

(*Paper No. 2210.*)

“The Wells and Borings of the Southampton Waterworks.”

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WELL-SINKING and boring are so frequently attended with great and unforeseen difficulties, that the Author thinks an account of the large borings executed for the Southampton Waterworks may be of interest, as they are the largest yet sunk at one operation, and have been completed in a remarkably short time, at a cost far below that of ordinary hand-sunk wells of corresponding efficiency.

In July 1884, the Author was instructed to draw up a scheme of water-supply from the Chalk, just above its outcrop at Otterbourne, 8 miles north of Southampton, as recommended by Mr. W. Whitaker, Assoc. Inst. C.E., who had been consulted as to the geological conditions for obtaining at least 3,000,000 gallons per day within a reasonable distance from the borough.¹ The outcrop of the Chalk takes place along a fairly regular line running about east and west, and, about $\frac{1}{4}$ mile eastward from the site selected, is intersected at right angles by the River Itchen, which, along its whole course is fed by more or less copious springs from the Chalk. About $\frac{1}{3}$ mile south of the site, a subsidiary valley runs parallel to the line of outcrop, and opens into the main valley of the Itchen; while westward it dies out gradually, and is the seat of considerable springs. At a distance of 5 miles to the west, the limit of the watershed of the Itchen is reached; and the land, together with the water-line in the Chalk, falls towards the valley of the Test. To the north, the Hampshire chalk Downs extend for many miles.

A hydrographic survey of the district, including an area of 36 square miles, gives particulars of about ninety existing wells, from which a series of water-gradients were obtained, and a remarkable convergence of these towards the proposed site was found to exist (Plate 1, Figs. 1-7). The average gradient, for about 2 miles around the site, is $12\frac{1}{2}$ feet per mile; beyond this, owing to the

¹ “Report upon the Water-Supply of Southampton,” by W. Whitaker.
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varied contour of the country and local circumstances, it becomes somewhat irregular.

At the outset, the Author made three trial borings, first one of small size to ascertain the actual presence of water, and then two of larger diameter, to make certain of a sufficient yield before executing the requisite works at an estimated cost of £60,000. The small boring, 3 inches in diameter, was sunk to a depth of 105 feet, in five and a half days at a cost of £58, which included £20 for temporary occupation of the site. The Chalk was reached $2\frac{1}{2}$ feet below the surface; it was found hard and dry, without flints, to a depth of 18 feet; beyond this it was white and fairly firm, with occasional flints, to a depth of 85 feet, and at 65 feet there was a bed $1\frac{1}{4}$ foot thick; while from 85 feet to 105 feet it was white and pasty with a few flints. Water was found at a depth of 20 feet, and upon being pumped at the rate of 3,000 gallons per hour was lowered 3 feet, the normal height being quickly regained upon ceasing to pump. Two 12-inch borings were then sunk, each at a distance of 50 feet from the small boring; all three being arranged in a line parallel to the line of outcrop. The average time occupied in sinking each boring was eleven days, and the two cost £380, including £12 for occupation of the site, £16 for reinstating the land upon completion, and £160 for pumping to test the yield of the borings. Pumping simultaneously from both borings was carried on day and night for sixteen days, the mean discharge, as measured over a short thin-edged weir, being 20,960 gallons per hour, with a loss of head of 9.62 feet, the depression of water-level in the small boring at the same time being only 2.92 feet. After the trials were completed the water rose rapidly to its normal level, which is maintained here with very little variation during all seasons. These trials were so satisfactory that an Act was obtained, and the permanent works commenced.

