SEWAGE PURIFICATION IN AMERICA.

A DESCRIPTION OF THE MUNICIPAL SEWAGE PURIFICATION PLANTS IN THE UNITED STATES AND CANADA.

BY

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WITH 79 ILLUSTRATIONS AND AN INDEX.

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PREFACE.

All who have not closely watched the progress of sewage purification in this country will doubtless be surprised to learn that the sewage of about 30 municipalities in the United States and Canada is now purified to a greater or less extent.

Most of the sewage purification plants in use have been built within the last five years, and in the next five it is probable that a yet greater number will be erected. The subject of sewage purification being comparatively new, the demand for information relating to it is accordingly great, especially for the facts regarding plants actually in operation.

To meet this demand, or more properly that part directly relating to descriptions of plants in operation, the information contained in the following pages has been gathered, mainly by personal visits to the different works described, and correspondence with the engineers who designed the plants or the officials now in charge of them.

The descriptions are all reprinted from Engineering News of the past year, after careful revision and a classification by the system of purification employed.

It is believed that the articles will be appreciated in their present compact form even by those who have read them from week to week in Engineering News, while for those who have not the files of that journal this is practically the only form in which the complete series of articles can be secured.

Since the book was ready for publication, the articles have been continued by a description of a plant located at Canton, O. (In issue of June 1, 1893). The Canton works employ chemical precipitation, using lime and sulphate of alumina and treating the sludge with a filter press. Several other plants are being built or are projected with fair prospects of construction.

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Introductory.

Among the many almost unworked fields of American engineering sewage purification is one of the greatest. The reason for this is evident. Until quite recently only a few American cities, and those the larger ones, had even an approach to a complete sewerage system. As new systems were built so much emphasis was placed upon the abolition of cesspools and similar nuisances that but few persons thought of the unsanitary conditions which would in many cases be caused by discharging the sewage of thousands of people into a stream or body of water. If only the sewage could be conveyed away from the premises of individuals and out of the town or to the outskirts of the town, even though discharged into a stream within the town limits, the majority of the people were satisfied.

The "self-purification of rivers" theory, or fallacy, tended to set at ease the minds of those few who raised the question whether the waters receiving sewage would not finally become fouled.

The work of the various River Pollution Commissions of England and similar work performed in Europe in later years, together with the development and gradual acceptance of the germ theory of disease, finally directed the attention of American sanitarians to the subject of the purification of sewage before its final discharge into natural bodies of water. The Massachusetts Legislature and State Board of Health, a few other State Boards, the American Public Health Association and a few sanitary engineers have in late years been doing much educative work. This educative work, coupled with the rapid pollution of streams and similar factors which have prompted it, has resulted in the adoption of some form of sewage purification in about 30 towns in the United States, and many more communities are discussing the subject.

The progress of sewage purification has been greatly retarded by the desire to find some method which would make a commercial success of the process. While such a result is highly desirable and its desire very creditable, attempts to secure it have not yet met with the success they have seemed to promise. Consequently some engineers and municipal officers dismiss the whole subject of sewage purification by saying, in effect, that no process has yet been devised which will pay its way, thus putting financial before sanitary considerations.

While sewage purification has been retarded as just stated, the same or a similar cause, apparently, has forwarded its progress in the West, where the demand for every available drop of water for irrigation has already led to the use of the sewage for irrigation in at least ten localities, as described in detail in this volume.

The evident demand and need for knowledge on this subject, both among engineers and the general public, and especially the relation between sewage-polluted streams, water supplies and disease, have led us to undertake a thorough investigation and description of all that has yet been done in the way of town sewage purification in this country.

All of the town sewage purification plants known to be in operation, or ready for operation on April 1, 1893, are included in the following pages. The plants which had been previously described in Engineering News are less fully described than the others, the aim having been in such cases to bring the information down to date, with as little repetition as possible.

Nearly all of the purification works in the East have been visited by the writer during the preparation of these articles and the information regarding the other works has most of it been furnished by the engineers who designed them or the persons now in charge of them.

Purification in the Drainage Area of the Boston Water-Works.

The efforts of Boston to prevent the pollution of the city water supply, coupled with the authority of the Massachusetts State Board of Health and the co-operation of the town and its efficient sewerage committee have resulted in the establishment of a sewage purification plant at South Framingham, which is one of the most successful in the country and compares favorably with any in existence elsewhere. In addition a second plant has been built, at Marlborough, and others are proposed, all to divert or purify sewage which naturally would have polluted the water supply of Boston. Toward the cost of each of these plants Boston has contributed largely, or offered to, although under no legal obligation to do so. In addition the city has for some years treated chemically the sewage of several tanneries in the Mystic River drainage area.

As early as 1879 Mr. Desmond Fitz Gerald, M. Am. Soc. C. E., of the Boston water-works, to whose reports we are indebted for some of this information, began to urge the importance of excluding sewage from the sources of the water supply of Boston. Mr. Fitz Gerald made numerous reports on the subject, and after several years the water board was enabled by energetic action in the courts to carry out his plans and suggestions.

From the start an effort was made to exclude sewage from the streams tributary to the main sources of supply. Several times the city was beaten in the lower courts, but finally the State Supreme Court rendered a decision which established the city's power to prevent the direct contamination of its water supply by turning sewage into it. The decision was rendered in the "Case of Augustus P. Martin, Mayor of Boston, vs. Luther Ellis Gleason," the mayor of Boston having applied for an injunction to prevent Mr. Gleason from discharging the sewage from a hotel in Natick directly into Pegan Brook, which brook empties into Lake Cochituate, one of the sources of the Boston water supply.

The case is so important in sanitary history that some space may be profitably devoted to it here, the citations being from the report of the Boston Water Board for the year ending April 30, 1885.

In 1846 the legislature authorized Boston to take, hold and convey to, into and through said city the water of Long Pond, so called (now Lake Cochituate), in the towns of Natick, Wayland and Framingham, and the waters which may flow into and from the same, and any other ponds and streams within the distance of four miles from said Long Pond, and any water rights connected therewith.

The decision, somewhat abbreviated, is as follows:

The city of Boston was authorized by Section 1 of that statute to take the water of Long Pond, and the waters which may flow into and from the same, and any other ponds and streams within the distance of four miles from said Long Pond, and any water rights connected therewith, so far as may be necessary for the preservation and purity of the same, for the purpose of furnishing a supply of pure water for the said city of Boston. This declared purpose relates back and illustrates the extent of the authority conferred. Water-rights may be taken so far as may be necessary for the preservation and purity of the water. The words "and any water-rights connected therewith" are not limited to the immediate antecedent, namely, the "other ponds and streams" there referred to, but they also include Long Pond itself, and the waters which may flow into and from the same. It was designed to give a broad and comprehensive authority, for the purpose of furnishing a supply of pure water for the city, and to confer the power to take everything included within the meaning of the antecedent words, so far as might be necessary for the preservation and purity of the water. Section 15, imposing a penalty for wantonly or maliciously diverting the water, or any part thereof, of any of the ponds, streams or water-sources which shall be taken by the city, or corrupting the same, rendering it impure, confirms this view. Under this authority, the city might lawfully take any water-rights connected with the waters flowing into Long Pond, including the prescriptive rights which the plaintiff contends that he then had to discharge sewage into Pegan Brook. It appears that this brook is and always has been a feeder of Long Pond; and that the whole of it is within four miles of the pond. A prescriptive right to foul the waters of a stream is included under the term "water-rights." This, indeed, is asserted by the defendant in his answer. It is a right in respect to the water of the stream; and the statute conferred power to take all water-rights which might interfere with the purity of the waters taken. It is contended for the defendant that, if it was necessary to preserve the brook or the purity of the water, power was granted to the city to take the land on each side of the brook, and thus cut off any use either of it or of its waters, and, indeed, that the water-rights could not be taken separately from the land. But it does not appear to us to be necessary, even if it was competent, for the city to take the land on the sides of the brook in order to extinguish any prescriptive right to foul the water of it.

Assuming that the defendant had such prescriptive right, it is further contended that the city did not take it, but that the taking of the waters of the brooks and streams entering into Long Pond only appropriated the water as it flowed into the pond at the time of the taking, and subject to all legal burdens and uses then existing. This, however, is too narrow a construction of the description of what was taken. The city, after reciting the whole of the first section of the statutes, took all the waters of Long Pond "and other brooks and streams, whether permanent or temporary, entering into the same," "and all the water-rights thereunto belonging or in any wise appertaining, for the sole use and benefit of said city." This language does not exactly follow the language of the statute; but we cannot doubt that it is broad enough to include Pegan Brook, and the taking of "all water-rights thereunto belonging or in any wise appertaining" includes any right then existing to foul its waters. It is urged, by way of illustration, that, if a mill existed on the brook, the right to use the mill was not taken. But it is not necessary to consider that question here. It does not appear that there was any mill on the brook. If there was, the use of the water for turning its wheels might not foul the water, and might therefore be consistent with the purposes and rights of the city. But the right to use the brook as a discharge for sewage in large quantities, as practiced by the defendant, is inconsistent with such purpose. If, therefore, the defendant had any such prescriptive right to foul the water of Pegan Brook, as he claimed, such right was taken and extinguished by the act of the city under the Statute of 1846; and by Section 6 of that act the city was liable to pay all damages sustained thereby. The defendant, if he sustained damage, might have applied by petition for the assessment thereof at any time within three years from such taking. This remedy was the exclusive one.

It was not seriously contended in the argument that the defendant has acquired a prescriptive right to foul the waters since the taking by the city in 1846. Such prescriptive right could not be acquired, because the fouling of the water, since the right to foul it ceased. would be a public nuisance. (Morton vs. Moore, 15 Gray, 576. Brookline vs. Mackintosh, 133 Mass., 125, 226.)

Finally, it was contended for the defendant that, by reason of constructions erected by the city at the mouth of the brook, since the taking in 1846, the waters of Pegan Brook do not, in fact, contaminate the water of the pond, and that, therefore, the city is not injured. It appears, however, as a fact, that the water of the brook is contaminated by the acts of the defendant. The city has a right to be protected against the necessity of maintaining works for the preservation of the purity of the water from such a cause. If the acts of the defendant in fouling the stream have made it necessary for the city to resort to extraordinary means for preserving the purity of the water of the pond, he cannot justify the continuance of such illegal fouling by showing that the city has thus far been able, by the maintenance of special works, to prevent the natural result of his acts.

The result is that the petition for an injunction is maintained.

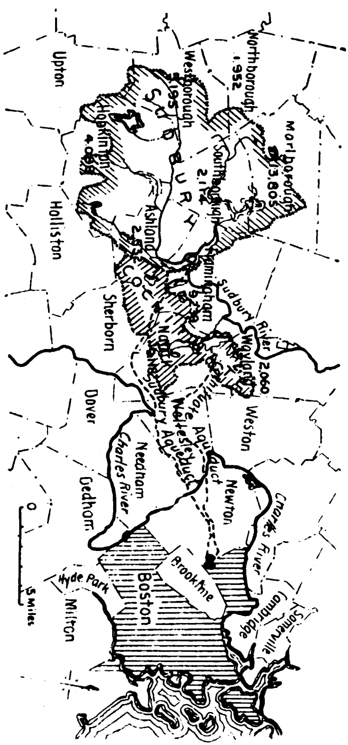


FIG. 1. TOWNSHIPS ON DRAINAGE AREAS FROM WHICH BOSTON'S WATER SUPPLY IS DERIVED.

(Populations are for whole townships, whether in drainage area or not.)

Since this decision was rendered the Boston Water Board and its agents have entered on a systematic campaign for stopping the pollution of the water supply, compelling individuals to find some other means of disposing of their wastes than discharging them into streams conveniently near. Probably the pressure thus brought to bear upon individuals has hastened the adoption of sewerage systems in some of the towns in the drainage area of the Boston water supply. As no town or city in Massachusetts can now construct a sewerage system without the approval of the State Board of Health of its plan for disposal, and as the Boston Water Board has offered to help pay for sewage purification plants whenever these towns would put them in, we find, as has been stated, that first South Framingham and then Marlboro constructed well designed sewage purification plants, while other towns are taking steps in that direction.

The relation of the towns named to the Sudbury and Cochituate gathering areas of Boston's water supply can be seen by referring to the accompanying map, Fig. 1.

The total population of each "town" or township wholly or partially included in the drainage area are given on the map. These populations include both the village and rural inhabitants, and, as is evident from the map, are not all on the drainage areas, Northborough, for instance, having only a small part of its area coincident with the drainage area in question. But while the "towns" of Marlboro, Framingham and Natick are largely outside this area, their more densely inhabited portions are within it.

The sewage of South Framingham and Marlboro has been entirely removed from the feeders of the Sudbury River, as that of Westboro will also be. The total population of these towns is about 28,000, and the principal villages within their limits are also in the Boston water supply area.

Already, according to the reports of the officials of the Boston water-works, there is a marked improvement in the character of the water supply from this area. When Natick, whose sewage with more or less directness, contaminates Pegan Brook, tributary to Lake Cochituate, constructs a sewerage system which removes its sewage, and when Southboro and Westboro take similar steps all the grosser impurities will be removed from this drainage area.

The State Board of Health and the Boston Water Board obtained the passage by the 1890 legislature of a law whereby the State Board of Health has authority to prohibit the depositing of manure, excrement, garbage, sewage or any other polluting matter within 100 ft. of the high water mark of any stream or body of water used as a source of water supply. Massachusetts is now and for some time, if not always, has been far in advance of any other state in the Union in its sanitary regulations of water supply and sewerage systems.

INTERMITTENT FILTRATION.

South Framingham, Mass.

The best example of intermittent downward filtration combined with broad irrigation as used for the purification of the sewage of a town in this country is to be found in South Framingham, Mass. Although this plant was not put in operation until the fall of 1889, it is the oldest of its kind in Massachusetts, where the greatest attention has been paid to sewage purification. A small intermittent filtration system at Medfield, Mass., was put in operation late in 1886 or early in 1887, but broad irrigation is not used there.

The steps which led up to sewage purification at South Framingham are interesting. As was stated in the preceding section, Boston was influential in the establishment of this plant, it having taken the water of the adjacent rivers and ponds to increase its supply in 1878, directly after which efforts were made to secure the exclusion of sewage from its new water supply.

This agitation on the part of Boston and other localities interested in the general subject of abating nuisances caused by the sewage of towns led to the appointment in 1884 of a State Drainage Commission to investigate methods of sewage disposal and the protection of the water supplies where needed. Mr. E. C. Clarke, M. Am. Soc. C. E., was engineer of the commission, which recommended that South Framingham and Natick construct a joint system, purifying the sewage about as it is now done at South Framingham and as proposed at Natick. Messrs. J. P. Davis and Rudolph Hering, M's. Am. Soc. C. E., indorsed the recommendations of Mr. Clarke. In January, 1887, Mr. H. H. Carter, M. Am. Soc. C. E., reported to the Boston Water Board also recommending land filtration as the best means of purifying the sewage of South Framingham.

In 1885 the Framingham Water Co. introduced a public water supply, increasing the need of sanitary improvement. In the same year, 1885, Boston instituted a suit against the town of Framingham, of which South Framingham is the principal village, for the abatement of the pollution of the former's water supply.

Without following out the further details of the movement, it may be said that Boston finally offered to contribute $25,000 toward the removal of sewage from its drainage area, provided Framingham carried out the plans which were finally adopted as outlined below. The town employed Mr. S. C. Heald, M. Am. Soc. C. E., of Worcester, Mass., as engineer of the system. Mr. Heald's plans were approved by Mr. Phineas Ball, C. E., also of Worcester. The construction of the plant was under the direction of Mr. J. J. Van Valkenburg, C. E., of South Framingham. The plant was put in operation in the fall of 1889.

Before describing the disposal area some facts may be given regarding other parts of the system.

The village of South Framingham is located in the town of Framingham. The population of the whole town in 1890 was 9,239, of which 6,000 may have been resident in the village. The separate system of sewers is in use. Feb. 29, 1892, there were connected with the sewerage system 268 buildings, of which 236 were dwellings and 32 business blocks and manufactories. A year later the total number of sewer connections had increased to 490, of which 39 were hotels and business blocks.

The main sewer leading from and out of the village to the receiving reservoirs at the pumping station is oval shaped, of brick, 24 x 36 ins.

The volume to be treated is materially reduced by underdrains laid in connection with about half of the sewers. In the spring of 1891 these drains discharged from 200,000 to 500,000 gallons of water daily, much of which would have found its way into the sewers otherwise, necessitating pumping and purification. The underdrains were laid in a bed of gravel placed beneath the sewer, with their flow lines 8 to 12 ins. beneath that of the sewer. The underdrainage discharges into Beaver Dam Brook, about 2½ miles from the point where the latter flows into Lake Cochituate. The city of Boston objected to this underdrain and refused to pay the $25,000 toward the cost of the system, claiming that it was not included in the original plans, and that leakage from the sewer would enter the drain and contaminate Boston's water supply. To Jan. 1, 1892, the amount had not been paid. The State Board of Health on Sept. 2, 1890, reported that an analysis of the water had been made before the sewers were put in use in the fall of 1889, and each month since January, 1890. The water from the drain had not been worse, on the whole, since the sewers were put in operation. But the board concluded that Boston's water supply would be better if the underdrain did not discharge into Beaver Dam Brook, and advised that the town of Framingham and the city of Boston co-operate in pumping the water to the filtering area.

The arrangement and dimensions of the gatehouse, reservoirs and pumping station are shown by Fig. 2, which gives a plan of them and a section through the reservoirs.

Screens were put in to remove some of the coarser matter from the sewage near the beginning of 1892.

The combined capacity of the reservoirs is 431,000 gallons. The reservoirs are ventilated by connecting them with the chimney, as shown by the plan. June 17, 1892, the writer visited this pumping station. The day was very warm, but no odor was noticeable about the reservoirs or buildings.

The pumping engine is a Davidson compound duplex condensing, guaranteed to deliver 2,000,000 gallons of sewage per day through 9,000 ft. of 12-in. pipe against a total head of 40 ft., not including friction.

The pumps are run each forenoon until the reservoirs are empty. June 17, 1892, about 200,000 gallons of sewage were pumped. The average daily pumpage was said to be about 250,000 gallons.

There are two horizontal tubular steel boilers, each 4 ft. × 13 ft. 2 ins., with 52 3-in. tubes.

The force main is of 12-in. cast iron, 9,740 ft. long to the first manhole, where it ends. From this manhole 2,000 ft. of Akron pipe, first 15 ins. in diameter, then 12 and 10 ins., is laid at a grade of 1 ft. in 1,000 across the disposal area. The highest ground on the farm is 44.2 ft. above the bottom of the reservoir and 27.2 ft. above the valves of the pump. The force main is laid to a grade so that its whole length may be drained back into the reservoir.

Along the line of the force main eleven 6-in. plugged branches were placed from which sewage could be drawn by those who wished to use it as a fertilizer. So far, or to June, 1892, no one had availed himself of this opportunity.

The location of the filter beds and irrigation field and of the other parts of the system is shown by Fig. 3. This map also shows the limits of the

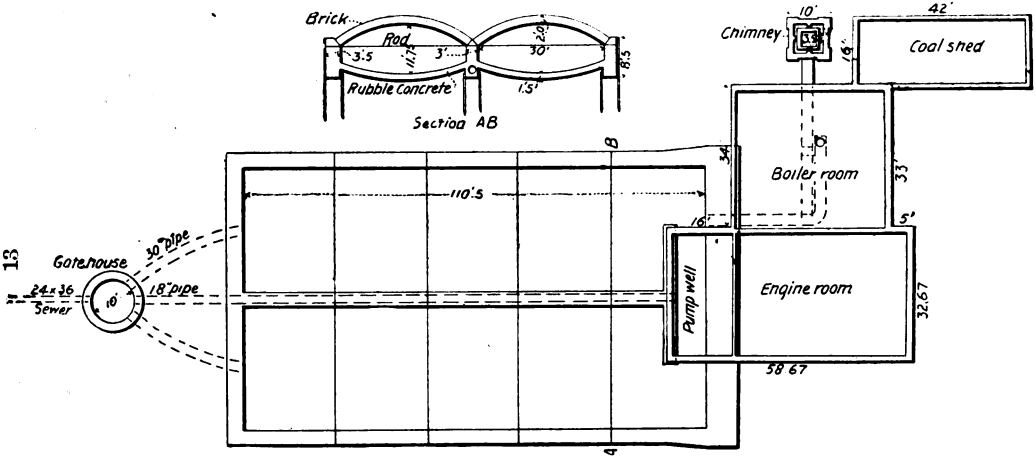


FIG. 2. PLAN OF RSERVOIRS AND PUMPING STATION, SOUTH FRAMINGHAM SEWERAGE SYSTEM.
S. C. Heald, M. Am. Soc. C. E., Engineer.

Beaver Dam Brook district of the Boston water supply. The disposal area, it will be seen, lies entirely outside this district.

There are 14 hexagonal manholes on the line of the pipe at the sewage farm. Generally there are four 8-in. regulating gates in the sides of the manholes, 1 ft. above the land which they are intended to serve.

The farm contains a little over 69 acres, about 12 acres of which has been laid out in eleven beds, as shown on the map, for intermittent downward filtration. About two-thirds of the entire area was formerly wooded. The timber was cut from most of the area but has been left standing on some of it. The soil is said to be very good for filtration.

The beds for intermittent filtration are formed by banks about 3 ft. high, 4 ft. broad at the top, with slopes of 1½ to 1. The bank containing the main pipe is somewhat higher in places. A ditch extends around some of the beds from which channels 9 ins. deep and 18 ins. wide extend and carry the sewage.

Six of the beds have a 6-in. underdrain laid 6 ft. deep, extending from near their centers to natural depressions or channels in the farm.

Broad irrigation has been practiced on the irrigation fields since the system was put in operation, but without any regularity. No attempt has been made to raise anything but grass on the fields, but in 1892 there were raised 400 bushels of corn (probably in the ear), three-fourths of an acre of potatoes and some squashes, all on the filter beds, which products were sold for $174.

All the sewage, except the larger particles screened out this year, goes to the disposal area, there being no settling tanks for the removal of the sludge. The surface of the uncultivated filter beds has never been touched for the purpose of working in any sludge which might have accumulated at the surface.

There has been no trouble with the filter beds dur-

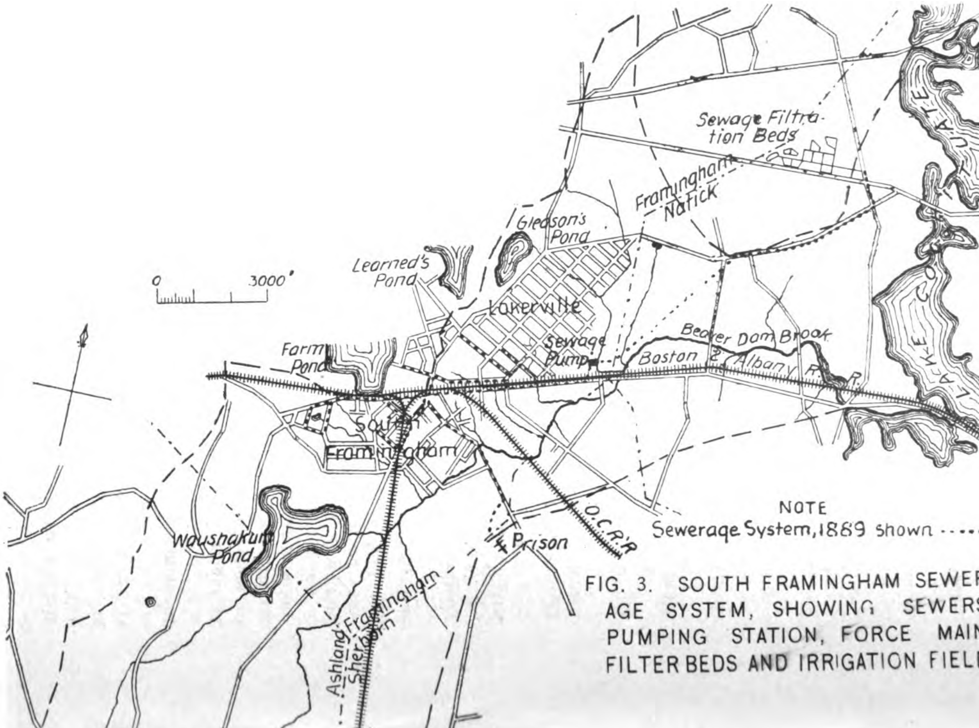


FIG. 3. SOUTH FRAMINGHAM SEWERAGE SYSTEM, SHOWING SEWERS, PUMPING STATION, FORCE MAIN, FILTER BEDS AND IRRIGATION FIELD.

ing cold weather, and two winters have already passed since the system was put in operation. The sewage, it is said, creeps under the snow so that its presence would not be known so far as the eye is concerned.

As has been stated, the South Framingham plant was visited on a hot June day. There was quite a breeze. No odor was noticed on the broad irrigation area and only a faint odor on those beds which were at the time being treated with sewage. Nothing connected with the plant was in any manner offensive.

The effluent, or filtered sewage, was very clear and quite cool. A couple of mouthfuls of it were sufficient to quench the writer's thirst, but had the source of the water not been known a glass of it would have been taken with pleasure.

The following table of analyses has been kindly furnished by Mr. F. P. Stearns, M. Am. Soc. C. E., Chief Engineer of the Massachusetts State Board of Health:

Analyses of Sewage, Sewage Effluent and Unpolluted Ground Water from the Sewage Field at South Framingham, Mass. Parts in 100,000.

	Color.	Total residue on evaporation.	Ammonia. Free.	Ammonia. Albuminoid.
Sewage	0.70	28.30	1.7898	.3750
Sewage effluent at underdrains	0.00	19.45	.0335	.0039
Sewage effluent at spring	0.00	7.23	.0000	.0029
Unpolluted ground water	0.00	4.70	.0000	.0008

	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
Sewage	4.07	.0080	.0001
Sewage effluent at underdrains	2.56	.6018	.0006
Sewage effluent at spring	1.77	.2350	.0000
Unpolluted ground water	0.20	.0083	.0000

Mr. Stearns' comments on these figures and the work of the disposal area as follows:

"In each case the analyses are the averages of several determinations. They represent, first, the sewage as it flows out of the carrier upon the beds; second, the effluent flowing from underdrains beneath certain of the beds, which afterward soaks into the ground and is filtered a second time before reaching the brook into which the effluent finally passes; third, the water of a spring located near the brook, which derives its supply to a large extent from the sewage effluent and represents the general character of the effluent when it reaches the brook; and, fourth, the unpolluted water from a flowing well near by.

"The efficiency of sewage filtration from a chemical standpoint is best indicated by the extent to which the nitrogen of the free and albuminoid ammonia is converted into nitrates. If, for the sake of clearness, we take these determinations from the table, we have the following, in parts per 100.000:

	Free ammonia.	Albuminoid ammonia.	Nitrates.
Sewage..	1.7893	.3750	.0080
Sewage effluent at underdrains	.0335	.0039	.6018
Sewage effluent at spring..	.0000	.0029	.2350
Unpolluted ground water...	.0000	.0080	.0083

"Only a small part of the sewage effluent comes out at the underdrains and you will notice that this is purified to such an extent that there is only 2% of free ammonia and 1% of albuminoid ammonia remaining, while the nitrates have increased greatly. At the spring the free ammonia is entirely removed and the albuminoid ammonia is less than one per cent. of that in the sewage. On one occasion an analysis of the spring water showed that it contained neither free nor albuminoid ammonia, while the excess of chlorine and nitrates over the amount found in the unpolluted ground water, as shown in the last line, proves without doubt that this spring contains a large proportion of sewage effluent.

"Bacterial examinations of the sewage and of effluent collected from the spring show that nearly, if not all, bacteria are removed by filtration.

"The effluent from this sewage field flows into a small brook and although the works have been in operation more than two years the discharge of the effluent into this brook has not produced any noticeable effect."

The original cost of the whole sewerage system, as described, but with about five instead of six miles of sewers, was about $145,000. The preliminary estimate of cost was $140,000. The cost of the purification works is not given separately in the reports. The total cost of labor, fuel, improvements and repairs for the whole system in 1891 was about $6,500, of which $656 was for fuel and $3,990 for labor and services.

The Effect of Snow and Frost Upon the Filter Beds at South Framingham, Mass.

One of the most serious drawbacks in connection with the purification of sewage by intermittent downward filtration through unprotected sand beds, or by broad irrigation, is the trouble which is sometimes caused by frost in cold climates.

During the cold weather of January, 1893, some observations of the effect of frost on filter beds were made by the sewer commissioners at the suggestion of Mr. Allen Hazen, Chemist of the Lawrence Experiment Station of the State Board of Health. The results of these observations were published in the Framingham "Gazette," from which the following has been abstracted:

A filter bed with an area of seven-eighths of an acre received no sewage from some time in September until Jan. 9. On this date there were 18 ins. of frost in the bed and 10 ins. of snow upon it, the thermometer reaching 6° F. below zero. On Jan. 9, 300,000 gallons of sewage were applied to the bed, and on Jan. 10, 150,000 gallons. It is said that the effluent appeared in the underdrain in six hours after the application of the sewage. On Jan. 11 the frost was entirely out of the bed in places, and on Jan. 12 it was nearly all gone and the sewage had all disappeared. The temperature of the sewage was 50° F.

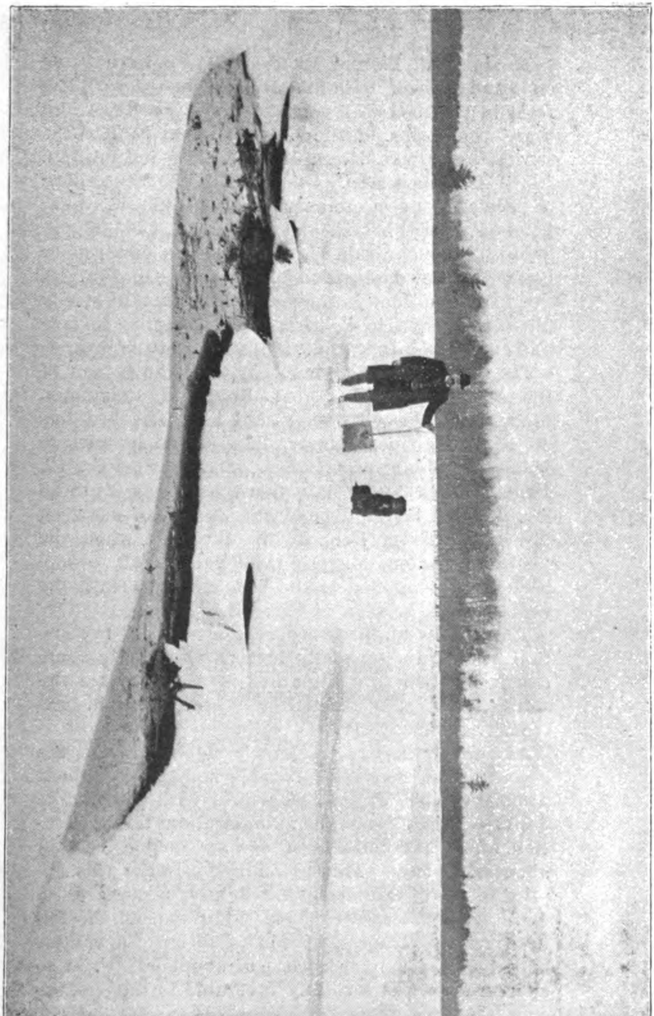


FIG 77. SNOW-COVERED SEWAGE FILTER-BED AT SOUTH FRAMINGHAM, MASS.

On Jan. 16, 17 and 18 observations were made on another bed, with an area of one acre. The frost in this bed was from 20 to 30 ins. deep, and there was 15 ins. of snow upon it. On Jan. 16 the thermometer was 6°, on Jan. 17, 20°, and on Jan. 18, 4° F. below zero. On Jan. 16, 500,000 gallons of sewage, at a temperature of 49° F., were pumped upon this bed, and on Jan. 17, 175,000 gallons. The underdrain started in seven hours after beginning the application of sewage. On Jan. 18, the frost had gone in places, and on Jan. 19 nearly all of the frost had disappeared, and the sewage had entirely disappeared.

The accompanying view, Fig. 77, shows one of the sewage filter beds at South Framingham, Mass., covered with snow and ice. The bed has an area of about ⅞ acres. It received no sewage from the middle of October, 1892, until Feb. 12, 1893. On the latter date there was from 30 to 36 ins. of frost in the ground and 30 ins. of snow on top of it. From Feb. 12 to March 1, when the view was taken, about 50,000 gallons of sewage per day was applied to the bed, going beneath the snow, as can be seen in Fig. 77.

The results of these observations appear to show that where an unusually large volume of sewage can be applied to a filter bed in a short time the sewage will pass through the bed, even in extremely cold weather.

At the South Framingham pumping station the underground reservoir provides storage for about 430,000 gallons of sewage, which, with the sewage delivered during pumping, would allow the application of 500,000 gallons of sewage to one bed in about six hours. This amount of sewage was applied to one of the beds, with an area of one acre, in one day, and 175,000 gallons additional on the following day. The application of so large a volume of sewage at a temperature of about 50° F. in so short a time was certainly favorable to the passage of the sewage, but the presence of 15 ins. of snow was decidedly unfavorable. It seems likely that the sewage found its way under the snow upon the bed without being much chilled, as previous reports state that the sewage at South Framingham commonly creeps under the snow, so that the beds appear to be covered with snow, only, and to have no sewage upon them. In the above experiments much of the sewage doubtless went down in spots, and all of it may have passed through the beds with only a very partial purification.

In the last report of the Massachusetts State Board of Health, Mr. Allen Hazen states that, as the results of experiments at Lawrence, it has been found that "frost checks both purification and nitrification, although the removal of organic matter is more complete than the oxidation of ammonia."

In winter, especially where sewage effluents are not discharged into water used for domestic purposes, a high degree of purification is obviously of less importance than in summer.

Mr. John H. Goodell is Chairman of the South Framingham Sewer Committee, and we are indebted to him and to Mr. F. P. Stearns, M. Am. Soc. C. E., for courtesies in connection with the above information.

Marlborough, Mass.

As explained under the South Framingham works Boston was largely influential in securing the introduction of a sewage purification system at Marlborough, and it may be added that it agreed to pay $62,000 toward the expense of the system, which, we understand, was the estimated extra cost for the sewage dispcsal plant. As shown by the map of this system, Fig. 4,* the sewage is now entirely removed from the drainage area of the Boston waterworks. A separate system of sewerage is in use at

* Figs. 4 to 12, inclusive, are on the accompanying inset sheet.

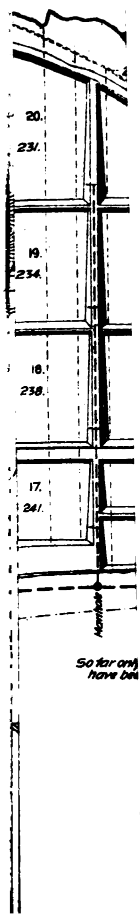
Marlborough, with downward intermittent filtration for purification, as at South Framingham and at Gardner. On June 23, 1892, there were about 350 sewer connections. To the close of 1891 there were about 50 sewer connections only. New connections are made at the rate of about five a day. As the total number of water connections at the close of 1890 was 1,794, and the population of the town in 1890 was 13,805, it is evident that at present the amount of sewage to be purified is small compared with what it will be in the future.

The town introduced water-works in 1883, and the consumption of water in the early part of this year was about 325,000 gallons a day, but at 4:30 p. m., May 12, 1892, after a dry spell, the flow through the outlet sewer was at the rate of 330,000 gallons a day, and on May 25, 1892, at 9 a. m., after heavy rains, the rate of flow was 790,000 gallons a day. The measurements on each date were made by observing the time taken to fill the separating tank once.

Ground water, of course, is the only explanation for this large flow through the sewers, for, as has been stated, not more than one-fifth of the water consumers are connected with sewers. Unfortunately, Marlborough is not the only town where an excessive amount of ground water finds its way into the sewers. Where sewage purification is attempted or the sewage is pumped, this is a serious and expensive trouble. The city of Boston would not allow Marlborough to put in underdrains because it feared that sewage would pass through defective sewer joints, and into the drains, and thus finally into the Boston water supply. If the underdrains could not be discharged into natural water courses tributary to the Boston water supply, then the ground water might as well work into the sewers, as it now does.

Mr. M. M. Tidd, M. Am. Soc., C. E., of Boston, Mass., was the engineer, with Mr. Fred. Coffin,

15"S
10"In
18"D
4"
Pave
Studs



So far only
have bee

C. E., as principal assistant of the system. Mr. Desmond Fitz Gerald, M. Am. Soc. C. E., represented the city of Boston. The construction of the plant was in charge of Mr. B. R. Felton, C. E., as resident engineer for Mr. Tidd. Since March, 1892, Mr. Felton has been city engineer of Marlborough.

The sewage filtration beds are located about two miles, in an air line, from the outskirts of the village, and some 3½ miles from the last house connection, measured on the pipe line. The nearest house is about 1,000 ft. from the beds. There are two other houses about 1,500 ft. away, and no more within about a mile.

The sewage passes from the village to the disposal area, through the outlet sewer mentioned, which is of vitrified pipe. A separating or settling tank removes the sludge from the sewage, after which the sewage passes through iron pipes to the several filter beds, of which there are now 14 in use, besides the six small beds used for emptying the sludge.

