

*(Paper No. 3422.)***“New Lanarkshire Middle-Ward District Waterworks.”**

By WILLIAM ARCHER PORTER TAIT, B.Sc., M. Inst. C.E.

THE county of Lanark, excluding the City of Glasgow and a number of royal and parliamentary burghs, is divided for administrative purposes into three districts, known respectively as the Upper, Middle and Lower Wards, the names having reference to their situation upon the River Clyde, which in its course to the sea flows almost entirely through the County of Lanark.

The Middle Ward, excluding the burghs of Hamilton, Motherwell, Wishaw, Airdrie and Coatbridge, comprises fourteen parishes. The total population in 1891 was 142,548 and is now 184,588, distributed partly in a number of towns of between 4,000 and 10,000 inhabitants, and in various villages and colliery-rows. In considering the district supplied by the Middle Ward water-undertakings, there must be deducted a small area supplied by the Airdrie and Coatbridge Water Company (now the Airdrie, Coatbridge and District Water Trust), and another much more limited area supplied by the Busby Water Company. A small portion of the district near the north-western end is supplied by the Corporation of Glasgow. The area of the Middle Ward so limited amounts to 275 square miles, or more than double the area of the County of London, and is probably the largest water-supply district which any local authority or company has been empowered to rate.

Prior to the passing of the Local Government (Scotland) Act of 1889 the duty of introducing water-supplies was, by the Public Health (Scotland) Act, 1867, imposed upon local authorities, who in urban areas were the Parochial Boards of the Parishes. These Boards were permitted to combine with one another for the purposes of water-supply, but were not allowed to impose a higher water-rate than 2s. 6d. in the pound. The Act of 1889 transferred all public health duties, including the introduction of water, to the District Committees of the County Council.

The District Committee found on taking office that nine independent Water Districts had actually been formed to include a number of the more important places in the Middle Ward, but that into three of these Districts water-supplies had not been introduced. Probably the main reason for this was the great difficulty of introducing an adequate supply at a cost within the limit of rating permitted by the Public Health Act. Even if supplies had been introduced into all the special Water Districts then formed, a very considerable area and population would have been left unprovided for. The Water Districts which had been formed were in general of very irregular outline, arranged in ribbon-like strips to take in a narrow width on each side of the public road, so as to include the most populous and valuable rating portion of the district. Some of the large works had introduced supplies of their own, and were able to resist having their workmen's houses included in the Districts. The revenue derived from the sale of water for trading purposes was inconsiderable. One Water District had a total area of about 3 square miles, but a perimeter of no less than 22 miles, showing how irregular was the outline. Properties just outside this District which obtained supplies were compelled, not only to lay their own pipes, but to pay very much higher water-rates than places within the District. All this was changed by reason of the appointment of the District Committee of the County Council, who duly considered what measures should be adopted for providing an adequate supply of water for the whole requirements of the Middle Ward District.

After considering Reports which had been made by various engineers with regard to the possibility of augmenting the supplies to the existing special and independent Water Districts, the District Committee considered a Report obtained from Messrs. J. and A. Leslie and Reid, on a proposed general scheme of supply, and resolved "that the only practical means for providing a supply of water to the towns and parishes requiring the same, except it may be to some of the villages in the parish of Shotts, and the village of Stane in the parish of Cambusnethan, is by a general scheme, the cost thereof to be derived from an assessment or assessments to be levied over the district." After carefully considering this scheme, together with the estimated cost, the District Committee found that the powers of assessment provided by the Local Government Act would not be sufficient to permit of the carrying-out of the whole scheme. They were, however, well advised by their clerk, the late Mr. E. P. Dykes, and found that they had representation in Parliament to effect the passing of an Act known

