see* Chart III.) to have occurred in the second fortnight of April; and in this area, after a sharp outburst occupying mainly the first three weeks of May, the epidemic abated considerably. This decadence of the fever did not, however, long continue. About the middle of June, there occurred fresh increase in the number of attacks, which culminated about the end of the month and the early part of July in an outburst of remarkable intensity. During the remainder of July and through August and September the fever in "Worthing" was maintained with occasional exacerbations but with gradual abatement. By October it had so far diminished that in that month but 18 persons are known to have been attacked. By December the epidemic may be considered to have been over, as three attacks only are known to have occurred in the previous month.

In the village of Broadwater one case of enteric fever is known to have commenced in the latter part of April, while two are recorded in the month of May, and two more in the beginning of June. Having regard to the comparatively few inhabitants of the village, the incidence of the enteric fever thus corresponds in time with the behaviour of the disease in "Worthing," although Broadwater suffered less than "Worthing" relatively to its population. But in Broadwater as in "Worthing," there was a marked recrudescence of the disease at the end of June and in the beginning of July; at this time, indeed, Broadwater suffered rather more than "Worthing" in proportion to its population. After the middle of August the disease would seem to have been in abeyance in Broadwater until October, when three cases are known to have occurred, and one more person was attacked in November. It will, therefore, be seen that, making allowance for the element of uncertainty always attaching to figures dealing with small populations, the rise and subsequent course of the disease in Broadwater was parallel with that in "Worthing."

But in "West Worthing" and in West Tarring the commencement and the progress of the enteric fever outbreak that occurred in these places were in some respects totally unlike what took place in "Worthing" and Broadwater.

In West Tarring, with the single exception of one case in the early part of May, no person is known to have been attacked by enteric fever until June 30th; moreover, the chief outbreak of the fever in this place did not occur until the end of July or the beginning of August; that is to say, not until nearly a month later than the time at which the incidence was greatest on "Worthing" and Broadwater. After the month of August occasional cases are known to have occurred in West Tarring up to November 14th, since when the disease does not appear to have manifested itself in the village.

In "West Worthing" no person is known to have been attacked by enteric fever prior to June 26th. In this district, as in West Tarring, the chief prevalence of the fever did not, as in "Worthing" and Broadwater, occur in May and again in early and middle July, but at the end of July and in the beginning of August. Here too, again, as in the case of West Tarring, the disease would seem to have made only occasional appearances after the month of August.

From the foregoing account it appears that as regards the date at which the disease became epidemic, and, as regards also that at which it reached its maximum, "Worthing" resembled Broadwater, whereas "West Worthing" resembled West Tarring; and, further, that "West Worthing" and West Tarring differed conspicuously from "Worthing" and Broadwater in this sense.

*Distribution over Area.*—Differences appear also as regards the extent to which the total area of each of the four invaded localities was implicated by

the fever epidemic. These differences are illustrated by the maps, to which I have already made reference, and which are appended to this report. The maps in question cover the period April 15th to October 13th, and on them the cases of enteric fever, as they occurred fortnight by fortnight, are represented by red dots. The fortnightly periods thus illustrated correspond with the fortnightly periods in Tables V. and VI. From these maps it will be seen that the fever was generally and well-nigh impartially distributed throughout "Worthing." Certain parts of this area, it is true, show now and then a thicker clustering of spots than is elsewhere noticeable; but these are the localities in "Worthing" which are most densely inhabited, and where, accordingly, with an equally diffused cause of fever, a closer aggregation of cases would be anticipated. In Broadwater, also, the distribution of the disease is observed to be general over the whole village. In "West Worthing," on the other hand, this indifference of distribution of the fever is not found. There was a large preponderance of cases (47 out of a total 58) in a block of streets occupying the south-east corner of "West Worthing." It is true that this is the part of "West Worthing" which is most densely inhabited, containing, as it does, 970 out of the total 2,116 persons in the place; but, with due allowance made for this fact, the proportion of cases occurring hereabouts shows a very special incidence on this section of "West Worthing." A similar special localisation of the fever is to be seen in the distribution of cases in the village of West Tarring, where a group of streets near the southern limit of the place was affected in much greater degree than the remainder of the village. The group of streets referred to contains less than two-thirds of the population of West Tarring village; and yet 51, out of the total number of 55 known cases of enteric fever, occurred in this particular locality.

Thus, as regards distribution over area as with distribution in time, the behaviour of the epidemic in "Worthing" resembled the behaviour of the epidemic in Broadwater; while the "West Worthing" outbreak resembled, in both senses, that in West Tarring. There can be no question then that the latter two places were invaded in different fashion from the two former. The disease was co-incident in time in, and general in its distribution throughout, both "Worthing" and Broadwater; whereas in "West Worthing" and in West Tarring the epidemic was later in appearing, and the fever when it came was to a great extent limited to a particular section of each of these areas. These discrepancies might, it was seen, be thought to suggest that the prevalence of enteric fever in the four invaded places had been due to diverse fever agencies; and, accordingly, in searching for the factor or factors responsible for the occurrence of the disease due regard was had to this aspect of the question.

### Cause of the Outbreak.

In searching for the factors concerned in the epidemic prevalence of enteric fever in these four localities, the general sanitary circumstances, the sewerage and drainage, the milk and the water supplies were in turn investigated. Each of these possible agencies of fever distribution I shall now pass in review.

#### *General Sanitary Circumstances.*

In "*Worthing*" *with* "*West Worthing*"* the streets are for the most part well constructed and are kept clean; the houses of the poorer classes are in fair condition; but in not a few instances open space around poor class dwellings is somewhat scanty. Excreta are removed by water carriage; the prevailing form of closet basin being the long hopper, not always, however, provided with a separate flushing cistern. Disposal and removal of house refuse leave a good deal to be desired. The lower parts of the town are liable to occasional flooding from backing up of sewer contents by the tide. A considerable nuisance is not infrequently caused by the odour arising from decaying accumulations of seaweed on the foreshore. These accumulations are sometimes very large, especially after a south-westerly gale.

In *West Tarring*† the roadways are on the whole fairly constructed and kept; the houses of the poorer class are in some instances in fairly good condition,

* It will be remembered that these places are under the jurisdiction of one and the same sanitary authority, the Town Council of Worthing.

† Under the jurisdiction of the East Preston Rural Sanitary Authority.

while in others they are old, indifferently lighted and ventilated, and occasionally damp and dilapidated. Disposal of excreta is partly by water-closets, chiefly of the long hopper pattern, partly by cesspit privies. Disposal of refuse is capable of much improvement: removal of refuse by the Sanitary Authority is somewhat irregular; and it is not universal, as the material is often made use of by occupiers on their gardens.

In *Broadwater** a considerable proportion of the houses are old, and some are badly lighted and ventilated; some are also damp. Roadways are in moderate condition of repair and cleanliness. Excreta are disposed of in privy cesspits or privy middens, intermittently scavenged; or by waterclosets, chiefly of the long hopper pattern and usually hand flushed. House refuse is for the most part made use of for garden purposes.

The general sanitary condition of these four places is, as the foregoing account shows, in several respects unsatisfactory. Nevertheless their defects are by no means such as to invite an outbreak of enteric fever of the severity and the dimensions that have been described. And, as matter of fact, exceptional incidence of the disease was not, in any of the four areas, noticed in those sections of them presenting most conspicuously defective hygienic conditions; indeed, large numbers of individual houses were invaded, to the sanitary arrangements and surrounding of which little or no exception could be taken.

*Sewerage and Drainage Arrangements.†*

"*Worthing.*"—The main sewers in "Worthing" are built in some instances of brick work, others are constructed of stoneware pipes. They are not all well made or in good condition. The following is an extract from a statement supplied to me by the Borough Surveyor regarding old sewers:—"I am informed that, until a few years back, cement was not used for the pipe joints, so it may be taken that the joints of the bulk of the old pipe sewers were made of clay. Prior to my appointment in 1891, I am informed it was usual to allow the pipe sewers to be cut into for house connections instead of using proper junctions; occasional excavations made bear out these statements: excavations made to the brick sewers show they are not water-tight and that silt accumulates where the gradients are not self-cleansing." As regards the gradients of the "Worthing" sewers, the Borough Surveyor states as follows:—"The general fall of sewers running north and south is good, with a few exceptions; the main sewer from the south end of Upper High Street to the junction in the Park is nearly dead level, with a *very* slight fall the wrong way, and the Montague Street sewer from Gratwicke Road to Surrey Street is in the same state; a few of the sewers running east and west are not self-cleansing." Ventilation of sewers is mainly secured by street gratings, and is in some instances satisfactory, in others insufficient.

Prior to April 1893, when the amount of the "Worthing" water supply was increased, the sewers were flushed by occasional release of considerable volume of their contents previously penned up at certain points by means of movable discs until a sufficient head of sewage had been gained. The surveyor states that after the increase of water supply in April 1893, "the sewers were well flushed by hose pipes at the man holes prior to the epidemic, and extra flushing was done during the epidemic both to sewers and house drains, the extra water pumped for this purpose daily often being at the rate of 25 gallons per head over the normal supply of 30 gallons per head." Owing to the low level of "Worthing"—of which the highest point on the ground surface is but 36′ above Ordnance datum, while in places it is only 9′ above datum—the sewers are tide locked during large part of the 24 hours. The "Worthing" outfall sewer is a 4 ft. barrel which discharges, about 1½ miles east of Worthing pier, into a 30″ iron pipe by which the sewage is carried out to sea. Some experiments conducted by the Borough Surveyor showed that "in dry weather the backing up of the sewer at entrance to waterworks yard during tidelock ranged from 2′ 0″ to 3′ 1″ above invert, with a water

* Under the jurisdiction of the East Preston Rural Sanitary Authority.

† Comprehension of the sewerage arrangements of the four areas under discussion will be facilitated by reference to the sewerage map (map 2) appended to this report. On this map the sewers of "Worthing" and West Tarring, which have their sewerage system in common, are shown by red lines: while the "West Worthing" sewers are shown by blue lines.

" supply of 30 gallons per head; in wet weather the backing up extended " to the bottom of South Street, and, during storms, along Montague Street " and up branch sewers." The amount of backing up thus set forth will be better appreciated when I state that the invert of the sewer at the entrance to the Waterworks yard (shown as an irregular blue patch near to Park Road, Worthing, in Map 1) is at Ordnance datum level.

House drains are in few instances properly ventilated and disconnected from the sewers. Disconnection of house drains from interiors of houses is usual as regards sink and bath wastes; but soil pipes are not infrequently ventilated by shafts of too small diameter, and are in some instances devoid of ventilation. The majority of waterclosets, however, are situated out of doors.

"*West Worthing.*"—The description just given of the "Worthing" sewerage and drainage arrangements applies equally to the "West Worthing" sewerage and drainage, although the "West Worthing" sewers constitute an absolutely separate system. They are at no point connected with the sewers of Worthing or of any other district, and they discharge by a separate outfall into the sea, about a mile to the west of Worthing pier. In "West Worthing" also the sewers back up during tidelock; main sewers have not always a proper fall, and old sewers are in the condition already described. As regards house drainage the unsatisfactory features referred to as existing in connection with "Worthing" are equally common in "West Worthing."

*West Tarring.*—The main sewerage arrangements in West Tarring village resemble the more recently and better constructed sewers of "Worthing," of the sewerage system of which the West Tarring sewers constitute a part. The whole of the West Tarring sewage, save that from 14 houses—which either drain into cesspools or have no drainage arrangements—passes into the village sewers, thence into the "Worthing" sewer, and so into the sea through the Worthing discharge pipe. House drainage in West Tarring resembles that of "Worthing" and "West Worthing."

*Broadwater.*—In Broadwater there is no system of sewerage. For the most part houses drain into cesspools, which are cleansed at irregular intervals. Disconnection of sink wastes is usual, and indoor waterclosets are rare. House drains are unventilated.

So far then as sewerage arrangements are concerned, it is clear that the main outbreak, which followed a parallel course in "Worthing" and Broadwater, cannot be attributed to sewer emanations, inasmuch as Broadwater has no drainage relations with "Worthing," and is indeed devoid of sewers. Nor was there, assuming sewer emanations as a cause of fever, in "Worthing" itself exceptional incidence of the disease on the inhabitants of houses in those streets known to be badly sewered. The two localised, though separate, outbreaks in "West Worthing" and in West Tarring respectively present perhaps behaviour more compatible with sewer infection; but even in these instances there must be hesitancy in attributing the disease to this cause. For the "West Worthing" and the West Tarring sewers are on separate systems, and the sewers of the invaded localities in those areas were in better condition than those in other streets that escaped or were but lightly touched by the epidemic; and, in addition, almost all the invaded houses in these two places were properly secured against entrance of sewer air into their interiors.

In short, the behaviour of the disease generally is opposed to any probability of sewer infection as a cause. Its behaviour in "Worthing" was similar to its behaviour in Broadwater village, and yet the "Worthing" sewers do not extend into Broadwater village, which is, as has been said, wholly without sewers. In "Worthing" and West Tarring, again, there were striking differences in the manner of rise and progress of the fever, notwithstanding that these two places have a common sewerage system. In "West Worthing," moreover, which has its own separate sewerage system, the disease behaved quite otherwise than in "Worthing," and instead closely followed the course taken by it in West Tarring, which is, as already stated, on the same sewerage system as "Worthing."

In view of these facts, it becomes apparent that a sufficient explanation of the cause of the outbreak of enteric fever in these four places is not to be found in infection propagated by emanations from sewers.

## Milk Supply.

In the rapidity with which they attained their maxima in the four places invaded, the enteric fever outbreaks displayed a feature usually to be found in epidemics of which the causation lies in milk. On the other hand, the persistence of these outbreaks, and their slow subsidence, did not harmonise with this method of causation of the fever, nor was there that especial incidence of the disease on women and children* so characteristic of milk epidemics. It did not seem probable, moreover, seeing that all four places receive their milk in large part from the same vendors, that two of these places should have been attacked in April and May, and again in June and July, while the other two should have almost entirely escaped until July–August. Nevertheless, careful inquiry was made into the possible operation of milk supply in causing any of the outbreaks in the four localities. In "Worthing" the source of milk supply was ascertained in the case of 1,231 out of the 1,257 persons attacked. The milk supply of these 1,231 persons came from one or other of all the milk vendors in "Worthing," who are 15 in number. Similarly the milk supplied to those persons who had contracted enteric fever in Broadwater, came from six different vendors; in "West Worthing" from eight; and in West Tarring from four sources. Attempt was also made to ascertain what proportion of the total customers of each separate vendor had been attacked; but the difficulties experienced in trying to obtain the number of customers in each instance were found to be so great as to forbid more than an approximate estimate on the subject. Sufficient was learned, however, to show that the proportion of cases to customers was in no instance so exceptional as to point to milk having acted as the medium of propagation of enteric fever in any of the outbreaks in the four places invaded.

## Water Supply.

In the absence of evidence implicating as cause of the epidemic any one of the possible agencies thus far discussed, water supply—which has so often been found elsewhere to have served as the medium of sudden and widespread propagation of enteric fever—naturally came under suspicion.

The four areas affected by the fever are supplied, as stated at an earlier stage of this report, with water from three sources, viz., the "Worthing" public service, the "West Worthing" public service, and local wells. A proper comprehension of the part that water may have played in bringing about the epidemic cannot be arrived at without a detailed account of the circumstances of these water supplies, and the different conditions of distribution of public water service in one and another of the several areas.

*The "Worthing" Public Service.*—The "Worthing" Waterworks are the property of the Worthing Corporation, and are situated within the borough. They are depicted as an irregular blue area on the annexed map (Map 1) showing the distribution of the watermains. The site is an enclosed plot of ground of about two acres in extent. The Chalk here lies at a depth of about 18 to 20 feet from the surface, the intervening soil consisting from above downwards of loamy mould, marl, and chalky marl. The supply is from certain deep wells and from headings therefrom driven into the Chalk, the water being pumped up by an engine on the site. This water is not filtered. The greater part of this supply is delivered directly into a rising main, by which it is distributed to "Worthing" and to Broadwater, but not to "West Worthing" or to West Tarring; the surplus passes into a tank situated at the top of a brick tower 90 feet in height. When this tank is full the engine ceases pumping, and the tank-water is distributed by gravitation until the tank is about three parts emptied; whereupon, this supply is stopped and the engines again pump from the wells directly into the mains and tank. The supply, therefore, is constant. Tank-water is usually distributed by the "Worthing" mains from 6 a.m. to 6.30 a.m., and again from 12 noon to 12.30 p.m. The pressure in the mains while the tank supply is being delivered is about 30 lbs. per square inch. The pressure when water is being pumped directly into the mains is 25 lbs. during the day and 12 lbs. during

* The incidence of the fever on sex and age was closely studied in view of this and of other considerations.

the night. If, however, the drains and water-mains are to be flushed during the night, the full pressure of 25 lbs. is kept up.

This water is obtained from three wells with three headings, two of the headings serving as connecting tunnels between the three wells. Comprehension of the relationships of these one to another, and of the historical description about to be given, will be facilitated by reference to the accompanying diagrams (Diagrams I. and II.).

The "Worthing" public service dates from 1857, when the well-shaft marked A in the diagram was sunk. This well, lined with iron cylinders, has an internal diameter of 5 feet, and is 68 feet in depth; and from the bottom of the well a 19 in. borehole proceeds for another 300 feet. It yields 4,500 gallons per hour, and constituted the sole public supply until 1867, when a second well-shaft, that marked B on the diagram, was sunk. This well (B), also lined with iron cylinders, has an internal diameter of 6 feet, and is 104 feet in depth; and from the bottom a 26 in. borehole proceeds for another 300 feet. It yields 9,000 gallons per hour. At the time when well B was sunk, it was connected with well A by a siphon; for which a tunnel was substituted in 1880. This tunnel is at a depth of 72·6 feet from the surface, and is 113·4 feet in length. It has an internal diameter of 6 feet by 4 feet, and is lined with brick in cement, a brick being omitted every 18 inches in the bottom row of each side to permit ingress of water. This tunnel yields some 2,000 gallons per hour. In 1885 the Corporation again sought to augment their supply, and, with this view, commenced sinking another shaft in the north-east corner of the waterworks enclosure. But at a depth of only 18·6 feet from the surface (just before reaching the Chalk and in circumstances unfavourable therefore to the quality of the discovered water), so large a quantity of water * was encountered that the proposed sinking at this spot was abandoned, and another shaft was sunk, also in 1885, at a spot about 60 feet to the south-west of the abandoned shaft. The new well in this way provided is that marked C on the diagram. In sinking this well (C) a small amount of water was encountered about 20 feet from the surface, after which a gradual increase was noted until the excavations terminated. This well, lined with brickwork in cement, is 72 feet deep, and has an internal diameter of 7 feet. It was not provided with a borehole, but a tunnel was constructed leading from well C to the tunnel connecting wells A and B. This tunnel is 72 feet from the surface, has a length of 234 feet, and internal dimensions of 6 feet by 4 feet, and is constructed similarly to the tunnel leading from well A to well B. The yield from this source and from well C (which supplies the major part) is 7,000 gallons per hour.