The arrangement and details of the purification plant are shown by the accompanying drawings, kindly furnished by the engineer. Fig. 5, on the inset sheet, is a plan of the filter beds. Only 20 of these, including the 6 sludge beds, were in use in June, 1892, but 51 beds are proposed. The 14 filter beds now in use, with their dividing embankments, cover about 13 acres. In the whole tract bought by the city there are 60 acres.

The separating or sludge tank is shown in plan and section by Fig. 6. It is of brick, in two compartments, with gates permitting sewage to be admitted to or drawn from either one at will.

The course of the sewage in passing through the tank is shown by the drawings. The screens perform only a slight service, as most of the solid matter settles before the sewage reaches the screens.

The sludge can be removed from either tank to the sludge carrier, by opening the cleaning-out gate.

The floor over the tanks is formed by iron gratings supported by I beams, 3¼ ft. c. to c.

The character of the 24-in. influent gates, and the 18-in. gate, which controls the passage of sewage directly to the beds, through the pipe on the partition wall, are shown by the 18-in. lift-gate in Fig. 7. There is also shown in Fig. 8 an 18-in. swinging gate, which is apparently used at the effluent end of the tank.

Fig. 9 shows, in detail, the screen used in the separating tank.

The sewage passes from the top of the tank through iron pipes along the embankments to the several beds, and discharges onto the beds through gates and short branches, the bed at the point of discharge being paved, all as shown in Figs. 10 and 11. Fig. 10 gives a plan and section of the outlet to the beds, and Fig. 11 shows the two-way 10-in. vertical gates used. A single gate constructed on the same principle as the two-way, is used where only one gate is needed.

The sludge passes through the cleaning-out gate, already mentioned, to the sludge carrier, shown in detail in Fig. 12.

Sludge was first removed from the tank in April, 1892. It remained upon one of the beds for a month, instead of being speedily removed, and became offensive. A farmer drew it away for it. On May 25 the sludge was removed from the tank the second time, and on June 11 the third time, in each case a farmer hauling it from the bed for it. The tank filled full, or nearly full, of sludge, each of the last two times.

The crust that forms on top of the filter beds, consisting of minute particles of matter suspended in the sewage, is harrowed in from time to time.

The effluent from the beds discharges through underdrains into Hop and Wash Brooks, which empty into the Sudbury River. These beds were visited June 17, 1892, at which time they seemed to be doing good work, and presented no unpleasant features. A strong breeze was blowing over the beds, but at their windward side only a slight odor was noticed.

The cost of the tank, tank house, filter beds, and all appurtenances, including engineering and excluding land, was $21,720. The outlet sewer was carried 2½ miles further than it would have been, had not sewage purification been adopted. The total extra cost caused by the construction of this extra pipe line, and the filtration beds and appurtenances, was about $62,000, which was met by the city of Boston as a return for removing sewage from its water supply.

Summit, N. J.

The township of Summit, N. J., is situated 20 miles from New York on the Delaware, Lackawanna & Western R. R. The population of the township in 1890 was 3,502, against 1,910 in 1880. A public water supply was introduced in 1889 by the Summit Water Co.

A sewerage system was put in operation in 1892, the sewage being purified by intermittent downward filtration before passing into the Passaic River. The sewage filter beds were put in operation on Aug. 2, 1892, when there were seven miles of sewers.

Dec. 1, 1892, there were nine miles of sewers, 180 house connections, 20 flush tanks and 168 manholes, all ventilated. The separate system is used.

About 1¼ miles of sub surface drains were laid where the sewers are in cuts. They discharge into the sewers, the underdrainage being estimated at 20,000 gallons per day.

The filter beds are located about a mile from the village, within the township limits. One end of the disposal area borders on the Passaic River, as shown in the plan, Fig. 45. The township owns 26 acres of land, only ten acres of which have been laid out in beds. Deducting the area occupied by embankments and a road there are about eight acres of land available for filtration. There are only a few scattered houses in the vicinity and those are at some distance from the beds.

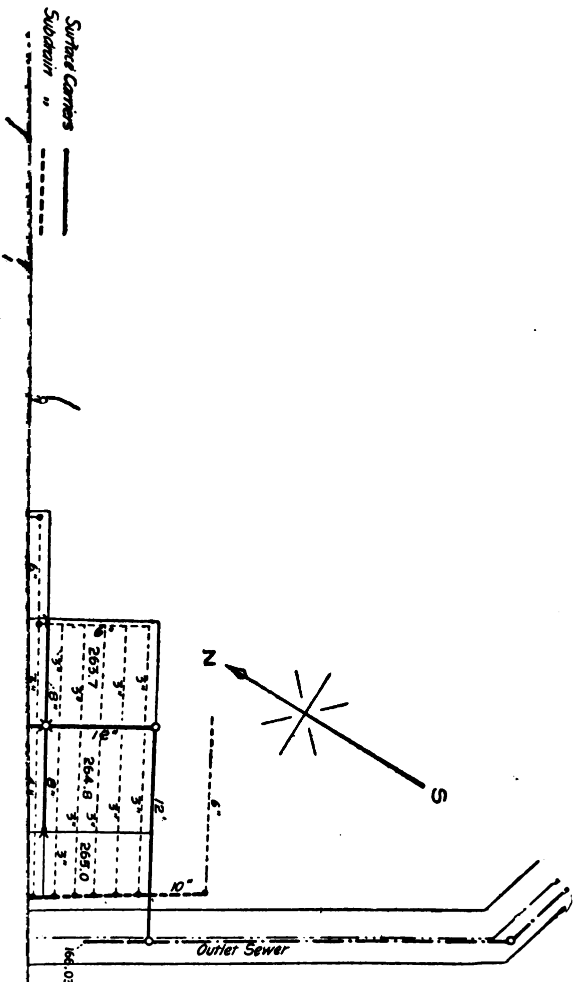
The sewerage system was designed by Mr. Carrol Ph. Bassett, M. Am. Soc. C. E. We are indebted to Mr. Bassett for the illustrations and for some of the information given herewith. Mr. Jas. H. Kelley, Treasurer of the Township Committee, is now in charge of the system, including the beds, and has furnished information regarding it. At present two men are employed at the beds at a monthly expense of about $50.

Mr. Bassett states that a design was made for the mechanical straining of the sewage before it passed to the filter beds, which was to be effected by upward filtration through vats. This feature, he adds, will not be introduced for several years, or at least until a much increased flow of sewage is received at the beds.

A public road passes through the disposal area. The land on the side of the road nearest the river slopes towards the river and the beds are laid out in terraces, as shown by Fig. 46, which is a reproduction of a photograph taken near the lower edge of the tract. The beds are separated by earth embankments. The lowest beds are some 20 ft. above the river. The effluent is discharged at the top of the abrupt river bank and finds its way down the bank into the river.

The writer visited the beds on Nov. 28, 1892, and found the effluent with only a slight cloudiness and but very faint musty odor. The river showed no sign of pollution and there was nothing about the disposal area which indicated to smell or by offense to sight the use to which it was put, except on raising a manhole cover, when a very slight odor was observed.

Regarding the care of the beds the attendant stated that their surface was raked up occasionally.



sett M. Am. Soc. C. E., Engineer.

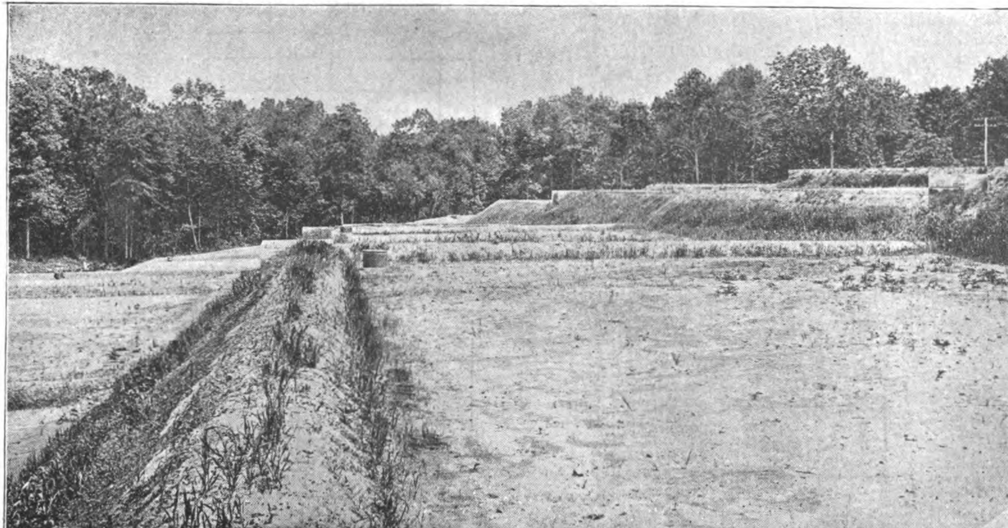
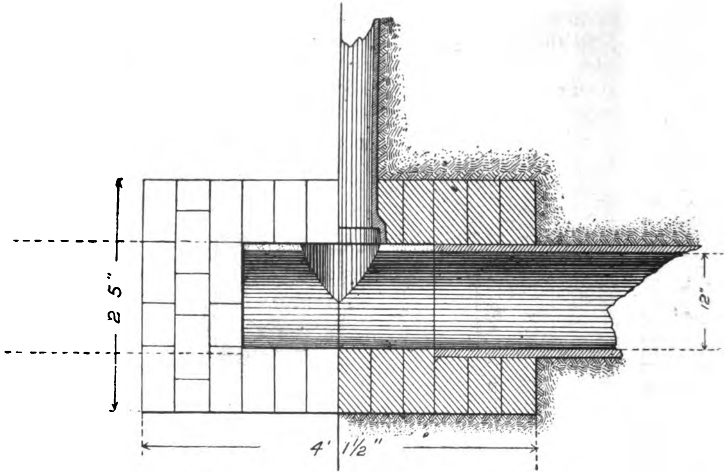
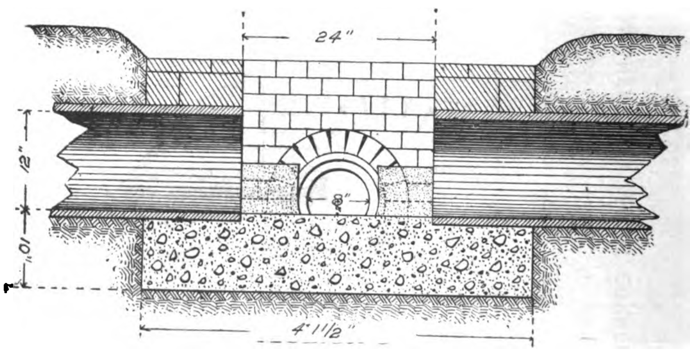


FIG. 46. VIEW OF FILTER BEDS FROM ROAD NEAR NORTHWEST CORNER.



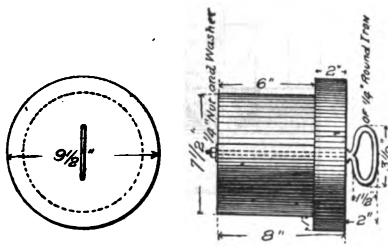
Plan and Horizontal Section.



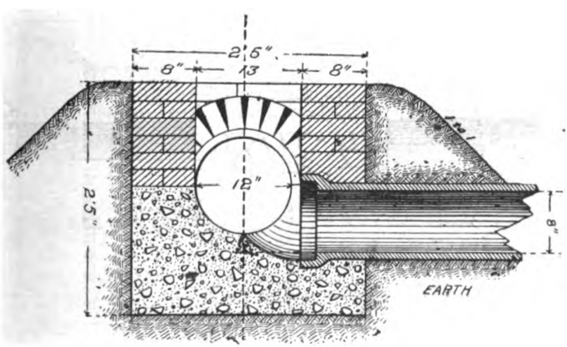
Longitudinal Section.

FIG. 47. DETAILS OF

He also stated that no fixed rule was observed as to the length of application of sewage to the beds, judgment being used in that respect. The drawing from which Fig. 45 was made showed one or two beds with no outlets to them, and the origi-

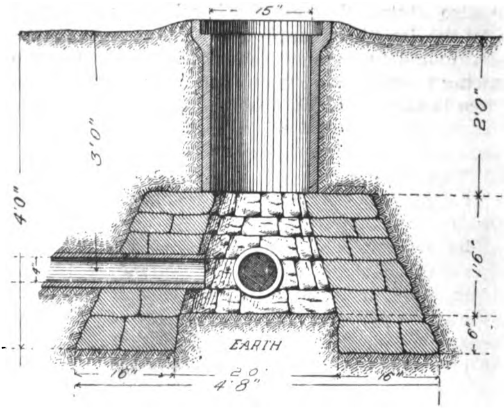


Plan and Elevation of Plug.

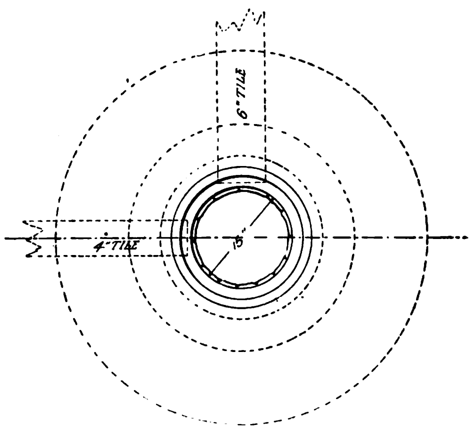


Cross Section through Branch.

SEWAGE CARRIER.



Section.



Plan.

FIG. 48 PLAN AND SECTION THROUGH TILE CHAMBER.

nal has been followed, but the attendant stated that all the beds laid out are in use.

The general arrangement of the beds, sewage carriers, outlet chambers, manholes, sub and main underdrains and tile manholes to give access to the latter will be seen by reference to the plan, and the accompanying explanatory symbols, Fig. 45. The underdrains are placed with their centers at a depth of 3 ft. below the surface of the beds and are 20 ft. apart.

The sewage is distributed to the beds through pipe carried in the tops of the embankments, from which it is drawn through chambers and short lengths of pipe at the corners of the beds, all located as shown in the plan, Fig. 45. The details of the main carrier and branches, including the plugs used to divert the sewage as may be desired, are shown by Fig. 47. Where the beds to be served are at a lower level than the outlet chambers, half tile, flat stone and V-shaped troughs are used to carry the sewage down or to protect the embankment. All the brick chambers and manholes are lined inside and plastered outside with cement and the brick manholes and some or all of the outlet chambers have board covers, painted.

At the intersection of sub and main underdrains tile chambers are placed, as shown in plan and section by Figs. 48 and 49. Fig. 49 shows the underdrains at changes of grade at embankments, where adjacent beds are on different levels. There are but two or three of the special sections, shown in Fig. 49, they being placed only at points where the underdrain beneath a bed is at least 2 ft. higher than the surface of the bed below. Instead of the curves, shown in Fig. 49, the pipe was laid in straight lines. The tile chambers have iron covers, as shown in Fig. 48.

The cost of the filter beds and accessories was about $17,000, it having been increased by the hauling of sand to the beds.

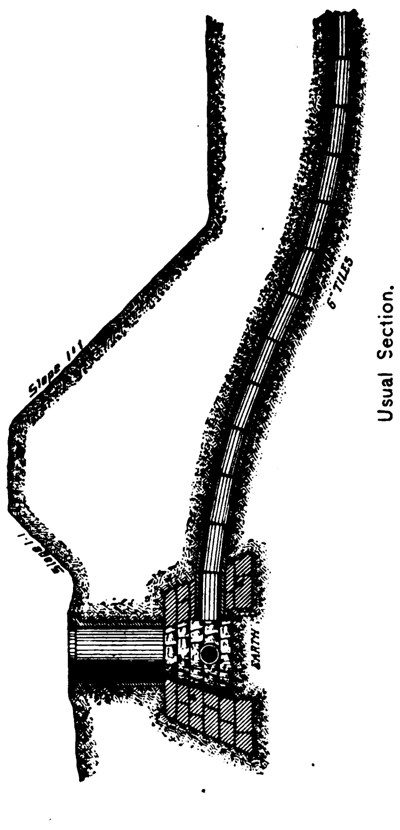
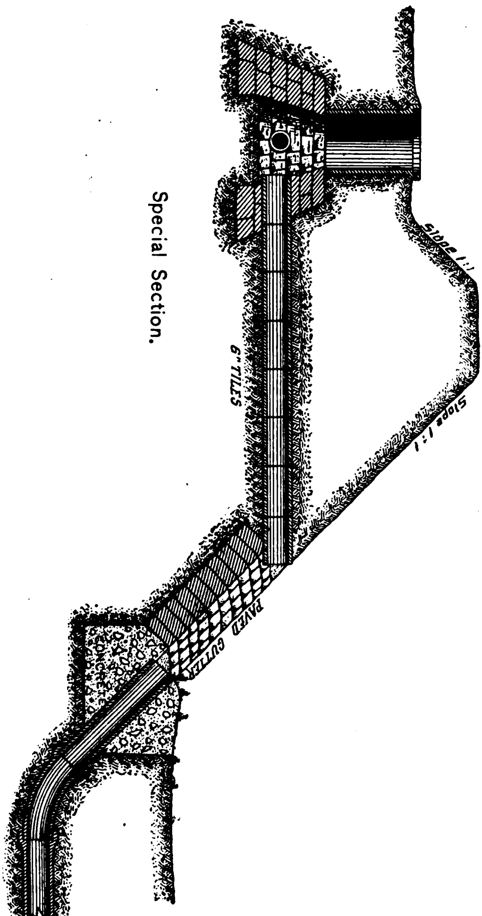


FIG. 49. SECTIONS THROUGH TILE CHAMBERS EMBANKMENTS,

Special Section.



AND UNDERDRAINS AT CHANGES OF GRADE AT SUMMIT, N. J.

The Effect of Snow Upon the Filter Beds at Summit, N. J.

A visit was made to the Summit filter beds on March 6, 1893, to ascertain the effect of the heavy snowfalls of the winter, which in that locality kept the ground continually covered with snow for a number of weeks.

At the time of the visit the ground in the vicinity of the beds was covered with about 6 ins. of snow, some of which had been quite heavily packed by rain and thawing weather, and afterwards frozen. The thermometer was a few degrees below the freezing point in the morning, but at noon the snow in the vicinity of the beds was thawing slightly. Most of the beds were entirely covered with snow or ice, or both, and all partially so. The snow filled some of the beds nearly to the top of the banks, while others were covered with ice and a small amount of snow, with a part of their surfaces exposed. All of the beds not wholly covered showed an open space between their surface and the ice and snow above. During the visit sewage was applied to at least six different beds, and in each case found its way beneath the snow and ice. One small bed became filled above the ice with sewage, necessitating the turning of the sewage elsewhere, but the attendant stated that it would soon disappear. Three beds showed the applied sewage running part way across them in channels, with the ice and snow melted above, but on two of these beds the volume of sewage was small. A bed not then in use gave some evidence that sewage had been finding its way down through an underground channel, and one bed, which was nearly full of snow and ice, showed that the sewage, when last applied, had run over the top of the embankment, beneath the snow.

The attendants stated that the snow upon the beds had prevented the usual repairs, and thus allowed the channels to form. Channels also form in summer, necessitating watching and repairs.

The smallest beds, and those in poorest condition, are used during the day and carefully watched. At night sewage is applied to six or seven of the beds, there being no night attendance.

The effluent coming from the underdrains appeared to be in good condition, but of course its character could be determined only by analysis.

Mr. John J. Connolly, with one assistant, takes care of the beds. Mr. Connolly stated that the filtering material had not frozen during the winter sufficiently to prevent filtration, and that the snow had not stopped the operation of the beds.

The open space between the top of the beds and the ice gives the air access to the beds and the passage of sewage beneath the ice and snow, as is the case on most of the beds, prevents the chilling which would otherwise result. As there is no settling tank, and raking of the beds has been impossible during much of the winter, some sludge has collected on their surface, but so far as was observed not a great amount. It should be stated that the sewage is admitted to one corner of each bed, and that it has sufficient head to give it a good start across the surface.

On the whole, it seems that the snow on the Summit filter beds this winter, which has far exceeded the usual quantity and duration, adds to the rapidly accumulating proof that the heavy snowfalls of northern latitudes can no longer be considered a valid argument against intermittent filtration. Of course snow and cold reduce the efficiency of filter beds, but provided public water supplies are not affected a poorer effluent can be tolerated in winter than in summer.

The Summit effluent is discharged into the Passaic River at least 20 miles above the point on the river at which the Paterson and Passaic supply is drawn, but both of these latter cities discharge crude sewage into the river only a few miles above the site of the present water supply intake of Jersey City and the recently abandoned intake of Newark. These larger populations ought not to complain if, in exceptional winter weather, the effluent from a comparatively small population, discharged into the river 20 miles above their intakes, is somewhat reduced in quality, while any impurities from Summit could hardly add to the pollution contributed by Paterson and Passaic to the Jersey City water supply.

Medfield, Mass.

The sewage purification plant at Medfield, Mass., combines mechanical separation, or straining, with intermittent downward filtration, and treats mainly the sewage of the Excelsior Straw Works, only a few residences being connected with the sewers. The town of Medfield is on the Charles River, about 17 miles from Boston. It had a population of 1,493 in 1890 and 1,371 in 1880. It is largely an agricultural town, the exception being the straw works, which employs a large number of hands.

Vine Brook having been polluted by the drainage from the straw works, much of which came from the vats in which the straw is dyed, in which dye wood is used, a sewer was built in the fall of 1886 to divert the sewage from the brook to filter beds.

The sewage disposal plant was designed by Mr. E. C. Clarke, M. Am. Soc. C. E., and constructed under the direction of Mr. Fred Brooks, M. Am. Soc. C. E. The following description of the plant is condensed from a paper by Mr. Brooks published in the Massachusetts State Board of Health Report for 1886-7 and reprinted, with slight changes, in the Journal of the Association of Engineering Societies for July, 1888.

In order to remove the dyewood from the wastes from the vats of the straw works, duplicate settling

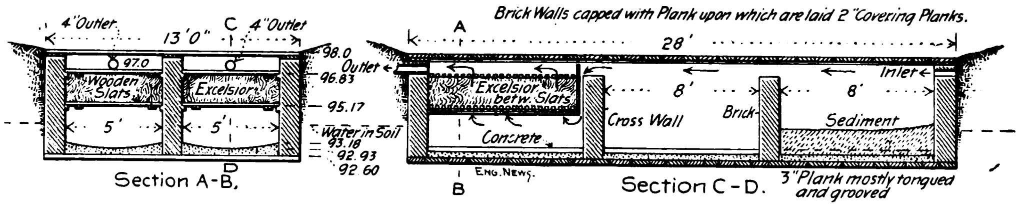


FIG. 54. SECTIONS THROUGH SEWAGE SETTLING AND FILTERING TANKS, MEDFIELD, MASS.; E. C. Clarke, M. Am. Soc. C. E., Designing Engineer; Fred Brooks, M. Am. Soc. C. E., Constructing Engineer.

tanks and excelsior filters are provided, shown in section in Fig. 54. The filter was used nearly a year before the excelsior was changed, but meanwhile the excelsior had rotted and was nearly ready to pass, piece by piece, into the sewer. The effluent from the tanks is joined by the other sewage from the straw works, after which the sewer changes from a diameter of 4 to 6 ins. This portion of the system, with branches to houses, was built at private expense. From the end of the

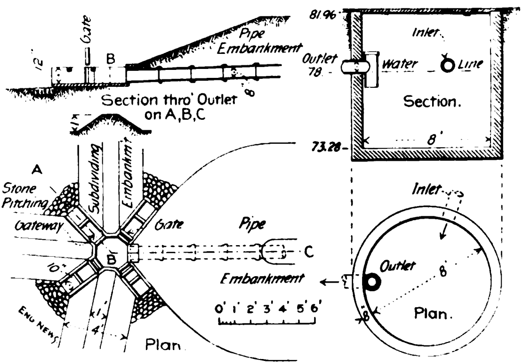


Fig. 55. Plan and Section through Sewage Outlets and Cesspool.

6-in. pipe the town laid one 8-in. sewer, with capped branch pieces for extensions through the village. Near the filter beds the sewage enters the cesspool shown in plan and section at the right in Fig. 55, the T outlet being designed to hold back objects that float or sink until chemical or other action changes them so they will flow out uniformly upon the bed.

The outlets in the middle of the filter beds are shown in plan and section at the left in Fig. 55.

The area of the filter beds is only one acre. This area is divided into four sections by embankments, three of which are about 1 ft. high, while the pipe embankment is 3 ft. high. The filtering material consists mostly of stones and gravel, from the size of a man's fist down. The natural level of the ground water being about 10 ft. below the surface, the beds are not underdrained.

The average daily amount of sewage throughout the year was estimated by Mr. Brooks, the latter part of 1887, as about 32,000 gallons, it varying with the force employed and work done at the straw works. Mr. Brooks gives the probable cost of the cesspool, pipe to outlet and filter beds as about $1,000. The land was given to the town.

In a letter dated Nov. 21, 1892, Mr. Geo. W. Kingsbury, chairman of the selectmen of Medfield, gave the following information:

The average yearly cost of caring for the filter beds thus far nas been about $50. The beds require plowing and harrowing once every year, and more than that if much sewage goes to them. There has been no trouble with the sludge upon the beds. The sewage runs upon each section about two days, thus giving each section about six days' rest. Surveys were being made on the above date to determine what territory could be made tributory to the works.

To April 11, 1893, the system had not been extended.

Gardner, Mass.

The town of Gardner, Mass., is situated in the central part of the state, 65 miles from Boston. It is on the divide between the Connecticut and Merrimac rivers, all but a small part draining into the Connecticut River. The population of the town in 1890 was 8.424 and in 1880, 4,988. It is largely engaged in the manufacture of chairs. The waterworks were built in 1882 by the Gardner Water Co. The daily consumption of water is about

300,000 gallons. In 1889 a report on a sewerage system was made and sewers were built in the three following years.

The town is made up of four villages closely united, South, Depot, West and Center. Of these the West village is the most thickly settled and contains the most factories. The South is also thickly settled, and has a number of factories. The Center is strictly a residential part of the town. The Depot village is not thickly settled. South Gardner has a number of large ponds, and quite a stream flowing through it, which are utilized for sewage disposal. No sewers have yet been built in this part of the town, but in a short time something will have to be done. The outlet of Crystel Lake flows through West Gardner, and until sewers were built received the filth from the greater part of the village. At one point the water is held back by a dam, thus making a pond in which the filth settled. After passing this pond the brook runs by several large factories and is shortly joined by a brook from the Center and Depot villages. It then flows through unoccupied land, crosses Broadway and flows by the filter beds. Here it receives the effluent from the beds and finally it finds its way into the Connecticut River by way of Otter and Miller rivers. The brook from the Center and Depot villages is polluted to a considerable extent.

The State Board of Health, fearing that in time the crude sewage, if emptied into Otter River, might create a nuisance, or worse, ordered the town to purify the sewage before allowing it to flow into the river. Intermittent downward filtration was adopted. The main sewer is a 12-in. pipe which extends through West Gardner. The Center and Depot villages are drained by a 10-in. pipe which joins the 12-in. pipe about one-half mile from the filter beds. Work was begun in August, 1890, and was carried on during the summers of 1890-1-2. A greater part of West Gardner, the Center and Depot villages had been sewered up to March, 1893.

The town is very hilly, has a large amount of ledge, and is, in places, quite wet.

The sewers were built in the ordinary way and need not be described here, note only being made of the fact that a gasket, wet in thin cement, was calked into the joints and that drop-manholes, shown by Fig. 63, were very successfully used.

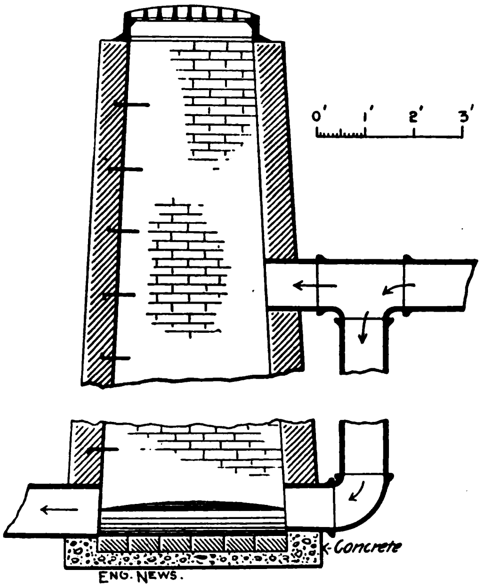


Fig. 63. Section of Drop Manhole.

There are 14 drop manholes, built wherever one sewer enters another at an elevation above the outlet greater than 1 ft. It was found to be cheaper to put in the drop manholes than to lay the higher of the two sewers at a lower grade. The channels in the bottom of the manholes were formed with brick and are of the same size and shape as the lower half of the sewer.

The separate system was used on account of its costing so much less than the combined and from the fact that the surface water can be easily and cheaply drained into the natural water courses without doing any harm.

There were in use, at the close of the summer of 1892, 5½ miles of sewers, 12 to 6 ins. in diameter, 128 manholes with perforated covers and 23 flush gates in manholes; also 139 sewer connections, of which 100 were from houses, 25 from business blocks, 10 from factories, with a total of 1,500 employees, and four from hotels. At the close of the summer of 1891 there was a total of 97 connections. The daily amount of sewage delivered at the filter beds is about 125,000 gallons. To reach the most available ground for a filter bed it was necessary to carry the outlet sewer down through a small valley and up onto a hill. This was effected by making the last 1,050 ft. of the outlet sewer of iron pipe, with a sag near the middle of 24 ft. A blow-off, discharging onto filter bed No. 50, used only in this connection, has been placed at the lowest point in the iron pipe. This is to be used only in case of stoppage. This gate has not been open for over a year and no trouble has arisen from solids collecting at this point and stopping the sewer.

The blow-off gate used is an 8-in. vertical lift gate, exactly like the one in use at the filter beds at Marlborough, Mass., shown on the inset, Fig. 11, accompanying the Marlborough description.

The iron pipe crosses the brook on a bridge and is housed in and packed in sawdust.

The outlet pipe discharges into a settling tank, shown in plan and section by Fig. 64. The tank is built of brick, with walls 12 ins. thick. It

is divided into two parts by a 12-in. wall, built through the center, thus giving two compartments, each 20 ft. long, 7 ft. wide and 5 ft. deep. The sewage first flows into a wooden box, shown in plan by Fig. 65, and also by the dotted lines in the plan of the tank, Fig. 64, and is diverted into either tank by means of a swinging door. Stop planks to prevent floating matter from reaching the gate chambers are placed near one end of the tanks. The sewage is drawn off at the surface by means of pipes leading into the gate chamber. The flow into these pipes is controlled by iron gates, a sketch of which is shown by Fig. 66. The sludge is drawn off by opening similar gates, shown in plan at the

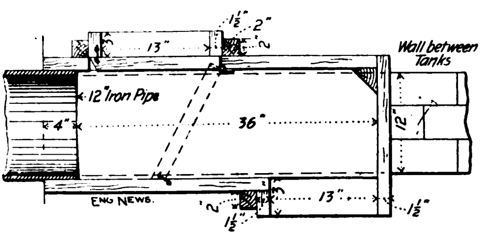


Fig. 65. Inlet to Settling Tanks.

bottom of the tank, Fig. 64, crude sewage being used to wash out the tanks. Extra pipes for future use have been built into the tank and gate chamber.

The flow from the gate chamber into the main carrier is also regulated by means of iron gates like the above. The gates are raised or lowered by means of chains, which pass over pulleys and through the wall of the tank, and are worked inside the tank house. A large amount of solid matter settles in the tanks, and is discharged onto the sludge bed, through the sludge pipe, as shown in Figs. 64 and 67.

Iron gates, like those just described, are used in connection with flush manholes, the gates being lowered to cover the outlet pipe, or both outlet and inlet, if desired, and opened again after the manhole has been filled from a pipe connecting with the water main.

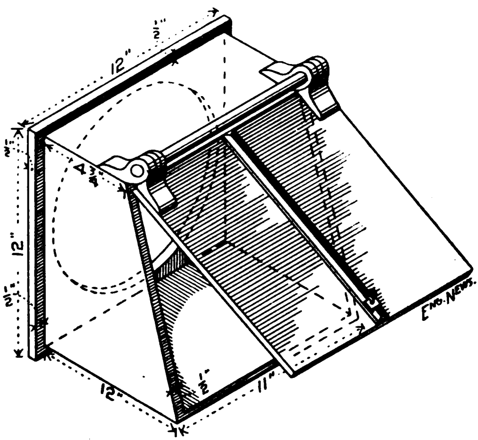


Fig. 66. Gates on Outlet Pipe from Tank.

In constructing the filter beds, the surface was first leveled, the surplus dirt being used to make the banks, and the bottoms of most of the beds being formed in clay. They were then covered with gravel to the depth of from 4 to 5 ft., carted on from a bank south of the settling tank, after which the outlet for the effluent and the tile drains leading into them were laid. Then the banks subdividing the beds were built. The bottom of these banks extend 1 ft. below the surface of the beds. All of the banks were then sodded. The 10-in. distributing pipes were then laid and connected with square wooden troughs, firmly fastened to cedar

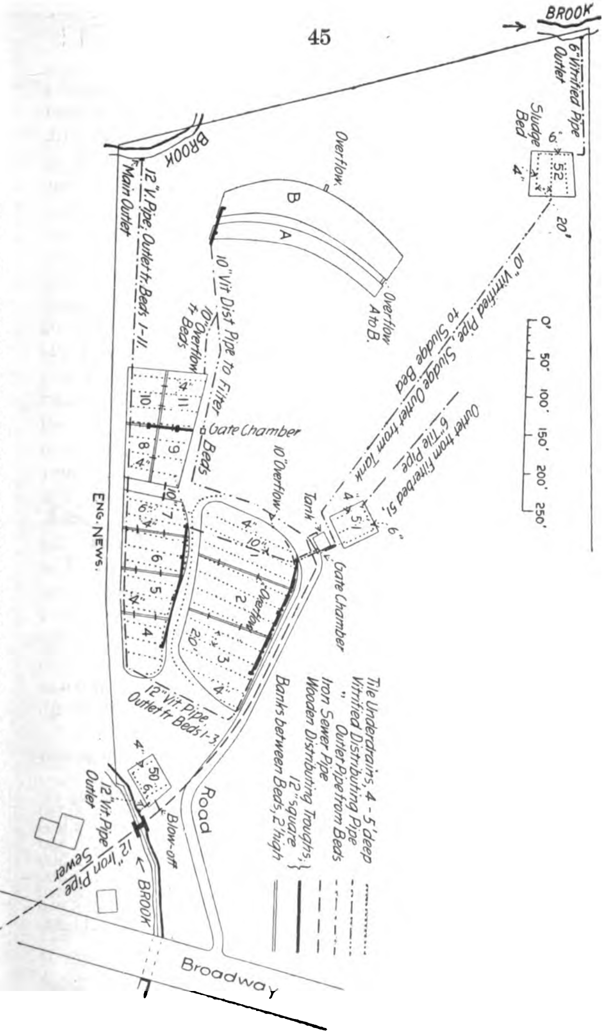


FIG. 67. PLAN OF SEWAGE FILTRATION BEDS; GARDNER, MASS.

posts set in the edge of the bed. These troughs are covered, but every other cover is hinged so that the interior of the troughs can be examined at will. The troughs have an opening at each bed and by means of a board, sliding in grooves, the sewage can be directed on any bed, as desired. These troughs are from 2½ to 3 ft. above the beds and the sewage falls onto a piece of stone pavement which prevents the washing of the beds. The tile drains are from 4 to 5 ft. deep and 20 ft. apart and the banks are 2 ft. higher than the surface of the beds. The surfaces of the beds are level. Beds A and B were constructed by simply leveling the bottom and building the banks. No tile or outlet pipe was laid and the effluent simply soaked through the ground. An examination of the plan of the filter beds, Fig. 67, will show clearly their general arrangement. All of the beds except No. 51 discharge their effluent directly into the brook. The effluent from No. 51 is discharged into the woods, and is allowed to flow over the ground. The effluent is practically colorless and odorless and has caused no trouble in the brook. Overflows have been built so that the sewage cannot flow over the banks in any case. Very little trouble has been caused by the extreme cold weather, as the sewage finds its way under the snow and ice and is filtered through the gravel.

The areas of the several beds are as follows:

No. of bed.	Area, sq. ft.	No. of bed.	Area, sq. ft.
1	9,520	9	3,240
2	8,570	10	3,850
3	8,790	11	3,850
4	4,400	50	2,500
5	4,300	51	2,300
6	4,400	52	3,370
7	4,000	A	5,000
8	3,240	B	11,000

Total, 82,330 sq. ft., or nearly two acres.

The above area does not include the space occupied by the main banks, but does include the division banks, the bottoms of which are only 1 ft. below the surface of the beds.

Bed No. 51 was at first used as a sludge bed, but the odor arising from the sludge while drying, as well as from that which had previously been taken off and piled up near the bed, led to this bed being converted into a filter bed, and the construction of bed No. 52 for a sludge bed. Since this change no trouble has been caused by the odor, as this bed is farther away, and is over the brow of a hill and surrounded by woods. No trouble has been caused by the filter beds, as there is no odor arising from them that can be detected a few feet away.

Sludge beds should always be located as far as possible from the line of travel, and care should be taken to cover the sludge with earth or bury it after it is removed from beds. The sludge is allowed to remain on the sludge bed until it is dry, when it is removed and placed in piles and covered with dirt. The sludge is discharged from the tank, and the filter beds are cleaned every two to three weeks. The sewage is discharged onto the filter beds in the following order:

First day.