as the "Public Health (Scotland) Amendment Act, 1891," which, amongst other things, authorized the County Council to impose and levy an assessment called the Public Water Rate upon all lands and heritages within the district, at a rate not exceeding 3*d.* in the pound. This Act having obtained the Royal Assent, it became a very much simpler matter for the District Committee to promote their scheme in the following session of Parliament. When they did so, they were successful in obtaining power to levy a general assessment of 3*d.* in the pound upon property, whether supplied with water or not. They were also empowered to levy a domestic rate, subject to a reservation to be referred to later. Now that most of the works are completed and have been in operation for some time, the advantage of a comprehensive scheme for the whole of the Middle Ward District, as against separate schemes for Water Districts in portions of parishes, becomes at once apparent. In addition to the public water-rate of 3*d.* in the pound upon all properties, whether supplied or not, there is a domestic rate throughout the Middle Ward, for persons supplied with water, of 11*d.* in the pound, which is borne in the proportion of one-half by owners, and one-half by occupiers. This rate of 1*s.* 2*d.* in the pound may be compared with the rate in some of the Water Districts which were actually supplied, namely 1*s.* in the pound in Bothwell in 1892, and 9*d.* in the pound in Cambuslang in the same year. In previous years these rates had been much higher, and the supply had not been comparable with the existing supply in efficiency.

The District Committee obtained an Act in 1892 authorizing the construction of two reservoirs on the Glengavel Water, a tributary of the Avon and the Clyde. The Act also authorized the construction of filters and clear-water tanks at Glassford, together with a considerable length of main piping, and service-reservoirs throughout the District. With the exception of the filters and clear-water tanks, the whole scheme has been very considerably modified; the lower of the two reservoirs was never commenced, and power to abandon its construction was obtained in a later Act. The principal or upper reservoir had a somewhat troubled history, which is referred to in detail later. For a variety of reasons this reservoir has not yet been completed to the full height shown on the parliamentary plans, and it is only in use to a limited extent.

The District Committee obtained other Acts of Parliament in 1896 and 1899, which gave them further powers, both for the construction of additional works and for extension of time, rating, etc.

In the accompanying map (Fig. 1, Plate 11) are shown all the reservoirs owned by the District Committee and constructed by them or their predecessors, and also the area of the Middle Ward District, excluding the burghs, etc., as well as the main- and distribution-pipes, filters and service-reservoirs, the latter forming an important part of a scheme intended to supply the population of a very scattered district at widely different levels. It will be seen that there is a considerable number of storage-reservoirs having drainage-areas of their own, from which drainage-areas, with the single exception of the Lintmill Reservoir, a daily flow of compensation-water has to be given. In general, the sizes of the mains have been kept fairly large in proportion to the quantity of water which usually has to be carried, with the result that surplus water can be brought from one District to another at times when that District might otherwise have been on short supply.

It was originally expected that a yield of $2\frac{1}{2}$ million gallons per day would be obtained from Glengavel, provided the upper reservoir only was constructed, but it was calculated that when the second reservoir was constructed for compensation purposes a total supply of 4 million gallons per day would be obtained for the District. This would be in addition to the existing supplies which are referred to later. The principal reservoir was to have a capacity of 660 million gallons, or about 165 days' storage both for the supply of $2\frac{1}{2}$ million gallons per day to the District and $1\frac{1}{2}$ million gallons compensation to the Glengavel Water.

In the spring of 1893, or shortly after the Act obtained the Royal Assent, contracts were let for the reservoir, for the supply of pipes, and for the laying and jointing of the main-pipe to the filters, and for several other mains. The contract sum for the reservoir amounted to £57,045, as compared with the engineers' parliamentary estimate of £44,814, independent of a sum for general contingencies. Mr. J. M. Gale, M. Inst. C.E., Engineer to the Glasgow Corporation, who was consulted at this stage by the District Committee, considered that the upper reservoir might safely be relied upon for a supply to the District of 3 million gallons per day, over and above the compensation flow of $1\frac{1}{2}$ million gallons per day. In dealing with the foundations for the reservoir embankment, Mr. Gale pointed out that the embankment on the east side would have old red sandstone rock for a foundation, but that on the west side a thick layer of drift overlay the rock, which appeared to slope off rapidly to the west. He also pointed out that the bluffs or scars which are common in that

district showed that the drift consisted of about 30 feet of sand, below which there was the same depth of close sandy till or boulder-clay, which appeared to offer a water-tight foundation for the puddle-wall. Mr. Gale also added that the bores which had been put down did not, so far as they had gone, give much more information, and he consequently apprehended that some outlay, in addition to that estimated for, would have to be incurred in order to reach a sound foundation for the puddle. He accordingly proposed to add £10,000 to the engineers' parliamentary estimate.