The quantity of water derived from these various sources, however, was again found to be insufficient for the increasing population of the district, and, accordingly, in the beginning of the year 1893 further supplies were sought for. With this view it was resolved to drive a heading in a north-easterly direction from the bottom of well C, and on March 13th this work was commenced. As the work proceeded several small fissures were encountered, and on April 13th, when the heading was 68 feet in length, the total yield was estimated at about 60 gallons per minute. On April 14th, at 2 p.m., a large fissure, estimated as yielding 2,623 gallons per minute, was cut into. The heading, of which the internal dimensions are 6 feet by 4 feet, and of which the structure is similar to that of the other tunnels, was at this time 70 feet in length. So sudden and so great was the inrush of water from the fissure now struck, that the men employed in the work of excavation had to forsake their tools and run for their lives. The additional water thus obtained was forthwith utilised for service to "Worthing" and Broadwater, and from this date forward the supply was derived from all the sources I have described.

*The "West Worthing" Waterworks* are the property of a Company and are situated in "West Worthing" on an enclosed piece of ground, which is rather more than two acres in extent. The position of this site is marked on Map 1. The soil here resembles that described under the heading *The "Worthing"*

* On making further excavations this water was seen to well up from a fissure at the surface of the Chalk at that point.

*Public Service.* The Company's water is obtained from two wells in the Chalk. One of these, stated to have been sunk in 1865, is an iron cylinder well, 32 feet in depth, and having an internal diameter of 12 feet. From the bottom of the well a bore hole, 8 inches in diameter, proceeds to a further depth of 38 feet. The other well, said to have been sunk in 1887, is an iron tube well 130 feet in depth, and without borehole. Water is pumped from these wells at the rate of 20,000 gallons per hour, and pumping is usually carried on in winter from 6 a.m. to 11 a.m., and again from 2 p.m. to 5.30 p.m. In summer, pumping is from 6 a.m. to 5.30 p.m. with an intermission of one hour, viz., 1 p.m. to 2 p.m. There are no means of storage or filtration, and the supply, which is limited to "West Worthing" and West Tarring, is an intermittent one.

The remaining sources of supply in the four places, namely, supplies from *local wells*, need little description. Most of the wells are shallow and they are commonly dry steined; some few, however, are deep and well constructed.

Reference to Map 1 will show the distribution of the two public services throughout the four areas. The "Worthing" mains, which are limited to "Worthing" and Broadwater, are coloured blue; the "West Worthing" mains, which supply water only to "West Worthing" and West Tarring, are coloured red. I have already stated approximately what proportion of these places are served by local wells; I now append in tabular form these facts in detail.

## TABLE VII.

SHOWING for each of the four areas invaded by ENTERIC FEVER the Number of Houses obtaining Water from one and another different source of Supply.

| Sanitary District. | Area invaded by Enteric Fever. | No. of Inhabited Houses. | No. of Houses on Public Service. | No. of Houses served by Local Wells. |
|---|---|---|---|---|
| Borough of Worthing | "Worthing" | 2,890 | 2,859 ("Worthing" Service) | 31 |
| | "West Worthing" | 347 | 326 ("West Worthing" Service) | 21 |
| East Preston Rural Sanitary District | West Tarring Village | 229 | 169 ("West Worthing" Service) | 60 |
| | Broadwater Village | 191 | 65 ("Worthing" Service) | 126 |

It is now, in the light of these facts, desirable to reconsider the data respecting the time incidence of the fever given in Tables V. and VI. and in the corresponding charts. Reference to Charts III. and IV. will show that the first fever case of the epidemic in "Worthing," attacked on April 16th, was followed in a few days by many more cases; and that in Broadwater the first case, occurring on April 27th, was followed by two further cases in May: whereas in "West Worthing" no case whatever of enteric fever occurred in either April or May, and in West Tarring one case only occurred (in early May) during these two months. With the exception therefore of this solitary case in West Tarring, to which I shall return later, every one of the cases (with which this Report deals) commencing in the months of April and May occurred in "Worthing" or in Broadwater; moreover, as has already been noted, the further course of the epidemic in these two places was very similar.

These two places, "Worthing" and Broadwater, it now appears, possess to some extent a common water service, that, namely, from the "Worthing" Waterworks, from which are supplied almost the whole of "Worthing" and rather more than one-third of Broadwater village. If, then, the "Worthing" water service were the means by which enteric fever was disseminated

throughout these two places, two results should follow, namely,—(1) That relatively to the total inhabitants in each area more persons should be found attacked by the fever in "Worthing," where there are few local wells, than in Broadwater, where there are many local wells; and (2) That persons in both places, residing in houses supplied from local wells, should be found to have suffered less fever than their neighbours who used "Worthing" water.

Of these expectations the first has been shown (at an earlier stage of this Report) to have been fulfilled: "Worthing" people, as a matter of fact, suffered, relatively to the population in each instance, three-eighths more fever than Broadwater people. The second, therefore, now requires consideration.

In "Worthing" there are 31 houses supplied with water from local wells, and of the inmates of such houses eight were attacked; or one person per four houses. On the other hand 2,859 houses in the place are supplied with "Worthing" water, and of the inmates of these houses 1,249 were attacked; or one person per 2·3 houses. This smaller incidence on houses supplied by local wells tends, moreover, to be reduced still further when the facts as to the persons suffering fever in them are studied in detail. For of these eight persons it has been ascertained that four had frequently drunk "Worthing" water unboiled, and other two had drunk lemonade made with "Worthing" water. Whether or not the remaining two persons had used this water could not be definitely ascertained, but it is worthy of notice that the earliest of these remaining cases occurred in September, by which time the "Worthing" soil may easily have become so far fever-fouled as to expose the water in local wells to considerable risk of pollution.

In Broadwater, on the other hand, 19 out of a total of 65 houses on the "Worthing" Service were invaded by enteric fever; whereas of 126 houses supplied from local wells only in 1[illegible] did the disease break out. Thus in Broadwater the fever invaded one out of every 3·5 houses on the "Worthing" Service, and only one out of 10 supplied by local wells. Similarly of the 267 persons who inhabited the 65 houses on the "Worthing" service, 27, or 10 per cent., were attacked; whereas of the 520 persons inhabiting the 126 houses supplied from local wells, only 14, or less than 3 per cent., suffered. But the contrast here between the two classes of houses and of persons is much more striking when, from those taken ill although residing in houses with local wells, there are deducted such as are known to have drunk "Worthing" water. Thus of the 14 Broadwater persons attacked by fever, notwithstanding that they lived in houses supplied from local wells, two were at service in and were brought home ill from "Worthing," and other two were at work daily in "Worthing." These four persons all of them admitted having drunk "Worthing" water unboiled, as also did three more of the 14. Of the remaining seven (of the 14) one was removed home ill from "West Worthing" where she was in service; two occurred in houses in which there had been previous cases; and one (a child) was subsequently declared by her medical attendant to be suffering not from enteric but from scarlet fever. The remaining three (of the 14) are unaccounted for. In this way it appears that of the 41 Broadwater cases no less than 34 had been in the habit of consuming "Worthing" water; one was not enteric fever, and as regards only six is there the statement that they had not before their illness used "Worthing" water.

It is evident, therefore, that there was comparative immunity from enteric fever of persons, whether in "Worthing" or in Broadwater, who habitually consumed water from local wells; and that there was heavy incidence of the disease on those who used the water delivered by the public service in these places.

But if the "Worthing" public service has been in fault, evidence should be forthcoming as to some alteration in its constitution parallel to the observed outbreak and maintenance of enteric fever among persons consuming it. In this aspect, the modification of this water service involved in the addition to it of water from a new source in April, 1893, at once presents itself for examination. Accordingly it is necessary to consider in detail the relations between the provision of the new source of supply and the outbreak of enteric fever.

The first case of the epidemic in "Worthing" and Broadwater was notified on May 3rd, and was quickly followed by several others. Enquiry

as to the actual dates on which all these persons first fell ill, established the fact that the first attack occurred on April 16th, the second on April 19th, and the third on April 21st. These, and one or two other cases occurring towards the end of the month, were followed, from April 28th onwards, by what may be called the main body of the first outbreak. But, as will be remembered, the large fissure, from which by far the greater part of the new supply was drawn, was not cut into until April 14th; only two days, therefore, before the first of these attacks. This fact, notwithstanding that the incubation period of enteric fever may be shortened when water is the medium of transmission, is of a sort to raise doubt as to connection between the admission of water from the fissure in question and the outbreak of the fever; and a fuller account has, therefore, now to be given of the proceedings that took place in driving the heading from which the new supply was in the spring of 1893 obtained.

In my previous and more curtailed account I noted that the very large yield from the fissure struck on April 14th was at once utilised. But I did not state what became of the water, relatively small in amount, which had been encountered in the new heading prior to April 14th, and this I now do. Before excavation of the new heading was commenced, a sluice valve had been fixed in the tunnel leading from well C to the tunnel between wells A and B. This sluice valve, which was fixed in the tunnel near its departure from well C, was intended to prevent water from well C, inclusive of water from the new heading, gaining access to the public service during progress of the new works; since these were necessarily of a nature to cause some turbidity of the water in well C. The fixing of this sluice-valve was completed on March 11th, and on March 13th excavation of the new heading was begun. The heading was driven during the daytime, and lined with bricks in cement each night. Meanwhile the water derived from the new heading in course of excavation, with that from well C, was to be pumped up and either discharged on the surface of the waterworks enclosure, or utilised for street-watering and sewer-flushing. But the water in question was not entirely thus disposed of, for the pump again and again became blocked (owing, it is said, to carelessness on the part of the brick workers at night); and when this happened the sluice valve was opened, and the accumulated water allowed to pass into the public service. Further, whether or not the pump was in working order, all water that accumulated in well C on Saturday afternoons and on Sundays was allowed access to the public service. So that the inhabitants of "Worthing" were drinking water in small amount from the new heading for some days before April 14th. The yield from the new heading prior to April 14th, estimated, it will be remembered, at 60 gallons per minute, was derived, it is not unimportant to know, according to Mr Harris the water engineer, mainly from a small fissure cut into on April 7th, when the heading was 53 feet long.

In view of these facts it may be inferred—given infective quality of the water encountered in the new heading—that the few straggling cases that occurred between April 16th and 22nd may have been infected through the medium of the small quantity of water intermittently added to the public service from this heading at a period antecedent to April 14th. The main outbreak, however, of late April and early May, occurred, as shown in Charts III. and IV., a fortnight to three weeks after the date on which the large fissure was cut into; that is, not until water from this new source had some time constituted a considerable proportion of the total supply. The incubation periods in this way indicated, alike for the initial cases and for cases included in the epidemic outburst in May, are accordingly altogether consistent with the total fever during April and May, in "Worthing" and Broadwater, having been due to infection conveyed in the water derived from this new heading.

[But, while these facts are such as not merely to harmonise with a theory that the "Worthing" public service acted as the medium of infection, but even to cast upon that service the most serious suspicion, a small amount only of the enteric fever prevalence in "West Worthing" and West Tarring, the other two invaded areas, is susceptible of similar explanation. For, as has been shown, no part of either of these places receives water from the "Worthing" public service.

As regards the earlier cases in these localities, indeed, much the same history was obtained as in regard of those persons in "Worthing" and Broadwater, who, notwithstanding that they resided in houses supplied by local wells, nevertheless suffered fever. Thus, in West Tarring, the person attacked in early May was a domestic servant in "Worthing" who was taken to her home in West Tarring after she had fallen ill. Similarly every case (except two) known to have occurred in West Tarring up to the end of the second week in July, either had resided in "Worthing" and gone home to West Tarring on falling ill, or was at work daily in "Worthing" and had drunk unboiled water there. Of the two exceptions, one had drunk aërated waters manufactured in "Worthing": the other is not to be thus accounted for. So, too, as regards "West Worthing," of the first six persons attacked (up to and inclusive of an attack on July 20th), four had drunk unboiled "Worthing" water: the two others could not be thus accounted for. There can be no question, therefore, that the occurrences of the disease in "West Worthing" and West Tarring up to mid July are to be regarded as part and parcel of the outbreak in "Worthing" and Broadwater. But the cases that occurred in these places in the latter part of July and the early portion of August require altogether different explanation. None of these persons are known to have drunk "Worthing" water. Here, then, we have at "West Worthing" and West Tarring, outbreaks,—later than the "Worthing" and Broadwater outbreak, but themselves concurrent in point of time,—which are not to be explained on a hypothesis that the "Worthing" water had been acting as the distributing agent of the enteric fever. The consideration of the causation of these two outbreaks will be resumed later.]

As to the fever in "Worthing" and in Broadwater which has been provisionally referred to the "Worthing" water supply, the question arises whether any circumstances have transpired pointing to the possibility of this service, especially the section of it which has appeared to be implicated in the fever, having been exposed to dangerous pollution.

The "Worthing" waterworks are on all sides surrounded by inhabited houses which drain into the "Worthing" sewers. Reference to the previously given diagrams (Diagrams I. and II.) will show the relation of the waterworks to the more important sewers in the neighbourhood; and also it will be seen from these diagrams that on the site itself there exist certain sewerage arrangements now disused. These are deserving of particular consideration.*

The sewerage arrangements, now disused, in the waterworks enclosure, date back to the time when "Worthing" sewage was delivered in the enclosure by the main sewer (entering it from High Street, which lies to the west of the waterworks,) into two brick tanks. These tanks, shown on the diagrams, were each 36 feet in depth, and their contents used to be pumped to a sewage farm, or into a neighbouring water-course, known as the Teville Stream. The tanks, marked respectively "sewage well" and "chain pump well," were connected at their bottom by a 15 in. pipe. From the "sewage well" two carriers passed in a south-easterly direction out of the waterworks enclosure. One of them was a 15 in. stoneware pipe, the other a 12 in. rising main made of iron; and by both sewage was conveyed to the sewage farm. These pipes were about 2 feet below the surface of the ground. From the "chain pump well" three 15 in. storm overflow pipes passed side by side in a north-easterly direction out of the enclosure; two of them discharged into the Teville Stream, while the third discharged into the Park Road sewer. These pipes were constructed of earthenware, and were laid side by side at a depth of about 15 ft. from the surface. In 1880, sewage pumping at the waterworks having been brought to an end, the sewer from High Street was bricked across at two points; one within the waterworks enclosure, the other in the street outside; the "Worthing" sewage from this time being made to pass along the new main sewer shown by a red line running north-east on the west side of the enclosure. At the same time the sewage tanks within the waterworks enclosure were filled up with earth. The carrier pipes, however, passing from the "sewage-well" to the (now disused) sewage farm, although rendered

* The diagrams show the water and sewerage arrangements on the site and in its neighbourhood as they were on April 14th, 1893, when the new water supply was struck.

useless, were nevertheless left undisturbed; and they remained so until September 1892, when those portions that lay within the waterworks enclosure were taken up. Meanwhile the three overflow pipes from the "chain pump well" had been, in 1885, blocked up at the north-east corner of the enclosure. The method employed in thus dealing with them consisted in taking up about 10 feet of the piping, and building a wall of bricks in cement across each end thus exposed, and filling in the space between the ends with earth. Accordingly, in April 1893, none of these structures had for 13 years been in use for dealing with sewage, though the three overflow pipes from the "chain pump well" remained, save for a length of 10 feet in each instance, intact. As before, two of them passed into the Teville Stream, while the third remained connected with the Park Road sewer. In the summer of 1893, when these overflow pipes came to be examined, they were found, at various points between the north-east corner of the waterworks enclosure and Park Road, cracked and broken; and they permitted leakage of their contents into the surrounding soil.* The particular pipe connected with the Park Road sewer had, between the waterworks enclosure and Park Road, a fall of about a foot, the exact levels being as follows :—

| | | |
|---|---|---|
| †In waterworks enclosure near well C | - - | 5·90 ft. above O.D. |
| †A few yards outside north-east corner of enclosure | | 5·38 ft. „ „ |
| †At junction with Park Road sewer | - - | 4·86 ft. „ „ |

If these data be accepted as correct, backing up of sewage through the Park Road sewer into this overflow pipe from the "chain pump well" need not, in view of the Borough Surveyor's experiments, quoted on p. 8 of this report, occur under ordinary circumstances; but it almost certainly would occur when heavy rainfall coincided with a tide-locked condition of the sewers. Under these conditions sewage would pass up out of the Park Road sewer along this pipe to the spot at the north-east corner of the enclosure where it was blocked; and would necessarily, owing to the leaky state of the pipe, escape into and pollute the surrounding soil. Sewage pollution of the soil, accordingly, might have occurred in this way, at least up to a point within 30 feet of the spot beneath which lay in the Chalk the new heading made in 1893.

But this overflow pipe-sewer is not the only sewer near the waterworks enclosure which, on examination made in the summer of this year, was found to be defective and permitting leakage into the soil. Another such was the Park Road sewer itself. This sewer, constructed of 12 in. stoneware pipes jointed with clay, permitted leakage at several points, some of its joints gaping widely. It lies parallel to the east side of the waterworks enclosure at a distance therefrom of 150 ft., and is at its nearest point some 160 ft. from the spot under which lies the extremity of the new head-

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* All these pipes contained solid deposit, but it was of different character in each. The pipe connected with the Park Road sewer was about half full of moist sediment, which was of black colour throughout; the pipe lying next to it was about three-quarters full of drier sediment, black on top and of grey colour elsewhere; and the third pipe contained a deposit about two inches only in depth, black on the surface, but white underneath and evidently composed of chalk. In view of the extent to which the "Worthing" sewers back up, it would follow that when this took place in wet weather the pipe connected with the Park Road Sewer might fill with sewage, whereas the pipes going to the Teville Stream would not. It might, indeed, be held that the presence of sewage in the pipe connected with the Park Road Sewer is indicated by the character of its contents; and that the tainted but less foul character of deposit in the adjacent pipes is explicable by leakage from the Park Road Sewer pipe contaminating the contents of the other two, of which the nearer showed most pollution. This different condition of contents of the overflow pipes, however, was found to obtain also in the case of those portions of them left in the waterworks enclosure, which were cut off in 1885 from the remainder of the pipes. The condition of their contents, therefore, cannot with probability be attributed to recent backing up of sewage. A more probable explanation of the condition of their contents is found in the fact that in 1885, prior to the blocking of these pipes at the north-east corner of enclosure, the water obtained from well C, then in course of construction, was pumped into one of these overflow pipes by which it was carried off. The pipe into which this water passed was the one now containing a clean chalky deposit; and, if it be assumed that the contents of all these pipes had formerly been black, it is conceivable that this water cleansed the pipe into which it discharged, and to some extent affected also the pipe lying next to this, to which it would gain partial access owing to the broken condition of these pipes. These considerations, however, do not militate against the conclusion, based on the data provided by the borough surveyor of Worthing, that occasional backing up of sewage would take place along the overflow pipe connected with the Park Road sewer.