Bed No. 1, from	7 a. m. to 10 a. m.
" " 2, "	10 a. m. to 1 p. m.
" " 3, "	1 p. m. to 5 p. m.
" " 4, "	5 p. m. to 7 p. m.
" " "A" and 5, from	7 p. m. to 7 a. m.

Second day.

Bed No. 6, from	7 a. m. to 9 a. m.
" " 7, "	9 a. m. to 11 a. m.
" " 8, "	11 a. m. to 1 p. m.
" " 9, "	1 p. m. to 3 p. m.
" " 10, "	3 p. m. to 5 p. m.
" " 11, "	5 p. m. to 7 p. m.
" " 51 and "B," from	7 p. m. to 7 a. m.

This has been found to give satisfactory results.

In summing up their description of the filter beds, the engineers state that the results have been entirely satisfactory; that there is no trouble to be feared from bad odors arising from the filter beds if ordinary care is used in running them, and that the sludge must be taken care of properly, as it is the odor from this that will give trouble, if any.

The cost of the filter beds and accessories, not including engineering and superintendence, was as follows:

Labor		$8,766
Vitrified pipe	684	
Tile pipe	238	
Wooden troughs	305	
Total cost of carriers and drains		1,227
Carting		28
Freight		13
Wood dams at Beds A and B		13
Iron gates and gate and gate chamber		99
Tank		600
Tank house		344
Miscellaneous		105
Total		$11,193

The cost of preparing the beds, with piping, was $10,046, or 12 cts. per sq. ft., the area being 82,330 sq. ft. The total cost of the beds, tanks and all accessories, was 14 cts. per sq. ft. of filtering area.

The general pipe system in place cost $40,530, including $1,719 for the 1,050 ft. of iron pipe in the outlet sewer, making the total cost of the system $51,723, not including engineering and superintendence.

The foregoing description was sent us by Mr. J. Leslie Woodfall, of McClintock & Woodfall, Boston, Mass., who were engineers for the sewerage system, and who also furnished the material for the illustrations.

The writer visited the Gardner filter beds on a warm and muggy evening in June, 1892, and also near the close of a hot day in the same month and year. Everything was apparently in good working order and wholly inoffensive.

At this time bed No. 51 was being used as a sludge bed, and on one of the visits sludge was being put onto the bed. The effluent from the sludge bed at this time was quite cloudy. It appeared at the outlet of the underdrains in about three-quarters of an hour after it was admitted to the bed, but the tank full of sewage, as well as the sludge, had been drawn onto the bed, as was said to be the usual practice.

The effluent from the filter beds was found to be very clear, and the brook which receives it gave but little evidence of the fact.

The attendant stated that the sludge was piled up in a heap, without dirt, when removed from the sludge bed, but it appears, from a statement above, that later in the season dirt was put upon the sludge.

The sewerage system was built and still is under the direction of three sewer commissioners, Mr. Chas. W. Conant being chairman, and Messrs. R. L. Bent and Ezra Osgood the other two members. The beds are cared for by an attendant who lives in a house located on the disposal area, Mr. Jas. French having been the attendant in the summer of 1892.

Hastings, Neb.

The use of intermittent filtration and broad irrigation for the purification of sewage of Hastings, Neb., is worthy of consideration by all localities where sewage purification is needed, and especially by those cities of the West situated, as is Hastings, with no available outlet for crude sewage, either on account of the distance of streams or because of the diminished volume of the latter in dry weather. One feature of the design and management of the Hastings plant is worthy of special notice and commendation: Purification is recognized as the first object to be attained in disposing of the sewage, the raising of crops for revenue being made the second. Indeed, from the information at hand, it seems quite likely that the most profitable use of the sewage consistent with proper purification has not yet been practiced, but the sewerage system has been in use only two years, and to Jan. 1, 1893, only 119 sewer connections had been made, so that criticism on this point is hardly in order yet. If operated as designed, there seems to be no reason why an eminently successful sewage farm should not be the result.

The following description of the Hasting's plant was prepared for us by the engineer of the sewerage and sewage disposal systems, Mr. J. M. Wilson, of Omaha, Neb.:

Hastings, Neb., is a thriving young city of some 15,000 (13,584 in 1890) inhabitants, situated on the plateau between the Platte River and the Republican. The Platte, about 16 miles to the north, is a broad, shallow stream, carrying in the spring and early summer a large volume of water from the melting snows in the mountains of Colorado and Wyoming; but in the late summer and winter the stream is largely lost in the sands of its many broad channels.

The Blue, a tributary of the Kansas River, about ten miles to the south, is a much smaller stream, but, being confined to a narrower channel, is more permanent in its flow.

These were the nearest and the only streams that could possibly be used for the discharge of sewage. Higher lands to the north cut off the outlet to the Platte. To reach the Blue would require that the line should follow the windings of some of the draws or valleys leading from the vicinity of Hastings to that river. This would so lengthen the line and increase the cost that all thought of reaching a running stream with the sewage was abandoned.

The only available method of disposal was a sewage farm. Upon investigation, the conditions at Hastings were found to be very favorable for the success of such a plant. Below the surface no water is found until a depth of about 100 ft. is reached, at which depth permanent water is found in sand and gravel. The subsoil here is quite pervious to moisture; after the heaviest rains the water disappears quickly from the surface, being absorbed by the 100 ft. or more of porous subsoil, without producing that condition of complete saturation which is so often found where the underlying strata are impervious or the permanent water level is near the surface.

In many cases in the lands which must, of necessity, be selected for sewage farms, these favorable conditions do not exist, and only a few feet of the upper strata can be made available by artificial drainage. The amount of sewage that such lands will absorb without saturation is, of course, very limited, and the condition of permanent moisture so near the surface gives, by capillary attraction, all the moisture, in most cases, that crops grown on the land can appropriate. The additional moisture supplied by the sewage is just so much excess. The result is that on most sewage farms where crops are raised, very little of the sewage is applied to the crops, or only such crops are raised as will endure excessive moisture. The profitable crops that will endure such conditions are very few indeed. On the contrary, in this plains region, with its great depth of porous subsoil and its moderate rainfall, the conditions for disposing of sewage successfully, either by discharging it intermittently on limited areas or by applying it to crops, were peculiarly favorable.

The general surface of this part of Nebraska is a gently undulating plain, rising to the westward at the rate of say, 7 to 10 ft. per mile. In the vicinity of Hastings the rate is 9 ft. per mile. The plain is broken by draws or valleys, down which the water passes to the permanent streams when there is any surplus. After heavy rains the draws are, for a few hours, quite respectable creeks; but ordinarily they are dry, and the surface where it has not been disturbed by the plow, is covered with a thick, strong sod. Along the sides of these draws the land has been lowered by the action of the water considerably below the general level of the surrounding plain, and yet left high enough above the bottom of the draw to insure adequate drainage.

With a pumping plant that would raise the sewage 15 ft., any one of the many smooth farms lying to the east was available for a sewage farm, practically graded and ready for the reception of the sewage. The objections to this arrangement were:

(1) The cost of erecting and maintaining the pumping plant, and (2) the difficulty that might arise in draining such a tract in case, as was likely, it should need drainage after the sewage was applied.

If the sewage was to be disposed of by gravity the only available fields were the lands before mentioned, lying adjacent to the draws. These were somewhat irregular in outline and elevation, and would require considerable grading to put them in shape for the application of the sewage; but they were so situated that good surface drainage was insured, and if it should become necessary to tile the farm later, the draw would afford a ready outlet for such drainage.

A small draw heading in the northeast corner of the city leads off toward the northeast about 1½ miles, where it intersects with a much larger draw from the northwest. Along the borders of this larger draw there are considerable areas which, while elevated enough above the bottom of the draws for drainage, are low enough to make it possible by careful economy in grades to reach them by gravity from every part of the city. It was found that the storm water could be sent off through the natural waterways by using short runs of large pipe at moderate depths. and with better fall than it was possible to secure for the sewer line to the farm.

This, with the limited areas available for receiving the sewage, and the difficulty of taking care of the storm water on such a farm, settled the question in favor of the separate system of sewerage.

After a careful study of the established grades for the streets, with the necessary additional levels taken, main lines were laid out, centering toward and in the northeast corner of the city, where all were collected into one 18-in. main leading to the farm.

The nearest land available for a disposal area was a tract of 70 acres, somewhat broken. To find smoother land upon which the sewage could be deposited by gravity would have necessitated a lengthening of the main pipe from 3,000 to 5,000 ft., and the crossing of several small draws. The additional cost of this part of the line would have more than overbalanced the necessary expense of grading, not to mention the extra cost of caring for and maintaining the additional line.

The 70-acre tract selected for the sewer farm is shown by Fig. 72, on the inset.* The southwest part of the tract is too much elevated to receive sewage, but is valuable farming land, and will furnish a desirable building site for the residence of a superintendent.

The northwest portion of the area north of the draw is very rough and cannot be utilized for sewage, except at heavy expense for grading and piping. The central part of the western half of the area has been graded into areas, as shown on the map, Fig. 72, each having its own level and separated from the adjacent areas by a low ridge of earth. The cross section at the foot of Fig. 72 shows the arrangement of these ridges and slopes. The elevations selected and the forms of these areas were determined largely by the question of economy in moving the earth.

* Figs. 72 to 76, inclusive, are on the accompanying inset.

These areas were brought to a uniform grade, except at the points where the sewage is received from the distributing gutters. Here the surface was slightly elevated to secure a better distribution over the surface when the sewage is first discharged on an area. The sewage is discharged first into a settling tank, shown in plan and section by Fig. 73.

This tank is provided with cast iron gates for controlling the flow of the sewage. It was the intention to provide a screen, but it was found that it was not necessary, as the paper and the small amount of solids which would make trouble by clogging the drains were all deposited in the lower part of this tank, from which it could be drawn off on the lower area, No. 8, Fig. 72, where it could be readily collected and disposed of when the water was drained out of it.

From this settling tank the sewage is conducted to distributing or outlet gutters so situated as to distribute the sewage on two or more adjacent areas. These gutters are built of brick laid in cement mortar and plastered with Portland cement, as shown by Figs. 74 and 75. The gates which regulate the flow are of 3-16-in. plate iron, faced with sole leather and set at an angle from the vertical, so that their weight, which is increased by a heavy cast iron disk bolted to the back, acts with the sewage to shut the gate snugly against the seat. The seating face is 2 ins. wide and built up of cement. The gate is opened by revolving it upward and backward till it rests on the top of the gutter, as shown in Fig. 74.

Areas Nos. 1 and 8 receive sewage from short lines of pipe leading from the settling tank, as shown by Figs. 72 and 73. Areas Nos. 2, 3, 4 and 5 are supplied by an 18-in. pipe from the settling tank, the sewage being distributed to each of the four beds by the four-way gutters shown in Fig. 74. A 12-in. continuation of the 18-in. pipe from ofu

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the settling tank carries the sewage to areas Nos. 6 and 7, the two-way outlet gutter here being similar to that shown in Fig. 75. An ordinary wooden sluice gate is the only means provided for supplying sewage to area No. 9. This gate is shown in plan and section by Fig. 76. Area No. 10 is supplied by one of the branches of the two-way gutter shown in Fig. 75. The other branch of this two-way gutter is designed to discharge sewage onto a part of the irrigable land nearest to the distributing basin, the remaining part of this section being provided for by the 8 and 12-in. outlets on the south side of the basin, all as shown in the plan, Fig. 72. The 18-in. main outlet is extended across the draw to the most distant part of the disposal area, this section being suitable for irrigation.

The farm is under the care of a superintendent of sewers and water-works. He visits the farm once a day, or as often as may be necessary to change the flow from one area to another. The time of discharge on any given area is determined largely by the season and the amount of rainfall, and must be regulated by the experience and intelligence of the superintendent. Occasionally the areas are plowed to facilitate absorption and to cover up deposits, which, with the carting away at intervals of the sludge discharged from the settling tank, is all the attention the farm receives.

Of course, with further development of the system, more time must be given to it. The works have now been in operation about two years. The first year was an unusually wet season, and the capacity of the soil for receiving sewage was for this reason much reduced, but it was all discharged in rotation upon the areas that had been graded. No offensive odors were perceptible from the fields, as everything was distributed before decomposition set in, and the sewage was not allowed to discharge or remain on one area long enough to become putrid. The only time when any odor is perceived is when the settling tank is opened to discharge the collected solid matter. At such times for a short interval there is a little odor when the discharge is first made; but it is only perceived in its immediate proximity.

Up to Jan. 1, 1893, the number of sewer connections that had been made was 119, mostly from the business part of the city and the larger residences. Outside of the business portion no attempt has been made to compel the making of connections. Other areas will need to be added as the use of the sewers becomes more general.

The lands marked on Fig. 72 as suitable for irrigation cultivation are all available for absorption fields; and if a larger area is needed, the lands along the valley to the eastward will afford opportunity for increasing the areas to any extent desired. By means of shallow ditches and furrows along the slopes the sewage may be conducted over these lands and used for irrigating crops, as with the water from irrigating canals in the arid regions of the West. No attempt, as yet, has been made to use it in this way, but at intervals the sewage is allowed to flow over the meadow land of this portion as far as it can do so without special direction and yet not escape into the draw.

The drainage or absorption areas now in use are not underdrained, but depend entirely upon the capacity of their soil for absorption. Ultimately tiling will be necessary, and this will convert them into filtering beds discharging their effluent into the draw. When the farm was first put in use it had been freshly graded, and it was not thought best to put in tile until all settlement of the fills had ceased. We also wished to test the capacity of these areas without the tiling. With the amount of sewage now disposed of the results are satisfactory, but I have no doubt that in time they will all require drainage.

In arranging this farm, while keeping in view the desirability and the possibility of using the sewage in the cultivation of crops and arranging for its use when the quantity of sewage would make sucn use profitable, these two facts have been kept steadily in mind: (1) That with all crops of value the amount of sewage that can be used with profit has very definite limits; (2) that the time during which it can be applied to any crop is ordinarily confined to only a limited portion of the growing season. To apply in greater quantities and at other times is to ruin the crop.

Hastings is a typical town of the Western plains, and suggests a solution of the sanitary problem that confronts a great many of these towns, by reason of their level areas and remoteness from streams of such magnitude that sewage may be safely discharged into them.

In addition to the above information from Mr. Wilson, Mr. G. W. Woodward, City Engineer of Hastings, writes us that the disposal area is about 1½ miles from the city; that each of the filtration areas is about two acres in extent, and receives sewage for a day or two at a time, with a rest until the sewage has been applied in succession to the other areas; and that the application of sewage to the land creates no nuisance, and causes but very little odor. Mr. Woodward states that he was city engineer when the sewerage system was built, and ected as constructing engineer, with Mr. Wilson as chief engineer.

BROAD IRRIGATION.

Wayne, Pa.

Wayne is a suburban residence village about 15 miles from Philadelphia, on the Pennsylvania R. R. It has been built up by Messrs. A. J. Drexel and Geo. W. Childs, who bought the "Wayne estate" some years ago. In June, 1890, its population was 997. Two years later a population of 2,000 was claimed. There are no manufactories.

Water-works were built by Drexel & Childs in 1881. Very shortly after Col. Geo. E. Waring, M. Inst. C. E., was engaged to extend the sewerage system of the village which then conveyed the wastes and roof water of a few buildings into a brook flowing through the valley.

Col. Waring extended the system on the strictly separate plan, collecting the sewage in a large flush tank from which it was discharged into the brook through an 8-in. pipe 2,925 ft. long, having a fall of 1 ft. in 400. An additional area being secured later a 12-in. outlet was laid parallel to the lower part of the first outlet.

The brook which received the sewage had a copious flow and discharged into Darby Creek, a stream polluted by manufactories. The brook gradually became fouled, to prevent which the sewage was finally delivered into a settling basin before passing to the brook. The effluent not being sufficiently cleared by this settlement it was discharged into a second, and later into a third settling basin.

The farm land along the brook gradually being taken up for residences complaints regarding the fouling of the stream increased and finally an injunction to prevent the discharge of sewage into the brook was threatened. When the works described below were recommended by Col. Waring in the spring of 1891, the move for an injunction was stopped under verbal protest.

Surface irrigation on somewhat isolated land at the lower side of the estate was decided upon. The disposal area is thus described by Col. Waring in an article in the "American Architect" of July 2, 1892:

The tract to be used was of unfavorable character. but it was the only one available. It consisted mainly of an old pond surrounded by ancient pollard willows, a large area of swamp through which the brook

meandered, about four acres of slightly sloping cleared land, and a very steep, thickly wooded and rocky hillside, rising about 100 ft. from the level of the brook to one corner of the nearly square tract.

The pond was obliterated, the willows and much other vegetation were cleared away, the brook was confined within stone walls and all except the steep hillside was thoroughly underdrained.

The disposal area includes eleven acres divided by the creek as shown in Fig. 37. Along the lower course of the brook much of the land was a nearly level tussock swamp. All growth less than 8 ins. in diameter was removed from the tract. The creek was straightened and deepened and the banks sloped back from the walls of the creek and sodded. But little grading was necessary on the left or south side of the creek, but the whole area on the other side was graded. The header drain of 6-in. pipe on the left side of the creek was laid to cut off the effluent from some slightly wet land. The stone drain is for the protection of the pumping station.

The land on the south side of the creek was divided into three nearly equal tracts by embankments about 1 ft. high, which converge at the distributing well. A road to the pumping station divides the land on the north side of the creek into two sections.

The outlet sewers already described were intercepted just above the old settling basins, from which point a 12-in. vitrified pipe with a fall of 1 in 125 extends to the edge of the disposal field. About 400 ft. above the edge of the field an 8-in. branch with a fall of 1 in 250 extends to a screening chamber. From this chamber the sewage is delivered at will onto tract D, or E, first passing over a bed of broken stone. The cinder banks on both sides of the creek are described further on.

The main outlet sewer is of vitrified pipe where in earth and of iron and cement where on piers. It ends in a brick screening chamber with a concrete bottom near the pumping station, shown in plan and section by Fig. 38. After passing through the screens the sewage flows into the receiving reservoir shown in plan and longitudinal section by Fig. 39. This reservoir has a capacity of 90,-000 gallons to the mouth of the inlet pipe. Its bottom is of concrete and slopes toward the sump into which the suction pipes extend. Six 6-in. pipes at the top of the tank lead to the creek as an overflow.

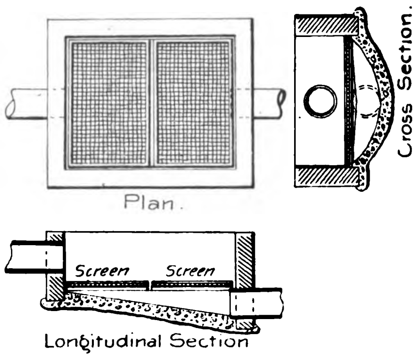


Fig. 38. Screening Chamber.

Two Barr duplex pumps with a capacity of about 22,000 gallons each per hour, or 525,000 gallons per day, force the sewage up the hill on the left of the creek to the distributing well. This 12-in. force main is of spiral welded steel pipe, 480 ft. long and has a rise of about 100 ft. The lower end of the force main was placed above ground to obtain a grade that would allow it to drain dry through the aerating pipe, mentioned below.

Both pumps are started when the receiving reservoir is nearly full, and the sewage is first delivered back into the receiving tank through a 4-in. aerating pipe, the object being to deodorize

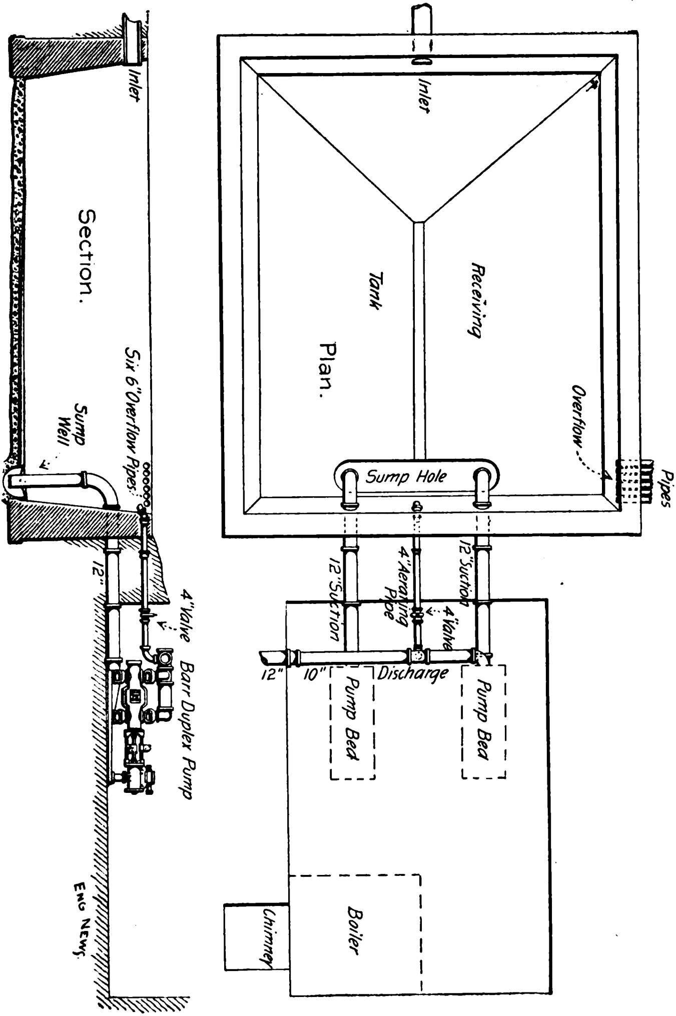


FIG. 39. RECEIVING TANK AND PUMP HOUSE.

the sewage and increase its oxygen. Aeration is maintained for from 60 to 90 minutes, after which the valve in the aerating pipe is closed and the sewage is delivered into the well.

The distributing well is shown in plan and section by Fig. 40. It is of brick, with a concrete bottom, and is covered by a small building shown

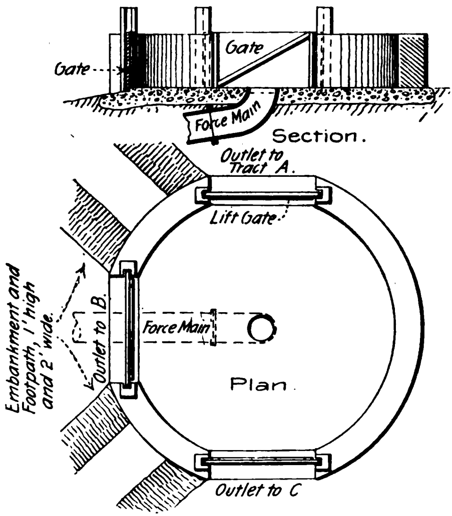


FIG. 40. DISTRIBUTING WELL.

in the distance in the view, Fig. 42. Lift gates, working in the masonry of the well, are provided to regulate the discharge of the sewage upon the tracts.

A bed of broken stone about 8 ins. deep and 50 ft. wide extends across the tract below the distributing well. Sewage is discharged into a depression along the upper edge of the stone bed. When this depression is filled the sewage flows down the bed, which has a fall of about 1 to 4, to a catch wall of broken stone designed to check the somewhat rapid flow of the sewage and to distribute it evenly over the land below.

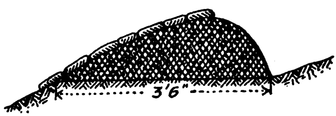


FIG. 41. CROSS SECTION THROUGH CINDER BANK.

The cinder banks shown in Fig. 41, are laid on graded strips following contours. The cinders, mostly from locomotives, are backed, to prevent washing, as shown by Fig. 41. These banks are designed to catch the sewage in its irregular flow down the steep hillside and start it again uniformly. Some of the sewage filters through the banks during the application of sewage to the fields, and all of it passes through when sewage is diverted to another tract.

Small and shallow carriers are cut with spades through all the disposal area to help equalize the flow of the sewage, in addition to the cinder banks.

The receiving reservoir fills in from 6 to 12 hours and is emptied in about five hours. The sewage disappears from the surface of the land in about a half hour after the pumps are stopped.

The field on the left side of the creek was put in operation in September, 1891.

The field at the right of the creek was put in use later, before well covered with vegetation. Col. Waring states that if the aeration of the sewage, as described above, proves sufficiently beneficial, a force main will be constructed to the field at the right and sewage delivered to it by pumping, instead of by gravity, as now.

Col. Waring makes the following statement regarding a visit to the disposal area in the summer of 1892.

July 1, I went to Wayne with the Sewerage Commissioner of a New England town, who desired to inspect the work. It was found that in June the broken stone tracts at the top of the hill had been forked over, and about six yards of fibrous matter removed. This was thrown in a heap, and had at no time been offensive. There remained among the stones a certain amount of half decomposed material, mainly paper fiber.

As the sewage was discharged at the upper edge of the stone tract, it was milky-looking water, such as flows in the gutters in the better parts of Baltimore. As it escaped from the stone tract, it was considerably blackened with carbonaceous refuse. It had no increased odor. This blackened appearance was entirely lost before the first barrier (x) was reached. As the water gathered behind the lowest barrier it was perfectly clear. A little below this, where a rill had gathered, the Commissioner filled a glass with it. Holding it to the light, he saw that it was absolutely clear; smelling it, he found it without odor; and tasting it, he found it without taste. The condition of the field had, at no time, been more satisfactory than on that occasion, and the man in charge said that it was getting better and better every day.

Most of the above information is abstracted from an article by Col. Waring which appeared in the "American Architect" of July 2, 1892. The illustrations, Figs. 37 to 41, with some changes, are from the same source. The views, Figs. 42 and 43, were reproduced from photographs kindly sent by Col. Waring, who added some information to that given in the above named article.

Oct. 27, 1892, the writer visited the Wayne purification works, and through the courtesy of Mr. Frank Smith, Manager of the Wayne estate, and Mr. C. D. Slaw, Superintendent of the sewer-

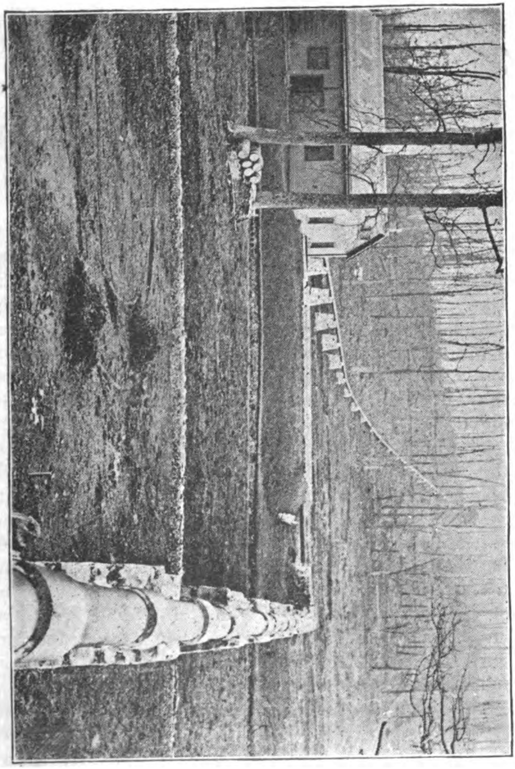


FIG. 42. GENERAL VIEW OF WORKS FROM NORTH SIDE OF CREEK.

age system, obtained the additional information which follows.

There are now about 600 acres in the estate. All buildings on the property are connected with the sewerage system, there being about 275 connections at present. No charge is made for connections with the sewers and no yearly rentals are charged except in the case of a few connections from buildings outside the estate. The average daily consumption of water in Wayne is stated to be about 200,000 gallons. The average pumpage was given as about the same, but from all the data at hand it would seem to be higher. Two days out of five, according to the information given, the sewage flows by gravity onto the north part of the area.

The first screens used at the screening chamber at the receiving reservoir had a 2-in. mesh. This mesh proved to be too coarse, and screens with 1-in. mesh are now used. The rakings from the screens average about two barrels a day, there being more on Saturday, Sunday and Monday than any other day. Lime is put upon the rakings as they accumulate beside the chamber before removal.

The pumping station is kept open throughout the 24 hours and the pumps are run from 16 to 18 hours a day, requiring about 110 lbs. of buckwheat coal per hour. Two engineers are employed at the station and Superintendent Slaw divides his time between it and the part of the sewerage system within the village. In addition laborers are employed when necessary, which, it would seem, is not often. Sewage is turned upon each tract for only one day at a time so that each tract has a rest of five days.

The material in the barriers has never been changed and the broken stone at the top of the hill on the south side of the creek, Mr. Slaw stated, has never been cleaned except that one section has had one cleaning. The broken stone at the head of the areas on both sides of the creek showed only a small amount of rags and paper which had been caught. At the dam of broken stone at the top of the steep hillside and at the first barrier below sludge accumulates and has to be shoveled out. Except at the first, or

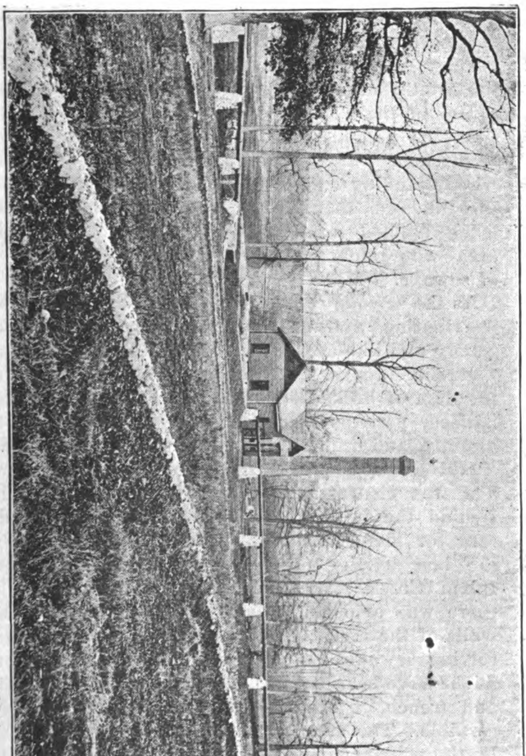


FIG. 43. GENERA- VIEW OF WORKS FROM SOUTH SIDE OF CREEK.

stone, barrier the sewage rarely runs over the top of the banks, unless they are stopped by leaves, as is likely to be the case just at this time of the year. The sewage has a tendency in the first part of its course to run down the steep hillside in channels and to some extent this has been encouraged, or rather several small channels have been formed in order to keep the sewage from flowing down in one large one.

There was scarcely any trouble from frost in the winter of 1891-2, the little occurring at one corner of the field.

At the pumping station and tanks only a very slight odor was noticed, and the same was true when standing on the broken stone at the top of the hill. On the hillside where the sewage was being applied no odor was noticed. The whole area was remarkably free from any suggestion of sewage.

As the sewage came from the middle gate of the distributing well at the top of the hill it was cloudy and like any sewage not affected by manufacturing wastes. At the second barrier, counting the dam of broken stone as one, little change was noticed, perhaps because the sewage came quite directly and rapidly from the first through two or three channels. At the third barrier the sewage was clearer and a dog drank freely of it. Behind the fourth barrier a clear looking liquid four or five inches deep was found. Below the last barrier no sewage could be seen. At Iphan Creek, which flows through the grounds, there was evidence of some seepage through the walls of the creek below the section which was receiving sewage, but the seepage was slight and might have been natural. At the ends of the drain and trench of broken stone no effluent was discernible. The creek showed no signs of pollution by the effluent, and small fish were observed in it.

In the pumping station there was a corked bottle of sewage taken in August, 1891, after having passed through three barriers. It was slightly flocculent at the bottom and on being uncorked gave off a faint odor. In Mr. Smith's office was another corked bottle of the effluent, said to have been taken Aug. 31, 1891, which appeared to be clear and colorless and was without odor.

At least five crops of grass were raised on each side of the creek in 1892, and a man was engaged in raking up a fair crop of grass from the field north of the creek on the day of the writer's visit, Oct. 27.

Pullman, Ill.

The sewage farm at Pullman, like Pullman itself, has attracted much attention from engineers and others. A detailed description of the farm and the sewerage system was given over ten years ago in Engineering News,* less than a year after it was put in operation. Information regarding the present apparatus of the sewerage system and sewage farm and other facts of interest have just been furnished us by Mr. Duane Doty, C. E., engineer for the Pullman company. This information has been combined with such of the matter previously published as is necessary to make the present article complete and intelligible in itself. Mr. Benezette Williams, C. E., was engineer for the whole system, and Mr. E. S. Chesbrough, M. Am. Soc. C. E., was consulting engineer.

Pullman is situated upon the west shore of Lake Calumet, 14 miles south of the Chicago Court House, where the Pullman interests have about 4,000 acres of land. It is reached by the Illinois Central Ry., and by recent annexation now forms a part of the city of Chicago. Lake Calumet is 3½ miles long by 1½ miles in width, and connects with Lake Michigan by the Calumet River. According to Mr. Williams' description in 1882, Lake Calumet is from 1 to 8 ft. deep, and connects with the Calumet River by a small channel. With varying stages of water the lake discharges into the river or water from the river into the lake.

* Engineering News, June 17, 1882. The description was slightly condensed from a paper on "The Pullman Sewerage," by Benezette Williams, C. E., engineer for the system, read before the Western Society of Engineers, June 5, 1882, and published in the "Journal of the Association of Engineering Societies," vol. I., pp. 311-319.

The land upon which the city stands is blue clay, 90 ft. in depth, resting upon lime rock, and its surface is from 9 to 20 ft. above the lake level.

Work was begun upon the town by the Pullman Palace Car Co. in May, 1880; the first family went there Jan. 1, 1881, and it now has a population estimated at 12,000. The present industries there are the Pullman Car Works, employing over 4,000 operatives, the Allen Paper Car Wheel Works, the Union Foundry, the Pullman Iron & Steel Works, the Standard Knitting Mills, the Paint Works, the Terra Cotta Works, the Screw Factory, and the Drop Forge & Foundry Co.'s Works. These various industries, with the car works, employ a total of about 5,500 operatives.

Oct. 18, 1881, the sewerage system was put in operation by starting the sewage pumps. Lake Calumet not being a suitable body of water to receive the sewage of Pullman, and an outlet to Lake Michigan requiring pumping through 6½ miles of pipe, it was decided to purify the sewage by broad irrigation, supplemented by intermittent filtration.

The separate system of sewerage was adopted to save expense and insure better results at the disposal works. The latter part of October, 1892, there had been laid 16,230 ft. of brick and 140,236 ft. of vitrified pipe storm sewers, the latter including drains for storm water from over 1,800 tenements. The brick storm sewers are laid in the middle of east and west alternate streets and discharge into Lake Calumet. The pipe storm sewers are of the following sizes and lengths:

Size.	Ft.	Size.	Ft.
18-in.	1,826	9-in.	14,537
15-in.	16,223	6-in.	73,072
12-in.	13,458	4-in.	21,120
Total.			140,236

To Oct. 22, 1892, the extent of the vitrified pipe sanitary sewers, by sizes, was as follows:

Size.	Ft.	Size.	Ft.
18-in.	4,340	9-in.	7,210
15-in.	3,170	6-in.	32,250
12-in.	1,220	4-in.	31,350
Total.			79,540

Manholes are placed from 140 to 165 ft. apart, and on the sanitary sewers have perforated covers, provision being made for the catching of the dirt which passes through the perforations.

The 9, 12, 15 and 18-in. sanitary sewers are flushed directly from the water mains. Additional flushing is secured, or was in 1882, from automatic flushing basins which receive all but the water closet wastes of several houses and discharge it by means of siphons. The basins also act as grease traps, the siphons being especially designed to remove grease and scum from the basins.

Sewage is received in a 300,000-gallon reservoir, 60 ft. in diameter and 15 ft. deep, located beneath the water-works tower. The outlet sewers at the reservoir are about 16 ft. below the general grade of Pullman.

The reservoir is ventilated by means of eight flues, each 165 ft. high, lined with 12-in. sewer pipe, built into the buttresses of the water tower, and also by a 20-in. pipe leading to the chimney of the car shops.

Both the sewage and water-works pumps are placed about 10 ft. below the ground surface on a masonry floor, supported by piers, covering the sewage reservoir. There are two 2,500,000-gallon pumping engines, built by the Cope & Maxwell Manufacturing Co., of Hamilton, O. The pumps have special valves, described in Engineering News of June 17, 1882. Connected with the force main at the pumps is a stand-pipe with an overflow 54 ft., and a second, 90 ft. above datum (not defined). These overflows connect with the reservoir, so if all the outlets at the farm were by accident closed without the pump being stopped no accident could occur. A 20-in. force main about three miles long leads to the sewage farm.

The amount of sewage pumped yearly from the reservoir to the sewage farm has been as follows:

Year.	Gallons.
1882	211,620,160
1883	358,354,420
1884	443,815,480
1885	468,302,120
1886	472,748,080
1887	573,700,640
1888	588,607,760
1889	602,250,000
1890	657,001,360
1891	617,664,000
1892 (9 months)	513,996,060

The amount given for the nine months of 1892 is at the annual rate of 685,328,090 gallons.

The cost of operating one pump for 20 hours and pumping 1,800,000 gallons of sewage is given by Mr. Doty, as follows:

Cost of coal used	$1.73
Cost of oil and waste	.57
Engineer's wages	3.75
Total	$6.05

This is at the rate of $3.36 per million gallons.