The ease and rapidity with which the trial-borings had been sunk, by the ordinary "chisel and shell" method, suggested to the Author the practicability of boring two 6-foot wells, in place of a single well of great size sunk by hand in the usual manner, which would require powerful temporary pumping-machinery to deal with the 3,000,000 gallons per day required. Moreover, as it was proposed to erect a pair of engines to pump from the well when completed, the further advantage would be gained, if the pump work of each engine was suspended in an independent well, that should any accident happen to either of them, pumping from the other would not be interfered with; also, if it should at any time become necessary to deepen either well, or to drive adits,

this work might be executed from the one without interfering with the clearness of the water in the other; while, owing to the close proximity of the two, there would be little difficulty in keeping the extension works dry. It was therefore decided to sink two bored wells, each 6 feet in diameter and $11\frac{1}{2}$ feet apart from centre to centre, one being under the beam end of each engine (Plate 1, Figs. 11 and 12), to a depth of 100 feet from the surface of the ground, and commencing from the upper side of the pump-chamber floor, 28 feet from the surface, the net depth of each bored well thus being 72 feet (Plate 1, Fig. 11). The work was entrusted to Messrs. Legrand and Sutcliffe, by whom the three trial borings had been sunk. The price for the actual borings was at the rate of £5 14s. 6d. per lineal foot for each well.

The excavations for the deeper portion of the engine-house were first got out; the "spoil" was raised in barrows by means of a friction-hoist, operated by a single lever and driven by an 8-HP. portable engine running continuously, and with a lift of 36 feet; it was capable of raising 140 barrow-loads of chalk per hour. In sinking the lower 10 feet of this excavation below water-level, a 12-inch by 6-inch chain-pump was employed, after a rotary pump had failed from choking, the water being very chalky; it was also driven from the 8-HP. engine, and when discharging at the rate of 30,000 gallons per hour, could just keep the work dry.

Two heavy cast-iron cylinders, 6 feet by 6 feet, with strong outside flanges at the upper ends, were then fixed in the bottom of the excavated pit, each to form the entrance to a well and to act as a guide for the boring-tools. Around the upper portion of these cylinders, and over the whole of the bottom of the pit, a layer of Portland cement concrete, 3 feet thick, was laid in the pit when dry; after which pumping was stopped gradually, and the water allowed to rise slowly to its normal level, about 6 feet over the concrete. Upon pumping being resumed at the expiration of three days, a perfectly level and sound floor in one block, 37 feet by 25 feet by 3 feet, was found to have been formed; and, when it was subsequently necessary to cut a small portion away, proved to be of the best possible quality.¹ The footings of the engine-house foundations were laid on this floor, and the brickwork in cement

¹ The cement when passed through a sieve having 2,500 meshes to the square inch, left a residue of only 1 per cent., and when tested bore, after three days' immersion in water, a tensile-strain of 304 lbs., and after seven days of 375 lbs. to the square inch. The concrete was made with 1 part of cement, well aerated previous to use, added to 2 parts of sand and 4 parts of gravel, well washed.

carried up to above the normal water-line (Plate 1, Fig. 11). The pump was then removed, and the subsequent operations were carried on without pumping.

Preparatory to boring the 6-foot wells, a strong working floor was laid over the top of the aforesaid brickwork, with a square opening and hinged doors over the centre of the well to be sunk; above this a heavy framed stage was erected, and covered with a strong flooring at the ground level, upon which the boring-winch was fixed. The staging was so contrived that, upon the completion of one well, it could be moved on rollers to the position for sinking the second. The boring-tools and rods were raised and lowered by means of a 2-inch cable, making four turns around the barrel of a double-purchase steam-winch, having two 7-inch cylinders; it was fixed on the upper stage, and fed with steam from a 12-HP. portable engine, which at the same time worked the friction-hoist by which the "spoil" was raised in small wagons.

The boring-rods were of iron, 3 inches square, in 10-foot lengths, weighing 34 lbs. to the foot, coupled together, and to the tools, with screwed joints, and were suspended from the lifting-cable by a swivel and shackle; the winch was kept running constantly, and upon the slack end being hauled taut by four men, the cable was wound upon the barrel and the rods raised; on being released, the cable ran back and the rods dropped. A succession of these operations, with the chisels attached to the rods, broke up the chalk and flints, so that the *débris* could be gathered up and raised to the surface by the miser. While punching, a rotary motion was imparted to the chisels by long levers clamped to the boring-rods and "walked round" by two men on the lower floor.