† These measurements are from O.D. level to the invert of the pipe in each instance.

ing. In addition, to the west of the waterworks enclosure lies a 3-ft. brick barrel main sewer, some 210 ft. distant from well C, and some 250 ft. from the extremity of the new heading. This sewer was also found to be in a leaky condition near the waterworks enclosure. Since it lies at a considerably greater depth than either of those already referred to, it is full of backed up sewage when tide-locked; that is to say, twice every 24 hours.

It is sufficiently obvious, therefore, that the soil overlying the Chalk in which were sunk the wells and headings furnishing the water supplied to "Worthing" and Broadwater, was liable to sustained pollution by sewage. It does not, of course, necessarily follow, because the overlying soil was thus liable to pollution, that water taken from headings deep below in the Chalk would likewise be liable to dangerous pollution. Such pollution would, however, be very likely to occur if surface-water were to readily gain access through the Chalk to the water below, and there is reason to know that free communication did as matter of fact exist between the soil above the Chalk and the new heading in the waterworks enclosure. It will be remembered that in the description given, at an earlier stage, of the "Worthing" waterworks, reference is made to the fact that in 1885 a shaft that was being sunk near the north-east corner of the enclosure had to be abandoned owing to the large amount of water of very doubtful quality that was encountered within 18·6 ft. of the surface. The water in this experimental shaft was at the time observed to well up from a fissure in the Chalk; and this fissure was situated almost directly over the spot to which the new heading had been driven when the large inrush of water of April 14th, 1893, was encountered.

With the view, therefore, of ascertaining whether or not the fissure in question communicated with the new heading, I caused the old shaft of 1885 to be re-opened to a depth of 22 ft.; and into this re-opened shaft I had thrown, on August 17th, a ton of salt in solution. A sample of the water contained in well C was taken just before the salt solution was thrown down the shaft, and afterwards samples of this water were taken at intervals on the same and on the two following days. These samples were subsequently chemically analysed for chlorine. The addition of the salt solution occupied a period of an hour and a quarter, viz., from 11.30 a.m. to 12.45 p.m., and by 1 p.m., as will be seen by reference to the figures set out in Appendix A., the chlorine in the water of well C had enormously increased, while it had returned to its usual proportions a few hours later.

This experiment suffices to indicate that the fissure at the bottom of the abandoned shaft freely communicates with the new heading,* and it is evident that, given contamination by sewage of the ground above and in the neighbourhood of that fissure, dangerous material could readily gain access to the public water supply. Had circumstances permitted, similar experiments would have been conducted with the overflow pipes from the chain pump well and with the Park Road sewer. But, owing to a misunderstanding of earlier instructions given, a considerable length of these pipes had been already removed, and the ground filled in; and with the result that the conditions were so much changed from those prevailing in April that the value of experiments in this direction would have been open to much doubt. However this may be, it is now abundantly evident that opportunities for dangerous pollution of the "Worthing" water supply were not lacking, and it remains but to note the actual condition of this water as shown by chemical and by bacterioscopic examination.

Several chemical analyses of the "Worthing" water before as well as after the date on which the new supply was utilised, are given in Appendix B., and from these it will be seen that, as not infrequently happens, chemistry failed to detect any definite impurity in the water. But the results of bacterioscopic examinations, given in Appendix C., furnish conclusive evidence of contamination of this water supply by fœcal matter. In a sample taken from well C on July 26th, and submitted to examination on July 27th,

* This was subsequently confirmed in another way. In the course of some diving operations in the new heading at a later period, it was observed that air bubbled up through the water standing in the bottom of the abandoned shaft, and that this phenomenon was repeated whenever the divers were at work at the extremity of the new heading.

there was found a considerable amount of bacterium coli, a certain index of fœcal pollution. Again, on August 8th, another sample was collected drop by drop during a period of 24 hours from the rising main which distributes to "Worthing" and Broadwater water from the combined sources of the "Worthing" waterworks. This sample was submitted to examination on August 9th and in it was found the enteric fever bacillus, as well as abundance of the bacterium coli.

Thus the chain of evidence against the "Worthing" water is complete. It has been shown that the epidemic of enteric fever in "Worthing" and Broadwater was intimately related in point of time to the admission to the "Worthing" service of water from a new source of supply; that thereafter the disease became general throughout the areas supplied by this service; and that within the limits of these areas the incidence of fever was almost wholly on houses supplied with this water. Further, it has been shown that certain apparent exceptions to this rule, were, for the most part, persons who had elsewhere consumed the water in question. And now it appears not only that this new source of water supply was open to dangerous contamination, but also that, by the aid of bacterioscopic examination, demonstration is forthcoming of such contamination having actually occurred.

Attempts to ascertain whether specific infection from a previously known case of enteric fever in the district might have gained access to the water supply, were unsuccessful. Only two cases notified as enteric fever occurred in "Worthing" in 1893, prior to the prevalence at the end of April. One of these died in the infirmary on January 17th, of what was certified to have been typhoid fever and pneumonia. But this date is three months anterior to the outbreak now being considered, and it is difficult to suppose that here is to be found the source of the outbreak. Moreover, it would seem that doubts exist as to whether this was in reality a case of enteric fever. The other case of enteric fever was one that proved fatal on February 20th in West Buildings, "Worthing." This person was, throughout her illness, treated at the place above named. Sewage from that house would, on its way to the outfall, pass along the main sewer lying to the west of the waterworks enclosure, which sewer, it will be remembered, was found to permit leakage into the surrounding soil. But this case also occurred at an interval sufficiently distant to justify hesitation in accepting it as a probable source of the subsequent outbreak. Dr. Kelly, the medical officer of health for the district, has suggested that excremental fouling of the new heading by workmen employed in its excavation, a fact of which he possesses evidence, may have been the cause of the April and May outbreak. No evidence, indeed, is forthcoming that any of the workmen employed were at that time suffering from enteric fever, though of course it is not to be denied that slight and "ambulant" attacks of the disease are not always recognised. However this may have been, the sudden multiplication of attacks in the beginning of July, may, with some probability, be attributed to pollution of the water supply on a large scale by infective material, derived from the cases of the April and May outbreak. The excreta of almost all these persons would, like those of the fatal case of February 20th, pass along the leaky main sewer that lies to the west of the waterworks enclosure; and, in addition, it has to be borne in mind that the defective Park Road sewer, which was connected with one of the overflow pipes previously referred to, received the Infirmary sewage. In the months of May and June, a large number of persons suffering from enteric fever were admitted into and treated at the Infirmary. Into this institution were admitted 27 cases during May, 14 during June, and 9 during July. No cases of enteric fever were admitted after July 9th. The Park Road sewer was reconstructed in June, but up to June 26th the old sewer remained in use. Accordingly up to this date, enteric excreta were passing along a defective sewer situated on the east side of the waterworks enclosure, in addition to the enteric excreta passing along the west side in the main sewer already referred to.

There still remain for consideration the fever-prevalences in "West Worthing" and West Tarring, both of which developed, it will be remembered, long after the epidemic had become established in "Worthing" and Broadwater.

Each of these other fever-prevalences—in "West Worthing" and in West Tarring respectively—is divisible, as will be seen from Table VI. and Chart IV., into two series of cases consisting:—

(1.) Antecedent to mid-July, of a series of earlier cases, few in number, and irregularly distributed in both places, but tending chiefly to affect one particular locality in each.

(2.) During, and in weeks subsequent to, mid-July, of a considerable outburst of fever almost entirely localised in "West Worthing" and West Tarring, in that section of each of these areas which had already especially suffered from the malady.

The first series, *i.e.*, antecedent to mid-July, has already been accounted for; the persons attacked during that period, whether in "West Worthing" or in West Tarring, having almost without exception become infected in "Worthing." It is the outbursts, constituted by the second series of cases, in "West Worthing" and in West Tarring respectively, that require explanation, and for the following reasons:—

(*a.*) They were found not to be directly referable to antecedent fever either in Worthing or in their own localities.

(*b.*) They were not attributable, as has already been shown, either to defective general sanitary circumstances or to infective emanations from sewers or drains.

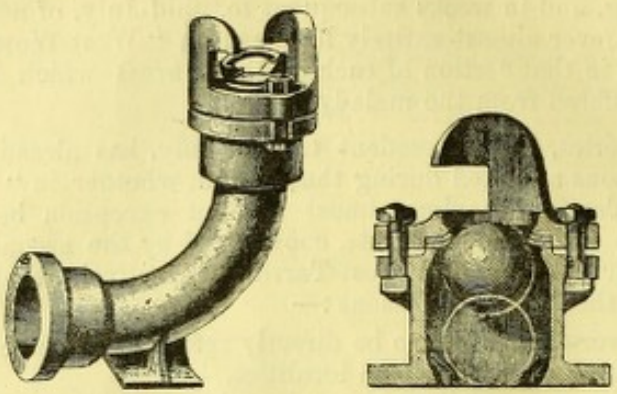
(*c.*) Milk supply, as has been shown in a previous section of this report, did not aid in the dissemination of this fever.

(*d.*) They could not be considered, if regard be had to the escape of large sections of each locality, referable to water-supply, unless limited areas of their common water service can have become infected simultaneously by separate (or preferably by a single) fever agency.

There are, however, certain facts in connection with the "West Worthing" water-service, *which is, as just stated, common to the two places*, that tend to throw some light on the matter. These facts in no way throw discredit on the water at its source, which, as has already been stated, is the Chalk below the town, the water being pumped from a couple of wells furnished with boreholes. Chemical analysis of this water (*see* Appendix B.) has invariably attested its purity, and no change has been made in the source of the supply during several years. Moreover, such enteric fever as has in other years occurred in the area supplied by this service has never been distributed in fashion suggestive of contamination of the water supply as a whole. If, therefore, the "West Worthing" water is to be thought of as concerned in the localised fever witnessed in 1893 in "West Worthing" and West Tarring, there is almost involved a presumption that this water supply became contaminated after withdrawal from its source; namely, in the mains of the water-company. And there is, to say the least, possibility that specific infection in this sense of these water-mains, or some of them, may have occurred in 1893; as will be seen from the considerations that follow.

The conformation of the ground in "West Worthing" is such that its highest points are to be found along a ridge which runs through it from east to west. This ridge is to the north of a line drawn east and west through the centre of the place. From this ridge the ground slopes gently on one side to the south and on the other to the north. Most of the houses in "West Worthing" lie on the south of this ridge; and all the houses in West Tarring to the north of it. The water-mains follow the contour of the ground. As the "West Worthing" water supply is usually intermitted for a considerable interval of time between the afternoon of one day and the morning of the next the higher portions of the water-mains tend to become emptied as the water flows down into the lower portions of the service. I have satisfied myself by personal inspection that this condition may exist, and the accompanying diagram (Diagram III.) illustrates this state of things. The invaded area in "West Worthing" is at the lowest inhabited point of the slope on the southern side of the ridge; the invaded area in West Tarring is at the lowest point of the slope on the northern side. If, then, any infective material were to gain access to the higher "West Worthing" water-mains it would, under the conditions described, gravitate to these two areas, and tend to

lodge in the water-mains there. Owing to the kind of street-hydrant with which nearly all mains on the "West Worthing" service are fitted the contained water is especially liable to risk of pollution from matters cast on the roadways. The prevailing pattern of hydrant is that known as the "ball-hydrant," of which illustrations are annexed.



This hydrant consists of an iron pipe which communicates with the water main below and in which is enclosed an ebonite ball. This ebonite ball is driven by the pressure of the water below up against a flange lined with india-rubber, and when thus situated prevents egress of water and ingress of foreign material. The whole is enclosed in an iron box with keyhole; the lid of the box being usually flush with the surface of the roadway. The interior of the box not infrequently contains filth which has gained access by the keyhole of the hydrant box. When the pressure in the main falls below a certain amount, stated to be about 6 lbs. per square inch, the ball drops, and filth from the hydrant box or from the roadway may readily pass into the water mains. I ascertained by actual inspection at a time when the engines had for several hours ceased pumping, that the balls in the hydrants of the "West Worthing" service actually had dropped in the majority of instances, and that fouling of water in the mains below was thus rendered possible. Infective material, therefore, might in this way have gained access to the mains of the "West Worthing" water service, near the summit of the ridge above referred to, and might then, owing to the conditions that I have just described, have especially affected the two localities in which the disease was found chiefly to have prevailed. As matter of fact, there was in 1892 a small outbreak in "West Worthing" and West Tarring which was localised in much the same way as the outbreaks now under discussion, and which Dr. Kelly, in his report on that outbreak, attributed to infection of water mains through ball hydrants.

With a view of ascertaining whether the water in the "West Worthing" water mains differed bacterioscopically from the same water at its source, samples of the supply were submitted to Dr. Klein from the rising main at the water-works, and from a tap in Brunswick Road, a street situated in that section of "West Worthing" where there had been exceptional prevalence of fever. Unfortunately, however, this was not done until August 21st, when the acmes of the fever outbursts in "West Worthing" and West Tarring were passed: and, whether for this or for other reason, the result of Dr. Klein's examination of the water was negative. Neither in the water from the rising main, nor in that from the main situated in the fever invaded section of "West Worthing" was either the enteric fever bacillus or the bacillus coli discovered. (*See* Dr. Klein's report in Appendix C.) But while this bacteriological evidence fails to afford confirmation of the belief that specifically infected material had gained access to the "West Worthing" water-supply, it cannot be held as proof that this water was free from infection at the time when fever was most prevalent (during the period mid-July to mid-August) in the invaded areas, nor, indeed, that it (or some of it) was not specifically polluted at the time when the samples were collected. For specific organisms are usually present in water in small amount only, and may readily be absent in small samples selected for examination out of the total bulk of water.

Upon a balance of considerations I incline to belief that the fever outbursts in "West Worthing" and West Tarring, during the period mid-July to mid-August, and in subsequent weeks, are referable to localised infection of water-mains in the invaded sections of these places.

In what particular way the water in the "West Worthing" water mains may have become specifically infected there is not sufficient evidence to show. It has been suggested that the "West Worthing" and West Tarring outbreaks might be explained by the fact that during a few days in July and August 1893, the "West Worthing" streets were, for the first time for 2½ years, watered with "Worthing" water. This step was taken owing to an unusually heavy drain on the "West Worthing" supply, which was being utilised to fill with drinking-water tanks scattered about "Worthing." It is easy to see that if the "Worthing" water used to water "West Worthing" streets contained infective material, contamination of the "West Worthing" water supply would readily take place when the balls of the hydrants had dropped during intermission of water-pressure in the mains; and that "Worthing" water distributed by water-carts along the crown of the ridge before described, would gravitate during intermission of the "West Worthing" service to the lowest points of the water mains in "West Worthing" and West Tarring respectively.

There is, however, some discrepancy in the evidence as to the exact date on which "Worthing" water was first employed in this way. The foreman, whose duty it is to look after street watering, maintains that "Worthing" water was thus used for the first time on July 28th, whereas the "West Worthing" Waterworks' books show that no "West Worthing" water was used for street watering from July 25th to August 8th, both dates inclusive. There was no rain on the 25th or 27th July to render street watering unnecessary. But even assuming the 25th to have been the date on which the "Worthing" water was first employed for street watering, the circumstance of its employment cannot be considered as accounting for the earlier part of the outbreak, *i.e.*, that on July 27th and days following, unless, indeed, the incubation period in these earlier cases was more than ordinarily brief.

Examination of the rainfall register given in an appendix (Appendix D.) suggests that possibly infective matter may have been washed during a rain storm into the mains when the hydrant balls had dropped from lessened pressure. It will be noticed that there was heavy rainfall about the 15th and 16th July, that is, some 12 days before the commencement of the outbreak, and at a time, therefore, consistent with relation of cause and effect between the exceptional rain fall and the outburst of fever in "West Worthing" and West Tarring. A considerable amount of rain fell also on July 19th and 20th, and again on July 23rd.

The conclusion to be arrived at on the whole of these facts is that the subsidiary outbreaks in "West Worthing" and West Tarring resemble the outbreaks in "Worthing" and Broadwater in their having been due to infective material which gained access to and was distributed by the water-service. But they differ from the manifestations of the disease in "Worthing" and Broadwater in so far as they were not general throughout the whole of "West Worthing" and of West Tarring, but were almost entirely limited to two localities in these areas; and they differ also in that the evidence points rather to local infection of water in the mains than to pollution at its source, as was the case with the "Worthing" service. How the infective material of enteric fever gained access to the "West Worthing" water-mains there is not sufficient evidence to show.

### Action taken by the Town Council of Worthing as Urban Sanitary Authority.

In view of the outbreak of fever in May, 1893, a special meeting of the Sanitary Committee was held on the 15th of that month and the following recommendations were made, viz.:—

"(*a.*) To empty, cleanse, and hot limewash the reservoir on top of the water tower.

"(*b.*) To cleanse and flush out the water mains, hydrants, and dead ends of mains.

"(*c.*) That notice be given to the inhabitants, by placards and by advertisement in the local papers, to boil all water and milk previous to use.

"(*d.*) To flush the house drains and sewers.

"(*e.*) To disinfect excreta of infected patients.

"(*f.*) To provide hospital accommodation, and nurses to attend the sick.

"(*g.*) To submit samples of water to bacteriological analysis."

Consequent on these resolutions the following steps were taken, viz. :—

The reservoir on the top of the water tower was emptied, cleansed, and hot limewashed during the night of the 15th—16th May. This procedure was repeated on June 1st and on September 22nd. The work of placing hydrants at all dead ends of watermains not already provided with these was begun on May 15th. On the same date the water-mains were flushed and the hydrants blown out. This flushing of water mains was frequently repeated every day for a fortnight, and at occasional intervals up to the end of November. Besides the publication of warning advertisements in the local papers, a card was sent to each house in the borough cautioning the inhabitants against the use of unboiled water or of unboiled milk. Printed notices and handbills containing similar instructions were freely distributed on several occasions. Samples of water were taken and sent to Professor Crookshank, King's College, London, for bacterioscopic examination, as follows :—

From well C, May 16th (this was broken in transit).
From tank, May 15th.
From well C, May 22nd.
From well C (two samples), June 5th.

At subsequent dates the following further steps were taken in connection with water supply :—On June 17th a circular letter was sent to all owners of property and house agents in the borough, requesting that all drinking water cisterns should be cleansed and wiped dry. In the case of empty houses this was required to be done forthwith. Tanks for a special supply of water for drinking and cooking purposes were placed at convenient points in the streets on July 18th. At this date, and for some time afterwards, water was supplied to these from the "West Worthing" Waterworks.

On July 29th, under direction of the Sanitary Authority, an attempt was made by a skilled diver to close the fissure in the new heading from well C at the Worthing Waterworks, but without success. A second and more carefully considered attempt was made on August 23rd by two experienced divers, but this also failed. The object in view in making these attempts to close the fissure, was the exclusion from the "Worthing" public service of the water contributed thereto from this fissure. In this way it was hoped that further pollution of the public water supply would be avoided.