Fig. 56 is a photographic view of the tower and Fig. 57 a vertical section through half of it. This unique structure, with its many uses, is 68 ft. square at the base, changes to octagonal form, as shown by the view Fig. 56, and is 195 ft. high to the base and 210 ft. to the top of the flagstaff. The foundation extends nearly 40 ft. below the ground surface, where it rests on a very hard blue clay.

The tower was built to afford elevation for the water tank at its top, which is of boiler iron, 55 ft. 10 ins. in diameter, 30 ft. 1 in. deep, and has a capacity of about 550,000 gallons. The tank is supported by iron trusses, resting on four wrought-iron columns, which extend to the foundations.

In December, 1890, the second floor of the tower was occupied by the electrical department of the

Pullman car shop; the third and fourth floors were used for making mirrors and other glass work; the fifth floor was occupied by a branch of the paint department, and the floors above were used for light storage, elevators being provided to reach the different stories.

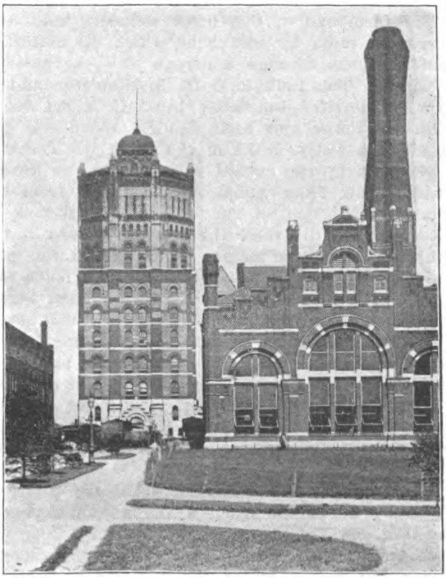


Fig. 56. Sewage and Water Pumping Station and Water Tower; Pullman, Ill.

The building at the right of the tower contains the Corliss engine which furnished power for Machinery Hall at the Centennial Exposition at Philadelphia in 1876. This engine has been in operation at the Pullman Car Works since April 5, 1881.

The accompanying illustration, Fig. 58, shows the screening tank and automatic regulating valve at the farm end of the force main. The following description of these devices is from Mr. Williams' paper, mentioned above:

The farm end of this main connects with a closed screening tank, by means of which all material that will not pass through a screen of ½-in. mesh is intercepted. The tank is 6 ft. in diameter and 24 ft. long, made of ¼-in. boiler iron. It is set vertically. with its lower end high enough above the floor to admit of a wagon being driven under it. The material intercepted by the screen is lodged in the lower part of the tank, from which it is removed from time to time.

On leaving the tank the sewage passes through a pressure regulating valve, which limits the pressure that comes upon the pipes leading to the fields to about 10 lbs. As an additional precaution against high pressure, an overflow pipe is provided, which will absolutely, under all conditions, prevent the pressure from rising above the limit. This pipe comes into play occasionally when the pumps are started suddenly, without giving the valve time to act. The valve is purposely made to act slowly, in order to avoid the influence of pulsations in the engines, and irregularities from other causes.

The action of the tank and valve are better understood by an examination of the accompanying drawing (Fig. 58).

A pressure on the interior of the thin steel discs above the valve, raises the plunger and closes the port through which the sewage passes. If the pressure falls, the ports open gently. Vibrations of the valve from sudden changes of pressure are prevented by a plate between the valve and the steel disks, through small holes in which the sewage has to pass in order to increase or diminish the pressure on the discs.

The upper part of the tank above the screen is an air chamber, and answers the usual purpose of such an adjunct in preventing shocks from irregularities in

the pumps, or by the sudden stopping of the flow of sewage. The tank and valves are housed in, and can be kept warm to prevent freezing in cold weather.

The reason for introducing the pressure regulating valve between the screening tank and the field, is to make it possible to distribute sewage safely through clay sewage pipes under pressure.

The sewage farm embraces 140 acres piped and underdrained for the reception and purification of sewage. All this land can be irrigated, and it is all underdrained. Vitrified pipe, from 6 ins. to 1 ft. in diameter, conducts the sewage through the fields. This piping, laid from 5 to 6 ft. deep, and hydrants at convenient intervals of 300 or 400 ft., distributes the sewage over the surface.

The underdrains in the farm are of 3 and 4-in. farm tile, laid in rows 50 ft. apart.

There are also 15 filter beds, about an acre each, formed by earth embankments, and underdrained with lines of farm tile said to be 2 ft. apart.

Mr. Doty states that the only analysis of Pullman sewage and effluent in his possession was made in the office of the Massachusetts State Board of Health, Nov. 30, 1887, with results as follows, analysis of water from the farm well being also given for comparison:

	Ammonia, Free.	Ammonia, Albuminoid.	Chlorine.	Nitrogen.
Pure sewage....	2.3000	.3200	1.98	None
Filtered sewage from manhole on filter bed....	.8500	.0480	2.31	1.560
Filtered sewage from mouth of main underdrain..........	.0026	.0108	3.78	.650
Water from farm well....	.0900	.0166	.1.78	.033

Mr. Doty states that the use of sewage for growing crops depends upon the season. In dry seasons it is freely used with the vegetation needing it most. Irrigation is practiced at all seasons, and the water filters through the soil as well in the winter as during the summer. The crops which have so far proved most successful are onions, potatoes, cabbages, celery, beets, parsnips, carrots, sweet corn, and squashes. Potatoes are the least successful crop, celery, asparagus, and cauliflower coming next in order as not growing so well on this farm. Properly cultivated, twice as much can be raised on land irrigated with sewage as upon adjacent land unirrigated; and with onions the results are still better. It is stated that there never has been trouble with deposits of sludge upon the surface of the farm.

The effluent from the farm passes through the underdrains into Lake Calumet.

Regarding what proportion of the sewage is used for broad irrigation and what proportion is passed through the filter beds, and as to whether the sewage is always purified before passing into Lake Calumet, Mr. Doty sends the following, under date of Nov. 28, 1892, which he gives as "the language of the superintendent of the farm:"

The sewage when not needed upon the fields of the farm is run onto the filter beds, and these filter beds are plowed up four or five times a year so as to loosen the soil and expose as much of it as possible to the air. At times, all the sewage is used upon the farm, and in wet weather not more than half of it. Some seasons have taken all the sewage upon the fields. At rare intervals only, when it has been necessary to clean the receiving tank at the farm end of the iron main, is raw sewage run into Calumet Lake, and then for very brief periods, and not enough of it to do any harm.

That this statement from the superintendent of the sewage farm is not in accord with observations made at Pullman by five different persons is shown by the statements given below. The remarks of Mr. Allen in the report mentioned and a conversation with Mr. Hazen, together with the fact that the Pullman plant has for many years been widely known and cited as a successful example of American sewage farming, led to a somewhat thorough investigation of the subject, the results of which are herewith presented and need no comment further than the remark that because profit is put before purification at Pullman, it does not follow that sewage purification by means of broad irrigation is in any degree a failure.

Mr. Geo. H. Benzenberg, M. Am. Soc. C. E., City Engineer of Milwaukee, Wis., wrote as folows on Nov. 21, 1892:

I have not been at Pullman for a number of years, and hence cannot give you any information whatever as to what they are doing there now, but I know that as early as previous to 1887, a large amount of crude sewage was run into Lake Calumet. This I found to be the fact upon a visit to the farm, and which finally the superintendent admitted and excused by saying that it was necessary in order to save the crops. The sewage was being run in a large open ditch, covered by bushes growing on each side, from near the farm to the lake. As to their success in disposing of sewage by intermittent filtration, I am not at all acquainted.

About a month after the date of Mr. Benzenberg's letter, Mr. Rudolph Hering, M. Am. Soc. C. E., of New York, corroborated the above by stating that he visited the farm in 1886 and also in 1887. He found that a large amount of crude sewage had been run into Lake Calumet just prior to his visit, as the large open ditch leading from the farm to the lake was still partially filled with crude sewage. The superintendent likewise admitted to him that it was necessary to do this occasionally to save the crops.

In his report on the "Sewage Disposal of Worcester" Mr. C. A. Allen, M. Am. Soc. C. E., City Engineer of Worcester, Mass., describes a visit to the Pullman sewage farm, made January, 1887, as follows:

The farm has an area of about 140 acres, nearly all of which is devoted to irrigation; there are 10 acres, however, set apart for a filtration area, this being thoroughly underdrained, the drains being about 2 ft. apart.

Upon the day of our visit it was quite warm, the thermometer registering 40° F. We found that the sewage was being discharged upon the filtration area, the first section of which was covered with sludge to a depth of about a foot. The sewage was running over this, to the second section, which was partially covered with ice, and then over the remaining area, which was entirely covered with ice, and was finally discharged into the effluent trench without having been filtered in the least.

The entire area was completely covered with sewage, and there was evidently no filtration taking place. as about the same quantity passed off at the lower end of the beds as was discharged upon the upper end.

The manager of the farm was away, but we were given the following facts by his assistant, which we subsequently verified:

The farm is run for the purpose of making money, the purification of the sewage being a secondary consideration.

During the summer months when vegetation has received all the sewage it will bear, it is simply turned into Lake Calumet in its crude state.

We were told that not a particle of sewage has been applied to the farm proper this winter, it all having been simply passed over the area as already described.

What Mr. Benzenberg, Mr. Hering and Mr. Allen saw and learned in 1886 and 1887, and more, was still to be seen and learned in 1891, according to a letter recently received from Mr. Allen Hazen, Chemist in Charge of the Lawrence Experiment Station of the Massachusetts State Board of Health. Mr. Hazen states the condition of the filter beds, and gives a mechanical analysis of the surface soil of the filter beds. His letter is as follows:

I visited the Pullman sewage farm in October, 1891. The superintendent was absent, and I was shown about by a man who had worked on the farm for some years. He told me that with the application of sewage, worms developed in the soil and destroyed the crops, and for this reason no sewage had been applied for two or three years. Large quantities of horse manure from Chicago stables are applied to the land, but no sewage whatever. After broad irrigation was abandoned, so-called intermittent filtration was tried on ten acres of soil on which no crops were grown.

The filter was not in use at the time of my visit, nor did it have the appearance of having been used. My guide thought that it was at least a month since any sewage had been applied, and a much longer time since any considerable quantity had been treated. The sewage of the entire town was being turned directly into Lake Calumet, from which quantities of ice for Chicago are cut.

A sample of the surface soil of the filter had the following mechanical analysis:

Finer than .24 mm.	87%
" " .12 "	42 "
" " .06 "	28 "
" " .03 "	16 "
" " .01 " organic	8 "

Albuminoid ammonia, 225 parts in 100,000.

The analysis shows the material to be very much finer than the sands successfully used in Massachusetts, and it would hardly be possible to put upon it, with good results, any large volume of sewage.

On Nov. 21, 1892, a representative of this paper visited Pullman. Neither the superintendent or foreman of the farm were to be found. The building which covers the screening tank at the end of the iron force main is represented as having "a decidedly shiftless and unused appearance," the interior being used as a storage room for plows, cultivators, harrows, including the part originally designed for loading wagons when cleaning out the screening tank. Sewage was found to be flowing through the ditch leading to Lake Calumet. This ditch is about 4 ft. wide, 2½ ft. deep, and ¾ miles long. Located on Lake Calumet are two large ice houses belonging to Swift & Co.

The only person about, who said that he was a time-keeper, stated that the matter flowing in the ditch was the sewage as it came from Pullman and was all the sewage from the city.

Berlin, Ont.

So far as can be learned, the only sewage purification plant yet built in Canada, aside from a few for public institutions, is located at Berlin, Ont. This plant consists of a sewage farm which will first be systematically operated in 1893. Mr. Willis Chipman, M. Am. Soc. C. E., of Toronto, Ont., designed the sewage farm, and Mr. H. J. Bowman, Town Engineer, was in charge of construction. We are indebted to Mr. Chipman for the material from which this article has been prepared, and also to Mr. Bowman for the information mentioned below.

Berlin is the county town of Waterloo County, and is located two miles north of the town of Waterloo, with which it is connected by a street railway. The population of Berlin, by the Canadian census of 1891, was 7,425 and of Waterloo, 2,941. There are a number of manufactories in Berlin, including a large tannery and a glue factory.

Water-works were built by a company in 1888. The construction of sewers was begun in 1892, and is still in progress. To March 1, 1893, about 6,000 ft. of 12 and 9-in. sewers had been built, as also the outfall sewer, which is about 10,000 ft. long and 18 and 15 ins. in diameter. In March the quantity of sewage was about 50,000 gallons per day, diluted by some 75,000 gallons of subsoil water. In January, 1893, the temperature of the sewage at the farm was about 48° F.

The grading of the farm was completed late in 1892. During the winter, sewage has been applied to the farm, but not systematically. The sewage has a very dark color, and when stagnant for a short time gives off a highly offensive odor.

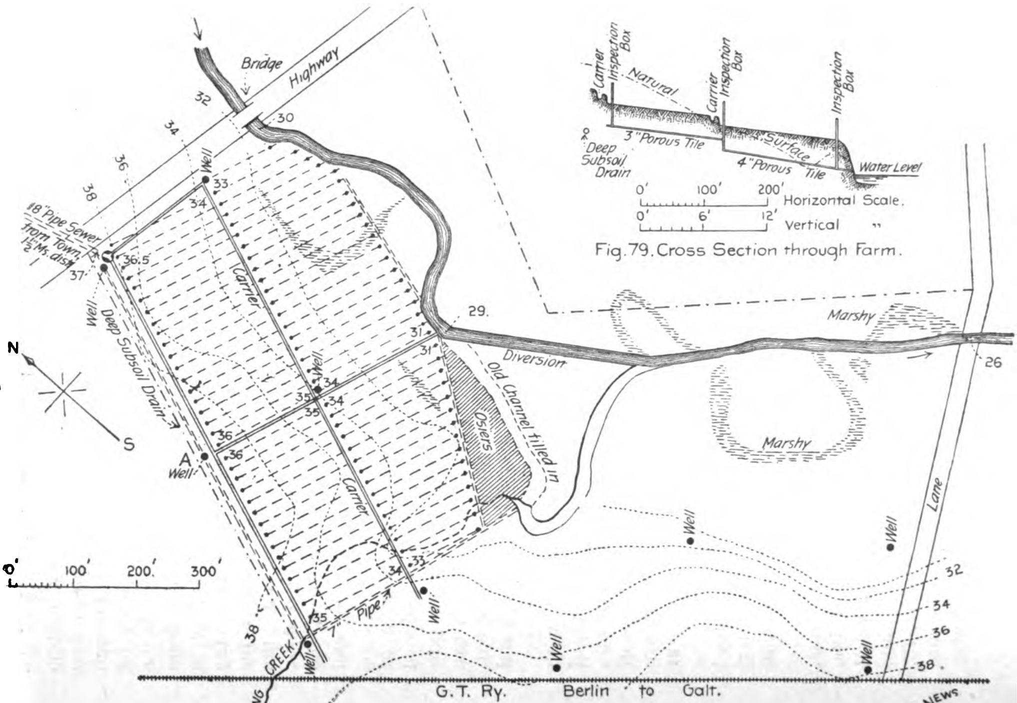


Fig. 79. Cross Section through Farm.

Fig. 78. Plan of Farm.

PLAN AND SECTION OF SEWAGE FARM AT BERLIN, ONT.

The farm is located about 1½ miles south of the town hall and a mile south of the closely built-up section of the town. A stream with a summer flow estimated at 200 cu. ft. per minute passes through the farm and receives the effluent, as shown by the plan, Fig. 78. One branch of this stream is the natural drainage channel of the town, and from the other a part of the public water supply is pumped. About two miles below the farm the main stream is ponded so as to back water for about a half-mile. Between the pond and the farm the stream has a rapid, unobstructed flow. There are farmhouses near the sewer farm, the nearest one being about 100 yds. from the end of the outfall sewer.

The farm bought by the town has an area of about 20 acres, nearly an acre of which is included in the bed of the stream. The total area purchased, aside from that occupied by the brook, can be used for sewer farming by grading, as the greatest elevation of the tract is only 3 ft. above the end of the outfall sewer.

Most of the surface soil is loamy or sandy, with a subsoil of gravelly clay. In places pockets of sand and gravel were found in a tough clay soil, and in other places there were shallow deposits of vegetable mold. The treatment of these irregularities in the soil is not stated in the information at hand.

About eight acres of the farm have been graded and underdrained, as shown in Fig. 78. The underdrains are of 3 and 4-in. tiles, with open joints, in lines 16⅔ ft. apart.

A section across the farm, parallel to the drains, is shown by Fig. 79. Inspection boxes, 6 ins. square, made of plank and covered, are provided at each end and the middle of the underdrains. Wells have been dug, as shown in plan, by Fig. 78, to facilitate observations of the height of the subsoil water. The trenches in which the underdrains are laid were backfilled for about a half of their lower portion with gravel from a pit about a half-mile distant.

It will be seen by referring to Fig. 78, that a stream which formerly entered the west corner of the farm has been diverted to a 7-in. pipe, and that the brook below the point where the effluent is discharged has been straightened. The plan and the section, Fig. 79, also show that a deep subsoil drain, ending in the 7-in. pipe just described, has been built along the west border of the farm. This was laid to divert as much subsoil water from the farm as possible.

The location of the two main sewage carriers is shown by the plan, Fig. 78. The upper carrier from the sewer outlet to the point A is made of an 18-in. split pipe, bedded in sand and gravel. The other carriers are simply ditches. A channel has been built across the farm to the brook to permit the discharge of sewage directly into the brook, if desired.

Mr. Chipman has recommended that Italian rye grass be raised on the two north divisions of the farm, and on the remainder mangolds and the other root crops, onions, oats and clover. On the low land bordering the stream osiers are proposed, they being raised for profit in Brantford, Ont., where dependence is had upon the freshets of the Grand River for irrigation.

Mr. Chipman states that the farm is suitably arranged for every known system of irrigation and every variety of crops, and that if properly operated he believes it could be made to pay running expenses, not including interest on its cost. He also states that it is quite probable that two of the four divisions of the farm will be converted into level areas this season.

No settling tank has been provided at the farm, preference being given to the application of solid matter directly to the land, where it can be dug in, or from which it may be raked off, as is found most desirable.

When the amount of sewage exceeds the capacity of the farm filter beds can be constructed at its south end with gravel from the pit already mentioned as being located a half mile from the farm.

Mr. H. J. Bowman, Town Engineer, informs us that $2,000 was paid by the town for the sewage farm of 20 acres, and that the cost of grading and underdraining the portion now ready for use was about $3,000. These items of cost are paid from an issue of sewer bonds bearing 5% interest, but the bonds sold at such a premium as practically to make the rate of interest 4½%.

Greenfield, Mass.

A few words may be said regarding the sewage disposal of this town. It appears that the method adopted was designed to utilize the sewage and with no idea of purifying it, but as the same plan with slight elaboration might often be employed, and in fact is so employed, both for utilization and purification, a brief description of it will not be out of place.

The population of Greenfield in 1890 was 5,252. Water-works were built by the fire district in 1870. A main sewer was built about ten years ago. It seems that when this sewer was built the owner of some meadow land arranged to have the sewage brought to the land, which was near a stream of considerable size. The outfall sewer, a circular brick sewer about 2 ft. in diameter, was therefore abruptly terminated at the edge of a road embankment a few feet above the meadow, and beside a small stream. The mouth of the sewer was rudely closed with plank and the sewage diverted to a wooden flume and thence to a sewer pipe extending down the embankment, and, apparently, out on the meadow to a hole in the ground. Ditches extended over the meadow for the distribution of the sewage.

In June, 1892, when the writer visited Greenfield, no efforts were being made to control the flow of the sewage, the owner of the land having recently died. Some of the sewage was leaking from the flume and sewer pipe, flowing directly into the brook, and some was going down onto the meadow. Parts of the meadow had apparently been flooded with sewage during the spring. In places the grass was growing luxuriantly.

So far as could be learned, the owner of the land gained an advantage from putting the sewage upon it while he lived, and since his death the matter has been neglected. The town clerk of Greenfield, Mr. F. L. Greene, thinks that the sewage of the town has increased beyond the capacity of the land.

Through neglect the outfall end of the sewer, in June, was in a very objectionable condition. It is close by two or three houses, and deposits of solid matter were putrefying and giving rise to very offensive odors. But this, it must be remembered, is all owing to improper construction and neglect.

In the West the sewage of several cities is used during the summer months for irrigation, more to eke out scanty water supplies than to fertilize the crops by applying sewage. Why cannot the same thing often be done in the East, where a gravity outfall sewer and tillable land can be brought together? This might not often be practicable except in connection with small towns, but growing demands for sewage purification will make the idea worthy of consideration in at least a few communities. It often happens that crops are light in the East through lack of rain, when there is sewage which might at a nominal expense be diverted to some of the parched fields, giving moisture and fertilization at the same time. Of course the best plan in many instances would be to establish a sewage farm. When purification is desired filter beds could be combined with the farm to care for the sewage when irrigation is not needed, or, if only the removal of the grosser organic matter from the sewage was desired settling tanks could be used, and the sediment, or sludge, be made into a compost for a fertilizer. With the latter plan sewage could be partially purified at a very small expense the year around, and, if tillable land were near, the terrors of a drouth could always be averted over a greater or less area, depending both upon the amount of sewage and land in proximity to each other.

In connection with the above it must be said that eastern farmers, at least, are very conservative, and through conservatism or neglect might not utilize sewage in the ways mentioned. In fact, at South Framingham and Amherst the farmers have not availed themselves of the opportunity afforded to utilize sewage on their land. Eastern farmers, however, know nothing of the practice of irrigation, and in the West sewage is already used for that purpose.

THE USE OF SEWAGE FOR IRRIGATION IN THE WEST.

Considering the general development of the two sections of the country, the western part of the United States has been more forward in the purification of sewage than the eastern. This is accounted for in three ways: (1) The very low stage of western streams during the hot dry season often renders sewage discharged into them an unbearable nuisance, or there may be no natural stream near by or sufficient size to receive sewage. (2) The familiarity of the people with irrigation, and (3) the value of all available water for this purpose naturally leads to the application of sewage to crops when any method of purification is necessary.

For the above reasons all but two of the sewage purification plants west of the Mississippi River employ irrigation, and one of the two exceptions, Hastings, Neb., uses intermittent filtration and will probably raise crops eventually, while the other, Leadville, Colo., only strains the sewage through a small area of sand.

General Information Regarding the Use of Sewage for Irrigation in the West.

	Population, 1890.	Ready for use.	Irrigation adopted on account of—	Ownership of irrigated land.	Rental.	Crops raised or proposed.
Colo. Springs, Colo.	11,140	1889	Lawsuit, account of pollution.	Private	$300[1] per year, 5 years.	Alfalfa, hay, garden truck.
Trinidad, Colo.	5,523	Fall 1892.	To prevent pollution of water used for domestic purposes.	"	$500[1] "	Blue grass proposed.
Fresno, Cal.	10,818	Jan., 1890	Best available method.	"	$5,000[1]	Chinese truck gardens.
Pasadena, Cal.	4,882	1893	Evidently some purification necessary.	City	....	B'rly, hay, fruit, vegetables proposed.
Redding, Cal.	1,821	1888	To prevent pollution Sacramento water supply.	Private.	$300[1] first year, and yearly increase.[2]	Grain, potatoes, vegetables, fruit.
Los Angeles, Cal.	50,395	Prior 1887	To provide water for irrigation.	"	No rental formerly[3]	Probably garden truck.
Santa Rosa, Cal.	5,220	1889 or earlier.	Lawsuit, account of pollution.	City	Leased without rental.	Garden truck.
Helena, Mont.	13,834	1889	Means of providing park.	"	Leased: lessee makes improvements and cash payment.	Vegetables, nursery stock.
Cheyenne, Wyo.	11,690	Prob. 1893	To provide water for irrigation.	Private.	No rental.	....
Stockton, Cal.	11,424	1892 or '93	To provide water for irrigation.	"	....	....

[1] Paid by the city. [2] Increase yearly proportionately with assessment roll. [3] City may charge $3 pe acre for land covered by new outfall.

As shown below eight of our western towns are prepared to apply sewage to land for irrigation in the season of 1893. In addition, Los Angeles may also be ready to so dispose of its sewage in 1893, and until three years ago had been so doing for some time, while at Cheyenne, Wyo., sewage was for seven or eight years delivered into an irrigating ditch and used for irrigation, this use being stopped only by a change in the outlet sewer.

Some of the leading points regarding these sewage farms are given in the accompanying table, from which it appears that sewage was first used for irrigation at Cheyenne, Wyo., probably in 1883. It is not certain when the sewage of Los Angeles was first applied to land, the information at hand referring to the "boom" period as a time when the use of sewage began to be discontinued on account of cutting up the sewage irrigated land into building lots.

Where domestic water supplies are not affected it is evident that sewage purification is most needed in the summer time, when the sewage flow is largest, the streams the lowest and, in the West, very fortunately, water for irrigation in great demand. This combination of circumstances favors sewage farming in the West, and seems likely to lead to the adoption of this mode of purification in many other western towns. In several instances the farmers seem to have doubted the practicability of applying sewage to crops, but upon trial they and their neighbors have become convinced of both the practicability and value of the process. There seems to be reason for believing that with good management many of our western cities can materially reduce the cost of desired sewage purification systems by utilizing the sewage for irrigation. Oftentimes such utilization would either render long outfall sewers unnecessary, or, where these pass through irrigable country the sewage could be sold, as is proposed at Los Angeles. As we have previously suggested, this latter possibility is also worthy of consideration in the East, wherever outfall sewers could be made to serve cultivated or pasture lands. Where sewage purification is necessary it should always be placed before revenue, and as yet no profit-making method of sewage purification has been devised, nor is one likely to be soon; but the expense of sewage purification, at least in arid or semi-arid regions, can certainly be materially lessened by using the sewage for irrigation. The subject is well worth study, for the common mode of sewage disposal by discharging it into streams, often those used for public water supplies, cannot and will not always be tolerated. Massachusetts and a few other states are already protesting against the practice, and others will follow, let us hope, with rapidity.

The use of sewage for irrigation in the various localities mentioned in the table is described in detail as follows:

Colorado Springs, Colo.

Colorado Springs adopted the method of sewage disposal described below in order to avoid law-suits instituted to prevent alleged stream pollution by sewage.

The population of the city increased from 4,226 in 1880 to 11,140 in 1890. Water-works were built in 1879 and a sewerage system in 1888. Sewage was first used for irrigation in 1889. Jan. 1, 1893, there were in use 20.4 miles of separate sewers, 239 manholes, all with perforated covers, 683 house connections and 18 flush tanks.

A statement of the causes which led to the use of sewage for irrigation, and a description of the sewage farm have been sent to us by Mr. H. I. Reid, City Engineer and engineer of the disposal plant, as follows:

In the utilization of sewage for irrigation purposes at Colorado Springs, no attempt is made toward treatment or purification other than by natural means and in a rather primitive manner. The system was adopted as a compromise measure to avoid suits for damages for the alleged pollution of the stream into which the outfall sewer originally emptied, "Fountain Qui Bouille," commonly known as Fountain Creek. This stream has a normal flow at the sewer outlet of 50 cu. ft. per second, but at times during the irrigating season this is reduced to almost nothing, although during the same season floods may be expected, when for a few hours or days the creek becomes a swift flowing river, with a fall of 30 to 40 ft. per mile.

The original sewerage system was put in operation in 1888. The following year a ranchman, living some two miles below the outlet point, shown in Fig. 68, instituted injunction proceedings to prevent the sewage from being turned into the stream, claiming that his well, situated near the stream, was so polluted as to render it unfit for drinking purposes, and that the water in his irrigating ditch, the head gate of which is ¾ miles below the sewer outlet, was so foul that stock would not drink it. Before the suit came to trial the city council appointed a committee, of which the writer was one, to try and arbitrate the matter. This was done and the suit was withdrawn, the city paying all costs of proceedings to that date, and agreeing to divert the sewage at some point on the outfall and utilize it for irrigation on the lands designated on the accompanying map, Fig. 68.

A contract was made between the city and the owner of this land, whereby the city was to deliver the sewage at the point B, Fig. 68, by the line A B, and to pay annually $300 for five years, said owner to receive the sewage at this point and use the same for irrigation purposes in such a manner as he deemed best, provided, however, that he prevent the sewage from flowing directly into

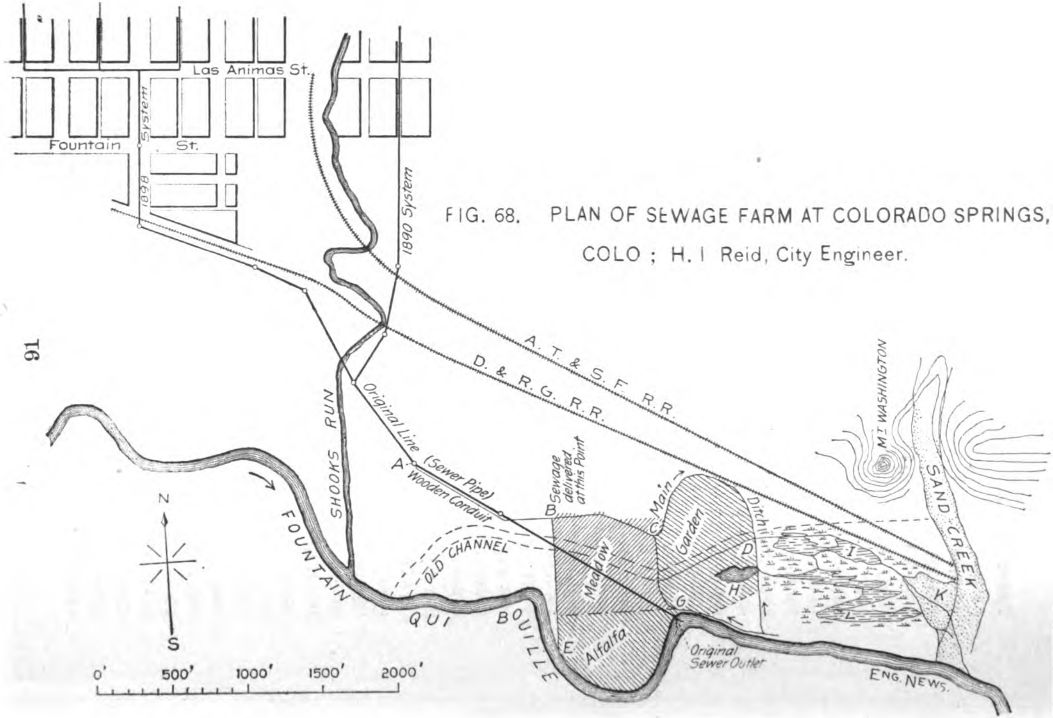


FIG. 68. PLAN OF SEWAGE FARM AT COLORADO SPRINGS, COLO ; H. I Reid, City Engineer.

the creek, and provided, further, that if the method of irrigation was not satisfactory to the ranchman bringing the suit, or to the city, then the city should have possession of the land and use such methods as it thought best. At the expiration of the contract the city has the option of buying the land at a stipulated sum, and probably will buy it, although there are now many parties who would pay for the sewage delivered to their land.

The city tapped the outfall at the point A, Fig. 68, and by means of an underground wooden conduit on a less gradient than the original outlet delivered sewage on the surface of the ground at the point B, whence the lessee takes charge of it and delivers it to grounds by the ditches B E, and B C D, and thence by laterals to any desired point.

The map shows that many years ago the stream followed a different channel than the present one, the depression of which extends through the entire tract from west to east, and is from 3 to 4 ft. lower than the north bank of the creek at corresponding points at right angles thereto. The old channel is the medium whereby the surplus sewage is carried off without flowing directly into the creek.

The sewage is distributed by means of small ditches or furrows through the garden tract, whence all liquid matter not absorbed by the earth flows back into this old channel, and thence into the depressions, forming small reservoirs at H, I, L, Fig. 68. The small laterals radiating from the main ditch irrigate the northern portion of the lands, and in a similar manner any surplus flows into the same reservoirs. During the irrigation season, which, in this instance, is from March 1 to Nov. 1, there is but little surplus, the character of the soil being such that the greater portion is absorbed or carried off by underflow.

In constructing the outlet sewer, we found throughout this entire tract of valley land from the surface to a depth of 2 or 3 ft. loose black loam, then a 2-ft. stratum of sand, below which was coarse gravel and sand, through which water was flowing with considerable velocity, so that at a depth of 6 ft. it was found necessary to dig a parallel and deeper trench to carry off the water, in order to facilitate pipe-laying. This probably explains the rapidity with which the sewage matter is absorbed when applied for irrigation. As soon as sufficiently dry, after each application of sewage, the soil is thoroughly pulverized and any accumulation of solid matter turned under before receiving more sewage.

When irrigation is not in progress the entire flow is carried through the main ditch and emptied into the old channel and depressions mentioned. The upper pools or reservoirs, Fig. 68, were ploughed out by the action of surface water; the lower or most easterly one is a reservoir, the dam of which was built up through a similar agency. Immediately north of the railway tracks are sand and gravel hills, some 200 ft. higher than the valley and very steep. During the rainy season flood water flows into Fountain Creek, across the valley at right angles to the old channel. At such times the debris brought down has been deposited upon the lower level of the valley and a sand dike several hundred feet wide and 5 or 6 ft. higher than the lowest portion of the valley has been formed, thus converting the valley at this point into the basin, K, Fig. 68, the area of which is some three or four acres. All surplus sewage matter collects in this basin and rapidly seeps away into the underflow and finally into the creek. All solid matter is deposited in the basin, and that it will in time cement the bottom and fill it up is very probable, but no trouble of this kind has been experienced to this date, and to all appearances there is very little deposit of any kind. It is said that no unpleasant odor is experienced on any portion of the farm at any time.

So far as practical results are concerned the disposal area is a success, inasmuch as the city is relieved of costly litigation, and also from the care and maintenance of the outlet lines. The lessee is well pleased because of the enormous crops raised and lack of trouble from the vexatious problem of "priority of water rights." The amusing side of the situation is that the ranchmen several miles below the outlet, seeing the sewage farm well supplied with water at times when they had none, threatened to enjoin the city from using it for this purpose, and compel the sewage to be turned into the stream for their benefit.

The sewage farm comprises at present an area of about 35 acres, but may be added to as future needs require. In 1892 the sewage was used on 25 acres, 15 in meadow and alfalfa and 10 acres in vegetables, but a larger acreage could be used with the present amount of sewage. The crops produced are enormous, and owing to close proximity to the market the farm is a paying investment. As already stated, the city has nothing to do with the management of the farm, but the probabilities are that when the lease expires the city will buy the farm and enlarge the system.

Under date of Jan. 24, 1893, Mr. Reid wrote that he had recently visited the sewage farm, and found the sewage running directly into the creek through a ditch cut from the reservoirs, shown in the plan, Fig. 68. This is in direct conflict with the terms of the agreement, but it may be that it was done to flood the lands of ranchmen below, who have recently been willing to take all the sewage they can get.

Trinidad, Colo.

The city of Trinidad is divided into two parts by the Las Animas River, a comparatively small stream during much of the year. The farmers below the city depend upon ditches leading from the river for water for domestic use, which makes especially necessary some form of sewage purification. Following the advice of Mr. Norval W. Wall, City Engineer, it was decided to purify the sewage by irrigation. A contract was therefore made with Mr. Jas. M. John, who was mayor at the time, to receive and dispose of the sewage on land owned by him, the city paying Mr. John $500 per year and delivering the sewage to him.

The population of Trinidad in 1890 was 5,523, and in 1880 it was 2,226. A public water supply

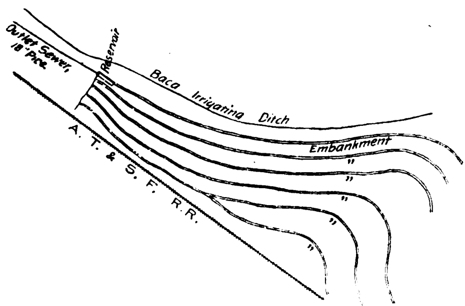


Fig. 69. Sketch Plan of Sewage Farm, Trinidad, Colo.; Norval W. Wall, City Engineer.

was introduced in 1879 by the Trinidad Water-Works Co. A sewerage system was put in operation in 1892, the outfall sewer having been completed about three months before the close of the year. Mr. Wall was engineer for the system.

On Jan. 1, 1893, there were in use two miles of separate sewers, 18 ventilated manholes, two Rhodes-William flush tanks and 12 house connections, mostly public buildings.

An 18-in. vitrified outlet sewer 7,100 ft. long leads from the city to the sewage farm. This outlet has a calculated velocity, when running full, of 2.58 ft. per sec.

At the farm end of the outlet sewer there is a masonry settling tank 50 ft. long, 5 ft. wide and 4 ft. deep. Mr. Wall states that in time of an epidemic the tank can be used to disinfect as well as to precipitate the sewage; also that more tanks are proposed when the sewerage system is extended.

The sewage farm slopes toward the Las Animas River at the rate of from 2½ to 3½ ft. per 100, and is laid out with embankments following natural contours, as shown in Fig. 69, except that a total of 15 embankments have now been made. The embankments are from 25 to 50 ft. apart and average about 1,500 ft. in length. Wooden sluice boxes provide means for the passage of sewage through the embankments to lower areas. To the close of 1892 about $1,200 had been expended by Mr. John in preparing the farm to receive sewage.

It is stated that blue grass is proposed as a crop on the farm, as it will stand more frequent irrigation than any other crop.