After stripping a considerable quantity of moss from the base of the embankment, and removing it to spoil altogether outside the works, a commencement was made with the excavation for the outlet-culvert, which ran straight through the line of the embankment, Fig. 2, Plate 11. From a comparatively early stage this culvert carried the flood-waters past while the embankment was being formed. The culvert was carried across the trench on a concrete pillar with the usual feathers on the sides to tie into the puddle. Several springs were encountered in the sinking of the trench, but these were disposed of in the ordinary way by iron pipes carried up the sides of the trench, which discharged into the outlet-culvert. The culvert had a waterway of 54 square feet and a gradient of 1 in 100, but on two occasions it was barely sufficient to deal with the flood-water. In August, 1895, there was a fall of 2·35 inches of rain in 4 hours on a drainage-area of about 4,000 acres. During this time the water rose in the reservoir to a depth of about 20 feet; that is to say, it accumulated a quantity of about 38 million gallons during the time that the culvert was carrying off what it could. When, however, the water-level commenced to fall, the whole quantity of water was drained off in about 3 hours.

The excavation of the puddle-trench on either side of the culvert was carried on simultaneously with the excavation for the culvert foundations. No trouble was experienced in getting a proper foundation on the east side of the culvert, nor for a length of about 250 feet on the west side of the culvert. From this point in a westerly direction the rock appeared to dip towards the west at a slope of about 1 in 3. This slope was ascertained in the first instance by the sinking of some bores, and afterwards by the opening up of the trench in which a couple of trial-pits were also sunk. In order that the filling with puddle of the already excavated trench might be continued without interfering with the excavation of the rest of the trench, a couple of feathered concrete

pillars were put in across the trench, with the result that the portion of the embankment round about the culvert was fairly well advanced at an early stage.

After the opening up of the trench on the west side the engineers reported that it had become apparent that some change would be necessary in the mode of construction, and that considerable delay might take place before the reservoir could be finished and made fit for storing water. During the flood already referred to, in August, 1895, a large quantity of water ran into the western end of the trench, but such of this water as did not get away through the surrounding strata was easily dealt with by pumps which were kept going all night. At a later date, when water got into the trench, and particularly into one or other of the two trial-pits which had been sunk in the bottom of the trench, it was found that although pumping was stopped the water never overflowed. These trial-pits were purposely put down in the trench with a view to proving the nature of the ground above the rock, as it was found from the contract prices, which had been arranged on the principle of payment in layers, that the price for continuing the trench at a depth of 120 feet or more would have amounted to an extravagant sum. In view of the engineers' report of November, 1894, steps were taken to discontinue expenditure on the open trench, and a number of bores were put down farther up the valley with the view of finding whether or not an embankment could be made on another site at reasonable cost. A series of bores, which are shown to some extent in Fig. 5, Plate 11, were put down, and eventually it was proposed that a reservoir should be constructed about a mile up the stream from the embankment of the uncompleted reservoir.

Before making any estimate of the cost, the engineers recommended that a couple of trial-pits should be sunk, to further prove the ground on the line of the proposed new trench. A contract was accordingly entered into with the reservoir contractors for the sinking of two pits, one to a depth of 110 feet, and the other to a depth of 80 feet. The latter was commenced at the end of July, 1895, and was carried down to within a few feet of the rock in the course of about a month, when a "blow" occurred and the pit was filled to a considerable depth with silt and gravel, the water rising rapidly to within a few feet of the surface. At the same time the water which was flowing out of the adjoining bore-holes sank in the bore-holes and ceased to overflow. Much more trouble was experienced with the sinking of the deeper pit, which was commenced with timber lining and was carried to a depth of about

30 feet. It had been a condition of the contract that payment was only to be made when the shafts were sunk to the required depth. The contractors abandoned the idea of sinking the deeper shaft with the aid of timber only and employed a steel cylinder, with the sinking of which fair progress was made for a time, notwithstanding the fact that a proper cutting-edge had not been provided. After a time the cylinder got to some extent off the plumb, and it was never properly righted; the work of sinking was stopped in April, 1896, when the cylinder had got down only to a depth of about 80 feet.