Steps were also taken with the view of acquiring a new and pure water supply of a permanent character. To this end, and in consequence of an application made by the Worthing Corporation for loan of 3,000*l.* for preliminary expenses in connection with works of water-supply, a public inquiry was held at Worthing on August 1st by the Board's Engineer Inspector, Mr. Arnold Taylor. At the inquiry it appeared that the source of such new water-supply had not yet been decided on, and up to the beginning of 1894 no definite scheme of works for a permanent water-supply had been submitted by the Sanitary Authority to the Board.

Meanwhile a shaft was sunk in the Chalk near the village of Broadwater, from which, it was hoped, a temporary supply would be obtained sufficient in amount to enable the Worthing Corporation to entirely and at once dispense with the existing polluted public service. From September 4th onwards the street tanks, before referred to as furnishing the inhabitants with a special supply of water for drinking and cooking purposes, were filled with water from this new well near Broadwater; and on September 22nd these Broadwater works had so far progressed that it became possible to pump the new supply into the mains of the "Worthing" public service. Since September 22nd, therefore, the polluted supply has been entirely replaced by the Broadwater supply. For a time, however, the street tanks still continued to be filled from the Broadwater new well, the water in the mains, which had not as yet been disinfected, being supplied chiefly

for drain-flushing purposes; but, according to Dr. Kelly, the Medical Officer of Health for the borough of Worthing, many persons probably took their water direct from the mains for drinking and cooking purposes. The provision of this temporary supply of water from the Broadwater well was due to the energy of Mr. Alderman Cortis, a member of the Worthing Sanitary Authority, at whose cost, indeed, the necessary initial works were taken in hand. Later, with the view of disinfecting the water-mains of the "Worthing" service these were, on the evening of October 21st, charged with limewater, and were kept so charged during the two days following.

*Isolation of Persons attacked by Enteric Fever.*—In the absence in Worthing of hospital accommodation for infectious diseases, the following special arrangements were made for the isolation of cases of enteric fever:—On May 16th the Committee of the Worthing Infirmary set aside nine beds for the treatment of enteric fever, and on May 19th two hospital tents, each containing eight beds, were erected for the same purpose in the Infirmary grounds. The following places were subsequently converted temporarily into hospitals for the reception of enteric fever, namely:—On July 7th, the Richmond Convalescent Home; on July 12th, the Newland Road Mission Room; on July 15th, the Lyndhurst Road Primitive Methodist Chapel; on July 17th, the "Travellers' Rest" lodging house; on July 18th, the Retreat, High Street; on July 26th, Mr. Ralli's private hospital on Marine Parade. In all 422 enteric fever cases from the borough of Worthing were admitted into one or other of the foregoing institutions. A staff of nurses was engaged for each of these places, and, in addition, the Nursing Association provided, at the expense of the Worthing Corporation, nurses to attend the sick at their own homes. Pony carriages were used to convey these nurses from house to house; and in this way persons treated at home were visited at least once and frequently twice each day.

*Convalescents.*—Accommodation for convalescents from all invaded areas was provided in homes temporarily taken at Goring, Findon, as well as at Chichester House and Milton House, Worthing. Expenses in connection with these homes were met by the "Mayor's Sick and Poor Fund."

*Disinfection.*—Infected rooms found to be overcrowded or in a dirty state were fumigated with sulphur and afterwards cleansed and whitewashed. Disinfectants were supplied gratis to inhabitants of the borough from May 8th to the end of August. After the latter date they were supplied to the hospital institutions only.

*Drain flushing.*—During continuance of the epidemic special gangs of men were employed in flushing, by means of fire hose attached to street hydrants, the drains of houses invaded by fever. This was done daily in the majority of cases and at least three times weekly in the remainder.

### Action by the East Preston Rural Sanitary Authority.

Similar precautions in the matter of warning inhabitants against drinking unboiled water or unboiled milk, and as regards disinfection and drain flushing, were observed in the villages of West Tarring and Broadwater. These places are devoid of hospital accommodation for infectious diseases and accordingly the following temporary arrangements were made. At West Tarring the public Reading Room was on July 14th utilised for the reception of cases of enteric fever, and on August 9th the Infants' School was devoted to the same purpose. In all 32 patients were thus accommodated. At Broadwater the Public Reading Room was, on July 20th, employed for the reception of cases of enteric fever, of whom 22 were in this way accommodated.

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The history that has been set forth of the severe outbreaks of enteric fever in the four areas of "Worthing," "West Worthing," West Tarring, and Broadwater, adds one more instance to the already lengthy list of examples of the disastrous consequences that may result from a specifically polluted public water supply. From it, as matter of first instance and of chief importance, the several Sanitary Authorities should learn the necessity of supplying a water pure at its source and free from risk of pollution after collection and during delivery. To fulfil this end they cannot display too great energy in pushing on the works necessary for the provision of a pure supply of a permanent character. The present supply procured from the well near Broad-

water village, while undoubtedly preferable to that which it has replaced, is nevertheless not one that can be regarded as beyond risk of contamination. It is too near the village of Broadwater and to other human habitations to be beyond suspicion of pollution. And indeed certain bacteriological analyses that have been made of the water supply by Dr. Klein, and of which an account is given in an appendix to this Report (Appendix C.), suffice to show that the water contains impurities which are of a character raising suspicion that it may in its turn become specifically polluted so as to distribute disease throughout the area of its supply. It is therefore most desirable that a water of undoubted purity should be made available for use as soon as possible. Further, the avoidance of risk of local pollution of water-mains should be a matter of the most serious care to the Sanitary Authorities of the districts concerned. That this is liable to occur in the case of an intermittent supply delivered through mains fitted with ball-hydrants is unquestionable; and accordingly this matter should receive most careful consideration.

The sewerage arrangements of the several areas dealt with in this report, are very unsatisfactory. In addition to the defective condition of many sewers in "Worthing" and "West Worthing" due to faults of construction and to insufficient fall, the two systems of sewers which serve "Worthing," "West Worthing," and West Tarring are tide-locked, and consequently sewage backs up in them during large part of the 24 hours. In Broadwater, again, there is no proper system of sewerage at all; such drainage as exists being into cesspools or into fields and ditches. It is the duty of the respective Sanitary Authorities to remedy these defective conditions without delay. The need for action of this sort has been recognised by the Worthing Town Council who have made applications to the Board for sanction to a loan of 36,300*l.* for works of sewerage. Enquiry as to the matter of this application was on December 14th, 1893, made at Worthing by the Board's Engineer Inspector, Mr. Arnold Taylor.

Other administrative shortcomings, referred to in the body of this report, those, for instance, in connection with house drainage and disposal of refuse and excrement, deserve the attention of the Sanitary Authorities of "Worthing," "West Worthing," West Tarring, and Broadwater; but in the first instance and principally they should deal with the important questions of how to provide pure and sufficient water supplies and efficient sewerage arrangements.

My thanks are due to the mayor and members of the Town Council of Worthing; to Mr. Verrall, town clerk of Worthing; to Mr. Aspinall, borough surveyor of Worthing, and his assistants; to Mr. Harris, engineer to the Worthing Waterworks; and to Mr. Vail, inspector of nuisances in East Preston Rural Sanitary District, for much information and sustained assistance. I have especially to thank Dr. Kelly, medical officer of health for the West Sussex combined district, of which the invaded places form part, under whose supervision the maps and charts appended to this Report were made, and who aided me in many other ways. Also I would expressly record my indebtedness to Mr. Gardner, inspector of nuisances for the borough of Worthing, for a great variety of data collated for me by him with much care and trouble.

THEODORE THOMSON.

January 9th, 1894.

## APPENDIX A.

SHOWING, in parts per 100,000, the amount of Chlorine present in certain samples of Water collected from Well C of the "Worthing" water-works prior, as well as subsequent, to pouring a ton of salt in solution down the 1885 shaft (re-opened for this purpose in 1893).*

| Sample. | Date and Hour when Sample was taken. | Chlorine parts per 100,000. |
|---|---|---|
| A | August 17th, at 11.30 a.m. | 5·0 |
| B | " " " 1 p.m. | 35·8 |
| C | " " " 3 p.m. | 8·8 |
| D | " " " 6 p.m. | 6·1 |
| E | " " " 9 p.m. | 5·7 |
| F | " 18th, at 9.15 a.m. | 5·0 |
| G | " " " 9.30 a.m. | 5·6 |
| H | " " " 3.15 p.m. | 5·0 |
| I | " " " 9 p.m. | 5·0 |
| K | " 19th, at 9.30 a.m. | 5·0 |
| L | " " " 7 p.m. | 5·1 |

## APPENDIX B.

CHEMICAL ANALYSES OF "WORTHING" AND OF "WEST WORTHING" WATER.

"WORTHING" WATER.

Report on a sample of water received from Mr. W. Horne on June 11th, 1885.

Sample contained in a Winchester quart bottle, stoppered. Stopper tied down with string. No label on bottle.

The water is slightly turbid and, on standing, yields a little deposit consisting chiefly of mineral matter but containing a few animalculæ. It has a very slightly musty smell. The amount of albuminoid ammonia yielded is somewhat high, and indicates a slight pollution, probably by surface drainage; this is also indicated by the strong traces of nitrous acid present, and the amount of oxygen absorbed from permanganate which, although not high absolutely, is rather higher than it should be in a pure deep well-water. The water is rather hard but becomes soft on boiling, and it might, perhaps, be advisable to submit the water to a process of softening. All other features are satisfactory.

ANALYTICAL DETAILS.

| | |
|---|---|
| Appearance | Slightly turbid. |
| Colour | Very light greenish brown. |
| Taste | —— |
| Smell | Very slightly musty. |
| Deposit | Slight (brownish). |
| Nitrous acid | Strong trace. |
| Phosph. acid | Slight trace. |
| Poisonous metals | None. |
| Hardness before boiling | 21 degrees, Clark. |
| " after boiling | 4 " " |
| Oxygen absorbed from permanganate | 0·030 grains per gallon. |
| Chlorine | 2·66 " " |
| Nitric acid | 1·46 " " |
| Total dry residue | 27·16 " " |
| Colour of residue | Very pale yellowish. |
| Behaviour of residue on ignition | Blackens very slightly burns off readily. |
| Ammonia | 0·0073 |
| Albuminoid ammonia | 0·0067 |

A. DUPRÉ.

Westminster Hospital,
June 18th, 1885.

* The salt solution was poured down this shaft on August 17th, 1893. The process commenced at 11.30 a.m., immediately after Sample A. had been taken, and continued until 12.45 p.m., when it terminated.

## "Worthing" Water.

Report on a sample of water received from Mr. Charles T. Gardner, Health Department, Town Hall, Worthing, taken from well C, from water at surface of the well.

The water is clear, almost colourless, inodorous, and yields no deposit on standing. It shows no indications of pollution by sewage and surface drainage, but has all the characteristics of a pure Chalk water. It is rather hard, but not to an objectionable degree, and becomes soft on boiling. It would, however, be improved for general domestic purposes by being submitted to a process of softening.

### Analytical Details.

*Taken May 2nd*, 1893.

| | |
|---|---|
| Appearance | Clear. |
| Colour | Almost colourless. |
| Smell | Inodorous. |
| Deposit | None. |
| Nitrous acid | None. |
| Phosphoric acid | Strong trace. |
| Poisonous metals | None. |
| Hardness before boiling | 20·3 degrees Clark. |
| „ after boiling | 5·0 „ |
| Oxygen absorbed from permanganate | 0·035 grain per gallon. |
| Total dry residue | 27·16 „ |
| Colour of „ | White. |
| Behaviour of residue on ignition | Darkens very slightly; burns off very readily |
| Chlorine | 2·73 grains per gallon. |
| Nitric acid | 1·44 „ |
| Ammonia | 0·00056 „ |
| Albuminoid ammonia | 0·0028 „ |

Medical Schools,
Caxton Street, Westminster,
May 6th, 1893.

A. DUPRÉ.

## "Worthing" Water.

Report on a sample of water received on May 8th, 1893, from Mr. Charles T. Gardner, Health Department, Town Hall, Worthing. Sample was taken 30 feet below the surface of water standing 27 feet below ground level in well C.

The water is clear, almost colourless and inodorous; it gives no deposit on standing.

The present sample is a distinct improvement on that of May 3rd, 1893; and the water has now all the characteristics of a pure chalk water, showing no signs of any pollution by sewage.

### Analytical Details.

*Taken May 6th*, 1893.

| | |
|---|---|
| Appearance | Clear. |
| Colour | Almost colourless. |
| Smell | Inodorous. |
| Deposit | None. |
| Nitrous acid | None. |
| Phosphoric acid | Trace. |
| Poisonous metals | None. |
| Hardness before boiling | 19·2 degrees Clark. |
| „ after boiling | 4·7 „ |
| Oxygen absorbed from permanganate | 0·006 grains per gallon. |
| Total dry residue | 27·16 „ |
| Colour of „ | White. |
| Behaviour of residue on ignition | Darkens, scarcely perceptibly. |
| Chlorine | 2·97 grains per gallon. |
| Nitric acid | 1·79 „ |
| Ammonia | 0·00168 „ |
| Albuminoid ammonia | 0·0007 „ |

Medical Schools,
Caxton Street, Westminster,
May 12th, 1893.

A. DUPRÉ.

## "West Worthing" Water.

Report on a sample of water received Aug. 10, 1886, from the West Worthing Improvement Commissioners. Sample contained in a Winchester quart stoppered bottle, secured by red tape and sealing wax, wax unbroken.

The water is clear, of a very pale greenish colour, and is free from smell. On standing, it yields a minute trace of deposit, chiefly mineral. It is somewhat hard, but becomes fairly soft on boiling. It has all the characteristics of a pure deep well water, and constitutes a first-class drinking water, although for general domestic purposes it would be improved by softening.

The analytical details are given in the table annexed :—

| | |
|---|---|
| Appearance | Clear. |
| Colour | Very pale greenish. |
| Smell | Inodorous. |
| Deposit | Minute trace. |
| Nitrous acid | None. |
| Phosphoric acid | A trace. |
| Poisonous metals | None. |
| Hardness before boiling | 19·0 degrees Clark. |
| „ after boiling | 5·5 „ |
| Oxygen absorbed from permanganate | 0·011 grains per gallon. |
| Total dry residue | 23·80 „ |
| Colour of residue | White. |
| Behaviour of residue on ignition | Does not blacken; no smell. |
| Chlorine (in chlorides) | 2·59 grains per gallon. |
| Nitric acid (in nitrates) | 1·68 „ |
| Ammonia | 0·0000 „ |
| Albuminoid ammonia | 0·0011 „ |

Aug. 13th, 1886. A. DUPRÉ.

## "West Worthing" Water.

*Dr. Dupré's Report.*

Report on sample of water received on January 14th, 1892, from Mr. Gardner, Sanitary Inspector for the Borough of Worthing.

Sample contained in a Winchester quart bottle, stoppered; stopper secured by tape and seal, both uninjured; bottle labelled "Water from West Worthing Waterworks "Company; drawn from tap on the mains, January 14th, 1892."

The water is bright, nearly colourless, and inodorous; it yields no deposit on standing.

The water is of high organic purity, and does not show the slightest trace of pollution by sewage.

It has all the characteristics of a very pure chalk water, practically uninfluenced by its proximity to the sea. It is perhaps a trifle hard, though by no means to an objectionable degree, and becomes soft on boiling.

### Analytical Details.

| | |
|---|---|
| Appearance | Bright. |
| Colour | None. |
| Smell | None. |
| Deposit | None. |
| Nitrous acid | None. |
| Phosphoric acid | Slight trace. |
| Poisonous metals | None. |
| Hardness before boiling | 18 degrees Clark. |
| „ after boiling | 4·2 „ |
| Oxygen absorbed from permanganate | 0·000 grains per gallon. |
| Total dry residue | 25·48 „ |
| Colour of residue | White. |
| Behaviour of residue on ignition | Darkens very slightly; burns off very readily. |
| Chlorine | 2·59 grains per gallon. |
| Nitric acid | 1·26 „ |
| Ammonia | 0·0000 „ |
| Albuminoid ammonia | 0·0033 „ |

# APPENDIX C.

SUMMARIES of Dr. Klein's Reports on Samples of "WORTHING" and of "WEST WORTHING" Waters submitted by him in 1893 to BACTERIOSCOPIC EXAMINATION.

The following samples of water were submitted to Dr. Klein for examination * :—

A. "Worthing" water supply, taken July 26th.
B. Do. do. taken August 8th.
C. "West Worthing" water supply, taken August 21st.
D. Do. do. do. do.
E. Do. do. taken December 7th.
F. "Worthing" *temporary* supply from Broadwater, taken November 29th.
G. Do. do. do. do. taken November 30th.
H. Do. do. do. do. taken December 7th.
I. Do. do. do. do. do. do.
K. Do. do. do. do. do. do.

*Methods of Examination.*

The methods of examination resorted to were as follows. With the view of ascertaining the quantity of micro-organisms per cubic centimetre of the water under investigation the ordinary method of plate cultivations was employed. This plan consists of adding to nutrient gelatine in a fluid state a small quantity of water to be examined (the amount employed varying from one c.c. to a fraction thereof), shaking the mixture so as to aid distribution of the water throughout the gelatine, and then pouring the mixture on plates. These plates, on which the gelatine mixture solidifies, are then transferred to an incubator and maintained at a temperature of 20° C.; and by subsequent observation the number and nature of the organisms that grow on the gelatine are ascertained.

Another method was resorted to in searching for particular microbes in water from a given source, and for the following reasons :—

(*a.*) The bacillus coli and the enteric fever bacillus, when present in drinking water, exist there for the most part in relatively small proportion. Thus, if only a small quantity of water, such as one c.c., be examined, it is likely that the organism, sparingly present in the total bulk of water, may not be present in a small sample, although present in a larger bulk.

(*b.*) If the number of other micro-organisms amount to several hundreds or more per c.c. —and this is usually the case when water is unfiltered—there is risk that the numerous colonies of these may on plate cultures obscure and prevent recognition of scantily present bacillus coli or enteric fever bacillus.

(*c.*) One of the bacteria most frequently found in water is the bacillus fluorescens liquescens, which grows much more rapidly than either the bacillus coli or the enteric fever bacillus, and liquifies gelatine very quickly. Abundance of the first-named bacillus in the water under examination would accordingly, by liquefaction of the gelatine mixture, tend to prevent detection of either of the last-named bacilli. With the view, therefore, of overcoming these difficulties the following means were adopted :

(1.) A considerable bulk of water (from 1,500 to 2,500 c.c.) was submitted to examination. For this purpose the quantity to be examined was passed through a sterile Berkefeld filter, which retained on its outer surface all or nearly all the particulate matter contained in the water. The matter thus retained on this outer surface was then brushed with a sterile brush into 20 c.c. of sterilised water and mixed therewith. Of this mixture 1 c.c. was added to each of a series of gelatine plates and broth† tubes. Accordingly these tubes and plates contained all or nearly all the particulate matter of the total quantity of water selected for examination.