We are indebted to Mr. Wall and Mr. John for the information presented, a part of which, only, Mr. Wall gave in a paper read before the annual meeting of the American Society of Irrigation Engineers in Denver near the close of 1892.

Fresno, Cal.

A very interesting example of the use of sewage for irrigation is found at Fresno, Cal., where the city pays $5,000 per year for the disposal of the sewage, and the fortunate man who receives the money distributes the sewage over land which he rents to Chinamen for market gardens.

The population of Fresno increased from 1,112 in 1880, to 10,818 in 1890. A public water supply was introduced in 1876 by the Fresno Water Co. The city put a sewerage system in operation in January, 1890. Shepard & Teilman, of Fresno, were engineers for the system, Mr. J. C. Shepard, of the firm, having been city engineer at the time. Sept. 5, 1892, there were included in this system about eight miles of sewers on the separate plan, not including the outlet sewer, which consists of about 4½ miles of 24-in. vitrified pipe laid to a grade of 3½ ft. per mile. The last three miles of the outlet sewer is ventilated once in every 1,000 ft. by a 24-in. vertical pipe extending above the ground. Jan. 1, 1893, there were in use about 600 house connections and six flush tanks. In addition to the flush tanks there is at four points a continuous flow of water into the sewers about equal to a 2-in stream under a 6-ft. head. The lower end of the outlet connects directly with an irrigating ditch.

We are indebted to Shepard & Teilman for the information here given regarding the sewage farm, the remainder of which is presented practically as reported by them on Sept. 5 and Oct. 21, 1892, as follows:

Prior to the construction of the sewers the city trustees thought the disposal of the sewage the great obstacle to be overcome; therefore they called for proposals to take care of the sewage for five years, the successful bidder to give a bond of $10,000 to protect the city from all damages which might arise therefrom after its delivery at the end of the pipe. Alexander McBean, of Oakland, was the lowest bidder, and his bid of $5,000 per annum was accordingly accepted. The contractor purchased 80 acres of land at the end of the outlet sewer, and for one year the sewage ran upon that land without any attention or care, except when occasionally some neighbor saw fit to take it for irrigation. The second year the contractor constructed ditches and leased the land to Chinamen for vegetable gardens, and for two seasons it has been used for irrigating gardens and vineyards.

Mr. H. Burley, of Fresno, superintends the renting of the land, which is all under cultivation with all the various kinds of vegetables commonly in the market, such as potatoes, yams, parsnips, lettuce, celery, beans, peas and corn. It is customary to irrigate vegetables in furrows only. Trees and vines would be irrigated in furrows also. Grasses would be flooded, but we have no knowledge of sewage being used on grasses.

As to the amount of sewage used on the 80 acres, we cannot say. The 24-in outlet sewer on a grade of 3½ ft. per mile runs continuously, we should judge, about one-third full, but what proportion of the flow is used on the sewage farm we do not know.

Mr. Burley, the superintendent of the farm, states that he can see no difference between irrigating with sewage and clear water. It is possible that the land may produce good crops longer by the use of sewage, but that is to be proved. The general impression is that sewage is superior to water for irrigation. The sewage farm is an exceptionally poor piece of land, but it produces pretty well with sewage irrigation. We do not know what a similar piece would do with clear water only.

When put upon the land, without more dilution than is given by the flushing water, unless the land is cultivated within a day or two, there is quite a stench, but when cultivated this disappears. There has been no complaint regarding the sewage farm, and the $5,000 is a yearly pension to the contractor.

When not needed on the farm, the sewage is allowed to float in the irrigating ditches for miles beyond, in which way it becomes very much diluted, and in the irrigating season is used throughout the country below the sewage farm proper.

Pasadena, Cal.

After an unfortunate experience with the Pacific Sewage Co., an organization which agreed with the city to construct a disposal system similar to that in use at Atlantic City, N. J., but failed to do so, and after two years of litigation over the right of way for the outlet sewer, the city of Pasadena in the middle or the latter part of 1892 began the preparation of a farm for the disposal of the sewage of the city. It is expected that this farm will be put in use in the season of 1893, as decribed below.

The city is of comparatively recent origin, its population in 1880 having been but 391. The present population is estimated at 6,000, the last census showing 4,882 inhabitants. Water was supplied here, probably in connection with irrigation works, as early as 1869, and at present several companies operate works. The construction of a sewerage system was begun in 1887, but for the reasons stated above there has been much delay in providing for the disposal of the sewage, which has prevented the making of house connections, although in 1891 nearly five miles of sewers had been built within the city limits. Mr. August Mayer, of Pasadena, is the engineer for the whole system, which is of the separate type. We are indebted to Mr. Mayer for the following information relating to the sewage farm, the matter having been prepared in November, 1892:

The city of Pasadena lies in the midst of the San Gabriel Valley, at the foot of the Sierra Madre Mountains, 10 miles northerly from the city of Los Angeles, and about 30 miles from the Pacific Ocean. Its elevation above the latter may be taken at 900 ft., or about 600 ft. above the main part of Los Angeles. The soil around the city, and especially that close to the mountains, is sandy, with excellent underdrainage. The general slope toward the ocean in the vicinity of the city is 2 ft. per 100 ft. The grades obtainable for sewerage in the city, with one or two exceptions, are excellent. The average annual rainfall amounts to 20 ins., which is precipitated chiefly during the months of January, February, March and April. The average temperature during the rainless eight summer months may be taken at 85° F. The air is dry.

Wherever water is obtainable for irrigation, citrus fruit is principally raised, while the unwatered land is fit only for the raising of some deciduous fruits, grapes and barley; the latter being chiefly cut, in this vicinity, before its maturity and used for hay. Bare land is worth $100 per acre without water, while watered land is held at about $600 per acre. Irrigation, therefore, makes the land valuable, and since water is here only obtainable from springs or storage reservoirs, of which latter we possess at this place none at the present, waste of water is hardly ever met with. It may seem, therefore, that the circumstances for successful sewage disposal, by means of irrigation, from a financial as well as sanitary standpoint, are in our favor.

The sewage farm is owned by the city, and comprises 300 acres of land situated about four miles from the city in a southeasterly direction, in a well settled part of the valley. The soil is a sandy loam, mixed with some alkali. It has the capacity of absorbing a considerable quantity of water. It is estimated that for the present only 40 acres will be required for the disposal of the sewage, but the latter may be spread over a much larger area for the purpose of irrigating crops on the remainder of the farm. Most of the land will probably continue to be devoted to the raising of barley hay, until fruit orchards are planted. The land originally cost $125 per acre, or a total of about $40,000, including some extra expenses. The gross yield in barley hay, without irrigation, is $4,000 per annum, or 10% on the cost; the net yield amounts to about $3,000, 7½% on the money invested.

It is the intention to devote the land irrigated with sewage to the raising of vegetables, berries, and citrus fruits, and perhaps walnuts and alfalfa hay. The latter yields about seven crops per annum, or about 10 tons per acre, and is sold for $10 to $15 per ton. It stands any amount of irrigation at all seasons, and the sewage may be crowded on it at any time. Vegetables are calculated to yield $25 net per acre, while berries, as a rule, yield from $100 to $200 per acre per annum. Citrus fruits often net from $150 to $400 per acre per annum. With sewage irrigation, these figures may possibly be exceeded.

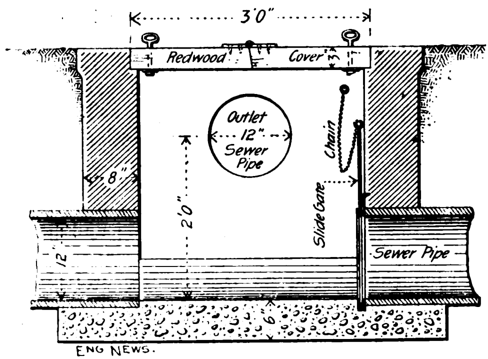


Fig. 70. Sketch of Sewage Outlet Gate, Pasadena, Cal.; August Mayer, C. E.

As seen from the section of the outlet gate, Fig. 70, the sewage is taken from the sewer in much the same manner as water from irrigating pipes by the simple closing of a cast iron slide gate, built into a manhole, through which the pipe leads. The sewage is thus backed up into the sewer until it rises nearly to the top of the manhole, whence it finds its way through a joint of sewer pipe into the main carrier, an earthen ditch 20 ins. wide at the top, 10 at the bottom and 10 ins, deep. This carrier has a grade from 4 to 6 ins. in 100 ft. The land which the main carriers cover is divided into fields 100 ft. in width, and from 200 to 400 ft. in length. The slope of the fields at right angles to the main carriers is 1½ to 2½ ft. per 100 ft. To irrigate the fields a dam of earth or of redwood board is inserted in the carrier at the lower end of the field, and the sewage is thus diverted into numerous small furrows from 3 to 6 ins. deep and 1 ft. apart, previously made with a common cultivator. Each field is expected to take the sewage for at least 12 hours. After the first soaking the dam is removed and the next field in order will receive its charge, and so on. As soon as the ground permits it, say, in about two days, field No. 1 will be thoroughly cultivated, to keep the ground from baking hard and to allow the air to act upon the soil. This is the common course adopted here for irrigation with pure water.

Fruit trees are planted in regular lines about 20 ft. apart each way, which permits the manner of irrigation here described. The side and bottom walls of the main carriers will be raked over with a garden rake whenever it becomes necessary to prevent the ditch from becoming foul.

Berries are to be planted in rows about 8 ft. apart, and the sewage will be led in between the rows so that the ground can be well cultivated. Vegetables may be planted in single or double rows, as the case may require, and the sewage will be conducted in between the rows or fields in flat trenches, which are to remain filled until the ground from trench to trench is thoroughly saturated with the sewage water, when the trenches will be drained, and after having dried off sufficiently they will be cultivated.

Redding, Cal.

Redding is one of the smallest towns in the United States using sewage for irrigation, or having a sewerage system; its population in 1890 was 1,821, and in 1880 but 600. The town was incorporated in 1888, and water-works built in the same year by the Redding Water Co. A separate sewerage system was built in 1889 by the town, with the city engineer, Mr. S. E. Brackins, as engineer, and Bassett & Touhey, Sacramento, as contractors, who also agreed to dispose of the sewage for 40 years. Jan. 1, 1893, there were 2.9 miles of sewers, and seven Field-Waring, 112-gallon flush tanks.

The following description of the sewage farm and matters pertaining to the disposal of sewage was prepared for this series of articles in the latter part of October, 1892, by Mr. L. F. Bassett, C. E., the present owner of the farm, and for eleven years city engineer of Sacramento:

Redding is situated on slightly rolling ground, at an elevation of 550 ft. above the sea. It is bordered on the northeast and southeast by the Sacramento River. The climate ranges from 16° above zero in the winter to 107° F. above in summer. Most of the season the atmosphere is dry and evaporation rapid.

It was the original intention of the town to discharge its sewage into the Sacramento River, but objection was made at Sacramento, where water is taken from the river to supply the city, and the State Board of Health gave notice to the authorities of Redding not to discharge the sewage into the river. The town authorities thereupon requested bids for taking care of the sewage, and a contract was entered into for a term of 40 years, the sewage to be disposed of at $300 for the first year, the amount of yearly payment thereafter to increase in proportion to the increase of the assessment roll.

The contractors immediately purchased a tract of about 100 acres of land within the corporate limit, shown by Fig. 71, and prepared a portion of it, about a mile from the built-up part of the town, for the utilization of the sewage by irrigation. The land selected is comparatively level and the soil a sandy and gravelly loam 4 to 6 ft. in depth, underlaid with gravel. Land better adapted to the purpose would be hard to find. About 10 acres have been prepared for irrigation by leveling and constructing open carrier ditches, elevated above the surface of the land to be irrigated.

The sewage is applied directly to the land by the broad surface irrigation system, either by being run in furrows between rows, or spread over the surface, according to the requirements of the crop.

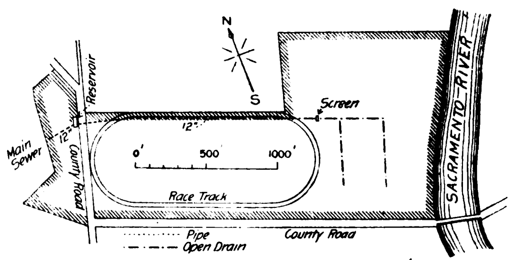


Fig. 71. Plan of Sewage Farm, Redding, Cal.; S. F. Brackins, Engineer; Bassett & Touhey, Contractors

The sewage has been applied to various crops, grain, asparagus, potatoes, turnips, beets, orchard and some garden truck. It has been principally used in raising fruit trees for nursery stock, the young trees being irrigated between the rows. About five acres are used as a nursery.

Generally the land is cultivated as soon after an application of sewage as the soil becomes dry enough. Part of the year it is necessary to put the sewage on land on which no crops are growing. It is then customary to run the sewage on the same piece of land for several days in succession, and after it becomes sufficiently dry to plow or cultivate it. This is more particularly the case in winter, when there is sufficient moisture for crops without irrigation.

The sewage is not allowed to flow continuously onto the land, as too much time would be required in taking care of it, besides which the ordinary flow is not of sufficient volume to operate successfully. As shown by the plan, Fig. 71, a reservoir was constructed at the outlet of the sewer, at the upper line of the sewage farm. This reservoir has a capacity of 75,000 gallons, which is about equal to the daily sewage flow in the dry season. Each morning the outlet to the reservoir is opened, and the contents discharged in from two to four hours, as desired. The bottom and sides of the reservoir are so constructed that everything gravitates to the outlet, and special cleaning is seldom necessary. An abundant supply of water from the town water-works is at hand for use, if required. The reservoir is covered with a rough board structure and a vent chimney of lumber is carried to an elevation of about 60 ft. This has been sufficient to prevent any nuisance, and none is complained of, although the reservoir is alongside the public road.

No difficulty has been experienced in preventing a nuisance on the irrigated lands. Care and attention to secure proper distribution and cultivation are required, and with these the results have been satisfactory. There is sometimes a slight odor in the immediate vicinity of freshly-irrigated land, or where it is ponded previous to its subsidence into the soil, but this odor is not noticeable at a distance of 200 ft.

A screen near the upper line of the irrigated lands (see Fig. 71) catches such large objects as might cause an obstruction in the ditches, or interfere with the free flow of the sewage over the soil. There has been no underdraining, as none is required, the soil being very porous and underlaid with an extensive bed of gravel.

There has been some prejudice against the sewage farm, but this is gradually dying out. The principal objection came from two owners of land immediately south of the tract under irrigation, who, from the first, objected very strongly to the location of the sewage farm so near them. One of these men in June, 1892, had the proprietor of the farm arrested for maintaining a public nuisance. At an examination, held shortly afterwards, the examining magistrate decided that the evidence was not such as would secure a conviction, and the case was dismissed.

The sewage farm is now the property of L. F. Bassett, C. E., of Sacramento, who gives personal attention to the manner in which the sewage is disposed of. Besides the sewage, fresh water from the Sacramento River, sufficient for 40 acres, is available for irrigation.

Los Angeles, Cal.

The use of sewage for irrigation at Los Angeles has been temporarily abandoned, with the exception of quite a small part of the daily flow, but preparations are being made for the future utilization of all of the sewage of the city during the irrigation season. The reasons for the change from the old to the proposed new plan of sewage disposal are given below.

Los Angeles grew from a population of 11,183 in 1880 to 50,395 in 1890, making it the second city in size in the state. Water is supplied by several different companies, some or all of which recently consolidated. The works of the Los Angeles City Water Co. were built in 1862. The date that sewers were first put in operation is not stated in the information at hand. Dec. 31, 1891, about 46 miles of separate sewers had been built.

The following account of the use of sewage for irrigation, the cause for its discontinuation, and an outline of the new disposal system was prepared for us by Mr. J. H. Dockweiler, City Engineer, on Oct. 21, 1892; we are also indebted to Mr. W. W. Robinson, clerk of the mayor, for information furnished:

Up to about three years ago, the entire sewage of our city, amounting to 7,000,000 gallons in 24 hours, was disposed of by irrigation on 1,700 acres of sandy soil adjoining the southern limits of the city.

The sewage was delivered to the South Side Irrigation Co., at the southern limits of the city, who distributed it to the different land owners through open ditches owned and controlled by the company. Previous to the time that this company handled the sewage and properly disposed of the same, the yearly rental value of the land was about $2.50 per acre, but as soon as sewage was used for irrigation, these same lands rented for from $15 to $25 per acre per annum. Save a few acres of land which were irrigated by the surplus waters from the irrigation ditches in the city of Los Angeles, this land, known as the Vernon District, could not be irrigated because of lack of water. The only water that could be depended upon by the Vernon District came from the city sewers.

During the "boom" of a few years ago a great deal of the land of the Vernon District was cut up into lots and sold. A great many residences and improvements sprung up, and the sewage became a nuisance from the following causes: It was carried in open ditches; the people had to take it whether they wanted it or not; the hitherto irrigable area was reduced by subdivisions into house lots, while the quantity of sewage was continually increasing; the owners of lands suitable for irrigation were more interested in selling their land for residences than developing it for cultivation.

At this stage injunction suits were brought against the South Side Irrigation Co. to compel them to carry the sewage in closed conduits through the lands of those who objected to open ditches, and also to restrain them from delivering sewage to lands when it was not required by them. The city had only one point of delivery, and could not control the volume of the sewage; whatever the sewer discharged at the south city line, the South Side Irrigation Co. had to dispose of. The injunctions were granted, so the company turned the sewage into the river, where it now goes to waste, save that a few acres are still irrigated by it.

The present feeling in this district, however, is that sewage would be used, if it were delivered in closed conduits, only when required.

The city has voted $395,000 worth of bonds to construct an outfall sewer 12 miles long from the southwest corner of the city to the Pacific Ocean. The line passes through a large section of country which cannot be irrigated at present for want of water. The sewer has been so located that it will deliver sewage upon the lands at the highest possible level; in fact, it was located as nearly as an irrigation ditch as is consistent with reaching the ocean in as short a line as possible. It is expected that the outfall will be completed by July, 1893. Provision has been made to supply sewage to land adjacent to the outfall by means of gates and hydrants located at the commanding points. There are at least 20,000 acres of sandy soil suitable for sewage irrigation directly under the location of this sewer, the owners of one-half of which have signified their willingness to irrigate with sewage. The city will deliver the sewage along the line of the outfall, the land owners to make the necessary provisions for getting it on the land. The special feature which will make irrigation with sewage a success by this plan is that when not required on the lands it will be turned into the ocean, thus making it possible to use it for nine months in the year. It is proposed to charge about $3 per acre per annum for the use of the sewage.

I have designed two inverted siphons, each three miles long, in connection with the outfall, to be made of wood stave pipes.

Mr. Dockweiler states that he believes that the above will be the first instance of the use of wood stave pipe in a sewerage system. In our issue of Jan. 19, 1893, there was described and illustrated a 24-in. wood stave outlet sewer extending for 800 ft. beneath the harbor at New London, Conn.

In the report of the State Board of Health of California for the two years ending June 30, 1890, there appeared a paper by Mr. D. G. McGowan, Health Officer of Los Angeles, from which the following extract is taken:

At the southeast angle of the city limits this water (sewage) is taken by the South Side Irrigation Co. and conducted through a 22-in. cement pipe a distance of six miles to the sandy plains below the town of Florence. Though eagerly taken at first by the Chinese market gardeners for irrigating and enriching their truck patches, its prolonged use has been found to be a detriment, lessening the productive qualities of the land when it becomes well saturated with the sewage matters. It is a fact that lands upon which it has been used constantly for several years have been abandoned by their cultivators, or it has been necessary to pipe pure water upon them to take the place of sewage for the purpose of irrigation.

The above statements, when taken in connection with the prior explanation of the abandonment of the use of sewage from the ditches of the South Side Irrigation Co., lose much of the force which they seem to have by themselves. It is doubtless true that the land was overdosed with sewage, and it is quite probable that little or no proper attempt at a rotation of crops was made.

Santa Rosa. Cal.

The population of Santa Rosa in 1880 was 3,616, and in 1890 it was 5,220. The Santa Rosa Water Co. built water-works in 1873. A few streets were sewered on the separate plan some years ago, sewage being discharged into Santa Rosa Creek, near the city limits. Complaints of pollution of the creek, followed by a lawsuit, led to the purchase by the city of between 18 and 19 acres of land about two miles from the city, to which an outlet sewer was built.

The farm is leased to parties who take care of the sewage for rental, using it for gardening purposes. The city can terminate the lease at any time. The year the farm was put in operation is not stated, but it was used as early as 1890, and probably at least one or two years earlier.

A slight rise near the end of the outlet sewer causes the coarser solid matter to collect. Once a day, or as often as is necessary, a gate is opened and the collected matter flushed out into a pit near the bank of the creek.

When not used for irrigation the sewage flows onto low land near the bank of the creek, which land is flushed at high water. Mr. Newton V. V. Smyth is city engineer, and to him and Mr. J. L. Jordan, City Clerk, we are indebted for the information given.

Helena, Mont.

About one-fourth of the sewage of Helena is used for broad irrigation on a farm owned by the city and leased to Mr. A. T. Newbury for five years from 1890, prior to which it had been leased for about two years to another man.

Helena had a population of 3,624 in 1880 and 13,834 in 1890. Water-works were built in 1887-8 by the Helena Water Co., and a sewerage system was put in operation in 1889. Jan. 1, 1893, there were 26½ miles of 6 to 24-in. sewers, receiving no rain water except from roofs. There were on the same date 810 house connections, 310 manholes with perforated covers and 76 flush tanks discharging 225 gallons once in 12 hours. Mr. G. N. Miller was engineer of the sewerage system.

From the last house connection in the city the outlet sewer extends about one mile, with branches not in use up to Sept. 11, 1892. Next comes 1,200 ft. of 12-in. vitrified pipe, then 700 ft. of wooden box sewer 12 ins. square. The end of the box sewer connects directly with the distributing ditches of the farm. The sewage, when not used for irrigation, runs across the farm into and through two ditches extending for about 2½ miles to Ten Mile Creek, a stream about 20 ft. wide and 1 ft. deep.

The city paid $6,100 in 7% bonds for the 40 acres of land, included in the farm, which has received sewage for about four years. The lessee pays the city a rental of $200 in cash, plants 100 trees and makes one acre of lawn per year, caring for the trees and lawn. It is said that the lessee raises vegetables and all kinds of nursery stock on the farm. In connection with the statement, made below, that the farm has never paid the interest on the cost it must be remembered that this could hardly be expected from the use to which the farm seems to be devoted; nor, for the same reason, can efficient purification throughout the year be expected.

The sewage is distributed over the farm by means of open ditches and is brought to the plants by flooding. It is utilized only in the growing season. The land is not underdrained.

The above information was given by Mr. Geo. K. Reeder, formerly city engineer, and by the present city engineer, Mr. Jas. S. Keerl. The following additional facts and opinions regarding the operation and success of the farm are given substantially as reported by Mr. Reeder, in letters dated July 31 and Sept. 11, 1892:

The sewage is only utilized in the growing season. During the winter months, or rather when the ground is so frozen that there is no absorption, the sewage is allowed to flow in the natural channels upon the surface. During some portions of the year, even when not used for irrigation, the sewage scarcely gets across the field before being absorbed or evaporated.

The farm has never proved a source of income to the city, in fact, it has never paid the interest on its cost, and has not proved a success in disposing of sewage throughout the whole year. My own opinion is that the soil is not suitable for the purpose, it being a quite gravelly, sandy loam for a depth of 6 ins., beneath which is a bed of quite impervious clay and gravel. The land may become more suitable after years of working. The city authorities, in their lease, have virtually turned over all control of the sewage to the lessee, and so far the tenants have done as they pleased.

As nearly as I could ever learn from the aldermen, the intention in establishing the farm was ultimately to convert it, or at least a portion of it, into a park, sewage to be supplied to the trees by means of porous tiles. My predecessor, as city engineer, intended to make it an absorption farm, sewage to be turned onto one portion until it would absorb no more, then to another, and so on, each portion after drying out to be turned over by cultivation to fit it for a new dose of sewage. This was to be done irrespective of seasons, and crops were to be a secondary consideration. City engineers propose but city councils dispose, and there never has been a time when the city engineer has had control over the farm, the lease having always been of such a character that his hands have been tied.

Cheyenne, Wyo.

Regarding the former use of the sewage of Cheyenne for irrigation, the following information has been given to us by Mr. Fred Bond, City Engineer, under date of Aug. 28, 1892:

The sewage, direct from the sewer outlet, was discharged directly into the irrigating ditch of a private ditch owner, and mixed therein with water already in the ditch, which was taken from the creek a little further up, or above the point where the connection with the sewer was made. In this way the creek water and sewage were mixed and carried to the land to be irrigated. The man who used the sewage did not pay for it, the obligations between the city and himself being considered mutual. He used the sewage seven or eight years, I believe. The sewage is now discharged into the creek about 2,500 ft. below the point where it formerly entered the private ditch.

Cheyenne had a population of 3,456 in 1880 and of 11,690 in 1890. The city built water-works in 1882 and sewers were put in use in 1883 on the separate plan. On Feb. 20, 1891, about five miles of 9 to 15 in. vitrified, salt-glazed sewer pipe had been laid.

The use of sewage for irrigation was stopped on account of the extension of the outlet sewer to discharge below the ditch of the man who made use of the sewage.

Stockton, Cal.

Provision for the use of sewage for irrigation has been made at Stockton, Cal., but the fact came to our attention too late to secure exact information. The construction of a sewerage system was begun in 1891, under the direction of Mr. George Atherton, City Surveyor. All the sewage is pumped into an outfall sewer 14 ins. in diameter and two miles long, discharging into the Stockton River. It is stated in the San Francisco "Chronicle" of Jan. 31, 1892, that at regular intervals on the outlet sewer gates are placed "by means of which the property owners turn the sewage upon the land during the dry season for irrigation purposes."

The population of Stockton in 1890 was 14,424.

SUBSURFACE DISPOSAL.

Lenox, Mass.—Old Plant.

The first American town to undertake the purification of its sewage was Lenox, Mass., the noted summer resort in the Berkshire Hills, six miles from Pittsfield. A public water supply was introduced here in 1875, and the town showed its good sense by immediately constructing a sewerage system, built in 1875-6. Col. Geo. E. Waring, Jr., M. Inst. C. E., was engineer for the sewerage system, which is of the separate type. To these improvements, as well as its natural charms, the town doubtless owes a large part of its popularity as a summer home. The enterprise of the town is especially commendable, since its population, including that outside the village, by the census of 1880 was but 2,043 and by that of 1890, 3,120. In 1876 the population was considerably below 2,000, perhaps not more than 1,200. Hundreds of towns in the United States larger than the Lenox of to-day are still without sewerage systems, although they have had public water supplies and leaching cesspools for many years.

The village is located in hilly country, so that its drainage naturally flows in two or three directions. When the sewerage system was put in it appears that the larger part of the population was on the western slope of the hill, while the Housatonic River, the only stream in the vicinity large enough to receive the sewage of the town, was in a nearly opposite direction at the foot of a hill and some two miles away.

The sum available for the construction of the whole sewerage system, it is stated, was not large enough to construct an outlet sewer to the river, so some form of purification was necessary.

The increase of sewage overtaxed the plant, and the growth of the village in another direction finally made necessary a new disposal area, so that at present the original plant is only used for a limited number of houses and wholly for surface disposal. Nevertheless the plant is well worth describing, both in its past and present state.

The whole scheme can be best described by quoting from the engineer's description in his "Sewerage and Land Drainage," as follows:

> The plan finally adopted and carried out consists of several miles of 6-in. pipe sewers connected at their upper end, for flushing and for ventilation, with the rain-water leaders of such adjacent buildings as were available. The various lateral sewers, four or five in number, were connected with a single 6-in. main sewer leading for a distance of about 2,500 ft. to the upper edge of a field somewhat isolated with reference to present or probable building. It here discharges into a flush tank having a capacity of about 500 cu. ft., separated into two chambers by a wire-cloth strainer to hold back obstructing material. This tank is discharged by a Rogers Field's siphon into a smaller chamber having two alternative outlets; one leading to a system of subsurface irrigation-pipes aggregating 10,000 ft. in length, and the other to a surface-carrier for the disposal of the outflow over the ground should a portion of the tiles become obstructed. The main sewer leading to the tank has also a branch outlet by which the direct flow may in case of need be turned on to the ground.

In the work from which the above quotation is taken Col. Waring states that there was much irregularity of distribution through the "absorption drains," the connection between the discharging main and distributing tiles often becoming clogged by the lodgment of a piece of paper or a rag over the opening. The connection, Col. Waring states, was formed by inserting as a part of the discharge main a short length of iron pipe having elbow connections from its bottom so that the full force of the flow should come directly into the elbow connecting with the tiles. These connections were finally changed to a more approved pattern, but apparently not for several years. By such clogging as has been described Col. Waring states that one line of drains would sometimes be cut off and rendered useless for weeks at a time. In addition it appears that the sub-surface pipes often became clogged with grease and other solid matters, some of the pipes at times being entirely filled in this manner.

After ten years of use the drain pipes were replaced by new ones laid on gutter pieces, the new pipes being nearer the surface and midway between the lines of the old ones. The drains were 6 ft. apart and the soil is not adapted for sub-surface disposal.

For the past few years the sewage has been discharged entirely upon the surface, much of the solid matter being removed by settlement in a tank. This sludge is now thrown into a pit and covered with earth. The liquid matter passes from the tank through a ditch, from the lower side of which it overflows and spreads over the surface of the ground, causing a rank growth of grass for some distance below the ditch and for from 10 to 20 ft. above it.

This tract of land, some 1½ acres, is about ¾ mile from the center of the village. There are but two or three houses near by. At present about 20 houses discharge into the sewer leading to the land, and in the height of the summer season these houses contain about 200 persons. Before the new plant, described further on, was built the sewage from the population of about 700 was brought to this disposal area.

The writer went over this disposal area on a hot June day in 1892. No odor was noticed on the land receiving the sewage and only a slight odor along the ditch.

The sewage from four houses flows to a tank in another part of the town, from which it is discharged upon the natural surface of the ground. In the past six houses have been connected with the pipe line to this tract. Since the above was written the town has voted to establish a pumping plant to discharge the sewage of this section of the town into the ontfall sewer leading to the new disposal area, described below, provided the necessary land can be secured.

Lenox.—New Plant.

In 1887 the construction of a new disposal system was begun under the direction of the Selectmen and a committee. In 1888 the construction of the plant was put in charge of Mr. T. Post, who has since served as a sewer commission of one and as superintendent. Mr. E. W. Bowditch, of Boston, was the engineer for this plant, which was put in operation early in October, 1888.

This plant receives the sewage from a population of about 1,000, and consists of a settling tank and large stone drains for sub-surface disposal. It is located near and on a hillside above the Housatonic River. A line of 12-in sewer pipe about 2¼ miles long leads from the village to the receiving tank at the upper side of the field, about 800 ft. from the river. There are 17 acres in this tract, not all of which are yet in use.

The outlet sewer ends in a circular well arranged to divert the sewage at will into either side of the settling tank, a hinged gate swinging to close diverging channels. The settling tank is of masonry, and each side can be used alternately to permit the removal of sludge. The liquid from the top of the tank is drawn off through a pipe line which connects with six brick manholes, or wells. In the bottom of each of these manholes is an iron stopper gate, smaller at the bottom than at the top. A rod extends upward from this gate and ends in an eye. By raising the gate slightly a small amount of sewage passes down through the bottom of the manhole. The discharge can be increased by raising the stopper higher. The sewage passes through the bottom of the manhole into stone drains formed by digging trenches and filling them with stone. The drains are about 2 ft. wide at the bottom, 4 at the top and 4 ft. deep. Near the top of the drain an Akron pipe is laid with the bell joints on the down grade end, and through these joints the sewage escapes to the drain. They are covered over with earth and extend for some distance, say 300 to 400 ft., from the manhole across the field into a wooded area, where they end abruptly. There are six of these drains in use. They were designed to have at least equal periods of work and rest, but in June, 1892, four were being used at a time.

A man is employed to care for this disposal area, and gives practically his whole time to it. Close attention is necessary in order to prevent the admission of too much sewage to any one drain, as in such an event the sewage appears at the surface of the ground or at the end of the trench, instead of passing off through the earth and after purification through the underdrains to the river.

The underdrains connect below the field and the effluent is discharged into the Housatonic River just above a mill dam; the mill-owners preferring that the drainage be above instead of below the dam. The crude sewage can be discharged into the river, but it is not intended that it shall for any great length of time. When the water is not flowing over the dam no unpurified sewage is discharged into the river.

When the writer visited Lenox the effluent was not perceptible when it entered the river. There was no odor at the end of the effluent pipe, at the manholes at the head of the drains or on the field. At the receiving tank there was a slight odor. The effluent discharges into the river only a few hundred feet from the Lenox depot, close by the railway track.

The sludge is drawn out from the bottom of the receiving tank through about 200 ft. of 8 or 10-in. pipe to an earth pit. From this pit it is removed to a compost heap, the sludge being drawn from the tanks at intervals of from 8 to 21 days. In the spring of 1892 a year's accumulation of sludge was placed upon ⅛-acre of land and the land planted to corn. The year's accumulation of sludge, with the dirt which had been put with it, made at the end of the year 52 cart loads (size of cart not stated) of material.

SEDIMENTATION.

Amherst, Mass.

About the year 1881 Amherst, Mass., put in a plant for the disposal of sewage upon land. Amherst is a well known and attractive New England college town, situated on hilly land with good natural drainage. The town had a population of 4,512 in 1890. The sewage disposal plant followed close upon the introduction of a public water supply, which occurred in 1879. The first sewer served only a few houses, but there was no suitable water course near at hand into which it could discharge. The sewage, therefore, was conducted to a settling tank from which the liquid matter was drawn onto land through ditches and the sludge removed and spread upon land. This tank was tended by a farmer, without expense to the town.

Some three years ago the tar and other wastes from a gas lighting plant, which discharged into the sewer near the settling tank, caused the disposal plant to clog so that its workings have since been imperfect.

The separate system is employed, it should be stated, only a few house drains being connected with the sewers.

In 1891 the sewers were extended and an outlet built to a new settling tank some two miles from the center of the village and about 500 ft. from Fort River. This tank is of stone, cemented, about 15 × 20 ft. × 6 ft. deep, in two equal compartments. On the main to the tank are several manholes designed to permit sewage to be drawn out for irrigating the adjacent farms, but none of the farmers along the line have yet expressed a desire to use the sewage for this purpose.

Mr. Henry Hastings has agreed to care for the new sewage tank for five years from 1891 for the privilege of using the sludge as a fertilizer.

A 10-in. sewer pipe leads from the village to the new tank, where it branches into two 8-in. pipes leading to the two compartments. The flow from each of the two branches can be controlled by a sliding gate so that the sewage can be turned into the compartments alternately.

The sludge is removed from the tank once a week, more or less, by simply raising a Chapman gate and letting it flow into a pit excavated in the sand. There are two of these pits, one for each compartment of the tank. When the sludge is drawn from the tank it contains much water. This rapidly drains off through the sandy soil.

No attempt has yet been made to purify the sewage further than by the settlement of the sludge. The effluent flows through a pipe sewer 520 ft. long to Fort River. This plant was visited June 11, 1892, on a warm day. There was scarcely a bit of smell at the tank and sludge pits and none a few feet distant. The settled sewage was but slightly colored as it discharged into the river, and appeared to have no effect upon the stream further than to cause a slight green deposit or growth upon its bed for a few feet from the effluent pipe. As the system has been in operation only since 1891 little can be said regarding the results obtained.

About three-fourths of the sewage of the town goes to the disposal tanks which are southeast from the town and near to no houses except two or three farm houses. The other one-fourth of the sewage passes through an 8 and 10-in. pipe line to an ordinary field having a sandy soil, located about a mile from the center of the village. At this field the sewage practically passes directly onto some 3½ acres of land through ditches. Three heavy crops of hay per year are cut from this land, which gave only one light crop before sewage was applied to it, some six years ago. There was a slight smell at the point where this sewage discharges upon the land. The tract is not underdrained, and the sewage, so far as could be learned, does not give trouble by collecting in hollows. The land has a slight slope.

There are about six miles of sewers in the town. Mr. W. W. Hunt is chairman of the selectmen and has had charge of the sewerage system for some time. Mr. E. A. Davis, of Amherst, did the engineering work for the town in 1891.

MECHANICAL SEPARATION BY FILTRATION.

Atlantic City, N. J.

The sewage purification works at Atlantic City are of unusual interest because a record is kept of the actual amount of sewage disposed of each day, all the sewage being pumped. The daily pumping records for a year have been obtained through the kindness of the superintendent of the system, Mr. A. M. Jordan, and are presented below, with the aid of diagrams and tables. The works are also of interest because of some details of the construction of the sewerage system, which have been given space here as worthy of record, although only indirectly connected with sewage purification.

The system of purification in use at Atlantic City consists of an elevated filter bed, in which sand with hay below is used as a filtering material, and from which the effluent falls in small streams or in drops some 3 ft. to gathering gutters which lead to an effluent pipe. It is claimed for this system that filtration is supplemented by aeration, and thus that greater purification is secured. The rate of filtration at Atlantic City is so rapid, as stated in detail below, that only partial mechanical filtration, or straining, can be expected, and this is all that is claimed for the plant, by its superintendent, at least.

Atlantic City is a well known seaside resort which has many visitors in the winter, but a much larger number in the summer. Its population in June, 1890, was 13,055, against 5,477 in 1880. It is said that during the height of the summer season as many as 150,000 people are to be found in the city on some Sundays.