When the engineers, in November 1894, drew attention to the delay that might take place before the reservoir could be finished, they recommended that steps should be taken to arrange for a temporary supply of water to the District until the works were finished. The filters were at this stage fairly well advanced, the main pipes had been laid to them from the site of the reservoir, and a number of other mains and distributing-pipes had also been laid. The filters at Glassford, which are situated at an elevation of 760 feet above ordnance datum, had been purposely kept at the highest possible level, so that the greatest portion of the Middle Ward District should be supplied with water without recourse being had to pumping, but in order to give effect to this the measuring-house at the reservoir had to be situated about 28 feet above the level of the sill of the outlet-culvert (Fig. 3, Plate 11). This meant that even if the reservoir had been completed, about 72 million out of 660 million gallons could not have been drawn to the District, but this extra space was available for settlement. As the embankment was not then in a state to impound water, the temporary pipe had to be carried up the glen till a sufficient elevation was obtained to enable water to be discharged into the measuring-house. A temporary intake was accordingly made on the Glengavel Water about 1,000 yards from the embankment, and a 27-inch pipe was laid from this to the measuring-house. It was found that a daily yield of nearly $\frac{1}{2}$ million gallons could be obtained at the intake except in dry weather, although the statutory quantity of compensation-water, amounting to $1\frac{1}{2}$ million gallons daily, was sent down the stream. For a considerable time this temporary supply was taken to the District, where it was of the greatest possible service, as the District was very much in need of it.

In September 1895, Mr. G. H. Hill, M. Inst. C.E., of Manchester, and Mr. William Crouch, M. Inst. C.E., of Glasgow, were desired by

the District Committee, first, to examine the embankment and puddle-trench of No. 1 Reservoir with the object of advising as to whether the embankment could be completed and the reservoir made available for the storage-reservoir, as was originally intended; or, if not, whether it could be completed and made available as the compensation-reservoir which the Committee were bound by their Act to construct further down the stream; second, to examine the journals of the bores made by Messrs. Leslie and Reid, and the pits or shafts put down farther up the stream, with the view of advising as to the suitability of a site for the embankment of a new storage-reservoir in the event of their being of opinion that the one in course of construction could not be made use of; and third, to examine and report on the whole works already executed at Glengavel. Mr. Hill and Mr. Crouch made a visit to the ground and submitted a joint report later in the month. They dealt at some length with the foundations of the puddle-trench, and with the information obtained from the bores, and stated that they were forced to the conclusion that there was no possibility of obtaining a rock foundation for the trench throughout its whole length, and that under these circumstances the point to be considered was whether or not any satisfactory and reliable foundation for the puddle-wall could be obtained even for an embankment of a reduced height. After very carefully considering the matter, they stated that they came to the conclusion that there would be a decided risk in constructing a reservoir such as was proposed, on account of several reasons, mainly that the material above the rock consisted of gravel, sandy clay, silt, mud, etc., and that the water in the trial-shafts in the trench, as already stated, never overflowed in wet weather, and on the cessation of rain fell slowly to a certain level at which it remained. They admitted that the result of attempting to store water in No. 1 Reservoir could not be predicted with absolute certainty, but stated that the retention of any large quantity of water in the reservoir could not be entertained without a long and gradual series of tests which could only be made after the completion of the proposed new reservoir a mile farther up the Glen. Taking all the circumstances into consideration, they did not anticipate any serious difficulty in the construction of a reservoir at the site indicated, as rock which they had every reason to suspect was of a close character was met with throughout, in the line of the trench.

The Committee, having agreed with the terms of this Report, obtained, in 1896, an Act providing for the construction of another reservoir about a mile farther up the Glen (Figs. 2, 3, and 5,

Plate 11). The authorities in charge of several of the Water Districts which were in existence when powers were being sought in 1892 opposed the District Committee, partly, they said, because their works were quite sufficient, and partly because they objected to an increase of rating, and they were successful to the extent that a clause was inserted in the 1892 Act which provided that no domestic water-rate could be levied by the County Council until the completion of the upper reservoir authorized by this Act. The delay in the completion of this reservoir was accordingly a serious matter for the District Committee, who had already spent a considerable sum of money, but who were only empowered to levy the public rate of 3*d.* in the pound. The Act of 1896 authorized the construction of two different reservoirs on independent drainage-areas, one of which was primarily intended to augment the existing supply to the Bothwell District of the County, and the other to supply the Harthill and Benhar District, which had never been supplied before. These works were shortly thereafter proceeded with, but even when completed they did not themselves fulfil the conditions of the Act of 1892 as to rating, and consequently other powers had to be sought before an assessment could be levied. This was ultimately provided for in an Act passed in the year 1899, by which time the available yield of the partly-completed works at Glengavel had been satisfactorily proved.