(2.) To prevent obscuring of the bacillus coli or the bacillus of enteric fever by other organisms that grow more rapidly than they, or that soon liquefy the gelatine, a small quantity of phenol was added to the culture media. For this purpose a 5 per cent. watery solution of phenol was used, and this solution was added to the culture media in the proportion of 1 of the former to 100 of the latter. The added phenol, which does not interfere in any way with the growth and multiplication of the bacillus coli or of the bacillus of enteric fever, exerts a marked inhibitory effect on such water bacteria as bacillus fluorescens liquescens, the proteus vulgaris, and others; and, by retardation or suppression in this way of growth of these latter organisms, better opportunity is afforded of detecting in waters examined the presence of the bacillus coli or of the bacillus of enteric fever.

* In such case a gallon of water, collected in a clean jar, was sent for examination. Prior to collection of the sample the jar was rinsed with water from the source from which the sample was about to be taken.

† Beef broth : alkaline : with one per cent. peptone and one per cent. salt added.

The gelatine-plate and broth-tube cultures thus prepared, were incubated at a temperature of 20° C. and of 37° C. respectively. From growths of the bacillus coli or the enteric fever bacillus obtained in these ways sub-cultures were made in the ordinary manner.

*Features characteristic of Bacillus Coli and of the Enteric Fever Bacillus.*

| Bacillus Coli. | Enteric Fever Bacillus. |
|---|---|
| Shorter and less mobile than the enteric fever bacillus. | Longer and more mobile than the bacillus coli. |
| Forms gas bubbles in gelatine shake culture. | Does not form gas bubbles in gelatine shake culture. |
| Curdles milk in 1–2 days at 37° C. | Does not curdle milk. |
| If grown in broth for several days forms indol. | Gives no indol reaction when grown in broth. |

The above tabular statement embodies the chief distinctive features of the bacillus coli and the enteric fever bacillus, derived respectively from the contents of the healthy human intestine and from the tissues of enteric fever. Other points are as follows. In gelatine stab-culture and in gelatine surface cultures these bacilli are alike in general appearance save in two respects, viz.: (*a*.) that the bacillus coli grows faster than the enteric fever bacillus, and (*b*) that in gelatine stab-culture the former organism forms on the upper surface of the gelatine a larger plate-like growth than does the latter. On gelatine plates both organisms form on the surface of the culture medium colonies which present the appearance of flat, crenated, or irregularly outlined patches, thinner at the periphery than at the centre, translucent by transmitted light, greyish by reflected light; while colonies of both organisms, growing beneath the surface and embedded in the gelatine, are rounder than surface colonies, and appear of a brownish colour by transmitted light. Neither organism liquefies gelatine. Their growth on agar and on potato affords no definitely distinctive feature; although, as a rule, the bacillus coli forms on potato a brownish growth, while the bacillus of enteric fever forms on the same medium a colourless growth.

## Reports on Waters submitted to Examination.

### *"Worthing" Water.*

*Sample A.*—Taken on July 26th from Well C. of the "Worthing" waterworks.

Cultivations were made on four non-phenolated gelatine plates in the ordinary manner. In this way the following common water bacteria were isolated.

(*a*.) Bacillus fluorescens liquescens; found in all four plates.
(*b*.) Cocci, non-liquefying and liquefying; found in all four plates.
(*c*.) Bacillus mesentericus; found in three plates.
(*d*.) Proteus vulgaris; found in three plates.
(*e*.) Bacillus fluorescens putidus; found in two plates.

Cultivations in four phenolated broth tubes and six phenolated gelatine plates were made with the particulate residue of 2,500 c.c. of this water sample driven through a Berkefeld filter, and with result as follows. Six varieties of organisms were isolated, which presented the following features:—

(*a*.) All six formed gas bubbles in gelatine shake cultures.
(*b*.) Five coagulated milk rapidly; while one made the milk thick but did not produce complete coagulation.
(*c*.) Five gave the indol reaction; while one did not give this reaction.

The appearance of the colonies formed by each of these organisms on gelatine plates, their manner of growth in shake and stab cultures, and the morphological characters of the individual organisms forming these colonies were typical of bacillus coli. At least five, accordingly, of these six organisms are to be regarded as bacillus coli.

No enteric fever bacilli were isolated from this water.

*Sample B.*—Collected, on August 8th, drop by drop during a period of 12 hours from the rising main in the "Worthing" Waterworks yard.* Of this water 1,500 c.c. were passed through a Berkefeld filter; and the particulate residue on the filter was distributed among several phenolated broth tubes and phenolated gelatine plates. In all these tubes and plates the bacillus coli developed abundantly; and, in addition, a few other colonies were detected—two in one plate and one in another plate—which, on sub-culture, presented, morphologically as well as culturally, all the characters of the enteric fever bacillus.

* The water passing along these mains is derived from all the wells, tunnels, and headings in the "Worthing" Waterworks yard, and includes, accordingly, water from well C. and from the new heading.

*"West Worthing" Water.*

*Sample C.*—Taken on August 21st from a house-tap connected directly with a main situated in a street within the area of "West Worthing" that showed exceptional prevalence of enteric fever. In this sample search was made only for the bacillus coli and the bacillus of enteric fever. Neither of these organisms was recovered from the cultures made.

*Sample D.*—Collected, on August 21st, drop by drop during a period of three hours from the rising main in the "West Worthing" Waterworks yard. As in the case of Sample C, search was in this instance made only for bacillus coli and the enteric fever bacillus; and here also with negative results.

*Sample E.*—Taken, on December 9th, from a tap in a house situated in Brunswick Road, West Worthing. This water was found to contain 230 microbes per c.c.; and of these microbes 50 were liquefying organisms. Search was made for the bacillus coli and for the bacillus of enteric fever, but with negative results.*

*Worthing Temporary Supply from Broadwater Well.*

*Sample F.*—Taken from water mains in "Worthing" on November 29th, 1893. The water in the mains was derived from the new well at Broadwater.

With the view of estimating the number of microbes per c.c. of this water, cultivations were made on four ordinary gelatine plates, $\frac{1}{10}$ c.c. of the water being used for two of these and $\frac{1}{4}$ c.c. for the remaining two. As result it was found that microbes were present to the very large amount of 50,000 per c.c. Of these microbes from 10,000 to 12,000 were liquefying organisms. In searching for bacillus coli and the bacillus of enteric fever 1,600 c.c. of water were employed. Among the colonies appearing in cultures made from the particulate residue of this water on the Berkefeld filter, some were observed which in aspect, size, and shape, bore a distant resemblance to one or other of the bacilli sought for; but, in sub-cultures, the growths that appeared from these did not show fundamental characters by which any one of them could be identified as either bacillus coli or the bacillus of enteric fever.

*Sample G.*—Taken, on November 30th, from the well at Broadwater from which was obtained the Worthing temporary supply. The procedure adopted in the case of this water was the same as that employed for Sample F. As in Sample F. there were about 50,000 microbes per c.c.; but of these only some 60 or 80 were liquefying organisms, a proportion much smaller than obtained in Sample F. In Sample G. organisms distantly resembling bacillus coli and the enteric fever bacillus were observed; but as in the case of Sample F., these could not on sub-culture be identified as belonging to either of the species they resembled.

*Sample H.*—Taken, on December 7th, from the reservoir in the town in the Worthing" Waterworks yard. The water in this reservoir was at that time derived from the new well at Broadwater.

This water was ascertained to contain 8,800 microbes per c.c.; of these microbes 150 were liquefying organisms. Several colonies were also observed which bore resemblance to either the bacillus coli or the bacillus of enteric fever; but none of these, on further examination by sub-culture, presented features characteristic of either of the species they resembled.

*Sample I.*—Taken, on December 7th, from a house-tap in "Worthing." The water obtained from this tap was derived from the new well at Broadwater.

The number of microbes per c.c. of this water was found to be 600; and of these microbes 10 were liquefying organisms. Search for bacillus coli and the bacillus of enteric fever revealed the presence of two colonies bearing resemblance to colonies of these organisms. They were, it should be noted, different in appearance from those noted in Sample H. as also resembling bacillus coli or the enteric fever bacillus. The organisms composing the two colonies found in Sample I. resembled the bacillus of enteric fever in their great motility, in their size, in their inability to form gas bubbles, in their aspect when growing on gelatine, whether in its surface or in its substance, in the slowness of their growth, and in their inability to curdle milk or to form indol; but they differed from the bacillus of enteric fever in not forming threads and chains, and in not growing at all well at 37° C. Therefore these organisms could not be regarded as enteric fever bacilli.

*Sample K.*—Taken, on December 7th, from a house tap in "Worthing." The water obtained from this tap was derived from the new well at Broadwater.

The number of microbes per c.c. of this water was found to be 600; among which were not observed any liquefying organisms. Search for the bacillus coli and the bacillus of enteric fever revealed in the cultures that were made the presence of two colonies exactly similiar in the characters they presented to the two colonies described in connexion with Sample *I.**

* On January 29th, 1894, while this report was passing through the press, three samples of the Broadwater supply and one of the "West Worthing" supply were forwarded to Dr. Klein for examination. Of the three samples of the Broadwater supply one was taken from the well at Broadwater, one from the reservoir in the "Worthing" water-tower, and one from a main in "Worthing." The three last-mentioned waters contained respectively, 68 microbes per c.c., 912 microbes per c.c., and 164 microbes per c.c. The "West Worthing" water contained 196 microbes per c.c. In none of these four samples was any bacillus discovered presenting the fundamental cultural characters exhibited by the bacillus coli or the bacillus of enteric fever.

# APPENDIX D.

## Register of Rainfall in 1893.

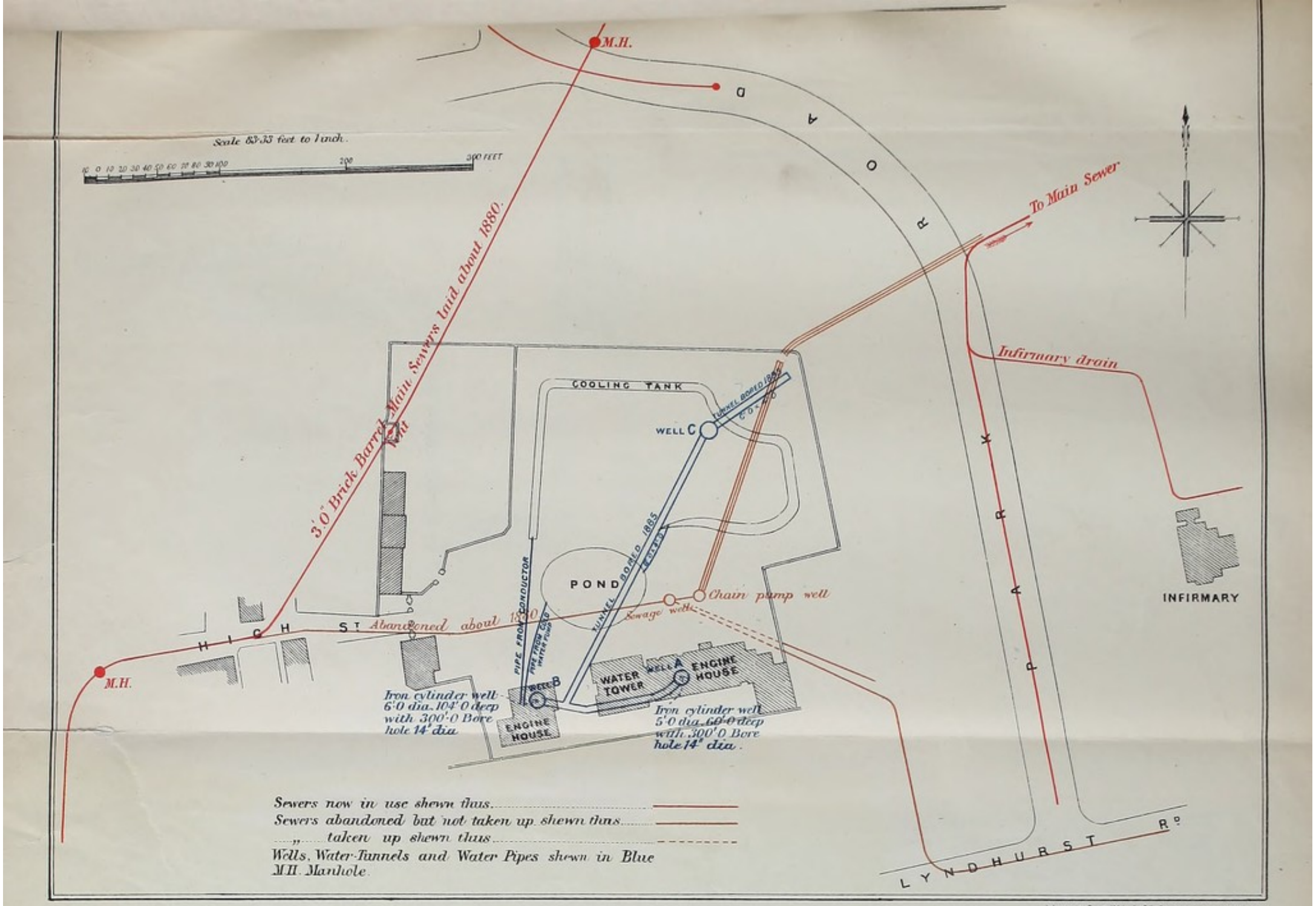
Kept at Ellesmere, Worthing, in the County of Sussex, by Chas. Kelly.

Time of Observation, 9 a.m.

*Rain Gauge.*

Diameter, 5 in.
Height of top above Ground, 1 ft.
" " " Sea Level, 26·16 in.

| Date. | Jan. | Feb. | March. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Date. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | |
| 1 | | | ·08 | | | | | 0·5 | | ·03 | ·21 | 1 |
| 2 | | ·02 | | | | | | | | ·22 | ·33 | 2 |
| 3 | | ·10 | | | | | | ·14 | | ·01 | ·01 | 3 |
| 4 | | | | | | ·01 | ·74 | ·16 | | ·18 | ·01 | 4 |
| 5 | | | | | | | | | | ·38 | ·05 | 5 |
| 6 | ·05 | ·07 | | | | ·04 | | | ·07 | ·18 | | 6 |
| 7 | ·03 | ·03 | | | | | | | | ·32 | | 7 |
| 8 | ·16 | | | | | | ·03 | | ·03 | | ·01 | 8 |
| 9 | ·52 | | | | | | | | ·06 | ·54 | | 9 |
| 10 | | ·22 | | | | | ·02 | | | ·08 | | 10 |
| 11 | | ·06 | | | | | ·24 | ·02 | | 1·95 | | 11 |
| 12 | ·01 | ·04 | | | | | | | | | | 12 |
| 13 | ·05 | ·09 | ·08 | | | | ·18 | | ·23 | ·11 | ·06 | 13 |
| 14 | | ·65 | | | | | | | ·02 | 02 | ·36 | 14 |
| 15 | | | | | ·02 | | ·46 | | ·04 | ·03 | ·04 | 15 |
| 16 | ·46 | ·14 | ·15 | ·06 | ·05 | | 1·18 | | ·46 | ·03 | ·24 | 16 |
| 17 | ·06 | ·04 | ·02 | | ·12 | | ·10 | | ·09 | ·73 | ·06 | 17 |
| 18 | ·88 | ·40 | | | ·03 | | ·02 | | | | ·11 | 18 |
| 19 | | ·06 | | | ·01 | | ·65 | | ·11 | | ·01 | 19 |
| 20 | | ·71 | | ·02 | ·06 | | ·21 | ·02 | | | | 20 |
| 21 | | ·04 | | | | | | ·09 | ·02 | | | 21 |
| 22 | | ·10 | | | | ·18 | | ·09 | ·34 | ·03 | | 22 |
| 23 | | | | | | | ·48 | | | | | 23 |
| 24 | ·02 | | | | | ·02 | | | 1·01 | | | 24 |
| 25 | ·01 | ·17 | | | | ·07 | | | 1·01 | ·15 | ·14 | 25 |
| 26 | ·33 | ·05 | | | | ·14 | ·41 | | | ·03 | ·05 | 26 |
| 27 | | ·21 | | | | ·12 | | | | | | 27 |
| 28 | ·03 | ·22 | | | | | | | | ·02 | ·01 | 28 |
| 29 | | | | | | | ·23 | | | | ·04 | 29 |
| 30 | ·03 | | | | | | | | | | ·08 | 30 |
| 31 | ·33 | | | | | | | ·10 | | | | 31 |
| Totals - | 2·67 | 2·82 | 0·33 | 0·08 | 0·29 | 0·58 | 4·95 | 0·67 | 3·49 | 5·04 | 1·82 | |
| Total from Jan. 1 | 2·67 | 5·49 | 5·82 | 5·90 | 6·19 | 6·77 | 11·72 | 12·39 | 15·88 | 20·92 | 22·74 | |

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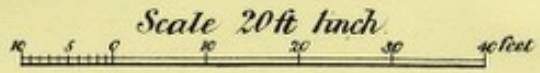
# Section of Worthing Waterworks Enclosure indicating the relative depths of various structures shewn on Diagram I.




Ground Line.

Invert Level at Yard entrance of old Sewer to Sewage well

ORDNANCE DATUM

Invert level at Yard entrance of existing Main Sewer

Well B under Engine House 104' 0" deep

26 inch Bore hole 300 feet deep below this level

Well A under old Engine House 68' 0" deep

Old Sewage Well 36' 0" deep

Old Chain pump Well 36ft deep

Well C in Waterworks grounds 72' 0" deep.

14 inch Bore hole 300 feet deep below this level

Level of old 15 inch overflow pipes to Main Sewer N E corner of Yard.

5' 0"

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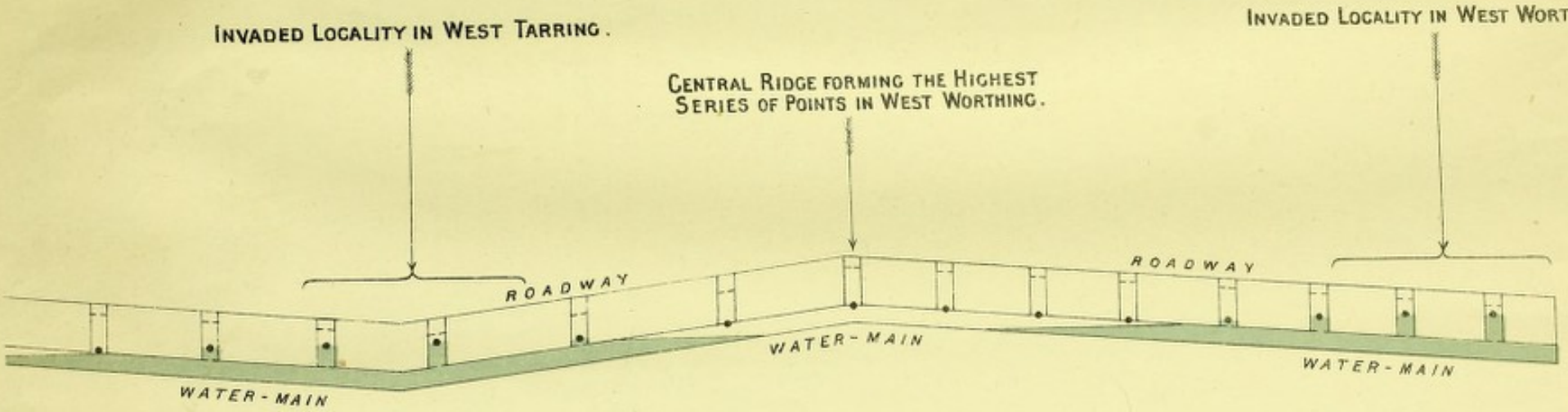
# DIAGRAM III.