Water-works were built in 1883 by the Atlantic City Water-Works Co., and in 1888-9 the Consumers' Water Co. built works. The city bought the works of the Consumers' Water Co. in the latter part of 1892, and the council has voted to buy those of the other company.

In November, 1884, the city granted a franchise for a system of sewers to the Improved Sewerage & Sewage Utilization Co. The system was built in 1885, with Robinson & Wallace, 129 East Twenty-third St., New York, as contractors, and with Mr. A. M. Jordan in charge of construction. Mr. Jordan has since been, and now is, superintendent. The old company went into the hands of a receiver, and was reorganized as the Atlantic City Sewerage Co.

The franchise provided that the sewerage system should be built under the "West Patent," granted to Mr. W. S. West, which covered some details of the pumping system, and also in accordance with designs for filter beds submitted to the city council by Mr. West, some features of which have since been patented. The National Sewerage & Sewage Utilization Co., of New York, now control the so-called "West System."

There are now about 26 miles of sewers in the city, with which 2,140 connections had been made up to Dec. 1, 1892. Aside from the admission of water from a few roofs, the system is on the separate plan. Most of the roof water is introduced at dead ends for flushing, but about ten houses are connected with the sewers, for which a rental of $2 per 100 sq. ft. per annum is charged.

Owing to the low level of the city all the sewage is conveyed to a well within the pumping station, shown with approximate correctness in the two sketches, Figs. 59 and 60. The pumping station is situated in about the center of the city, on the east and west line, but at the northern limit of the built-up portion, at the edge of the meadows. There are houses and other buildings close by it. A 20-in. cast-iron main conveys the sewage to the pump well.

In sinking the pump well, sheet piling, 3 ins. wide and 6 ins. thick, was used. As soon as water began to give trouble in the excavation, a pulsometer pump was used, which sometimes threw out 75% of sand. When the proper depth was reached, 20 carpenters were ready with a platform of planking on 6 x 8-in. timbers, which was lowered to place. The center piece shown in Fig. 60 was then placed, after which the pulsometer, which had been working until this time, was stopped, 3 ft. of concrete laid and water let in to harden the concrete. During the remainder of the work the pulsometer lifted water from a hole dug outside the sheeting. Above the concrete two courses of brick in Portland cement were placed, the first course on edge, the second flat. On top of the brick 3 or 4 ins. of cement mortar, 1 part sand, 2 parts cement, was placed. The sand used for mortar was brought from the mainland. The brick lining wall of the well is 27 ins. thick, including a 3-in. space to above the water line filled with coal tar, asphalt and sand, put in hot, enough asphalt being used to cause the mixture to harden. The wall was laid in Portland cement.

The pump well is 24½ ft. in diameter, and about 20 ft. deep, but only a part of the well is used for sewage, the pumps originally having been placed on a gallery floor in the well, shown in the section, Fig. 60.

As the sewage enters the pump well it passes through a screen of ½ or ¾-in. gas pipe, placed

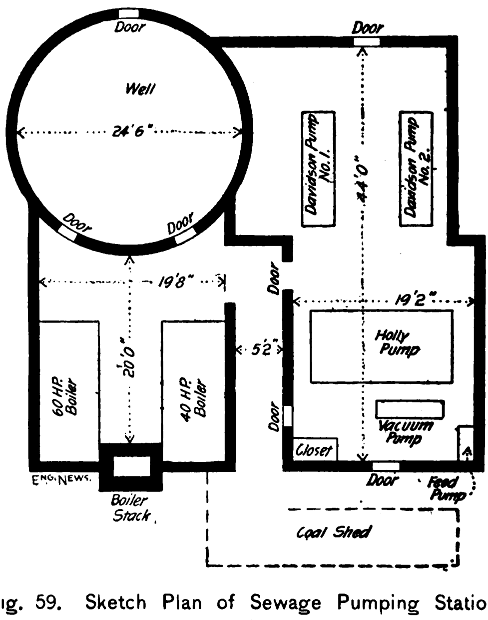


Fig. 59. Sketch Plan of Sewage Pumping Station at Atlantic City, N. J.

about 1½ ins. apart. In summer, it is stated, some three bushels of rags and other matter are retained by the screen, daily. A ventilation pipe extends from the pump well, above the sewage line, to an outer flue around the smoke flue of the boiler chimney. On descending to the floor in the pump well the writer found only a very slight odor, nor was there anything offensive in or about the pumping station.

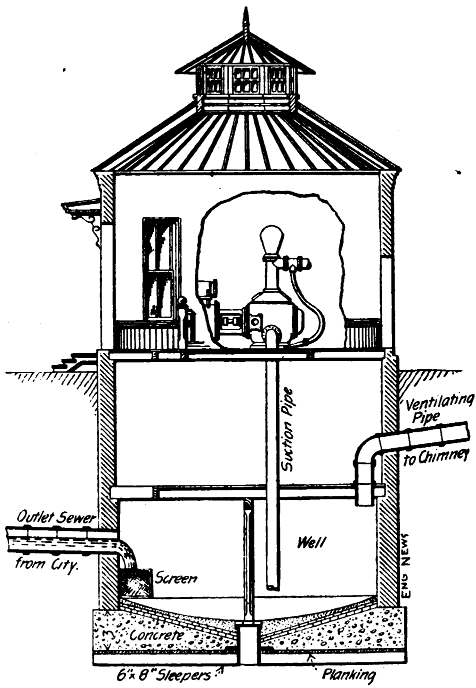


Fig. 60. Approximate Section through Pump Well.

As has been stated, the pumps were first located in the well, which, with the boiler room, constituted the station. For about two years the sewage was pumped with the pulsometer, but of course this proved to be too expensive, and for this temporary plant two Davidson pumps, each with a capacity of about 1,000,000 gallons, were substituted. Some two years or more ago a 7,000,000-gallon Holly pumping engine was added. The present location of the pumps and the 40 and 60-HP. boilers is shown by the sketch, Fig. 59. The addition of an 80-HP. boiler has been spoken of, for use in connection with the Holly pump.

A 16-in. cast-iron force main extends from the pumping station across the meadows to the filter beds, a distance of 3,200 ft. The force main was originally about 1,100 ft. long, ending in a filter bed nearer the city, and about half the size of the present bed. The filter beds are about 25 ft. above the bottom of the pump well. Mr. Jordan states that the pump register shows about 15 lbs. pressure when the pumps are run at moderate speed, and about 30 lbs. when run very fast.

The structure which supported the filtering material of the old filter beds, like the present ones, was of wood, which, after four years of use, became decayed. Meanwhile property owners who wished to sell lots in the adjacent section of the city complained that the beds were too close by their land, so when new and larger beds were built they were located as stated above.

The present filter beds are 30 ft. wide by 130 ft. long, divided into eight sections. A wooden trough, extending through the center of the bed, lengthwise, conveys the sewage to the different sections. The filtering material is supported by 2 x 10-in. plank on edge, 2 ins. apart, and consists of from 15 to 24 ins. of hay, generally heavy sedge grass, cut near the beds, above which is from 6 to 8 ins. of sand, dredged from the adjacent creek. Boards are laid on top of the sand, apparently with the intention of causing a more even distribution of the sewage over the entire area, the boards being laid a short distance apart, and being perforated with augur holes. The sewage passes from the central channel directly onto each compartment through openings which are closed, when desired, by boards moving vertically.

The effluent drops some 3 ft. onto a wooden platform, from which gutters convey it to a terra cotta pipe, 30 or 40 ft. long, ending in the creek.

In summer it is stated that the filtering material, both sand and hay, is renewed once in two weeks, four sections per week, and in winter, once in four weeks, two sections per week. The sludge from the surface of the beds is buried beneath sand, close by, and the waste material is used for filling in about the beds.

The writer visited the beds Oct. 27, 1892, early in the morning of a clear, cold day. About 4 ins. of sludge, the accummulation of a week, was found on one section of the beds.

The creek at the point of discharge of the effluent showed scarcely any sign of pollution, there being only a slight deposit of fine matter on the bank of the creek, which appeared to have come from the beds. Many small fish were observed in the water at the mouth of the effluent pipe. The attendant stated that there are always fish at this point.

A slight musty odor was noticeable at and about the beds, but appeared to come from the sewage soaked wood rather than from the sewage itself. At a distance of 400 or 500 ft. from the beds, facing a strong breeze from that direction, a slight odor, not especially unpleasant, was noticed. The effluent beneath the beds was found to be cloudy, which, with the presence of the fish at the mouth of the effluent pipe, as though securing food there, appeared to indicate that appreciable quantities of solid matter were passing through the beds. But notwithstanding the color of the effluent and the presence of the fish, the creek showed but a very slight pollution.

The fish just spoken of do not necessarily feed directly on solid matter from the sewage effluent, but may feed upon lower forms of life, which, in turn, feed upon the organic matter in the effluent.

The removal of the solid matter by straining is the principal object of the beds as now operated, and not the nitrification of objectionable organic matter in the sewage. That only the grosser particles of solid matter can be removed by the beds is evident from the rapid rate of filtration, as shown by the pumping records of the year ending Nov. 30, 1892, as follows:

Assuming that the available filtering surface is 3,800 sq. ft., the minimum amount of sewage filtered in one day during the year was 323 gallons per sq. ft. of filtering surface, or about 14,000,000 gallons per acre. The average daily rate of filtration for the whole year was 573 gallons per sq. ft., or nearly 25,000,000 gallons per acre. The month of July showed the greatest total pumpage of sewage of any month of the year, and gave a rate of 791 gallons per sq. ft., or nearly 34,000,000 gallons per acre, while the greatest pumpage in any one day during the year was at the rate of 1,036 gallons per sq. ft. of filtering area, or nearly 45,000,000 gallons per acre. When it is remembered that intermittent downward filtration through sand filter beds to the amount of 100,000 gallons per acre per day is a fair if not a high rate of filtration, it will be seen that only a very partial purification was effected during the year at Atlantic City, for, on an average, the sewage passed through the beds 250 times as fast as is consistent with thorough purification.

There has been no trouble with frost at the beds, it is stated, and at times in the winter the only open place in the creek is at the mouth of the effluent pipe.

The cost of the various parts of the disposal system is reported as $5,000 for the station and well, about $15,000 for the pumps and boilers, and some $1,500 for the last filter beds.

To operate the pumping station one engineer, at $75 a month, who makes necessary repairs, and two at $45 per month are employed. The yearly cost of coal is given as $1,200, and of lights, $50. A man is employed constantly at the filter beds at a salary of $40 per month, and for about eight months in the year an extra man is employed more or less of the time at $1.50 per day, more especially to aid in getting sand from the creek. Allowing 20 days' work per month for eight months for this extra man, the yearly cost of labor at the pumping station and filter beds is $2,700, which, with $1,200 for coal, $50 for lights, makes the total cost of operating the pumps and filter beds $3,950, not including incidentals. On the above basis the cost of operating the filter beds alone is $720 per annum.

Daily records of pumpage and coal consumption are kept by the company. The pump register is read at 12 m. each day, allowances being made for slip and wear of the plunger. The diagram, Fig. 61, shows the pumpage of sewage for each day from Dec. 1, 1891, to Nov. 30, 1892. The diagram also shows the rainy days of the year, and the maximum and minimum temperature of each month, by dates. The figures from which the diagram was compiled are given to the nearest thousand in Table I. Sundays and rainy days are indicated both in Table I. and the diagram, Fig. 61.

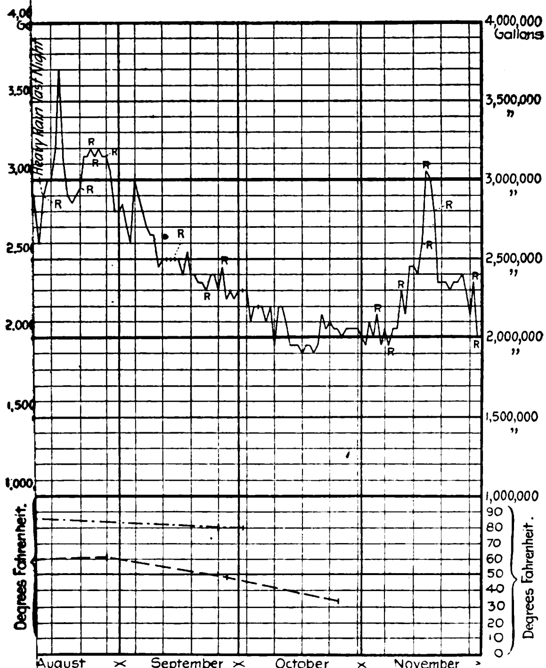
For an understanding of the diagram and the accompanying tables, it is necessary to state that there are two seasons at Atlantic City, a winter and a summer. The winter season begins about Jan. 15, and is said to continue often until June 15, when the summer season opens. In July and August it is said that in 1892 the average population was 100,000. The resident population is at present about 15,000.

TABLE I.—Daily Pumpage of Sewage in Thousands of Gallons at Atlantic City, N. J., from Dec. 1, 1891, to Nov. 30, 1892.

	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	
1	1,642	1,549	1,728	1,940 R	1,410	1,998 S	2,116	3,456 R	2,925	2,851	3,212	1,941	1
2	1,604	1,749 R	1,711	1,872	1,2[illegible]9	1,996	2,083	3,390	2,979	2,721	2,250 S	2,087	2
3	1,529	1,643 S	1,681	1,824	1,760 S	2,002	2,064	3,1[illegible]5 S	2,999	2,614	2,120	1,990	3
4	1,509 R	1,625	1,673	1,807	1,842	1,997	2,179	3,938 R[2]	2,862	3,001 S	2,208	2,133 R	4
5	1,638	1,615	1,719	1,767	1,762	1,832	2,218 S	3,198	2,822	2,897	2,208	1,932	5
6	1,530 S	1,740 R	1,757	1,647 S	1,87[illegible]	1,965	2,133	3,106	2,837	2,797	2,200	2,026 S	6
7	1,547 R	1,702	1,682 SR	1,705	1,965	1,897	2,112	3,087	2,880 S	2,681	2,101	1,928 R[2]	7
8	1,670	1,694	1,633	1,740 R	2,183 R	1,974 S	2,018	2,995	2,897	2,663	2,207	2,059	8
9	1,698	1,681	1,621	1,845	2,012 R	1,893	2,170 R	2,879	2,936	2,657	1,949 S	2,070	9
10	1,612	1,722 S	1,623 R	1,751 R	1,858 S	1,710	2,537 R	2,877 S	2,907	2,444	2,175	2,298 R	10
11	1,662	1,504 R	1,651	1,743	1,826	2,214 R	2,382	2,730	2,608	2,517 S	2,187	2,144	11
12	1,598	1,665	1,632	1,758	1,822	1,920	2,309 S	2,756	2,922 R[1]	2,475	2,119	2,472	12
13	1,561 S	1,794 R	1,790	1,745 S	1,818	2,082	2,602	2,852	2,976	2,477	1,958	2,550 S	13
14	1,559	1,619 R	1,694 S	1,732	1,911 R	1,979	2,416	2,874 R	3,004 S	2,515 R	1,947	2,419	14
15	1,509	1,712 R	1,709	1,651	2,057 R	2,165 S	2,142	2,820	3,181	2,486	1,933	2,600 R	15
16	1,637 R	1,751	1,698	1,604	2,062	2,515 R[1]	2,509	2,762	3,699	2,400	1,920 S	3,073 R	16
17	1,530	1,728 S	1,655	1,678	2,034 S	2,401	2,180	2,865 S	3,083	2,551	1,941	2,999	17
18	1,602	1,777 R	1,681	1,892 R	1,921	2,275	2,291	2,927	2,915	2,392 S	1,950	2,819 R	18
19	1,530	1,739 R	1,725	2,328	1,922	2,184	2,214 S	2,775 R	2,854	2,382	1,889	2,358	19
20	1,585 S	1,807	1,726 R	2,208 S	1,847	2,271 R[1]	2,293	3,466	2,912	2,338	1,952	2,374 S	20
21	1,561	1,796	1,676 SR	1,920	1,851 R	2,427 R	2,453	3,264	2,968 SR	2,347	2,168	2,362	21
22	1,542	1,740	1,746	2,004	2,451 R	2,260 SR	2,271	3,091	3,147	2,313 R	2,037	2,313	22
23	1,540	1,712	1,728	1,932 R	2,087	2,382	2,293	2,967	3,135	2,391	2,101 S	2,332	23
24	1,503 R	1,608 S	1,792	1,974	1,985 S	2,304	2,237	2,955 S	3,207 R	2,389	2,061	2,343	24
25	1,579	1,634	1,765	1,917	1,933	2,284	2,355	2,890	3,168 R	2,289 S	2,069	2,380	25
26	1,507	1,830	1,750	1,824 R	1,989	2,097	2,485 S	3,153	3,209	2,475 R	2,020	2,297	26
27	1,527 S	1,742	1,708	1,892 SR	1,911	2,191	2,387	2,881	3,128	2,244	2,029	2,141 S	27
28	1,563	1,739	1,728 S	2,074	1,821	2,216	2,368	2,821	3,150 SR	2,285	2,074	2,351 R	28
29	1,616 R	1,721	1,874	1,933	1,801 R	2,132 S	2,388	2,811	3,054	2,231	2,049	2,069 R	29
30	1,758 R	1,700	.....	1,889	1,896	2,029	2,369 R	2,865	2,813	2,278	2,014 S	2,019	30
31	1,623	1,680 S	.....	1,824	.....	2,048	.....	2,998 SR	2,820	.....	1,994	.	31
Total	49,100*	52,748	49,556	57,419	56,735	65,622	68,870	93,935	92,997	75,102	64 171	68,719	
Average	1,584	1,701	1,709	1,852	1,891	2,117	2,296	3,030	3,000	2,503	2,070	2,291	Year

S = Sunday. R = Rain. R[1] = Heavy rain previous night. R[2] = Rain previous night.

* Footings may not correspond exactly with totals given, as former include the odd figures omitted from hundreds column.



OM DEC. 1, 1891, TO NOV. 30, 1892.

It is stated that there are over 600 hotels and boarding houses and nearly 4,000 houses in the city.

That not all of the buildings are supplied with water, and that all so supplied are not connected with the sewers, is shown by the following figures:

Dec.	Number of taps. Atlantic City Water-W'ks Co.	Consumers Water Co.	Total.	No. of sewer connections.	Excess of water over sewer connections. Number.	Per cent.
1891...	2,273	500	2,773	1,849	924	50
1892...	2,463	500	2,963	2,140	823	38

The relative average daily amounts of water consumed and of sewage pumped from Dec. 1, 1891, to Nov. 30, 1892, are shown in Table II., the figures for the Consumers' Water Co. not being based on accurate records, but being estimated by the engineer of the company for use in this connection.

TABLE II.—Average Daily Water Consumption and Sewage Pumpage, by Months, at Atlantic City, N. J., from December, 1891, to November, 1892.

	Average daily consumption of water.			Average daily sewage pumpage.	Excess water over sewage.	
	Atl. Cy. W. W. Co.	Consumers' W. Co.	Total.		Amt.	Per cent.
Dec....	1,863.575	330,000	2,193,575	1,583,867	609,708	32
Jan....	1,960,374	380,000	2,340,374	1,701,537	638,837	37
Feb....	2,162,669	450.000	2,612,669	1,708,832	903,837	53
March	2,376,137	470,000	2,846.137	1,852,237	993,900	54
April..	2,543.735	500,000	3,043,735	1,891,182	1,152,553	61
May...	3,006,077	480,000	3,486,077	2,116,843	1,369,234	64
June...	2,604,730	518,000	3,122,730	2,295,652	827,078	36
July...	2,815,731	550,000	3,365,731	3,030,156	335,575	11
Aug....	3,550,273	540,000	4,090,273	2,999,913	1,090,360	36
Sept...	3,854,781	535,000	4,389.781	2,503,404	1,886,377	75
Oct...	2,919,584	520,000	3,439,584	2,070,024	1,369,560	66
Nov....	2,232,419	475,000	2,707,419	2,290,624	416,795	18
Year..........			3,142,682	2,172,059	970,623	45

These figures show that the excess of average daily water consumption over sewage pumped ranged from 11% in July to 75% in September, and averaged 45% for the year. As stated above, there were 50% more water taps than sewer connections at the beginning of the year, and 38% at its close. The relative monthly consumption of water and pumpage of sewage is also shown graphically by the diagram, Fig. 62.

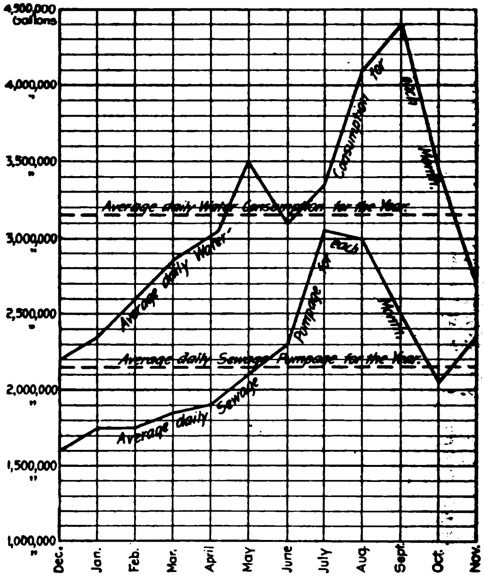


Fig. 62. Diagram Showing Average Monthly Sewage Pumpage and Water Consumption for One Year at Atlantic City, N. J.

The greatest amount of sewage pumped in any one day during the year was 3,937,720 gallons, which, it is interesting to note, was on July 4, on which date a large crowd of people generally visits the city. The least pumpage on one day was on

TABLE III.—Maximum and Minimum Daily Pumpage of Sewage, by Months, at Atlantic City, N. J., for the Year ending with November, 1892.

	No. sewer connections first of each month.	Average.	Maximum.		Minimum.		Variation.
			Amount.	Date.	Amount.	Date.	
December	1,849	1,583.867	1,757,760[1]	30	1,502,592[1]	24	255,168
January	1,887	1,701,537	1,830,432[2]	26	1,503,744[3]	11	326,688
February	1,892	1,708,832	1,873,728	29	1,620,672	9	253,056
March	1,910	1,852,237	2,328,192[4]	19	1,603,584	16	714,608
April	1,912	1,891,182	2,450,784[1]	22	1,228,896	2	1,221,888
May	1,961	2,116,843	2,515,584[5]	16	1,710,112	10	805,472
June	2,[illegible]04	2,295,652	2,601,888	13	2,017,728	8	584,160
July	2,035	3,030,156	3,937,720[6]	4	2,730,144	11	1,207,576
August	2,051	2,[illegible]99,913	3,699,344	16	2,607,744	11	1,091,600
September	2,[illegible]61	2,503,404	3,001,440	4	2,230,656	29	770,784
October	2,081	2,070,024	2,312,160	1	1,888,512	19	423,648
November	2,109[7]	2,290,624	3,072,864[1]	16	1,927,584[8]	7	1,145,280
Year	....	2,172,059	3,937,720	..	1,228,896	..	1,708,824

[1] Rain on this and preceding days. [2] Very cold. [3] Rain. [4] Rain previous day. [5] Heavy rain previous night. [6] Rain previous night. [7] 2,140 on Dec. 1, 1892. [8] Rain in night.

April 2. The maximum and minimum daily pumpage for each month in the year, with the date of the same, and also the variation between the two. the average for the month and the number of sewer connections on the first of each month are shown by Table III.

It will be seen by referring to the diagram, Fig. 61, and Table I., showing each day's pumpage for the year, that nearly every rainy day was accompanied or followed by an increase in the amount of sewage. The foot notes to Table III. show that for six months of the 12 the maximum pumpage was preceded or accompanied by rain, but the same was true of the minimum pumpage of three of the 12 months, though no heavy rains are mentioned in connection with minimum as with maximum pumpage. As has been stated, the separate system of sewerage is in use at Atlantic City, with a few roof connections, principally for flushing. Some leakage would be expected under the most favorable curcumstances, and actually occurs, as stated above. The maximum pumpage for January was on a day reported in the pumpage records as "very cold."

To see what, if any, effect temperature had upon the amount of sewage the maximum and minimum temperatures of each month were compiled from the United States "Monthly Weather Review," as given in Table IV., and then plotted on the diagram, Fig. 61. Low temperatures in winter, through waste of water to keep plumbing from freezing, and high temperatures in summer, might be expected to cause an increase in the amount of sewage, and doubtless do, but the figures compiled and plotted have a bearing upon only two days in each month, and are of little or no help in the study. Unfortunately, the "Weather Review" does not give daily temperatures, which would be of interest and value in this connection. As showing something of the temperatures of the whole of each month, the mean maximum, mean minimum, and the half of the sum of the two are given below for the year, in connection with the maximum and minimum temperatures and their dates. The total monthly precipitation and the average pumpage of sewage for each month is also given at the right, as of interest in this connection. The figures for November were not available.

TABLE IV.—Monthly Temperatures and Precipitation at Atlantic City, N. J., for Eleven Months Ending with October, 1890.

	Degrees Fahrenheit.								
	Max.	Date of max.	Min.	Date of min.	Mean max.	Mean min.	Mean max. and min. ÷ 2.	Precipitation, ins.	Av. daily sewage pump'ge.
December..	56	4	15	18	48	34	41.0	3.19	1,583,867
January...	53	2	10	21	39	26	32 5	3.02	1,701.537
February...	57	8	10	13	40	29	34.5	1.43	1,708,832
March.....	55	7	14	15	42	.8	35.0	3 69	1,852,237
April.......	76	6	28	12	53	40	46.5	3.05	1,891,182
May.........	80	16	40	8	64	51	57.5	5.51	2,116,843
June.......	89	22	51	11	74	63	68.5	4.44	2,295,652
July......	90	28	57	8	76	64	70.0	4.23	3,030,156
August.	86	9	61	28	79	68	73.5	3.26	2,999,913
September.	80	25	48	27	72	59	65.5	1.08	2,503,404
October....	80	1	33	25	63	47	55.0	0 30	2,070,024

The total and average daily coal consumption for each month, and also per million of gallons pumped, together with the number of sewer connections on the first of each month, and the total and average daily pumpage for the month is shown by Table V.

The total coal consumption for the year was 913,140 lbs. or 456.57 tons. The coal consumption per million of gallons pumped was 1,149 lbs. for the year, and ranged from 1,440 in December, the month of minimum pumpage, to 969 in July, the month of maximum pumpage. As stated above, the bottom of the pump well is about 25 ft. below the top of the filter beds, and the pumps work against a pressure of from 15 to 25 lbs., as shown by the pressure gage, the pressure generally being in the vicinity of 15 lbs.

TABLE V.—Monthly Sewage Pumpage and Coal Consumption at Atlantic City, N. J., for the Year ending with November, 1892.

		Pumpage, galls.		Coal consumed, lbs.		
	No. sewer connections.	Total.	Average daily.	Total	Average daily.	Per million galls.
December..	1,849	49,099 872	1,583,867	70,720	2,268	1,410
January....	1,887	52,747,646	1,701,537	68,340	2,205	1,296
February...	1,892	49,556,140	1,708,832	58,720	2,025	1,184
March......	1,910	57,419,350	1,852,237	71,680	2,312	1,249
April........	1,912	56,735,460	1,891,182	70,400	2,317	1,242
May.........	1,961	65,622,119	2,116,843	87,360	2,818	1,332
June	2,004	68,869,560	2,295,652	82,560	2,752	1,198
July	2,035	93 934,840	3,030,156	91,040	2,937	969
August....	2,051	92,997,306	2,999,913	92,520	2,985	990
September.	2,061	65,102,102	2,503,404	77,280	2,576	1,029
October	2,081	64,170,748	2,070,024	70,320	2,268	1,095
November..	2,109*	68,718 734	2,290,624	72,200	2,407	1,051
Year.....		794,973,877	2,172,059	913,140	2,495	1,149
Av per m'nth		66,247,823	... .	76,095	... .	... .

* 2,140 on Dec. 1, 1892.

The cold weather during the first part of January, 1893, seems to have had a marked effect upon the amount of sewage, the temperature and pumpage for each of the first 20 days of the month having been as follows, the thermometer and pump register being read at 12 m. each day:

	Temperature. F. °.	Pumpage. galls.		Temperature. F. °.	Pumpage. galls.
Jan. 1 ...	40	2,179,584	Jan. 12.......	22	2,393,168
2.	38	2,199 936	13	9	2,401,344
3 ..	29	2,194,941	14.......	12	2,497,162
4	18	2,250,528	15.......	18	2,301,960
5	24	2, 43,776	16.... .	4	2,295,960
6.... ..	24	2,152,472	17..... .	6	2,312,352
7.........	18	2,173,632	18.......	10	2,343,360
8.......	22	2,191,776	19..... .	21	2,246,208
9.........	24	2,208,288	20.......	16	2,261,160
10.........	14	2,263,968			
11........	7	2,326,272	Total		45,343,250
			Averages..	19	2,267,163

The average daily pumpage for January, 1892, was 1,701,537, against 2,267,163 for the first 20 days of January, 1893, and 2,172,059 for the year ending Nov. 30, 1891. The number of sewer connections increased only about 16% between January, 1892, and January, 1893, while the daily amount of sewage pumped in the first 20 days of January, 1893, was about 33% greater than the average for January, 1892. For the year ending Nov. 30, 1892, the lightest pumpage was in the month of January. From these figures it appears that the recent cold weather greatly increased the amount of sewage at Atlantic City, although there may have been other causes contributing largely to the increase, such as an unusually large number of visitors in the city, which seems hardly probable.

We are indebted for the above information to the president of the company, Mr. A. J. Robinson, of New York; to Mr. J. J. Deery, of the National Sewerage & Sewage Utilization Co., of New York; to the Atlantic City Water-Works Co., and the Consumers' Water Co., of Atlantic City; and especially to Mr. A. M. Jordan, of Atlantic City, who is superintendent of the company.

Leadville, Colo.

The coarse, solid matter in the sewage of Leadville, Colo., is removed by passing the sewage through a body of sand and gravel 24 ft. sq., and 6 or 7 ft. deep, the effluent being discharged into a stream, already polluted, called California Gulch. The sand and gravel are in two sections, which alternately receive the sewage for four or five days. When the solid matter at the top of the beds has had time to dry it is moved to a dump some distance from the city.

March, 1891, there were 8,900 ft. of 8 and 6-in separate sewers in use, with 15 ventilated manholes, 40 connections and four Rosewater flush tanks, each discharging 250 gallons once in 12 hours. The yearly cost of caring for the filter beds is given as $450. The sewerage system was built in 1886 by the Leadville Sewerage Co., of which Mr. Thos. W. Jaycox was engineer, and Mr. C. N. Priddy is superintendent. We are indebted to Mr. Jaycox and Mr. Priddy for the information given above.

The population of Leadville in 1890 was 10,834, it having fallen to this figure from 14,820 in 1880.

CHEMICAL PRECIPITATION.

Worcester, Mass.

The chemical precipitation plant for the purification of the sewage of Worcester, Mass., was described and illustrated in Engineering News of Nov. 15 and 22, 1890. Since that description was written some changes and experiments of interest have been made, and at present the daily capacity of the plant is being increased by adding 10 new tanks, which will make 16 altogether. It is expected that the new tanks will be in operation by June, 1893, and that the added capacity thus obtained will make possible the treatment of the entire dry weather flow of the city, which in April, 1893, was reported by City Engineer F. A. McClure as varying from 11,000,000 to 15,000,000 gallons per day. When first put in operation, June 25, 1890, and for some time, only 3,000,000 gallons daily were treated. Later the amount treated was increased, and on June 19, 1891, the daily treatment of 6,000,000 gallons was begun. This amount was in excess of the capacity of the plant, but it was considered better to treat this amount partially than a smaller amount thoroughly, as all the untreated sewage goes into the Blackstone River. When the writer visited the plant on June 17, 1892, about 4,000,000 gallons were being treated daily.

In 1886 the Massachusetts Legislature passed an act requiring Worcester to purify its sewage before discharging it into the Blackstone River. This river had become fouled with sewage, and its daily flow was so polluted that the manufacturers and residents along its course below the city united and secured the passage of the above law.

Mr. Chas. Allen, City Engineer, visited European sewage purification works, and finally recommended the construction of the chemical precipitation plant put in operation June 25, 1890.

The combined system is almost exclusively used in Worcester, a few lines having been built recently on the separate plan where there was a good opportunity to dispose of the storm water aside from the sewers.

The sewage of the city formerly found its way to the Blackstone River through Mill Brook, which is being gradually inclosed with masonry. This dilutes, but at the same time increases the volume of the sewage to be treated. Measurements have shown as high a daily flow of the brook as 19,500,000 gallons and as low a flow as 6,000,000 gallons, the latter in August and September and on holidays when the mills were not running. Measurements are made from time to time by turning the full flow of the brook into the settling tanks connected with the purification plant. On June 17, 1892, about 14,000,000 gallons were passing through the brook.

Mr. Allen has recommended the separation of the waters of the brook and the sewage.

From Mill Brook sewage is brought to the purification works through a 42-in. circular brick sewer with a fall of 6 ins. to 1,000 ft. and a daily capacity of 15,000,000 gallons.

The precipitating chemicals are admitted to the sewage after it has passed through screens, on its way to the settling tanks, and thoroughly mixed with the sewage by means of arms which project into the channel. The sewage passes slowly from one to another of the six tanks, and after being clarified by precipitation passes from the sixth tank into the Blackstone River. The sludge drains into a tank, when the settling tanks are cleaned, is raised by a centrifugal pump and passes to sludge beds.

Before considering the disposal of the sludge attention may be given to the process of purification. This, as practiced at first, was very fully described in our issue of Nov. 15, 1890.

When the works were first put in operation large and constant quantities of lime and sulphate of alumina were used. It was soon found that the character of the sewage was extremely variable, and tests have established the fact that at times, with proper manipulation, no chemicals are necessary. This change in the character of the sewage is due to the admission to the sewers at intervals of four to five hours of acids carried in manufacturing wastes. At present when the arrival of the acid sewage is detected it is at once treated with lime until thoroughly alkaline. The acid sewage flows about 1½ hours, and tanks Nos. 1 and 2 become charged with it. When this acid flow stops the adding of lime to the sewage is also stopped. The crude sewage passes into tanks Nos. 1 and 2, where the excess of chemicals is generally sufficient to serve as a precipitant for added sewage until the next discharge of acid sewage appears. In this way the amount of lime has been reduced to about one-half of that originally used. The sulphate of alumina is but little used now, there being ferric sulphate in the sewage, which, together with the above described treatment, is sufficient for clarification.

Originally the lime was ground at the works, but now it is slaked in a vat, a ton at a time. In this way about 23% of lime and 30 HP. is saved, which is partially offset by the fact that the lime must be slaked by hand. Either sewage or water may be used for slaking.

The agitators formerly used to mix the chemicals are still used, but this is because there is no other means of getting the lime through the pipes to the sewage below.

Lime made at North Adams, Mass., is now bought by the carload from L. J. Follett & Co.

During the year ending Nov. 30, 1891, there were treated 1,399,000,000 gallons of sewage, or about 3,830,000 gallons daily, from which 22,042,000 gallons of sludge was precipitated, the sludge having been pumped to sludge pits. The solids in the sludge aggregated 1,230 tons, or about 3⅛ tons a day, all of which was diverted from the river.

The amount of lime used during the year was 757.78 tons, and of alumina 64.645 tons. As has been stated, these chemicals were used in varying quantities, and often the alumina was not used at all, still giving the averages for what they are worth, and we find that for the whole year the average amount of lime used per gallon was 7.6 grains and of alumina 0.65 grains.

The disposal of the sludge, the solid part of which amounted in 1891 to 3⅛ tons per day, has been a serious problem from the start. At first the sludge was put in heaps and covered up, but this did not give satisfaction. Three different sludge furnaces were tried, but the labor involved was too great, although the sludge formed its own fuel, after once kindled. In one of these furnaces sludge containing 50% of water burned quite rapidly, while some containing 72% of water burned at the rate of 2.225 tons in nine hours, unaided by other fuel. In the spring of 1892 the sludge which had accumulated since September, 1891, was carted away at the expense of the city and put onto farm land.

As late as the spring of 1891 there were only eleven sludge beds, covering an area of about three acres. These had been overworked until they were almost useless. When the sludge on the beds did not exceed a few inches in depth it was found that it dried quite rapidly. An area of 5.7 acres was therefore added to the sludge beds. The first beds were not underdrained, but the later ones have been. The sludge passes to the beds through wooden troughs.

The new tanks will have the same capacity each as the old ones, but will be of a different shape, their dimensions being 40 × 166⅔ ft., 5 ft. deep from the top of the weir. Sewage will discharge about 18 ins. deep over the weir. The old tanks were 66⅔ × 100 ft., 5 ft. deep. As has been stated, there will be ten of these tanks, increasing the capacity of the plant to 15,000,000 gallons per day.

In considering results at Worcester it must be remembered that the plant has generally been operated far beyond its capacity, and that no attempt has been made to treat the whole sewage of the city. Consequently those who opposed the scheme from the start and the people on the river below have expressed dissatisfaction with the results obtained. So far as can be learned the plant has given a very good effluent when not overworked, and most of the adverse criticism has been made by those ignorant of what was being attempted. It should be borne in mind that the city of Worcester is not trying to manufacture drinking water, but to prevent the most objectionable part of the sewage from going into the river. This it will undoubtedly accomplish as soon as its plant is large enough. The fact that storm water and the waters of a brook have to be handled as well as sewage is also to the disadvantage of the plant.