The sinking of the bores and the trial-shafts for the proposed upper reservoir at Glengavel had drawn the engineers' attention to the quantity of water which was likely to be encountered in the sinking of the trench, and elaborate preparations were made in the contract drawings for dealing with this water.

Messrs. Hill and Crouch, in September 1895, estimated the cost of this reservoir at £100,000; but in 1900, after the preparation of contract drawings, specifications and schedules, the engineers made a new estimate amounting to £200,000. Offers for the work have not yet been taken.

On observing the quantity of water likely to be met with in the sinking of the trench, the engineers formulated a proposal for improving the temporary supply from the Glengavel Burn by extending the pipe up to the site of the proposed upper reservoir, and tapping the gravel-bed there. Two advantages were expected from this, both of which were realized. One was that a greater quantity of water would be obtained, and the other was that when drawn from the gravel-bed the water would be to some extent

filtered before being taken into the pipes to the district. It was also a part of this scheme to make use to a limited extent of the uncompleted reservoir, so that compensation-water might be stored to a depth of about 28 feet, giving about 70 million gallons, or a little over 40 days' supply to the stream. It was absolutely necessary that some such storage should be provided if the Committee intended to take more water in dry weather than the $\frac{1}{2}$ million gallons per day already referred to. After due consideration a scheme was adopted which involved the fitting up of a balanced Stoney sluice on the mouth of the outlet-culvert, Fig. 4, Plate 11. This sluice was installed in the Autumn of 1898. Previous to this the pipe was being extended up the Glen from the original temporary intake and carried into the gravel-bed above the site of the proposed upper embankment, at a depth of about 30 feet. The extended pipe terminated in a shaft from which a series of branch feeders were taken in different directions, as shown in Fig. 2, Plate 11. Intakes had previously been made at the proper level on some of the small tributary burns. The pipe passed close to the steel cylinder, but as there was a question then pending between the contractors and the Committee it was thought imprudent to make any connection to the shaft; this, however, was done at a later date, when all questions had been settled. The result of making the feeders in the gravel-beds and the intakes in the burns has been to give a supply of about $1\frac{1}{4}$ million gallons per day, while the full compensation supply of $1\frac{1}{2}$ million gallons per day has been maintained with the aid of the partly-completed reservoir. Greater supplies are occasionally drawn when there is available storage in some of the service-reservoirs throughout the district. Notwithstanding the fact that the Middle Ward Works have not yet been completed to their full extent, the District Committee have been able, during recent dry seasons, to provide a supply to the Burgh of Hamilton, the construction of the new works for which has been delayed owing to various causes. The charge made for this water has been at the rate of 6d. per thousand gallons, being the ordinary meter-rate for supplies within the Middle Ward District. Since the water was taken from the gravel-bed it has been found that the filters at Glassford are more easily cleaned, even when water is being taken in time of spate, than formerly when all the water was taken direct from the burn.

The sluice was purposely made to work with great freedom, so that in the event of a flood the reservoir-keeper might have it