*The upper horizontal line of the diagram represents the roadway surface: the space between the two lower horizontal lines represents the water-main. Each pair of vertical lines corresponds to a street-hydrant, the ball of the hydrant being always represented by a black dot. The level of the water in the mains when the service has been some time intermitted, is shewn by blue shading.*

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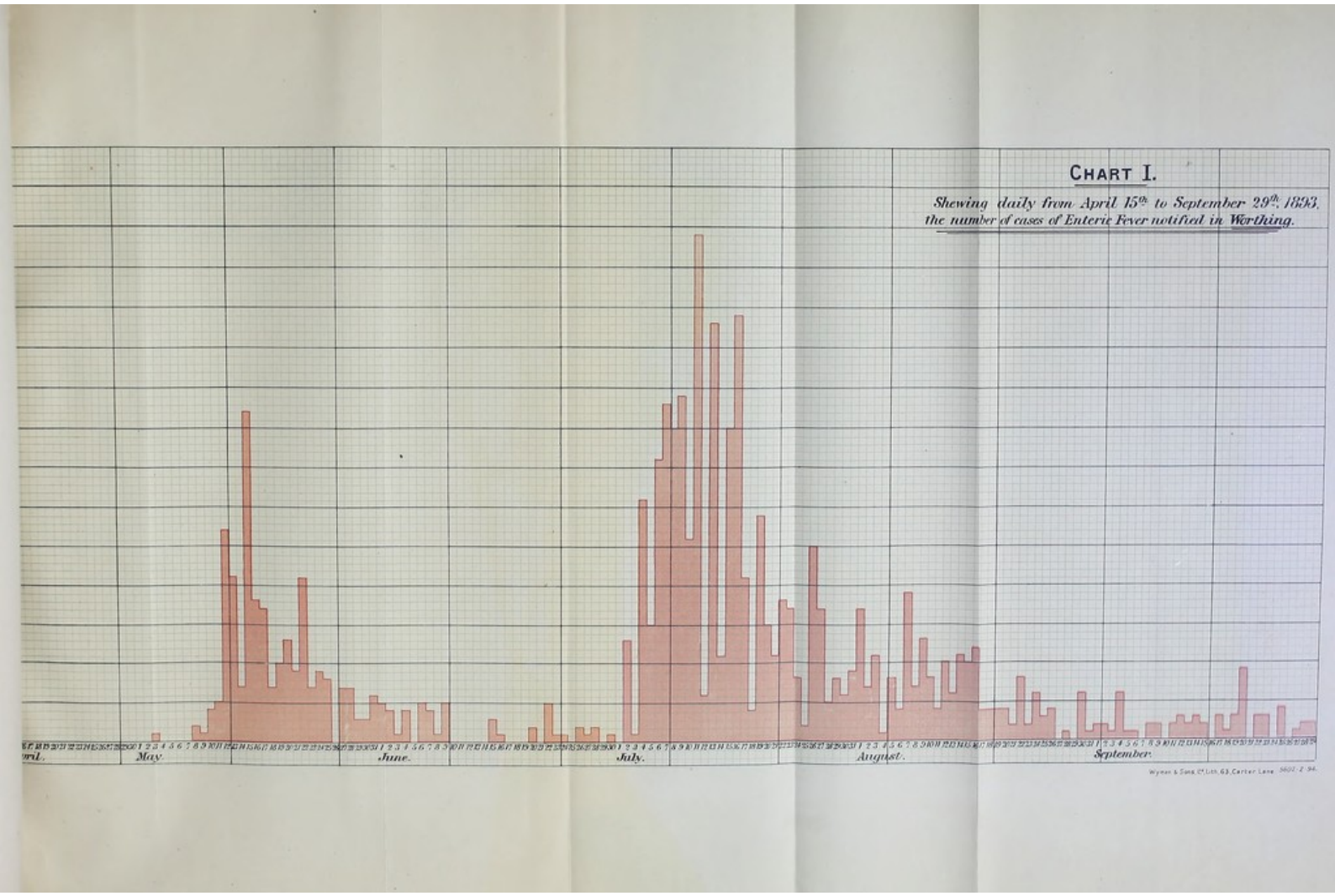


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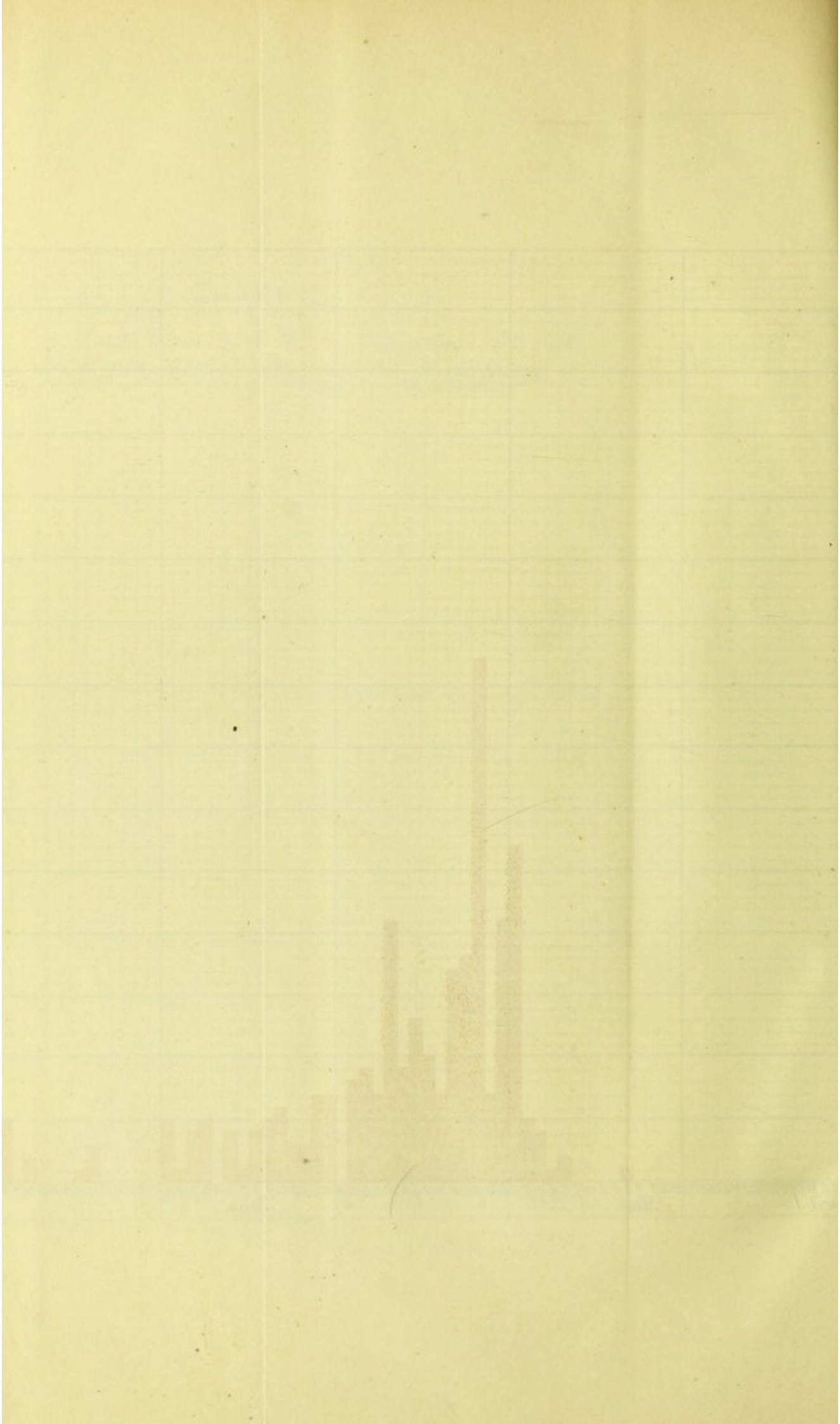
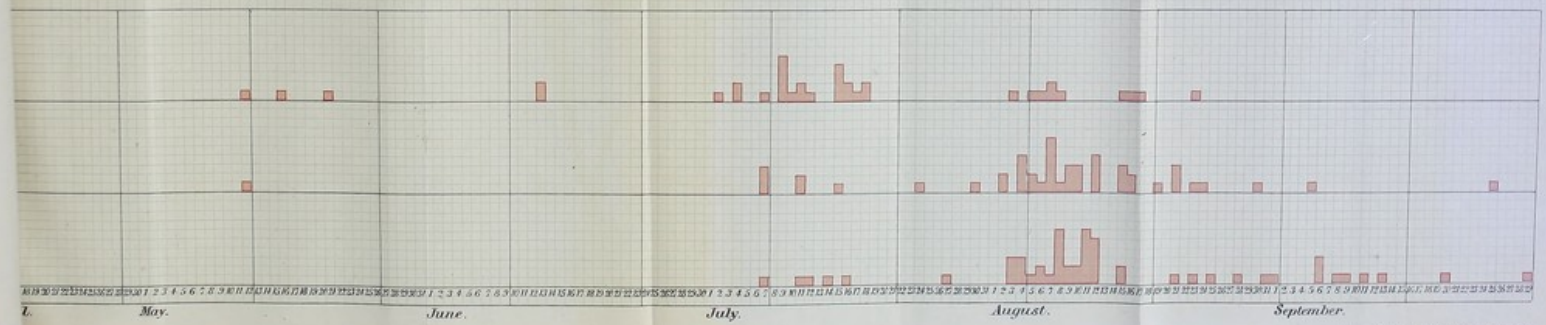


## Chart II.

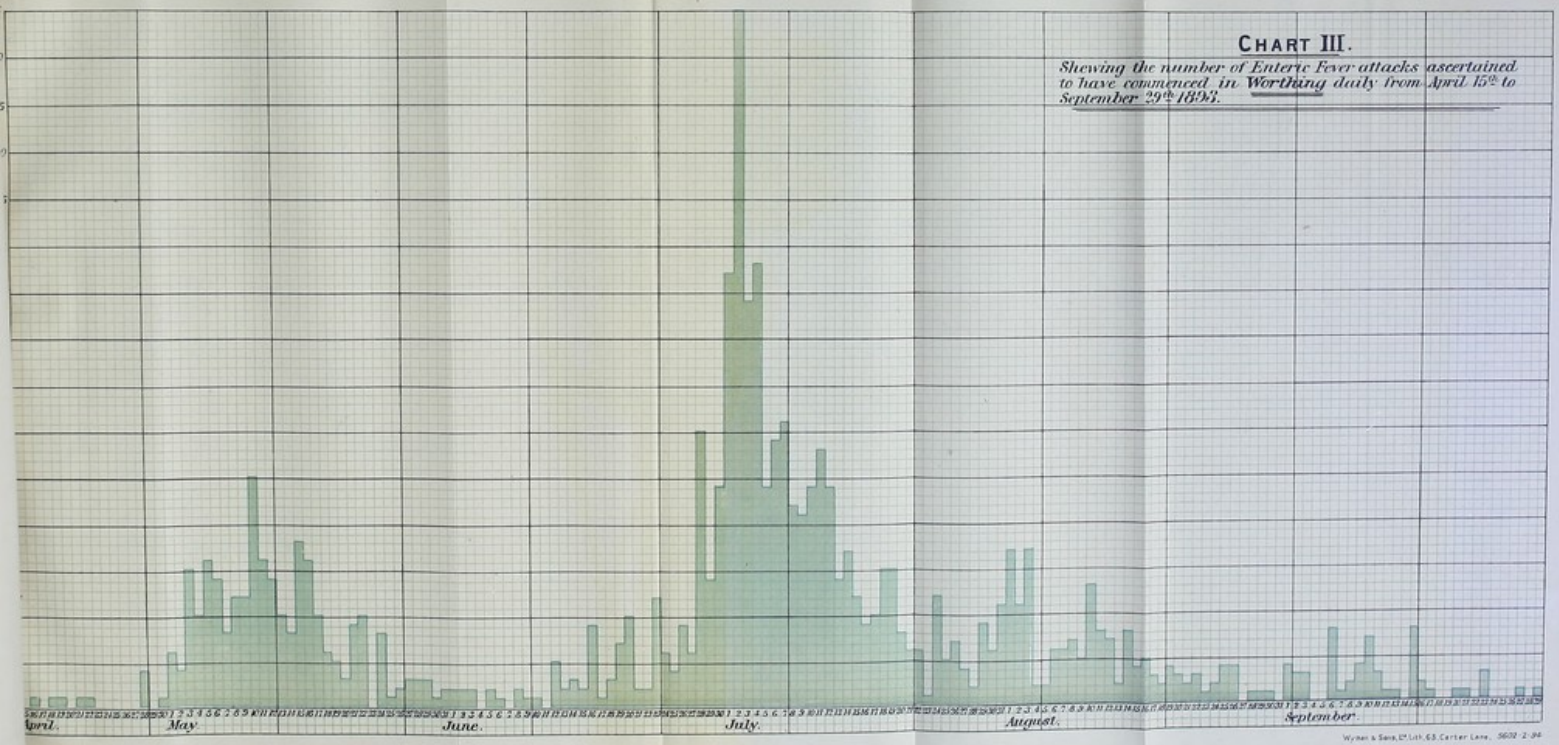
*Shewing daily from April 15th to September 29th 1893, the number of cases of Enteric Fever notified to West Worthing, West Tarring, and Broadwater.*



*April.* *May.* *June.* *July.* *August.* *September.*

## CHART III.

*Shewing the number of Enteric Fever attacks ascertained to have commenced in Worthing daily from April 15th to September 29th 1893.*

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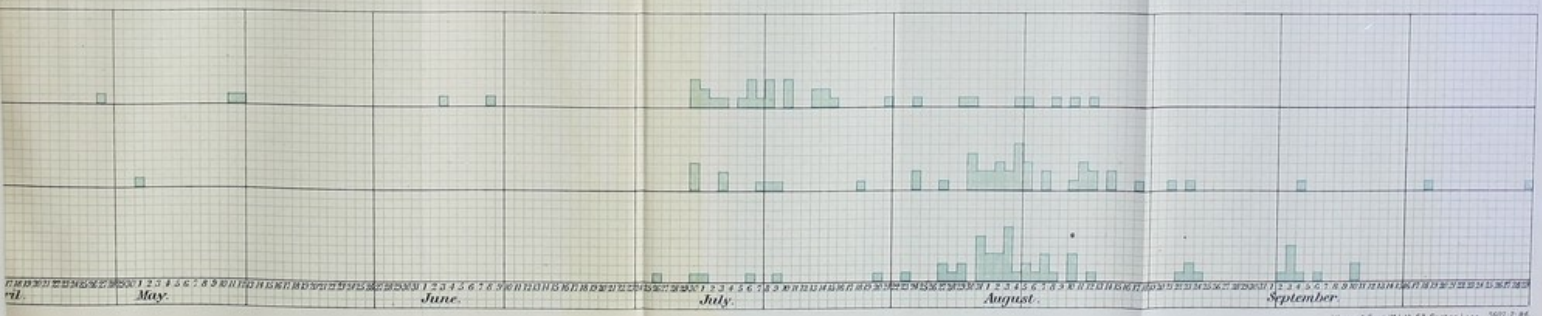
## CHART IV.

*Shewing the number of Enteric Fever attacks ascertained to have commenced in West Worthing, West Tarring and Broadwater daily from April 15th to September 29th 1893.*