In 1892 Mr. F. A. McClure, formerly superintendent of sewers, succeeded Mr. Allen as city engineer.

White Plains, N. Y.

The description of the sewage purification plant for the village of White Plains may be prefaced by the statement that there are three other plants in the State of New York for purifying the sewage of towns in which the same process is used. These plants are located at Round Lake, Sheepshead Bay and Coney Island, and all use the patented process and the machinery manufactured by Mr. J. J. Powers, C. E., of Brooklyn, N. Y. In this process chemicals are used to precipitate the solid matter and chlorine to deodorize and disinfect the sludge. If desired, the whole of the sewage may be treated with chlorine. The chemicals are admitted to the sewage automatically by means of floats acted upon by variations in the sewage level in the tanks.

White Plains is a suburb of New York located on the Harlem Division of the New York Central & Hudson River R. R., 22 miles from the 42d street station. Its population by the census of 1890 was 4,042, it having increased 1,661, or 69.76% since 1880. It is the county seat of Westchester County.

A public water supply was introduced in 1885 by the Westchester County Water-Works Co., the supply being pumped from "springs" to a stand-pipe. On Sept. 1, 1892, we are informed by the Moffet, Hodgkins & Clarke Co., New York, who control the water-works, there were about 15 miles of water mains and 450 taps, the consumption of water being at the rate of about 350,000 gallons per day.

The sewerage system was put in use about March 1, 1892, it having been under construction for some time previously. Mr. Wm. Landreth, M. Am. Soc. C. E., Schenectady, N. Y., made the plans for the whole system, which were approved in 1889 by the State Board of Health of New York. Mr. Wm. B. Rider, C. E., South Norwalk, Conn., was made engineer of the work after construction started and later Mr. E. D. Bolton, C. E., now of Brookline, Mass., was made engineer and under him the works were carried out until put in operation. Mr. Geo. R. Byrne, C. E., of Byrne & Darling, White Plains, was resident engineer in charge of construction under Mr. Bolton. The changes in engineers seem to have been caused by misunderstandings between the engineers and the village authorities. We are indebted to Mr. Bolton, Mr. Powers and Mr. Byrne for courtesies extended our representative while visiting the plant; also for drawings and information.

In September, 1892, about ten miles of sewers were in use. These sewers are 8, 10, 12, 15 and 18 ins. in diameter, while the trunk sewer to and from the purification plant is 24 ins. in diameter. From April 1 to Sept. 16, 1892, Mr. Robert Jackman, Sewer Inspector, informs us 222 sewer connections were made. Prior to April 1 Mr. Jackman thinks that about 20 connections had been made.

The separate system is used, with about 50 flush tanks, mostly Rhoads-Williams with a few Van Vranken. There are about 100 manholes in the system with perforated covers. As most of the roads or streets are of dirt these perforated covers admit much dirt to the sewers increasing the amount of sludge at the purification works. In addition, the attendant in charge of the works states that when new connections are made with the sewers some house owners take advantage of the opportunity to empty their cesspools.

Some 2½ miles of underdrains were laid about on the same level as the sewers, where deemed most necessary. These underdrains discharge into brooks where most convenient.

A 24-in. trunk sewer about 7,000 ft. long leads to the purification plant which is located about 5,000 ft. from the village on the west bank of the Bronx River close by the tracks of the Harlem Division of the New York Central & Hudson River R. R. This outlet pipe is of cast iron except the last 600 or 700 ft. which is vitrified pipe. Mr. Byrne states that cast iron pipe was probably used in order to exclude ground water. The effluent passes from the purification works through about 3,000 ft. of 24-in. vitrified pipe laid parallel to the Bronx River, into which it finally discharges just below a mill dam.

The plans and sections on the accompanying inset show the arrangement of the purification works. All of the plant except the large settling tanks is inclosed in a brick building, and the large settling tanks are covered over. The tanks inside the building have special covers. The plant is duplicated in order that one set of tanks may be in use while the other is being cleaned.

The main sewer from the village terminates in the well at the end of the building, shown on the inset, Fig. 13.* From this well the sewage may be turned into either set of tanks through the gates provided for the purpose. The enlarged section of the channel through which the sewage flows when it reaches the tank decreases its velocity so that much of the solid matter would be deposited without the aid of chemicals.

As the sewage enters it receives lime from the tank shown on the plan, and also perchloride of iron. It then passes through the tanks in the direction indicated in the plan, Fig. 13, and as is further shown by the longitudinal section in Fig. 13 and the several cross-sections in Fig. 14. Finally it falls over the weir into the long narrow chamber next the central wall. When this chamber fills it is emptied automatically by a 10-in. siphon. The varying levels in this chamber cause the discharge of the chemicals into the sewage, making this discharge automatic and maintaining a fixed relation between the quantity of chemicals and sewage, as is described in detail further on. The discharges from this siphon are received in another chamber and flow in a thin sheet over a long weir into the final settling tank, thus minimizing the disturbance of the sewage during settlement. When the large settling tank is full it also discharges by means of a siphon, passing through the outlet well or manhole to the effluent pipe already named. The last siphon is 12 ins. in diameter and all are of the Powers patent. The vertical screens shown on the plan, Fig. 13, remove the larger solid matter in the sewage. These screens, of which there are two for each set of tanks, are shown in detail by

*Figs. 13 to 17, inclusive, are on the accompanying inset sheets.

Fig. 18. They are made of ½-in. wire, 1 in. mesh, and are fitted with hinges to facilitate cleaning the tanks.

As the first compartment of the tank is deeper than the others, much of the solid matter settles and is retained in it, going to the bottom by its own weight. The chemicals deposit more of the sludge as the sewage flows slowly on. A sludge pit is provided in the center of each final settling tank, as shown in Fig. 13.

The sludge from the above pits and from the first compartment of the precipitation tanks may be

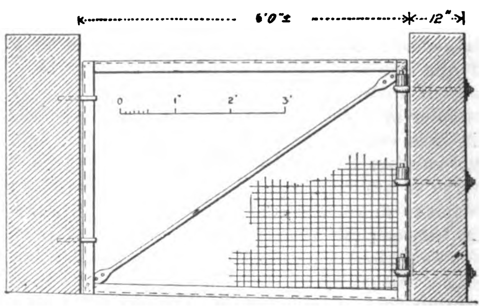
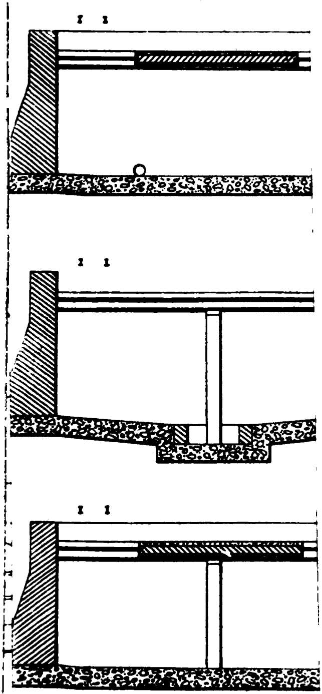


Fig. 18. Hinged Screen in Sewage Tank.

lifted by the 4-in. centrifugal pumps through the piping shown in Figs. 15 and 16 and discharged into the opposite side for further treatment. The "primers" of the pumps are charged through 1-in. galvanized iron pipe from the force main described above. The pumps are driven by engines supplied with steam from the boiler room. These pumps were made by Arthur Van Wie, Syracuse, N. Y. The sludge can be removed finally by means of the bucket, car and tramway shown in section in Fig.



HROUGH TANKS.

ING AND SETTLING

, N. Y.

16, the tramway being shown extending the whole length of the tanks, as shown in Fig. 15. The buckets have a capacity of ¼ ton, are of steel, self-dumping and are raised by differential one-ton hoisting blocks and tackle, which runs on an overhead single-rail tramway of one ton capacity.

The two dump cars are of ¼-in. boiler iron, one ton capacity. The car tramway consists of 60-ft. rails 2 ft. c. to c., clamped to the top of iron beams.

Before the sludge is removed from the tanks it is rendered less liquid and more easily handled by the addition of "German bog," said to come off the top of peat beds. This bog comes in bales 2 × 2½′ × 3½ ft. and is a good absorbent.

All the sludge which had been removed from the tanks from the time the plant was put in operation until Sept. 2 was outside the building in a pile on that date. Some of it was colored brown by the peat, some pink, presumably by the iron, but much of it had the appearance of ordinary lime and sand mortar, due of course to the lime used as a precipitant and to the further fact that much dirt is admitted to the sewers through the perforated manhole covers, as stated above. This large heap of sludge was perfectly free from odor, quite as inoffensive as a pile of mortar. Neither was there the slightest offensive odor anywhere about the works.

This lack of odor, aside from the fact that fresh sewage is not the foul matter that many people think it to be, is owing to one part of the treatment which remains to be described. In Figs. 15 and 16 the location and elevation of two pairs of chlorine generators are shown. The gas from these generators is carried through perforated lead pipes around two sides of the tanks below the sewage level. This deodorizes the sludge and stops decomposition. The chlorine is applied only to the sludge but the whole volume of sewage might be treated in the same way. Chlorine, it may be stated, was considered by a committee appointed by the American Public Health

Association to investigate the whole subject of disinfection as one of the best known disinfectants.

The sludge has been removed from the tanks and the chlorine used about once a month thus far. At the works it was stated that it should be removed once in two weeks.

The tanks may be washed perfectly clean by the use of water from a small reservoir on the hill or by direct pressure from a small duplex Deane pump provided to fill the reservoir. This pump also affords fire protection for the building. The pump has 10-in. steam and 6-in. water cylinders with 10-in. stroke. A 6-in. suction pipe extends to the river, only a few feet distant. A 4-in. force main extends from the pump to the reservoir on a hill near by at a sufficient elevation to give a pressure of 47 lbs. at the works. From the force main a 2-in. galvanized iron pipe extends through the building and connects by means of 1-in. cast iron pipe with the chlorine generators and tanks. Connections are also made with all the plumbing where water is needed. Linen hose, 200 ft. in length, is provided for washing the tanks and for fire use.

The reservoir is of stone, cemented, 20 × 10 × 5 ft. and, according to the specifications, covered with a building and connected by an electric indicator with the pump room.

The settling chambers inside the building have rolling covers, the wheels running on I-beams, the wheels of one set of covers running on the upper and of another on the lower flange of the beam so that the covers of one side may be rolled over or beneath those of the other (see section in Fig. 13). The specifications call for a tackle so rigged that one man can roll the cover. No such tackle was in use when the writer visited the plant and the covers were moved with difficulty.

The final settling tanks are covered with 8-in. brick arches supported by 90-lb. I-beams resting on 12-in. brick piers. Openings 6 ft. long and 12 ft.

wide with sliding covers are provided in each corner of the covering of these tanks.

The bottoms of all the tanks are composed of 18 ins. of Portland cement concrete. The specifications state that all walls and piers to the height of the cross walls must be laid in Portland cement mortar and plastered with the same where brick is used; also that the entire inner surface of the tanks must be covered with two coats of asphalt paint up to the coping. Provision has been made for heating the building, including the settling tanks, by steam.

There are two lime tanks, as shown in Fig. 13, each of riveted wrought iron, $1\frac{1}{2} \times 2 \times 10$ ft. There are also two 2,000-gallon riveted $\frac{1}{2}$-in. wrought iron tanks for holding the perchloride of iron.

A hand hoist or elevator is provided in the chemical storage room (see Fig. 15) for lifting the chemicals to the mixing tray of the chlorine generators and for lifting materials for storage in the second story.

Fig. 17 is a front elevation of the building which covers the plant. The other elevations are very plain.

The details of the rolling covers for the tanks in the building are shown in section and elevation by Figs. 19 and 20. The covers are of tongued and grooved Georgia pine some 4 to 5 ins. wide by 2 to $2\frac{1}{2}$ ins. thick. The cover for one set of tanks rolls on the top flange, and those of the other on the bottom flange of a 12-in. I-beam.

The method of supporting the rails for the sludge tramway so they will not interfere with the rolling of the tank covers, just described, may be seen in Fig. 21.

In order that the chemicals used as precipitants may be admitted to the sewage automatically and in fixed proportion, the mechanism shown in Fig. 22 is employed for the lime and that shown in Fig. 23 for the perchloride of iron. Each of these devices depends for its action upon the varying levels of the

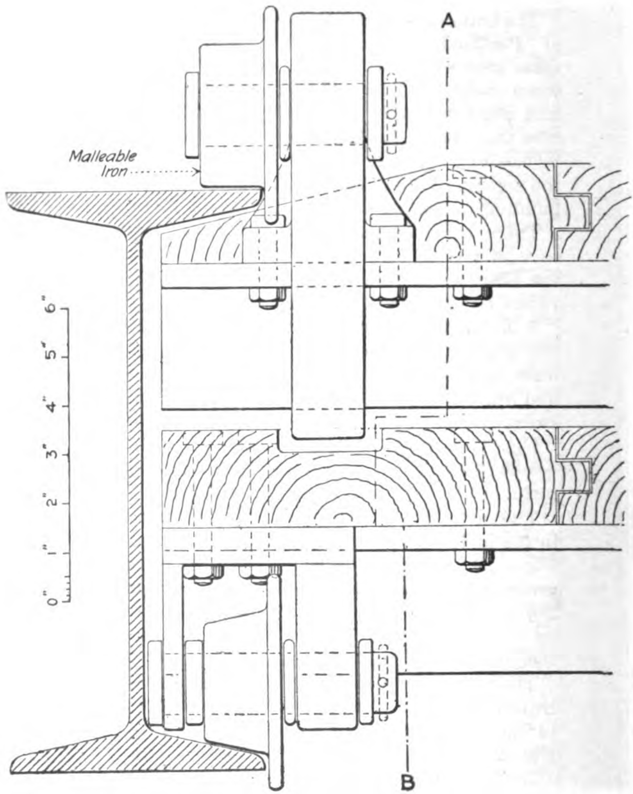


FIG. 19 CROSS SECTION THROUGH END OF PRECIPITATING TANK COVER.

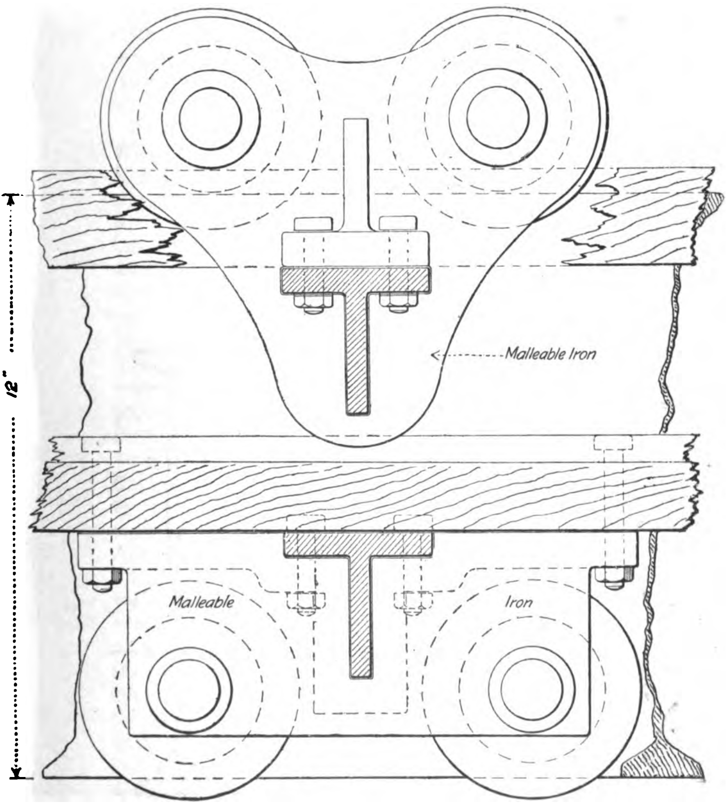


FIG. 20. SECTION AB (SEE FIG. 19).

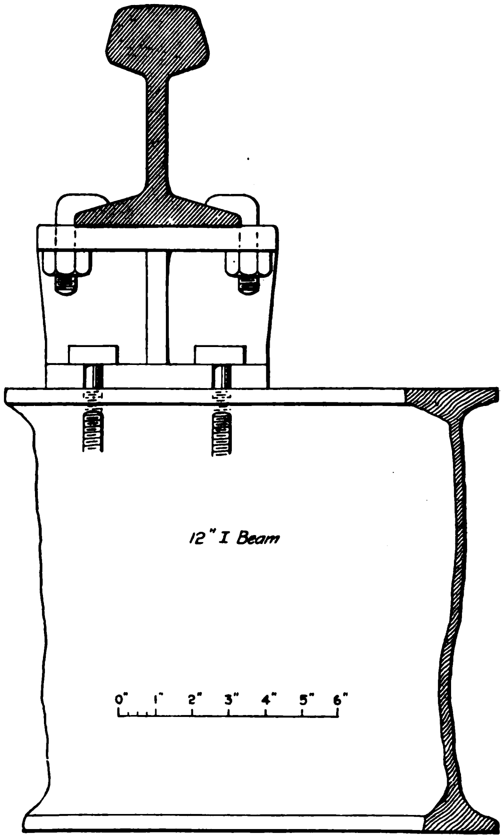


Fig. 21. . Chair for Supporting Tramway Rail on I-Beams.

sewage in a tank which contains a float connected by a lever with a cock, all so arranged, as described below, that the chemicals will be discharged in quantities and at intervals as desired.

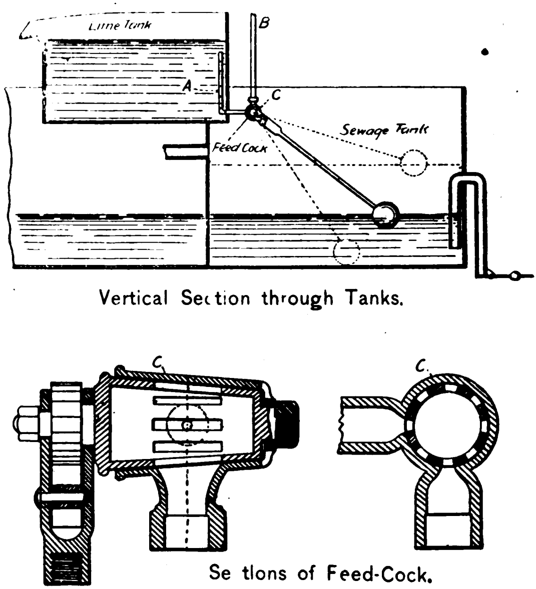
Both Figs. 22 and 23 are designed to illustrate the principles upon which the mechanisms work and not to show their exact arrangement at White Plains, although they do very nearly show the latter.

The lime is slacked in the lime tank, Fig. 22. Water is added to make a milk of lime which is fed into the sewage over the lip of the lime tank. Water is admitted to the lime tank through the pipe A which is supplied from an elevated tank on a hill through the pipe B and the feed cock. The water tank gives a pressure of 47 lbs. per sq. in. in the building. The pipe B is perforated at different levels, to cause the water to be discharged horizontally in order to stir up the lime, much of which would otherwise remain at the bottom of the tank.

The pipes A and B connect with the casing of the cock C, as shown in the two enlarged sections. The cock is inserted in this casing and is provided with longitudinal slots at regular intervals on its circumference, which are so arranged that whenever one of these slots opens against the contracted end of the pipe A another will open against the end of the pipe B and vice versa.

The float is connected with the plug in such a way that when it rises the cock is not turned, but when it falls a pawl engages with a ratchet and turns the cock so when the float is half way down the slots come opposite each pipe and water is discharged into the lime tank and lime carried over the lip into the sewage. If the feed cock was opened with the rise of the sewage it is obvious that the slower the flow of sewage the greater would be the discharge of lime.

The device for admitting the perchloride of iron, Fig. 23, is slightly different in that it is designed to measure this chemical accurately and to draw it from a storage tank of considerable size. To do this the storage tank is connected through a three-way cock with a small measuring tank placed on a lower level. The port of the cock which connects directly with the measuring tank is larger than the

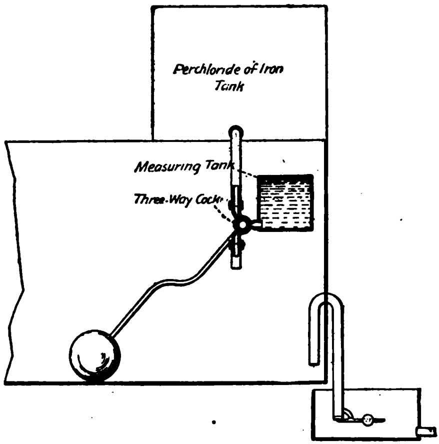


Vertical Section through Tanks.

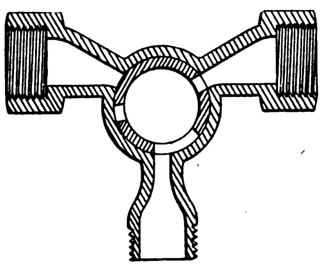
Sections of Feed-Cock.

Fig. 22. Automatic Feed-Cock from Lime Tank.

others and is always open. The third port connects, when in the proper position, with a pipe having its lower end over the sewage tank. The cock is turned automatically by the rise of the sewage so that the measuring tank is always emptied when or just be-



Vertical Section through Tanks.



Section of Cock.

Fig. 23. Automatic Three-Way Cock for Perchloride of Iron Tanks.

fore the float and the sewage are at their highest level and at no other time. The sewage is at its highest level just before it is siphoned from the chamber to the large final settling tank, shown by the inset in our issue of Sept 22.

In preparing the perchloride of iron for use, the storage tank is first filled about half full of water, the desired amount of the chemical added and then the tank filled full. This method is followed to prevent injury to the valve. A 60% perchloride of iron is used, and two grains per gallon is considered a fair amount for ordinary sewage. The perchloride of iron is bought from Martin Kalbfleisch Sons Co., New York, for 3½ cts. per lb., or about $4.75 per carboy.

The probable chemical action caused by the addition of lime and perchloride of iron to sewage in the manner described has been given by Prof. J. H. Raymond, M. D., as follows:*

When the sewage enters the first tank it consists of: (1) Organic matter in solution. (2) Organic matter in suspension. (3) Chlorides. (4) Sulphureted hydrogen and sulphides. (5) Sulphates. (6) Carbonates, including ammonium carbonate resulting from the decomposition of urea. (7) Phosphates. (8) Other ngr. dients

As a result of the addition of the milk of lime, the following changes take place:

The ammonium carbonate $(NH_4)_2CO_3$, is decomposed, and ammonia is set free.

The lime unites with the sulphureted hydrogen to form calcium sulphide, CaS.

The lime decomposes the sulphates, carbonates, and phosphates,—calcium sulphate, $CaSO_4$, Calcium carbonate, $CaCo_3$; and calcium phosphate, $Ca_3(PO)$, being precipitated. As these fall they carry with them the suspended organic matters. If magnesia salts are present in the water supply which is provided for moving the sewage, these will be decomposed, and magnesium hydroxide will be precipitated. Any iron and alumina salts will be decomposed by the lime, with

* "Treatment of Sewage by Chlorine, Precipitation and Sedimentation." By J. H. Raymond, M. D., Professor of Physiology and Sanitary Science, Long Island College Hospital.

precipitation of the corresponding hydroxides. Furthermore, it is probable that lime has a tendency to combine with and form insoluble compounds with the soluble albuminoids. All these would fall with the sludge. One of the important reasons for treating sewage with lime is to precipitate these suspended organic matters. They would, in time, without any chemical treatment, subside; but this would require so much time that before it was completed decomposition would take place, and, besides, enormous storage facilities would be necessary. These difficulties are obviated by hastening the precipitation by the addition of lime.

When the supernatant liquid passes into the second tank, its composition is, in the main, as follows:

(1) Organic matter in solution. (2) Chlorides. (3) Calcium sulphide and other sulphides. (4) Soluble oxides and hydroxides of bases, chiefly potassium, sodium, and ammonium, formerly combined with sulphuric, carbonic and phosphoric acids, together with the milk of lime, calcium hydroxide, $Ca(OH)_2$, which is in excess.

To this fluid, perchloride of iron, Fe_2Cl_6, is added, and, as the result, some of the soluble organic matters are coagulated and some are not affected.

The chlorides are practically unchanged.

The calcium sulphide is decomposed and iron sulphide is formed, and some sulphur is set free.

From the oxides and hydroxides of bases, ferric oxide is formed, and the bases are combined as chlorides.

From the excess of calcium hydroxide, ferric oxide is formed, and calcium chloride.

The effluent practically contains all of the above ingredients in solution, excepting the ferric oxide and such of the organic matters as are precipitated; these settle to the bottom of the second and third tanks.

It will be understood that the above is an abstract presentation of the case based upon sewage in general and not that of White Plains or any other locality; also that it presupposes the addition of perchloride of iron after the lime has had time to act upon the sewage. As such it is given without further comment.

In passing from a consideration of the use of chemicals, attention may be called to the fact that the lime is admitted intermittently to sewage which has a continuous flow and therefore some sewage may pass the series of chambers of the first tank to the weir over which the sewage flows to the first siphon chamber without receiving any direct addition of lime. Such sewage would have little or no precipitation to this point, but it would have sedimentation owing to the slow rate of flow. Since lime is discharged each time the first siphon works every discharge of sewage into the final settling tank will contain lime, the only question being whether it is well mixed with the sewage. It would seem preferable to discharge the lime into the sewage continuously, or nearly so. This might be effected by arranging the float and feed cock, Fig. 22, so that the water would be discharged into the tank with every few inches rise of the float, still maintaining a fixed relation between the lime and sewage. Or better yet a constant flow of lime might be maintained and the quantity varied to correspond with the volume of sewage by slowly passing the latter through a rectangular trough containing a lever-float which, rising and falling with the volume of sewage, would regulate the flow of lime through a feed cock. The advantages of having the lime thoroughly mixed with the sewage the moment the latter reaches the first tank are obvious.

The chlorine for deodorizing the sludge, or for treating the total volume of sewage if desired, is made from common salt, black oxide of manganese and sulphuric acid. The salt and black oxide of manganese are mixed, 1 to 1, in a tray above the chlorine generators, and washed down into the generator with 2½ parts of water. The cocks being turned to allow the chlorine to pass through the pipes and into the sewage tanks, sulphuric acid is then slowly admitted to the tanks and the chlorine generated. Acid should be admitted only in sufficient quantity to develop a pressure of 2 lbs., the pressure being indicated by a gage. A safety water column and safety gage are provided to keep the pressure down to 5 lbs., the blow-off pipe from the safety gage extending up through the roof of the building. In addition the covers of the tanks being treated should all be tightly closed, and it is well to have the windows and doors open. As inhalation of any amount of chlorine would be injurious to the nostrils, trachea and lungs, the precautionary measures mentioned are advised on the printed directions for the generation and use of the chlorine and the safety gage is made a part of the plant. In practice, however, no trouble with the chlorine is experienced. It is obvious that since the chlorine is used to disinfect sludge or sewage it will be admitted to the tanks only when the perforated pipes are submerged, and if the chlorine should pass up through the sludge it would at once make the fact known, whereupon the acid could be turned off from the generators. In practice it seems probable that a deficiency rather than an excess of chlorine will find its way to the tanks. It may be added that Dr. Raymond, quoted above, favors the introduction of the chlorine as the sewage enters, but this would mean continuous use, which might prove too expensive.

The capacity of the final settling tank is about 27,500 gallons and of the small siphon tank or chamber which empties into it about 2,000 gallons, allowing for the sewage which flows into the latter while it is discharging. The sewage travels about 150 ft. in the first or precipitating tank and 50 ft. in the final settling tank, making 200 ft. in all.

The amount of sewage treated at White Plains early in September, 1892, was said to vary from some 200,000 gallons or under per day to about 300,000 gallons, or less, for which about one barrel of lime and one carboy, 10 to 12 gallons, of perchloride of iron was being used.

There were early in September, 1892, about 450 taps connected with the water-works and about 250 sewer connections, which, being taken to yield as much sewage as the consumption of water per tap, 780 gallons, would give 195,000 gallons per day of natural discharge into the sewers. If the above figures are all approximately correct only a small amount of ground water now finds its way into the sewers. When the plant had been in operation only a month, however, it is said that the daily flow through the tanks was 266,000 gallons. At that time there were but few sewer connections and the greater part of the flow must have been ground water. The tanks are sunk in the old bed of the Bronx River, the river having been turned when the Harlem division of the New York Central R. R. was built, and at first there may have been some seepage into the tanks.

To operate the plant an engineer and a laborer are required during the day and a watchman at night. About one ton of coal a week is consumed in generating steam. The coal costs $6 per ton, delivered.

The contract price for the purification plant alone, without allowance for superintending construction, was $50,049. This was increased about $3,000 by errors in grade which necessitated the lowering of the foundations, but should not be charged to the cost of purification.

At the outlet into the river the effluent was somewhat clouded, which might have been due, in part at least, to the lime used. For several hundred feet down the river some of the finer particles of sewage were deposited in shallow water having little motion. In places these deposits were 3 to 4 ins. deep, but they gave off little or no odor upon being stirred. The deposits may have been the result of improper management of the plant, especially too infrequent cleanings, which, as has already been stated, have thus far taken place but once a month. It may be that the lime does not become thoroughly mixed with the sewage, for the reasons mentioned above, in which case imperfect precipitation might be expected.

In this connection it should be remembered that in constructing and operating sewage purification plants the controlling factor is the degree of purification desired. This decided, the next question is how to obtain it at the least possible expense. The large and inoffensive pile of sludge outside the purification building at White Plains witnesses that a great amount of pollution has been excluded from the Bronx River and rendered harmless. The deposits of sewage in the river gave no offense early in September, even when stirred, and it is possible that the chlorine treatment had to a large extent rendered the deposits unobjectionable so far as decomposition is concerned.

Sheepshead Bay, N. Y.

The purification plants at Coney Island and Sheepshead Bay, the well known seaside pleasure and sporting resorts, are each in the town of Gravesend, on Long Island. Each plant has been built under the direction of the Town Board of Health. Sheepshead Bay is not an incorporated village. Coney Island village in 1890 had a population of 3,313 out of 6,937 in the whole town of Gravesend, so the population of Sheepshead Bay is probably 3,000 or less. Both communities have large floating populations during the summer.

The sewerage system at Sheepshead Bay was begun in 1891 and put in operation about the middle of 1892. The separate system is used. Water mains are laid by the town in the trenches with the sewers, there having been about 13 miles of sewers and 15 miles of water mains in September, 1892. The sewers range in size from 24 to 12 ins., and are of cement. The pipe was made by Wm. G. Pierson, Brooklyn, N. Y. J. J. Powers, C. E., Brooklyn, is engineer for the plant, with Mr. Horace Loomis, M. Am. Soc. C. E., New York, as consulting engineer.

Although the same process is used at Sheepshead

Bay as at White Plains the details of construction are in some respects quite different, which is largely caused by the circular plan of the works and the fact that it was necessary to construct it on a pile foundation. The village is very flat and the surface of the ground is near the water line of the bay. The purification plant is located on marsh land subject to tide flooding, near an inlet or creek.

The 24-in. egg-shaped cement outlet sewer from the village comes across the marsh, turns and enters the building from the water side beneath the effluent pipe to the creek. The low levels and flat grades necessitate a deep receiving well from which the sewage is pumped to the tanks. The plant is in the town of Gravesend.

In constructing the receiving or pump well a caisson was used. The accompanying sketch, Fig. 32, is designed to give a good general idea of the way the caisson was constructed. A water jet was used in sinking the 5 × 9-in. tongued and grooved sheet piling, which was sunk 25 ft. below the "meadow."

The pile foundations for the main building are shown by Fig. 24, on the inset. The sections Figs. 25, 26, 28 and 29 and the developed section, Fig. 27, also on the inset, in connection with the description of the plant at White Plains, show the construction and arrangement and general operation of the whole plant.

The lime and perchloride of iron are discharged into the sewage while the latter is in the pump well, after which the sewage is pumped into the tanks. The location of the pumps and their suction and discharge pipes are shown in plan in Fig. 25, section A A. The sewage flows as indicated by the dotted line in Fig. 25 and as can be better understood by aid of the developed section, Fig. 27. There are no final settling tanks.

The details of the turntable in connection with the tram car and tramway are shown in Fig. 30.

In order to screen the sewage before it passes to the pumps it is discharged onto the platform screens shown in plan in Fig. 25 and in section in Fig. 29. A length of sheet iron pipe, mounted on rollers, shown by Fig. 31, is used to extend the inlet sewer so that the sewage may be discharged on the opposite screen while the first one is being cleaned, and vice versa. In practice it has been found that one screen answers all purposes.

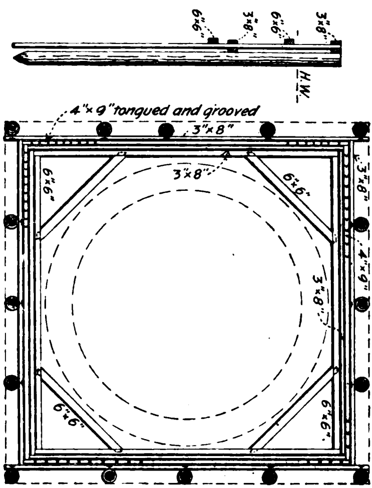


Fig. 32. Sketch Showing Method of Constructing Ca sson.

Two 50-HP. Wheaton-Harrison safety boilers, made by the Harrison Safety Boiler Works, Germantown Junction, Pa., are in use. The pumps are Deane, one 12, 16, 18-in., rated at 1,500,000 gallons and the other a 16, 22, 24-in., rated at 3,000,000 gallons daily.

A 6-in. centrifugal pump, driven by steam, and having a 6-ft. lift, was provided for handling the sludge but it is not used. Sawdust is now mixed with the sludge as an absorbent, after which it is shoveled into buckets, hoisted from the tanks and pushed out in the tram cars as at White Plains. The sludge is used to fill in about the building and was wholly inoffensive when the writer was at Sheepshead Bay, Sept. 12, 1892, as was everything else about the plant. The whole building is heated by steam and the village water supply is extended to the plant.

The effluent here, as at White Plains, was slightly clouded. This seems to be admissible here, as does the omission of the final settling tank, for the effluent goes into a considerable creek of salt water.

Chlorine generators are provided and the gas is used in the manner described under White Plains.

The saturated sand in which many of the sewers were laid at Sheepshead Bay, and also at Coney Island, necessitated especial care in preparing foundations; 6 x 6-in. piles were driven 9 ft. below low water mark, 6 ft. c. to c. The circular manholes were used where there was plenty of depth and the others in shallow places. All the 18 and 24-in. cement pipe used is egg-shaped, proportioned to give a flow equal to 18 and 24-in. circular pipe. The hubs are 2½ ins. deep.*

Provision is made for flushing the sewers from hydrants supplied by special flushing mains. Mathews hydrants with 4-in. branches and two 2½-in. connections are used.

Round Lake, N. Y.

Round Lake is a summer resort on the Delaware & Hudson R. R. near Saratoga Springs which has developed from a camp meeting ground

*Details of the pipe and manhole foundations are given in Engineering News for Sept. 29, 1892.

with tents for shelter to a collection of cottages and other buildings which serve a permanent population of perhaps 400 and a summer population averaging 1,500, perhaps, with 7,000 or more people on the grounds during some days. The cottages and property are owned by the Round Lake Association, of which Mr. J. D. Rogers is superintendent, financial and recording secretary.

Water-works and a sewerage system were built in 1887, the sewers having been laid in the same trench as the water mains. Money to pay for the water and sewer systems was raised by subscription and lot assessment.

A restricted amount of surface water is admitted to the sewers in the center of the village only. The buildings are so close together that a single house sewer serves from two to six buildings, thus reducing the total length of the sewers proper.

The only available water into which the sewage could be discharged was Round Lake, close by which the buildings are located. Some form of purification was therefore necessary. Broad irrigation was out of the question, as a sufficient area accessible by gravity could not be secured. An area of three acres was chosen for downward intermittent filtration, the location being governed by distance from the residence section rather than by suitability for the purpose. The land needed grading and underdraining. As nothing of the sort was done except to lay a few lines of tile, of course purification was not effected and a nuisance arose. It was finally decided to put in a plant for chemical treatment and the process of Mr. J. J. Powers, C. E., of Brooklyn, was adopted and has now been in use four seasons.

A sectional plan of the purification works is shown by Fig. 33 and several vertical sections by Fig. 35. All of the plant except the final settling tank and the sludge pumps is duplicated.

The pit A, Fig. 33, in the first compartment, is designed to retain a large part of the sludge. The screens S detain all large objects which have not settled, there being a screen or stop at the surface to intercept floating matter and a mesh screen placed across the channel. The sewage passes into the siphon chamber GB through the inverted trapped overflow O. The siphon SI removes the sewage automatically from GB to the long narrow chamber C, from which it overflows into D and again into L, from which the final siphon SI delivers it into the manhole N. From this manhole the effluent passes through a pipe to the lake, 700 or 800 ft. distant.

The lime is admitted to the sewage, as it enters the first compartment, from the left end of the lime tank LI. The perchloride of iron is admitted to the sewage before it passes through the first siphon, being discharged from the measuring tank MT, which is connected with the storage tank CI. Both the lime and perchloride of iron are discharged automatically through feed cocks worked by lever-floats, much as described under White Plains. For the lime tank a spring tripped by a cam on the lever is used instead of the revolving ports used at White Plains and Sheepshead Bay.

The chlorine generators CH are in a semi-detached building at the left ventilated by louvers.