quickly raised to allow the flood-water to run away full-bore through the culvert. Electrical communication was provided between the reservoir and the keeper's house, which was close by, in order that timely warning might be given of any sudden rise of the water-level in the reservoir. This was rendered necessary because no proper waste-weir had been constructed, and because the only overflow which could be provided at reasonable cost was to make an aperture on one side of the upstand-shaft. Such an overflow was made in the first instance, but it was found that the water falling down the shaft had a very considerable effect on the freestone at the bottom of the shaft, so much so that it was eaten out to a depth of about 18 inches. This damage was fortunately noticed in good time, and the space was filled up with concrete on the top of which heavy cast-iron plates were laid. These plates were continued for a little distance through the culvert. It will be observed therefore that about one-half of the supply to the District originally counted upon, with the aid of the completed reservoir is being obtained from the gravel-bed and the burns. In view of the trouble likely to be experienced in the construction of the upper reservoir, and in view also of the considerable cost entailed, the Committee have decided to delay for a time the construction of this reservoir, particularly as a large supply is being obtained from a reservoir constructed under the 1896 Act on the Logan Burn, which is a stream closely adjoining the Dunside Reservoirs, which were made in connection with the Bothwell Special Water District supply. This reservoir was originally intended to have a capacity of 150 million gallons, but during its construction arrangements were made with the contractor for raising the embankment and increasing the storage to 185 million gallons. In addition to the ordinary pipes throughout the district, a 15-inch pipe capable of carrying nearly 2 million gallons per day has been laid from Logan Reservoir (although not originally intended) and connected at a suitable point to the main between Glengavel and Glassford filters at a cost of about £34,000.

The Parliamentary estimates of expenditure were :—

1892 Act	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	£	278,160
1896 „	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	193,980	
1899 „	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	49,000	
																				Total	£521,140

The amounts expended in carrying out the works authorized by the various Acts are:—

	£	s.	d.
1891-2	1,801	3	6
1892-3	5,237	3	2
1893-4	64,235	9	6
1894-5	101,129	4	8
1895-6	52,800	7	10
1896-7	21,358	16	5
1897-8	31,513	12	2
1898-9	34,368	19	3
1899-1900	45,406	3	6
1900-1901	61,955	0	3
1901-1902	23,483	9	1
1902-1903 (15 May)	19,881	0	1
Total	£463,170	9	5

In the construction of the service-reservoirs, as also in the maintenance of the pipe-tracks, some little trouble has been occasioned by mineral workings, and damage has been done to more than one of the works. The service-reservoirs are in some cases open earthwork, and in other cases covered brickwork or circular steelwork tanks. One high-level village close to the filters is supplied with water by means of a turbine which is driven by the water from the reservoir as it enters the filters.

A great portion of the northern district at the extreme end of the piping from the reservoirs is situated at so high a level that the water has to be pumped from the pumping-station at New-house, situated at a level of 600 feet above ordnance datum. The water is taken into an open service-reservoir holding $3\frac{1}{2}$ million gallons, and is pumped from there to various service-tanks by a pumping-engine supplied by the Glenfield Company. The engine is of the horizontal, compound, side-by-side, surface-condensing type, the high-pressure cylinder being 16 inches in diameter, the low-pressure cylinder 30 inches in diameter, and the stroke 3 feet. Both cylinders are jacketed with live steam, and both are fitted with Meyer cut-off valves on the back of the main slide-valves. Steam is supplied at a pressure of 100 lbs. per square inch by a pair of Babcock and Wilcox boilers. The exhaust steam, after being drained from the surface-condenser, is delivered by the air-pump into a filter-tank, where the oil and grease are extracted and the condensed water is used over again in the boilers. The air-pump is worked from the low-pressure cylinder cross-head by means of connecting-links and a bell-crank. The

main pumps are set on the sole-plate directly behind the cylinders, and are worked from the piston tail-rods. They are of the double-acting piston type, $7\frac{1}{2}$ inches in diameter and 3 feet stroke. The pump-valves are of the multiple-type, there being seven small valves in each chest. The duty of the engine is to raise 500 gallons of water per minute against a head of 263 feet when working at 24 revolutions per minute, or to raise 420 gallons per minute to a height of 412 feet when working at 20 revolutions per minute, *i.e.*, 40 "pump" horse-power in the former case and 53 "pump" horse-power in the latter case.

The engine, at the test, gave 59·16 indicator-HP., and 49·47 pump-HP., an efficiency of 83 per cent.; and the feed-water used was about 20 lbs. per pump-HP. hour.

The whole cost of the scheme to date, including debts assumed and payments made on behalf of the old special Districts when taken over, is about £490,000, including a liberal settlement with the contractor for the reservoir for loss of profit on uncompleted work.

The works described in the foregoing have been carried out under the direction of the Author's firm, Messrs. J. and A. Leslie and Reid, Edinburgh, and particularly under the direction of successive partners of the firm, namely, the late Messrs. Alexander Leslie, R. C. Reid, and James Wilson, and the Author, who joined the firm in the autumn of 1894.