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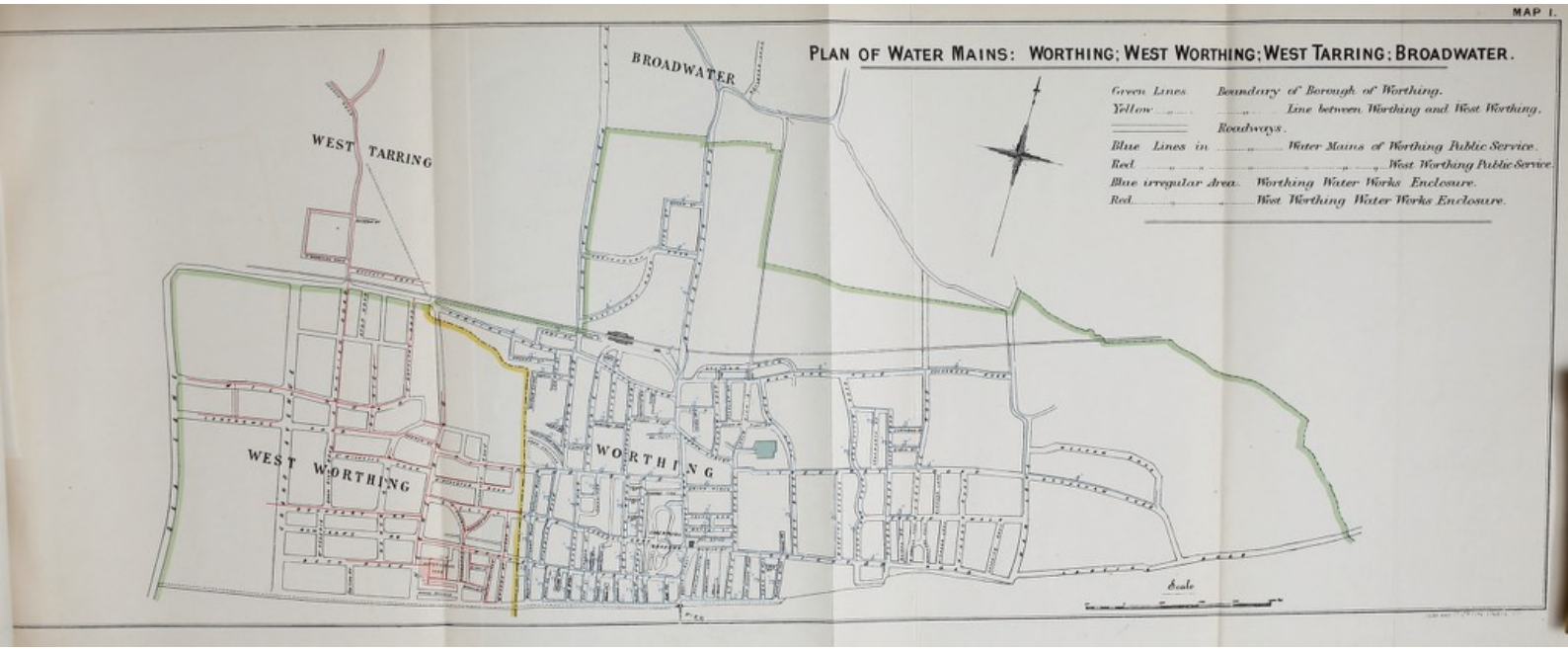
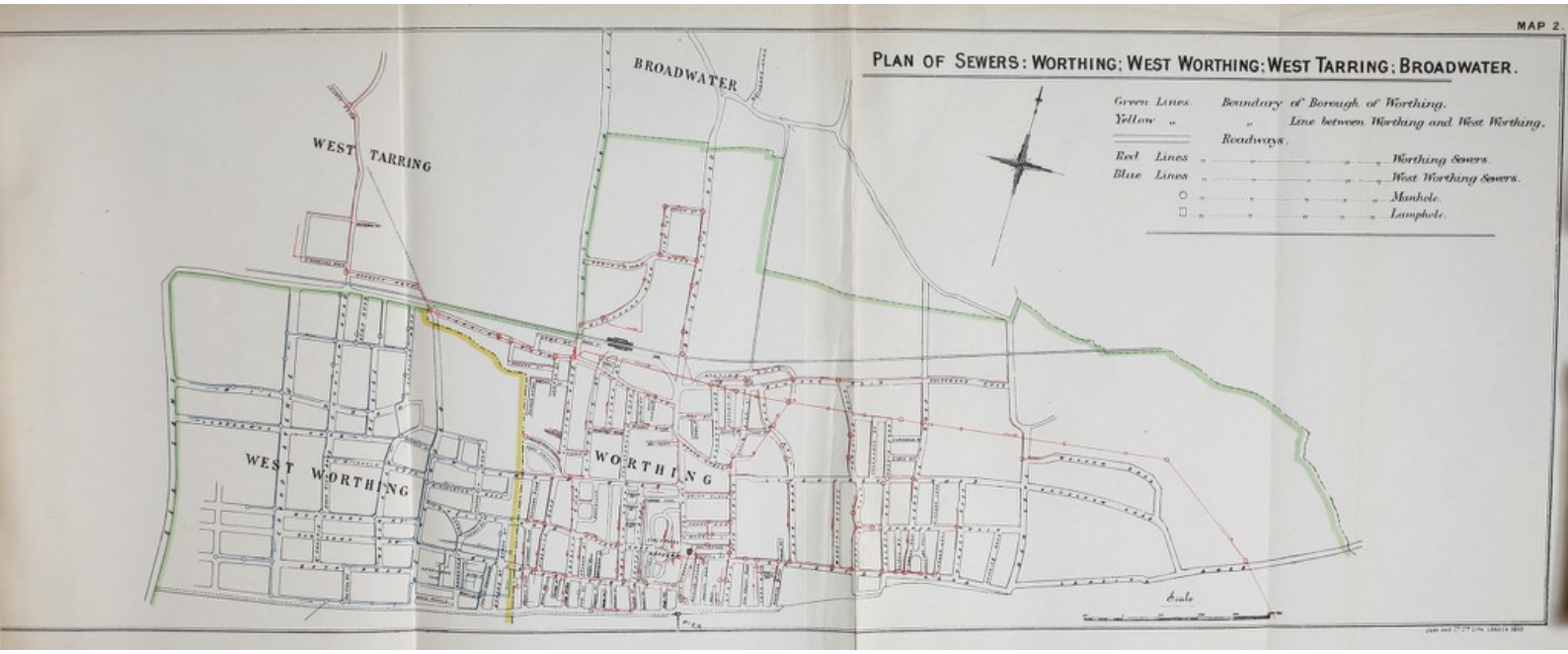

PLAN OF WATER MAINS: WORTHING; WEST WORTHING; WEST TARRING; BROADWATER.
Green Lines Boundary of Borough of Worthing.
Yellow " " Line between Worthing and West Worthing.
Roadways.
Blue Lines in " Water Mains of Worthing Public Service.
Red " " West Worthing Public Service.
Blue irregular Area. Worthing Water Works Enclosure.
Red " " West Worthing Water Works Enclosure.
BROADWATER
WEST TARRING
WEST WORTHING
WORTHING
Scale

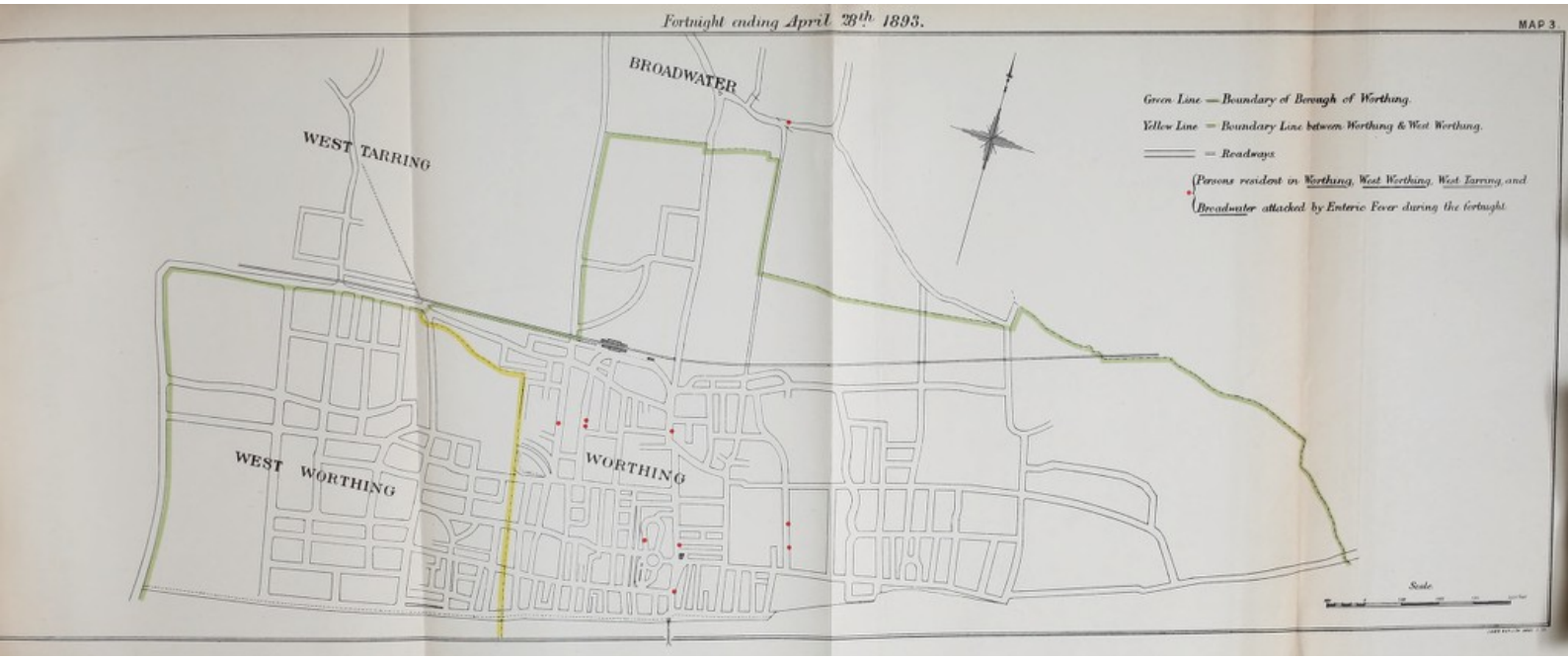
# PLAN OF SEWERS: WORTHING; WEST WORTHING; WEST TARRING; BROADWATER.



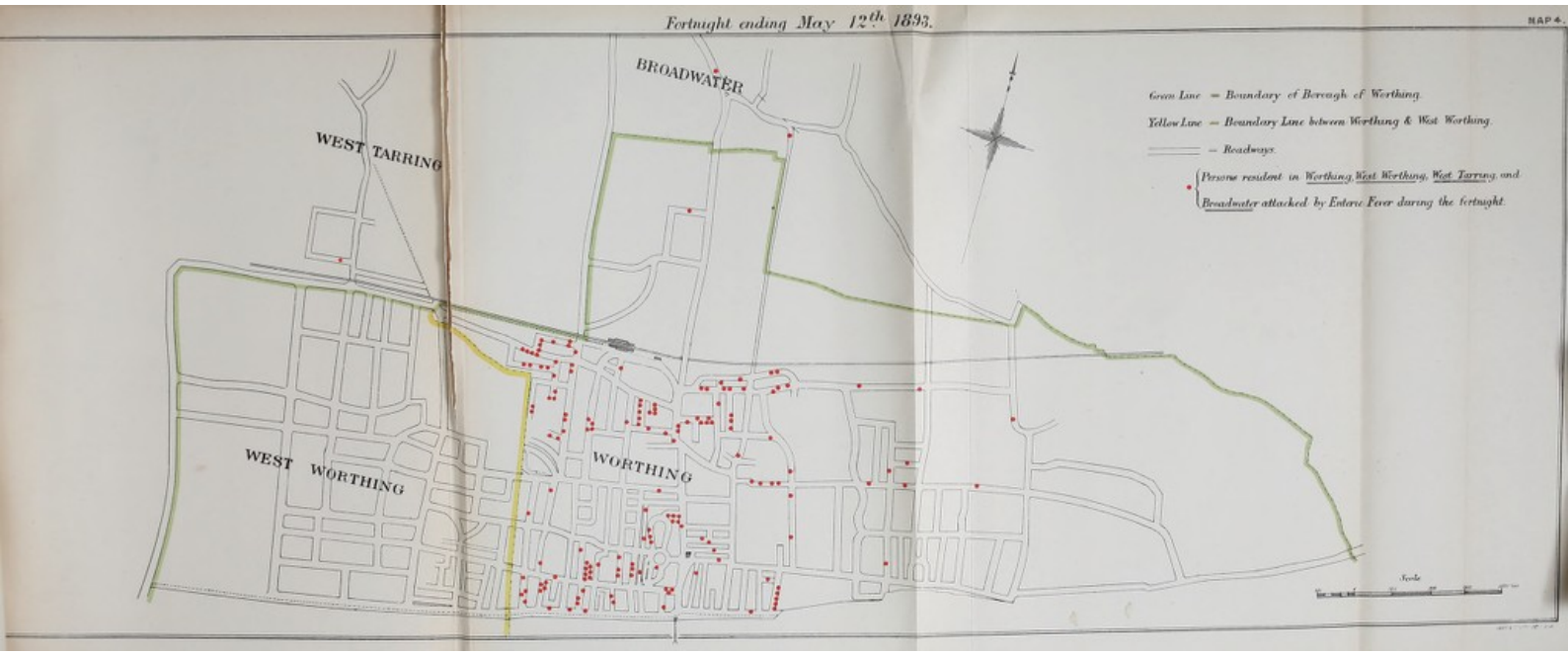

Green Lines. Boundary of Borough of Worthing.
Yellow " " Line between Worthing and West Worthing.
Roadways.
Red Lines " " Worthing Sewers.
Blue Lines " " West Worthing Sewers.
○ " " Manhole.
□ " " Lamphole.

*Fortnight ending April 28th 1893.*

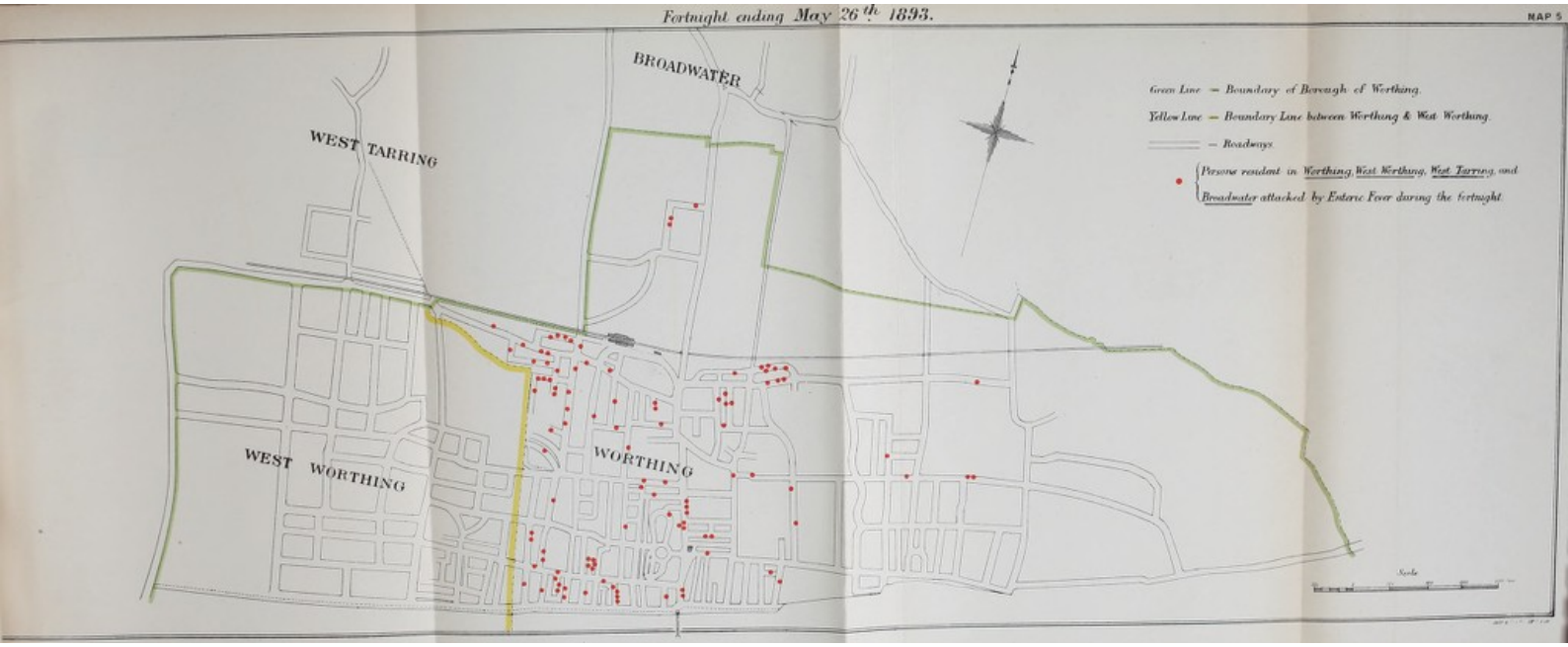
MAP 3.



Fortnight ending May 12th 1855.



Fortnight ending May 26th 1893.

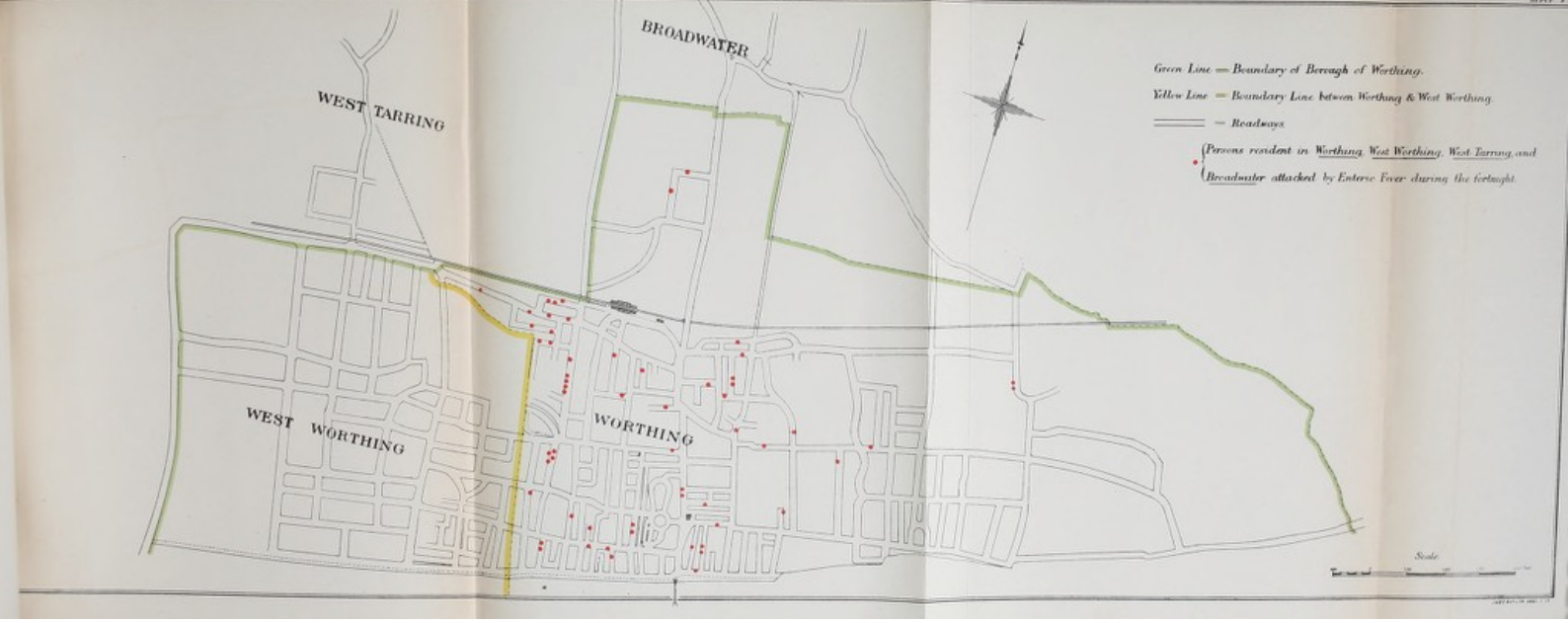


Fortnight ending June 9th 1893.