When the precipitating tank AEFGB is cleaned, the liquid is first drawn off into the final settling tank through the valves shown in the plan, Fig. 33, after which the more fluid portion of the sludge in the pit A is, or may be, pumped into the other side for further treatment by means of the centrifugal hand pump located at P, in compartment E. Provision seems to have been made, also, for pumping from the pits H and M by centrifugal hand pumps. Such sludge as is not pumped from pit A has some absorbent mixed with it (charcoal dust has been used some of the time) after which

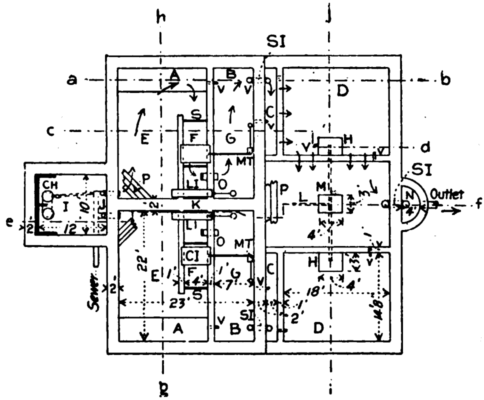


Fig. 33. Sectional Plan.

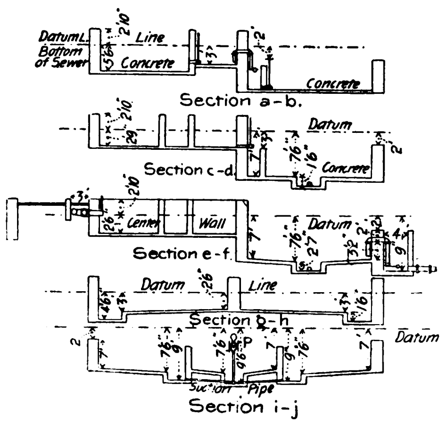


Fig. 34 Verti al Sections.

PURIFICATION WORKS AT ROUND LAKE, N. Y.

it is shoveled into an iron bucket, lifted by a differential hoist and finally conveyed to a cart by means of an overhead trolley.

The above description is condensed and the illustrations are taken from an article prepared by Mr. J. L. Fitzgerald, M. Am. Soc. C. E., which appeared in "Fire and Water" for Feb. 14, 1891. It therefore describes the operations of the plant as then practiced. Mr. Fitzgerald states that for the two seasons the plant had been in operation, 1889 and 1890, it had not been necessary to remove the sludge from the pits H and M more than once or twice in the season; that it was necessary to remove the sludge from pit A every four days during the season; that chemicals were not used in winter, sedimentation being sufficient for a population of only 400; that for the two years the average cost of labor and repairs had been $200 per year and of chemicals, $150.

Aug. 26, 1892, Mr. J. D. Rogers, superintendent, wrote us that during the past season lime and perchloride of iron had been used, but that chlorine, had not been used, because a cock could not be obtained that would "hold out against the corrosion of the chemicals more than a few weeks," after which it became dangerous. The plant had been run very well without the chlorine and the cost of its operation had thus been lessened. The cost of running the plant for 1892, Mr. Rogers stated, would be about $150, including chemicals and labor, while the resulting fertilizer would be worth about $30. Doubtless no extra labor is employed to operate the plant. In fact no labor is needed except for cleaning when a laborer or two employed about the grounds can do all that is necessary in a short time.

In criticising the plant Mr. Fitzgerald, in the article referred to, states that its most apparent defects are insufficient depth and area of the tanks and lack of thorough mixture of the lime with the sewage. The latter criticism coincides with that made regarding the plant at White Plains. Mr. Fitzgerald speaks of the rapid corrosion of the valves and wearing surfaces by the chemicals and says the use of chlorine gas as a disinfectant and germicide is the chief point of merit of the plant. If the latter statement be true it seems a pity to give up the use of chlorine to save the few cocks which might possibly be spoiled in a season. It may be added that chlorine is used at White Plains, Coney Island and Sheepshead Bay, where the cocks must be as badly corroded as at Round Lake.

The plans for these works were prepared by Mr. Wm. B. Landreth, M. Am. Soc. C. E., and the work carried out under the direction of Mr. J. Leland Fitzgerald, M. Am. Soc. C. E., both of Schenectady, N. Y. At the time the work was done these men were associated under the firm name of Landreth & Fitzgerald.

Coney Island, N. Y.

The sewage purification plant at Coney Island was first operated during the summer of 1887. At this plant the same process is used as at White Plains, Sheepshead Bay and Round Lake, but the details are simple, as the works at Coney Island were built first.

The extremely unsanitary condition of Coney Island in and prior to 1885 was reviewed at length by Mr. W. P. Gerhard, C. E., in Engineering News of Sept. 19 and Oct. 3, 1885. The condition there described must have grown worse until 1887, but since the sewerage system was constructed the sanitary improvement of the village has been great, especially since the erection of a garbage crematory in November, 1888. At present the sludge from the chemical precipitation plant is also burned in the crematory, rendering Coney Island unique among American cities in the disposal of its wastes.

For a full understanding of the unsanitary condition of Coney Island prior to the introduction of sewers the reader is referred to the two articles mentioned just above, which may be summarized as follows:

For many years the large summer hotels discharged their sewage into the surrounding salt water and the occupants of cottages and other small buildings used privies built over holes in the sand. These privies were sometimes moved and the pit filled with sand. Slops and kitchen waste were thrown or discharged on top of the ground. Gradually the beaches, bays and creeks became fouled with sewage. The fine sand of the island was not capable of rendering inoffensive the wastes it received and finally intolerable nuisances arose.

The large hotels were, naturally, first in attempting to improve their sanitary surroundings. Mr. J. J. Powers, C. E., of Brooklyn, the owner of the patents already described in these articles, states that as early as 1880 he put in a simple precipitating plant for the Brighton Beach hotel and at the same time, or later, a similar plant for the Brighton Beach Bathing Pavilion.

Mr. Gerhard describes the hotel works as two covered wooden tanks, each about 25 ft. long, 7 ft. wide and 3 ft. deep. Each tank was in two compartments. The first compartment had a screen and was designed to retain large solids. The sewage overflowed through a T into the second tank, where perchloride of iron was automatically admitted through a cock operated by a lever-float. A siphon emptied the second tank as soon as filled. Lime or gypsum and powdered charcoal were mixed with sludge to deodorize it before removal. It was then piled upon the meadows and at times was used for the hotel lawns. A pile of sludge found by Mr. Gerhard in August, 1885, he states, was inoffensive. The effluent from the tanks, however, be considered as imperfectly treated and as contributing to the pollution of the water which received it. The tanks were located about 1,000 ft. from the hotel and the effluent was discharged through a long pipe into Coney Island Creek.

The Manhattan Beach and Oriental Hotels and other buildings on Manhattan Beach belonging to the Manhattan Beach Improvement Co., had, in 1885, a joint sewer outfall discharging into a cove of Sheepshead Bay after mechanical separation of some of the solids. This separation was effected by passing the sewage through two long wooden boxes, for alternate use, near the end of which were two wire screens, the first having 1¼ and the second ½-in. meshes. From the end of these boxes the partially clarified sewage passed through a T-shaped overflow into the bay. The solid matter retained by sedimentation and screening was removed from the boxes, after gypsum and charcoal had been mixed with it, and spread upon a dock to dry. After drying, some of the sludge, it is stated, was used to fertilize the lawns about the hotels.

Mr. Gerhard states in his article that, while this process removed some of the solid matter, the effluent still fouled the bay. The sewage from these buildings is still treated by a separate plant owned and operated by the Manhattan Beach Improvement Co. The present plant, however, was built by Mr. Powers and is similar to the last three described in this series.

The necessity for a thorough sanitary reform at Coney Island led to the passage of an act by the New York Legislature in 1884, empowering the Board of Health of the town of Gravesend, of which town Coney Island is a part, to construct sewers and dispose of the sewage of any district of the town upon petition of a majority of the property owners of the district.

Before a system of sewage disposal was decided upon competitive plans were invited. The plans of Mr. Powers were selected by the board and were afterward approved by Mr. Robert Van Buren, M. Am. Soc. C. E., of Brooklyn. The Coney Island plant was put in operation in 1887.

The plan and longitudinal section, Figs. 35 and 36, show the general arrangement and operation of the plant before the use of lime was begun, about a week ago. Lime is now added to the sew-

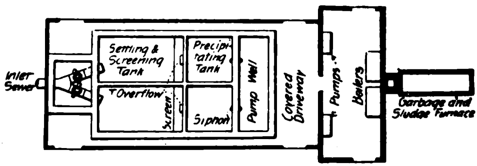


Fig. 35. Sketch Plan of Sewage Purfication Works at Coney Island, N. Y.

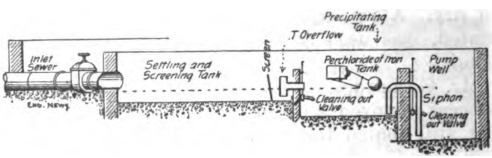


Fig. 36. Longitudinal Section through Tanks and Pump Well.

age as it enters the first tank. Perchloride of iron has been used from the start as a precipitant and chlorine as a deodorizer, as described in previous issues. The first year the works were operated the sludge was loaded into a scow, the works being close by Coney Island Creek. For the last few years the sludge has been burned in the crematory at the end of the building, shown by plan, Fig. 35. An overhead tramway is provided for moving the sludge after it has been shoveled from the tanks into buckets. Mixing with sawdust is employed to take up the moisture in the sludge and render it more easily handled. This also assists combustion, but is not at all necessary for that purpose. The two illustrations are intended as sketches, merely, scale drawings not being available.

Two 24-in. trunk sewers join into a 30-in. inlet pipe near the works. One of these sewers has a grade of 1 ft. in 1,500 ft. and the other 1 ft. in 2,000 ft., owing to the flatness of the island. The separate system of sewers is used, but a little roof water is admitted. Two Davidson pumps are provided to pump the sewage after treatment and discharge it through an effluent pipe into the creek or bay. There are two 50-HP. Wharton-Harrison safety boilers.

The crematory in which the sludge, in addition to the garbage from the town, is burned, was made by the Engle Sanitary & Cremation Co., of New York and Des Moines, Ia. The Board of Health collects the garbage and employs two men at the crematory, one for night service. In July and the first two weeks in August of this year an average of 100 bbls. of garbage were burned daily requiring about 1½ tons of coal per day. The crematory is run only during the summer months. Everything about the purification works seemed in good shape and was wholly inoffensive when visited on Sept. 12, 1892. A marked improvement in the waters of the creek and bay is said to have been effected by the sewerage and sewage disposal systems.

Coney Island, it seems hardly necessary to say in concluding, is a popular seaside summer resort a few miles from New York and almost adjoining Brooklyn. Its summer boarders and visitors combined doubtless exceed 100,000 for a few hours during some days. Its population in June, 1890, according to the Eleventh Census, was 3,313, against 1,184 ten years earlier.

Mr. John Y. McKane is President of the Gravesend Board of Health and Mr. I. G. Ring, is Engineer and Superintendent of Sewers and Water, a system of water-works having been built by the board in 1888 to flush the sewers.

East Orange, N. J.

The East Orange chemical precipitation and intermittent downward filtration plant for the purification of sewage was fully described in Engineering News of Jan. 5 and 19, 1889, and Feb. 15, 1890.

A brief description of the methods employed will be repeated before giving later information regarding the works.

East Orange is a suburb of New York with a population by the census of 1890 of 13,282, the township having grown to this size from a population of 8,349 in 1880. The present population is probably not far from 14,500.

The sewerage system was completed ready for house connections in the spring of 1888.

The sewage receives, and has thoroughly mixed with it at the disposal works, lime and sulphate of alumina. It then passes to settling tanks where much of the solid matter is retained and from which, after passing upward through a small amount of coke, the more or less clarified liquid flows to the filtration area. This area includes 14.7 acres, all underdrained, some of it being in beds 100 ft. long by 50 ft. to 100 ft. wide and the remainder having shallow furrows running in one direction 4 ft. apart, from which the sewage soaks into the land on each side. The filtration area being restricted in size, by local conditions, and the soil being of a retentive character it has been supplemented by small artificial beds of coke and gravel.

The sludge is drawn from the tanks, when the latter are cleaned, to a sludge well from which it is conveyed with the aid of air under pressure to Johnson filter presses and made into cakes.

The sewerage system and disposal works were designed by Mr. C. P. Bassett, M. Am. Soc. C. E.

On Nov. 24, 1892, the writer visited East Orange and obtained the following additional information from Mr. John J. O'Neill, Township Engineer, who has charge of the sewerage and sewage disposal systems:

There are now about 33 miles of sewers and 1,685 connections. There have been put in place more than 60 flush tanks, but, owing to a scarcity of water in the summer of 1892, many (nearly all?) were cut off, since which the sewers have been flushed by plugging up for 24 hours or so. Formerly the water company charged the township $20 for making a connection with a flush tank and $25 a year for water, but under a recent contract water for flushing is furnished without charge.

The daily flow of sewage is about 1,200,000 gallons, which is less than it was two years ago. The decrease is said to be due to the fact that the leakage of ground water into the sewers is decreasing. This leakage has in the past been estimated as equal to the total amount of sewage proper.

The chemicals used as precipitants have always been lime and sulphate of alumina. The amount of chemicals per gallon of sewage now used could not be ascertained, but in 1890 it was given as 3 grains of lime and 2 of sulphate of alumina per gallon. Mr. O'Neill states that about 5% more per gallon of the chemicals is used than at the time of the report of the Town Improvement Society, Feb. 2, 1891, which stated that one barrel of lime and 300 lbs. of alumina, at an expense of about $6 per day, were used, the average amount of sewage treated at the time having been estimated at 1,330,000 gallons.

The lime is bought of a local dealer at 95 cts. per barrel, delivered at the works. The sulphate of alumina costs about 1¼ cts. per lb., at the works, and is bought by the carload of Harrison Bros. & Co., New York. A porous alum has occasionally been used which costs 2⅝ cts. per lb., but is said to be more efficient than the sulphate of alumnia.

The chemical character of the sewage is quite constant, except as affected by ground water.

All of the sewage passes upward through a body of coke some 2 ft. in diameter and 4 or 5 ft. deep before passing onto the filtration area. This coke is renewed twice a week and is independent of beds of coke and gravel located in the midst of the filtration field which are used for downward filtration.

The sewage is put upon one tract of land for from 6 to 8 hours after which this tract has 36 hours rest.

Mr. O'Neill wrote under date of Nov. 26, 1892, that the cost of operating the disposal works for the nine months from Jan. 1, to Oct. 1, 1892, was $3,935 for labor and $2,146 for chemicals, coal, oil, canvas (for the filter press), sundries, repairs, etc. This makes a total of $6,080, which is at the rate of about $676 per month, or about $8,100 per year.

Appending the above cost of operating the disposal works for the first nine months of 1892 to the figures given in the report of the Town Improvement Society, we have the following operating expenses for the periods named, with the monthly averages for the same periods:

	For period.	Average per month.
July 9, 1888, to Feb. 28, 1889	$3,936	$562
Mar. 1, 1889, to Feb. 28, 1890	8,950	746
Mar. 1, 1890, to Jan. 2, 1891	8,815	881
Jan. 1, 1892, to Oct. 1, 1892	6,080	676

On a basis of 14,500 population, the average cost per year per inhabitant for operating the dis-

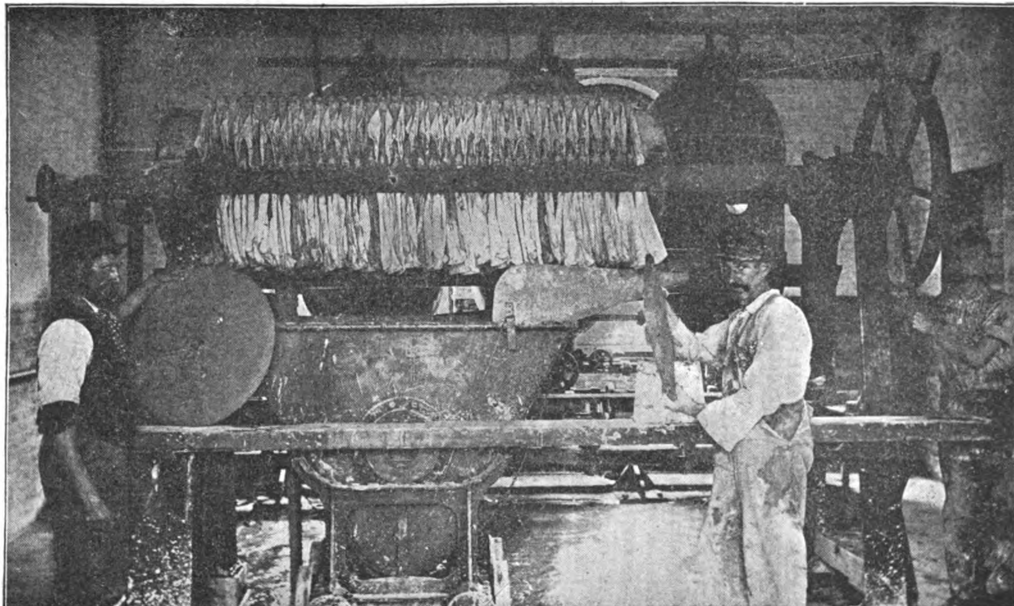


FIG. 44. JOHNSON SLUDGE FILTER PRESS, SEWAGE DISPOSAL WORKS, EAST ORANGE, N. J.

posal works during the first nine months of 1892 was about 56 cts. What degree of purification has been attained this year cannot be stated, but it is certain that no serious complaints have been made and the works, including the filtration area and the brook which receives the effluent, appeared to be in excellent condition on Nov. 24, 1892. Twice within a short time the writer has passed through the street upon which the filtration area abuts and close by which the chemical works are situated, without detecting anything to betray their character. The decreased cost of operating the works this year is said to be due to obtaining greater efficiency from the labor and not to using less chemicals.

The writer found the effluent as it was discharging into the brook to be somewhat cloudy but odorless. To the eye it appeared about like the effluent from the chemical precipitation plants described in this series of articles, but not as good as the effluent from the intermittent filtration plants visited.

The force at the works now includes a foreman, engineer and five laborers, one man being employed at night. The tanks are cleaned three times a week after which their sides are whitewashed or treated with some other disinfectant. The scum boards between the first and second compartments of the tanks, the attendant stated, did not float readily, as intended, and are now kept stationary at about 2 ft. from the bottom.

The Johnson filter press is shown by the accompanying view, Fig. 44. The sludge cakes from the press have an average thickness of fully 1 in. and a diameter of about 25 ins. There are about 35 cakes to each pressful and the attendant stated that the press is filled six or seven times a day. The sludge cakes are generally drawn to the township poor farm and there buried or disposed of otherwise. Farmers do not seem to wish the

& SONS, LITH. 36 VESEY ST., N. Y.

sludge, although it has been offered free for the carting away and some has been so taken. It is stated that some sludge has been sold at 50 cts. per load, but the amount is small. The sludge has been burned in a small furnace ventilated to the boilers, but objections were made on account of the odors, more probably fancied than real.

Both the attendant and Mr. O'Neill stated that there has been no trouble at the works from frost but the report of the Town Improvement Society, mentioned above, states:

A visit during the recent cold spell convinced the committee that the frozen ground prohibited any filtration through it, while the coke beds can be worked under all conditions of weather.

Sand and soil works its way into the underdrains and is removed at the junction of lateral and main drains through a vertical length of sewer pipe.

Long Branch, N. J.

Long Branch is a well known seaside summer resort. The population of the town in 1890 was 7,231, against 3,833 in 1880. A public water supply was introduced in 1877 by the Long Branch Water Supply Co. A sewerage system was put in operation in 1886 by the Long Branch Sewer Co., under a franchise granted by the town which provided that no objectionable matter should be discharged into the adjacent water. In order to discharge sewage into the ocean at the beach a system of mechanical separation aided by chemical precipitation was adopted, as described below.

On Dec. 1, 1892, there were in use about ten miles of sewers, over 400 connections, 118 manholes, all ventilated by 12 1-in. circular holes in the covers and provided with buckets below to catch the dirt from the dirt roads of the town. There are no flush tanks.

At dead ends the company has until recently connected rain water leaders to the sewers free of charge, but in the future a charge equal to one half the charge for an ordinary service connection will be made. In all about 100 rain water leaders have been connected with the sewers, those not on dead ends bringing in the revenue just mentioned. In this connection it may be added that the company's franchise provides that the yearly rental for sewer connections shall be two mills on the dollar on the assessed valuation of the property. Recently the town authorities passed an ordinance relating to houses occupied by more than one tenant, which provides that the yearly charge may increase directly with the number of tenants.

Aside from the rain water admitted to the sewers the separate system is used.

The sewage is all brought to a station located on Long Branch Ave., near Second Ave. The station is surrounded on all sides by shops and dwellings. A by-pass is provided to permit the sewage to be passed around the station, directly to the tidal chamber and ocean. During heavy rains in the winter season no attempt at purification is made, the sewage passing directly into the ocean. At all other times, it is stated, the sewage is treated.

The arrangement and operation of the purification works is shown by Figs. 50 to 53. As will be seen by the plan, Fig. 50, there are two receiving tanks, duplicates. These are constructed of concrete and are used alternately. Alum is admitted to the sewage before it enters the tanks. The sewage then passes beneath planks on edge, over walls, through submerged arches and finally over a wall to and through coke filters placed vertically, the flow being continuous. The coke is confined in removable wire cages 5 ft. deep and 1 ft. wide and the sewage passes through two of these, or horizontally through 2 ft. of coke.

The coke is renewed once a year. Doubtless it was originally intended that the coke should be renewed oftener. Its only purpose is to serve as a strainer. The coke for each renewal costs about $2.

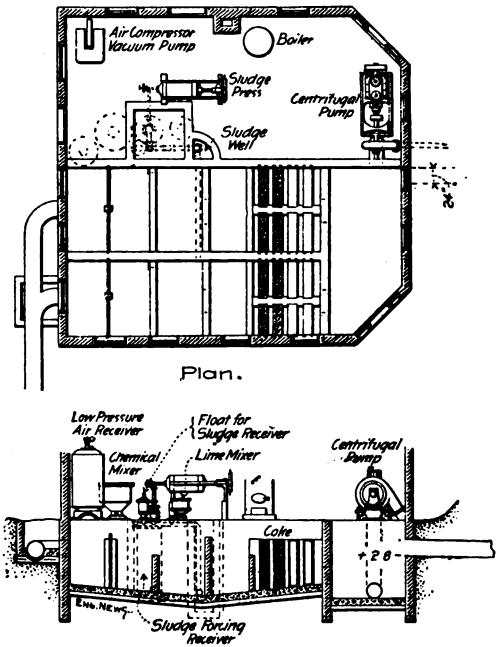


FIG. 50. PLAN AND SECTION OF PURIFICATION WORKS.

About 75 lbs. of alum per day, mixed with water in a 500-gallon tank, are used. It is said that about this amount has been used daily since the works were put in operation. The alum costs about 1½ cts. per pound, with freight from New York in addition.

Lime is used for treating the sludge only. The lime and alum mixers are shown in Fig. 50. "Sanitas" is used as a disinfectant about the station.

The sludge is removed by means of the apparatus shown in plan and section in Fig. 51. Fig. 52 is a photograph of the same apparatus which also shows the alum mixer. This apparatus includes an air compressor and vacuum pump, a low pressure air receiver. sludge receiver and Johnson filter press for pressing the sludge into solid cakes. In operation the air is exhausted from the sludge receiver, after which the valve in the pipe leading to the bottom of the sludge pit is opened and the sludge passes into the receiver. A float at the left indicates when the receiver is full. Lime is admitted to the sludge just before it enters the receiver. With the aid of the compressed air the sludge is forced from the sludge receiver into the cells of the filter press and there by the action of the compressed air the liquid is pressed out and the solid matter compacted into cakes.

At Long Branch the sludge is dropped from the filter press into the sludge car, without an effort to remove the cakes intact. The press has a capacity of 24 cakes but only 20 cells are now in use. A full press is said to contain about 21 cu. ft. of sludge. The sludge is given to one of the directors of the company and used on his farm. In summer the sludge is said to be removed once in three or four weeks. The officers of the company state that during the remainder of the year it is difficult to get enough sludge to show visitors the working of the sludge apparatus.

The small amount of sludge, the officials state, is explained by the fact that many sewer connections are made with cesspools, which retain solid matter.

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The sewage tanks were originally covered and were ventilated to a small furnace at the side of the boiler chimney, where tar was burned. The officials state that the perforated manhole covers afford all necessary ventilation. Therefore the tank covers have been removed and the ventilating furnace is not used. The effluent is pumped by a 6-in. Weber centrifugal pump, said to have a capacity of 600 gallons per minute. The pump is driven by a 20-HP. Westinghouse engine. The pump, engine and boiler were furnished by the Westinghouse Machine Co. All the other machinery was furnished by S. H. Johnson & Co., Stratford, England. No pumping records are kept and the amount of sewage treated is unknown.

The cost of operating the purification plant could not be obtained from the company, but it was found that one man is constantly employed at the station and that for four months in the year an assistant is employed. In addition a helper is occasionally employed. At 75 lbs. per day the total amount of alum used in the year would be a little over 27,000 lbs., provided it was used every day. But during heavy rains the sewage is not treated. Probably not more than 25,000 lbs. of alum is used in a year, the price in New York, as given above, being about 1½ cts. per lb.

The expense for lime and disinfectants must be light. Coal cannot be a great item, for the lift of sewage by the pump is small and the air compressor and vacuum pump is not often used. The officers of the company, with the exception of the secretary, do not have a salary. A 4% dividend has been declared recently.

The station is something over 2,000 ft. from the point where the effluent is discharged into the ocean. The effluent first passes through 1,200 ft. of 24-in. vitrified pipe which ends in a masonry chamber beneath the street, 400 ft. long, 8 ft. wide and with an average height of between 3 and 4 ft. A longitudinal and transverse section of this chamber is shown by Fig. 53. There is a manhole at each end and at the lower end there is a gate, operated by a rack and pinion, to control the outlet pipe. This chamber was designed to serve as a tidal chamber to allow sewage to be stored for discharge at ebb tide. The officials of the company state that quicksand was encountered in the construction of the chamber which prevented its being carried to the full proposed depth. Its capacity is only about 75,000 gallons and no use is made of it, purified sewage flowing through it constantly to the sea.

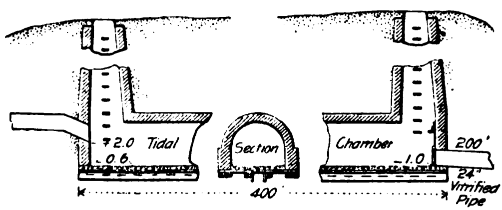
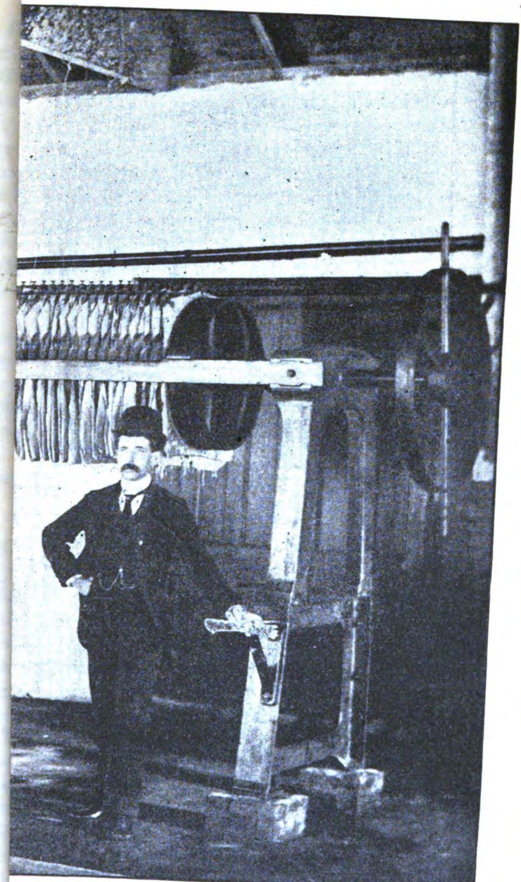


FIG. 53. SECTIONS THROUGH TIDAL CHAMBER.

The engineer of the sewerage system, Mr. C. P. Bassett, M. Am. Soc. C. E., states regarding the construction of the tidal chamber that "the original intention was never carried out by the company because of the expense, which was felt to be unnecessary."

From the chamber 1,200 ft. of 24-in. vitrified pipe extends to the beach and some 250 ft. of 16-in. wrought iron pipe across the beach and out into the sea. This wrought iron pipe is now protected by a jetty of piles driven 25 ft. deep. The pipe at the outlet turns down with an elbow 4 ft. long.

The cost of the lot and building used as a station is given as $8,000, and the cost of the machinery



arrol Ph. Bassett, M. Am. Soc. C. E., Engineer.

as $5,000. The tidal chamber is said to have cost $20,000.

The discharge of the effluent into the ocean is said to have given rise to no complaints. The effluent at the station was quite cloudy, as would be expected where only partial purification is attempted.

The writer visited the plant on Dec. 1, 1892, and obtained from the officials most of the information given. The balance of the information has been taken from a short description of the purification plant, prepared by the engineer, Mr. C. P. Bassett, M. Am. Soc. C. E., and published in the report of the New Jersey State Board of Health for 1887. Mr. Bassett also furnished the matter for the illustrations. The officers of the company are as follows: Secretary, Wm. R. Warwick, Jr.; Superintendent of Construction, R. C. Adamson; Treasurer, R. V. Breece; President, Chas. P. McFadden; Vice-President, Wm. W. Conover.

The Mystic Valley Works.

In the summer of 1878 the city of Boston, under the direction of the Water Board, constructed over four miles of main and branch sewers in the valley of the Mystic River to divert the sewage of several tanneries and some house drainage from the Mystic Lake, from which water is drawn to supply a division of the Boston water-works, to the lower Mystic Lake.

Towns adjoining the lower lake complaining that the sewage discharged into it was a nuisance, legislation was obtained in 1881 which compelled Boston to purify the sewage. After some delay, a system of sedimentation and partial filtration through a trench in gravel was installed. This, even after enlargement, having proved unsatisfactory, as did experiments with a Farquhar mechanical filter, the Boston Water Board, in 1887, instructed Mr. Wilbur F. Learned, C. E., to experiment and report upon chemical treatment of the sewage.

The precipitation works were put in operation in the latter part of 1888, and are described in the report of the Boston Water Board for that year as follows:

The new settling tanks have been completed, and are in successful operation. The works consist of a pump well connected by a brick sewer with the main sewer, a sewage pump, an engine, an engine house, four settling tanks, a sludge well, a sludge pump, and a series of settling basins for receiving the sludge.

In the engine house are three vats, so arranged that the precipitant is fed to the sewage from one vat placed lower and between the other two, in which the precipitant is dissolved; each vat is provided with a steam pipe for heating the water used, and with an appliance for stirring, which is run from the engine.

After the precipitant is fed to the sewage it is raised by pumping to the settling tanks, where, after a tank is filled, it is allowed to settle for about three hours. The clarified liquid is then drawn off by means of narrow stop planks, which are removed one by one. At this season of the year (winter) the tanks can be filled six times before it is necessary to remove the deposited sludge. This is removed through sluices which connect with a sludge well placed in the middle space between the four tanks. From this sludge well the sludge is pumped into a flume, by which it is carried to the settling basins.

The average flow of the sewer is about 400,000 gallons in 24 hours, 75% of which is between 8 a. m. and 8 p. m. After 12 p. m. the flow from the sewer is practically clear water.

The results of several experiments show that 1 volume of sludge is deposited in the tanks to 30 volumes of sewage received. The sludge contains about 4 parts of dry solids to 96 parts of water; the water disappears in the settling-basins, and we have remaining a product sufficiently dry to be easily handled, and containing 4 parts of solids to 12 parts of water. On this basis the amount of "dry product" would be

10 cu. yds. daily. The cost of the works, including the preparation of the settling basins and incidentals, was $10,410.

The operation of the works for the three years 1889, 1890 and 1891 is shown in detail by the following figures:

	Sewage treated, galls.	Pumps run, days.	Av. daily pumpage, galls.	Sulphate of alumina used.		Total amt. sludge, cu. yds.	Coal used, tons.
				Total, lbs.	Tons per 1,000,000 galls. sewage.		
1889......	99,882,850	308	324,000	403,270	2.02	......	162
1890......	119,119,670	335	355,500	323,650	1.36	2,611	191
1891	119,404,000	356	335,400	303,780	1.27	2,154	*195

*About.

In 1891 most of the sludge was carted away by a farmer for use as a fertilizer.

Further information regarding these works may be found in the reports of the Boston Water Board, and in a paper by Mr. W. F. Learned, C. E., entitled "Some Facts About the Chemical Treatment of Mystic Sewage," in the "Journal of the Association of Engineering Societies" for July, 1888, from which the above has been taken. Mr. Learned's paper consists chiefly in preliminary experiments made to secure the data for guidance in designing the plant.

SEWAGE PURIFICATION AND STORM AND GROUND WATER.

A new impetus seems likely to be given to the separate system of sewers by the present movement for the purification of sewage, which renders necessary or desirable the exclusion of ground and storm water from sewerage systems.

At Marlborough, Mass., as shown elsewhere in this work, the daily flow of sewage equaled the total daily consumption of water at a time when the number of sewer connections was less than one-fifth the number of water connections, or taps. This was in dry weather. After heavy rains the volume of sewage was about double the consumption of water. The admission of ground water to the sewers is the only explanation of these facts.

The ground water at Marlborough has not given trouble as yet, and need not in the future, provided available land is brought into use for the intermittent downward filtration there practiced. The danger, at Marlborough and elsewhere, is that no allowance having been made for ground water at the start its admission to the sewers will overtax the capacity of the disposal plant provided. Thus the sewage will not be thoroughly purified. Where filtration or broad irrigation is used for purification an excess of sewage may keep the ground so constantly water-soaked that its efficiency will be entirely destroyed, the land never having a chance to rest or, literally, to breathe. It is evident that if the interstices of the filtering material are constantly filled with water the air must to a large extent be excluded. This retards or stops the process of nitrification by which the harmful organic matters in the sewage are changed to harmless inorganic substances.

Chemical precipitation plants may be overtaxed by the admission of ground water to the sewerage system, as is the case at East Orange, N. J. There somewhat elaborate machinery and subsequent filtration are employed, and an increase in the volume of sewage to be treated is not merely a matter of adding more chemicals, but requires a more capacious plant.

At Worcester, Mass., the volume of sewage was originally far in excess of the original capacity of the purification plant, which has since been enlarged. This excessive amount of sewage was doubtless caused by both storm and ground water, although it is attributed to storm water alone. The eventual outcome of the difficulty at Worcester will doubtless be the separation of the storm water and sewage. Quite a step in this direction can be made by dividing the present outfall sewer into two channels, as is proposed. This outfall was originally a brook of some size, and still receives all the natural drainage to the brook. Sewage was turned into the brook before sewage purification was proposed, and separation can be effected only at a considerable expense. The brook has been turned into a closed channel through a part of its length.

When sewage purification is adopted in cities like Worcester, where the combined system is in use, as is the case in nearly all cities and towns of size, the problem of excluding storm and ground water is a serious one. Where sewers are being introduced separate systems can be used, and efforts can be made to exclude ground water.

Underdrainage may sometimes be effectively employed to overcome the difficulty, but the same cause which renders sewage purification necessary may make underdrainage inadmissible, as is well illustrated by the situation at Marlborough. At this place, as stated elsewhere, the city of Boston contributed to the expense of the sewerage system in order to remove and exclude the sewage from its water-supply. On the ground that a sewer pipe which would admit ground water would also admit sewage, Boston refused to allow underdrains, the town proposing, it would seem, to discharge the underdrainage into the same stream as the sewage had been excluded from. If the underdrainage were to be conveyed to the disposal plant, then it might as well be carried in the sewers as in underdrains, unless it was desired to lower the level of the ground water beneath the sewer line.

At South Framingham, Mass., Boston refused to contribute toward the expense of the sewage purification plant because underdrains had been put in for a part of the sewers, although none were proposed in the plans approved by Boston.

In an old town where cesspools and privies have been used for many years it is evident that the underdrainage, after the introduction of sewers, would be somewhat polluted, until the ground had become purified through the operation of nature. Therefore it might be desirable to exclude the ground water, when collected in quantity by underdrains, from any stream used for drinking purposes. In such cases it might require purification, and from this point of view its admission to the sewers would not be objectionable. But as has been said, sewers that will admit groundwater will emit sewage, which is highly undesirable, and for this reason sewer joints which will not leak are needed.

Thus far only the inefficiency of purification plants, as caused by storm or ground water, has been mentioned. Inefficiency can be avoided by constructing sufficiently large plants, but only at an increased expense for construction and operation.

Sewage pumping plants and long lines of outfall sewers, it may be added, are also rendered more costly by the admission of either storm or groundwater.

From what has preceded it is evident: (1.) That all storm water should be excluded from sewerage systems where purification is used. (2.) Ground water should also be excluded, provided it does not itself need purification. (3) All possible care should be taken in the laying of any sewer pipe and especially that in connection with sewage disposal plants to provide against leaky joints or cracks in the pipe through settlement or other causes. If there are any defects in the pipe itself attempts should be made to remedy them. (4) It may well be added that more data is needed to enable engineers to study the ground water problem with the care which it deserves.

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