The Paper is accompanied by a map, four lithograph-drawings, and fifteen tracings, from a selection of which Plate 11 has been prepared; and by a photograph of the pumping-engine.

Fig: 2.

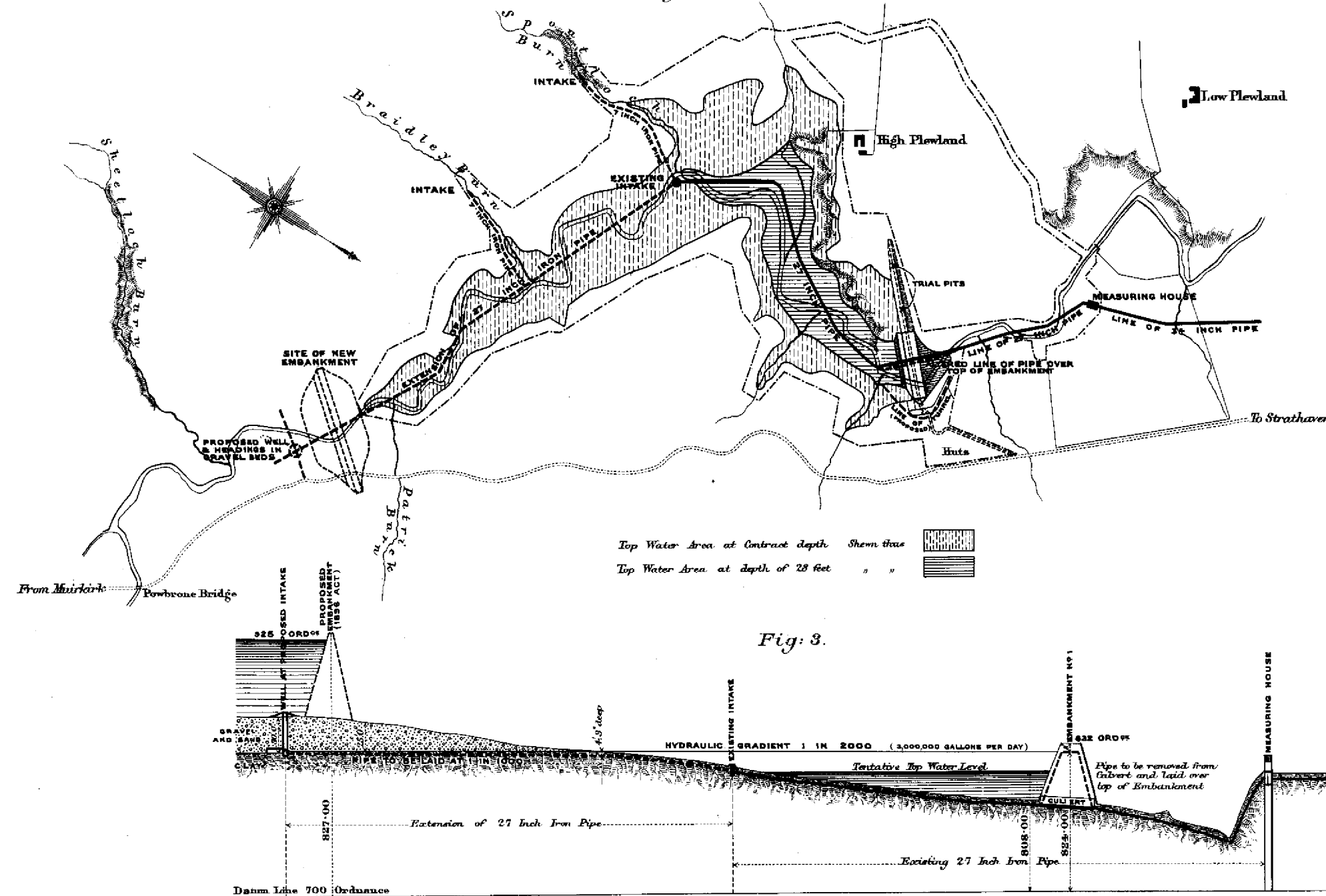


Fig: 4.