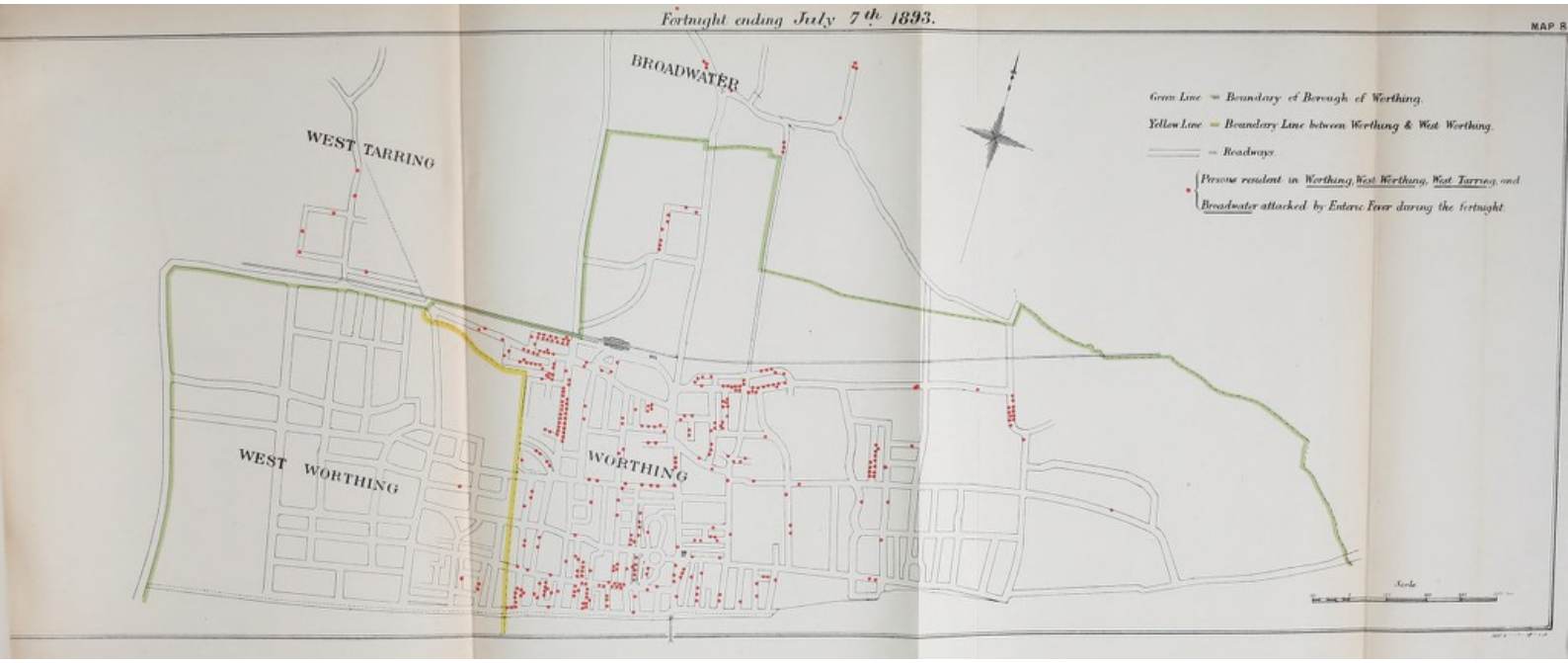
MAP 6

Fortnight ending June 23rd 1893.

MAP 7

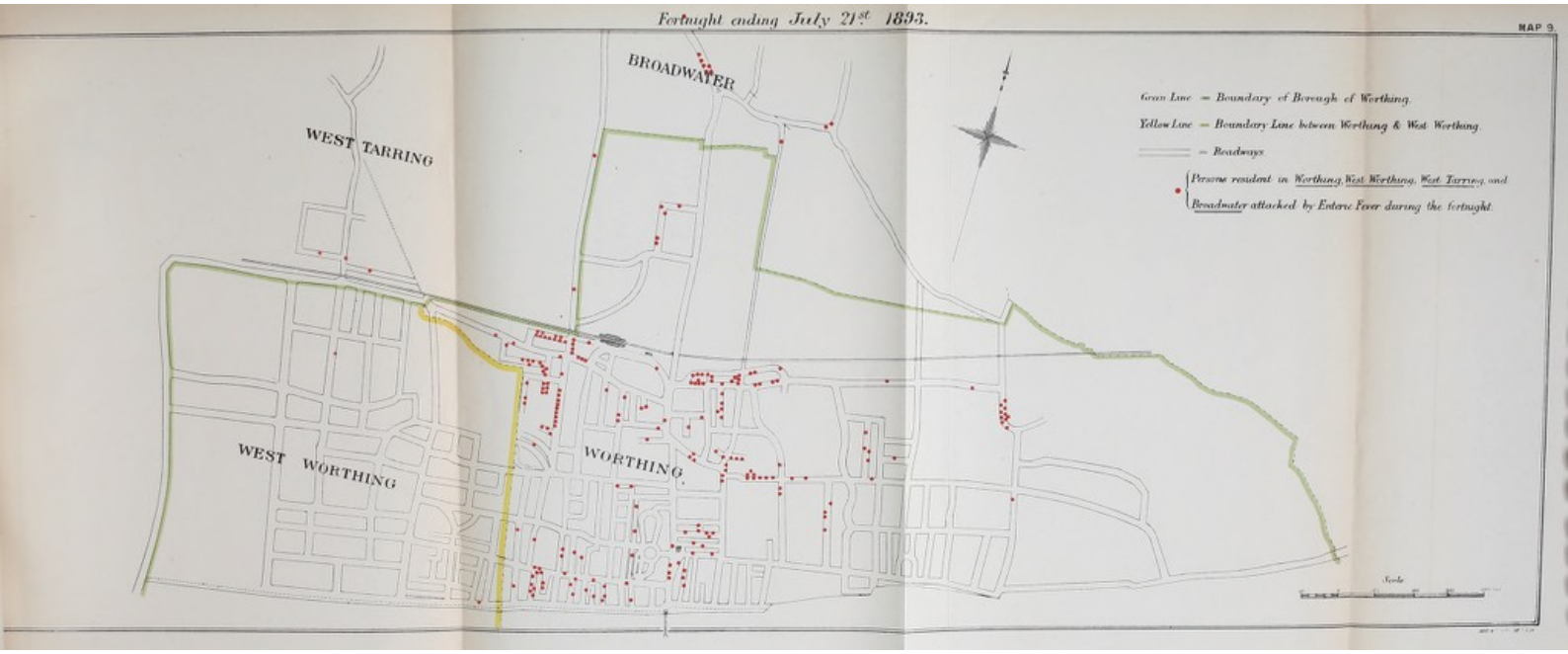


Fortnight ending July 7th 1893.

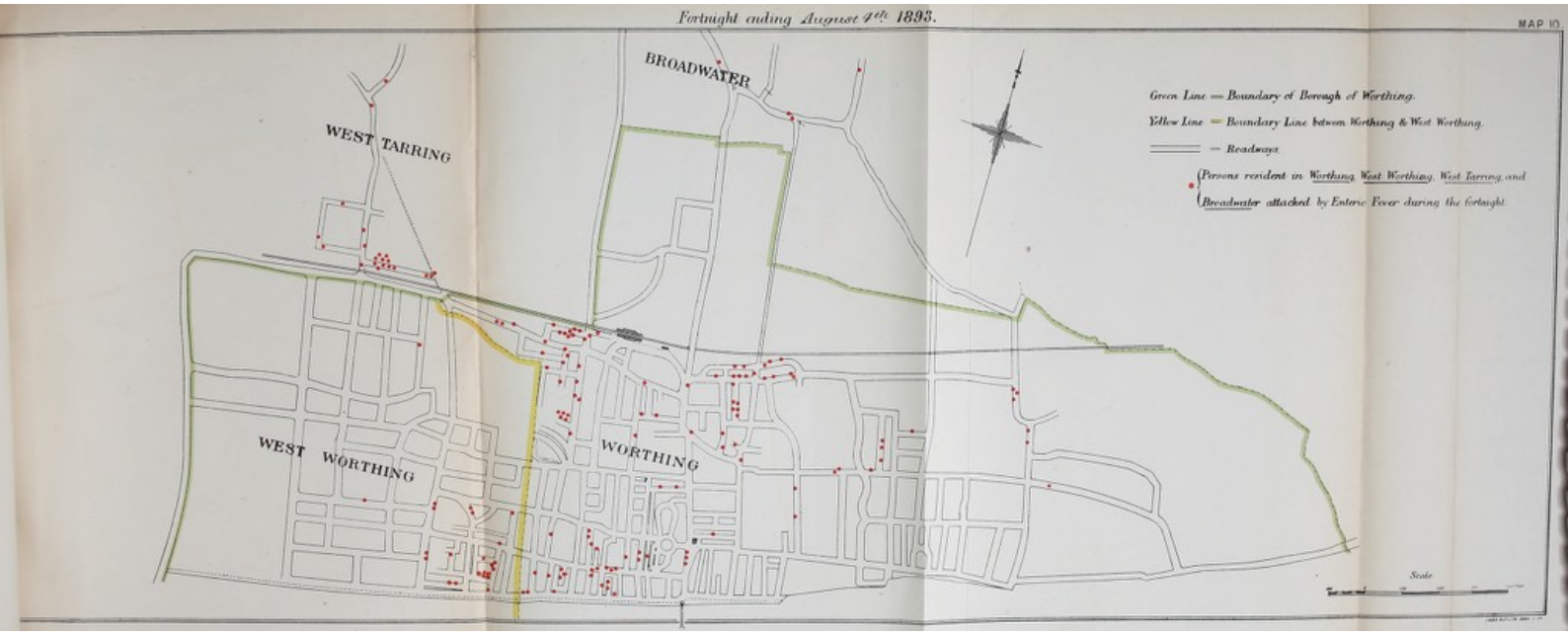


Fortnight ending July 21st 1893.

MAP 9.

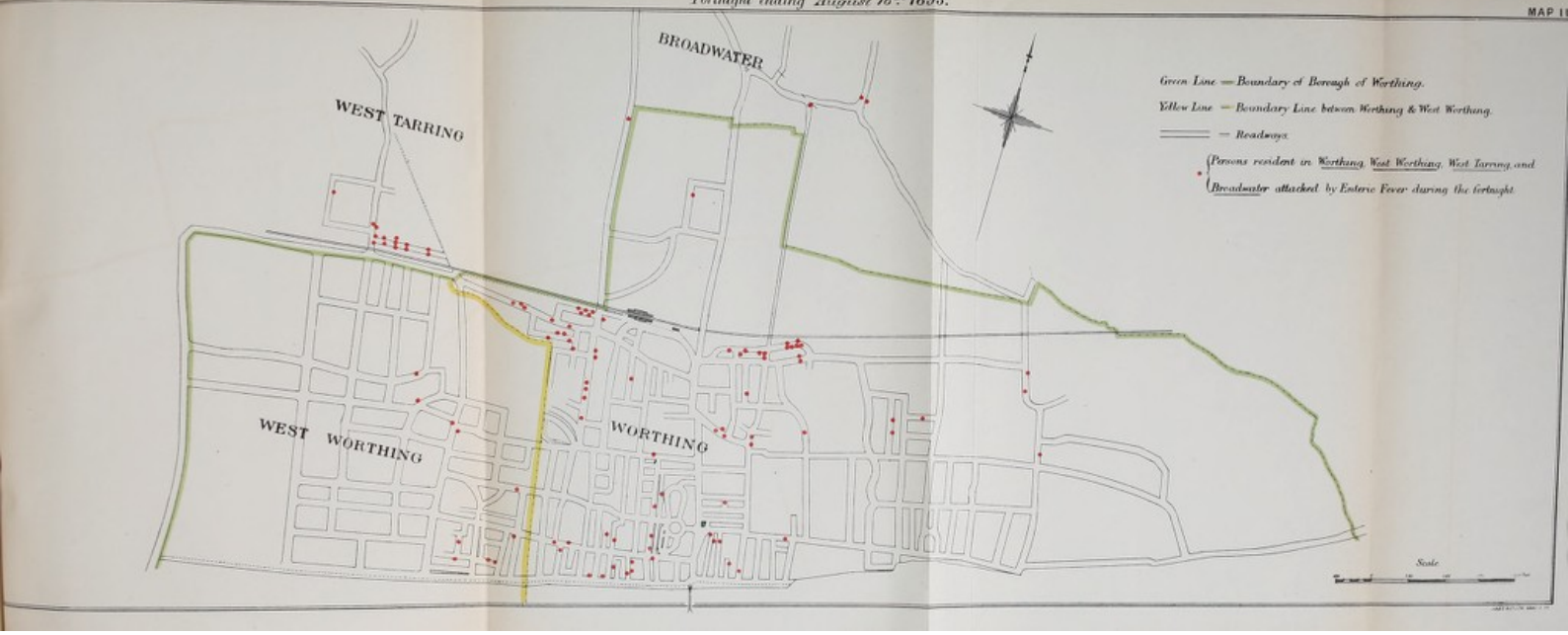


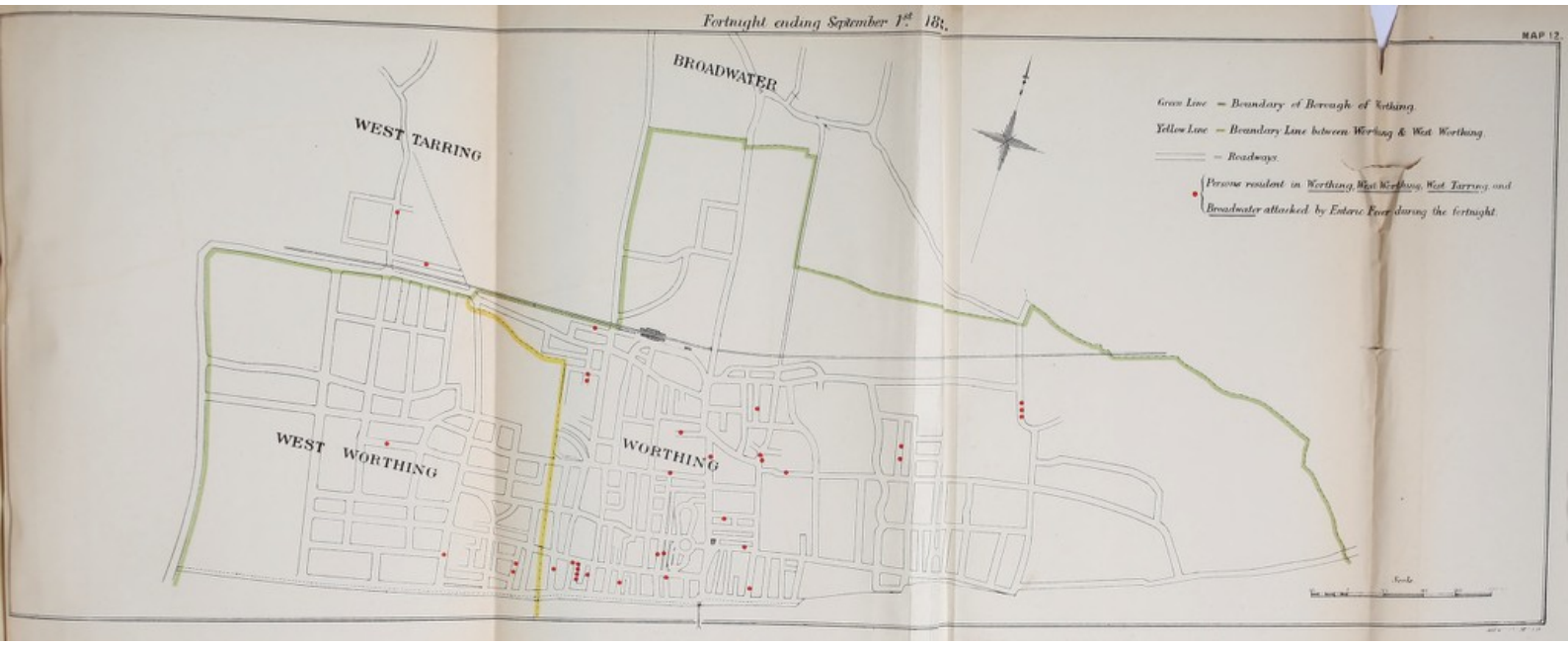
Fortnight ending August 4th 1893.



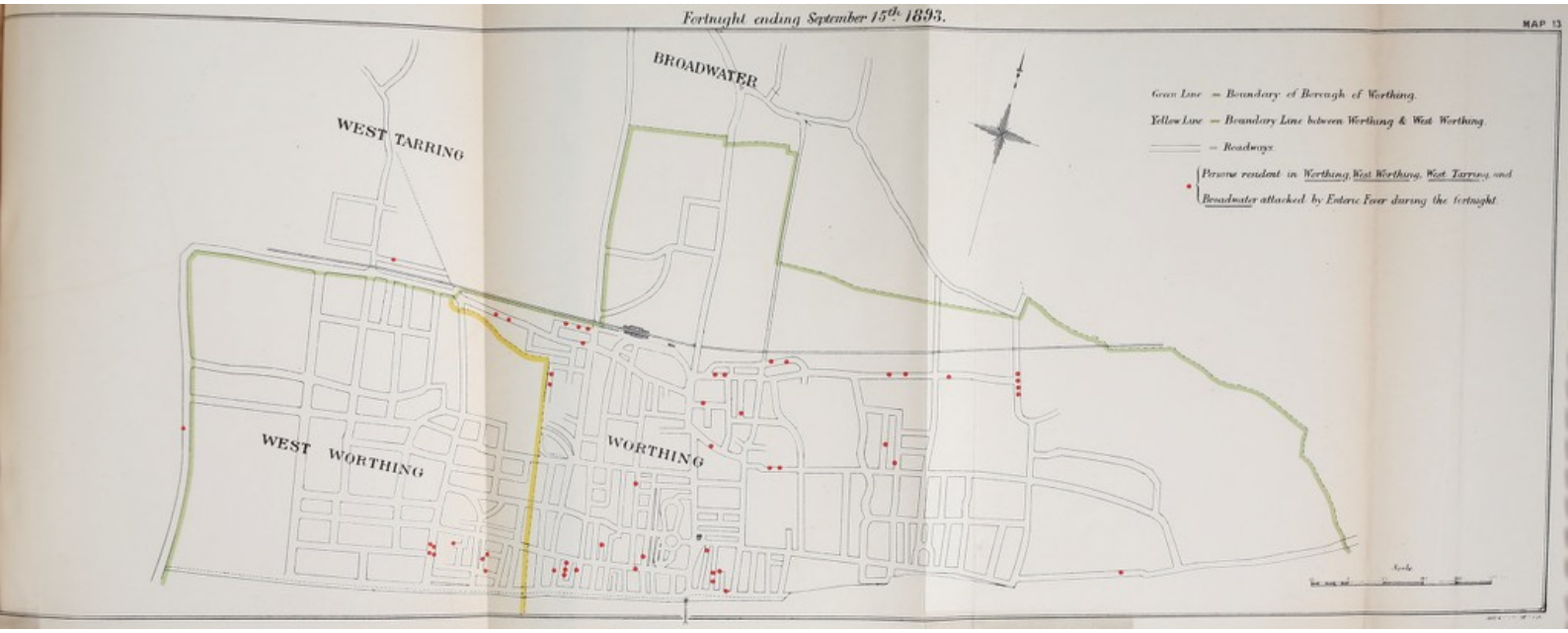
*Fortnight ending August 18th 1893.*

MAP I




Fortnight ending September 1st 183.
MAP 12.
BROADWATER
WEST TARRING
WEST WORTHING
WORTHING
Green Line — Boundary of Borough of Worthing.
Yellow Line — Boundary Line between Worthing & West Worthing.
— Roadways.
Persons resident in Worthing, West Worthing, West Tarring, and Broadwater attacked by Enteric Fever during the fortnight.

Fortnight ending September 15th. 1893.



Fortnight ending September 29th 1893.

MAP 14.

Fortnight ending October 15th 1893.

MAP 15