The three chisels (Plate 1, Figs. 8 and 9), of wrought-iron with steeled points, were affixed with heavy cotters to a wrought-iron cross-head; the centre chisel, with a plain blade, was longer than the outer ones, each of which had a tongue forged into its outer edge, to act as guides in keeping the tool from cutting into the sides of the bore-holes when being raised and lowered; and, being chisel-edged, to act as rimers when at work. In the first instance, all the chisels were of the diamond-point form; but, owing to a tendency to draw in towards the centre of the hole, the form of the two outer chisels was altered and "rock" points substituted, safety chains being added at the same time. The weight of this tool was $1\frac{1}{4}$ ton. The miser (Plate 1, Fig. 10) was of $\frac{3}{8}$ -inch boiler-plate, riveted to, and stiffened by, strong angle-irons and plates; each half of the lower portion was made tapering with a

helical twist, and where the upper edge of the one plate was brought nearly over the lower edge of the other plate, on either side a hinged flap (Plate 1, Fig. 10) was inserted, so as to confine the *débris* when it had been forced into the miser. The edge of each plate under these flaps was furnished with a steel dog-tooth cutter and set of points. Internally, the miser was divided into two compartments, so that in the event of one flap-valve failing to act, the whole efficiency of the tool was not destroyed; moreover, the motion of the *débris* entering by one passage did not tend to choke the action of the other, as would otherwise have been the case. A wrought-iron spindle, 4 inches square, with a guiding point at the lower, and a screw at the upper end, was fixed centrally through the miser, and secured to it by means of heavy castings and wrought-iron stays. The weight of this tool was $1\frac{1}{4}$ ton, and upon its being lowered into the bore-hole, already punched, it was "walked round" by twelve men in the same manner as the chisel, the *débris* being thus forced into the passages and past the flap-valves, where it was confined and afterwards raised to the surface to be emptied. The results obtained with this tool were most satisfactory; the valves acted readily, and it usually came up two-thirds full. The Author is, however, of opinion that the rotary motion could readily, and more economically, have been given to both the tools by mechanical means connected with the steam winch above.

The first well was bored in thirty-three days, considerable delay being caused through the fracture of two or three boring-rod coupling-screws, and the breaking of a chisel which fell to the bottom of the well, when it was nearly completed, and had to be recovered by a diver. The tools and rods were slightly altered and thoroughly overhauled before commencing the second well, with the result that it was completed, without the slightest mishap, in fourteen days, a rate of over 5 feet per day. Both wells were finally rimmed out with the miser, which had cutters bolted to it for this purpose, and were found to be perfectly cylindrical and vertical. Upon the completion of the first well, it was lined, as the chalk was of a somewhat unstable character; and it was feared that the vibration caused by the fall of the heavy tools in sinking the second well, would probably bring down the intervening wall of chalk, which is only $5\frac{1}{2}$ feet thick. Eventually the second well was also lined to ensure safety. The lining tubes are of mild steel, $\frac{1}{2}$ inch thick, 5 feet 11 inches outside diameter, in 6-foot lengths (Plate 1, Fig. 11), each in two segments, riveted with $\frac{3}{4}$ -inch rivets to inside cover strips, the rivets on the

outside being countersunk. The lengths were riveted one above the other as they were lowered into the wells, being secured with inside cover strips. Each tube has a heavy steel angle-plate riveted to its upper end and resting upon the floor of the foundation pit. Twenty-four 6-inch circular holes are formed in each length of tube, to allow of the free ingress of water. The whole of the tubes in the first well were lowered without difficulty by means of the steam winch. In lowering the second set of tubes, all went well until the last two lengths were reached, when, owing no doubt to a slight movement in the chalk-wall between the wells, they could not be sunk lower by their own weight; and after a pressure of 30 tons had been applied with no other effect than to damage the upper tube, the last length was abandoned as it was known that little, if any, water was obtained from the lower part of the borings. Heavy clinkers and large flints were therefore tipped into the bottom of the well, up to the level of the lined portion, to prevent the possibility of a fall of the sides, and at the same time to allow of a free passage for any water which may be present. The lining of the first well was much delayed, but the second was lined in seven days; the total cost for both being about £780.

These are, the Author believes, the largest bored wells in this country. Shafts of larger diameter have been sunk on the Continent by the "Kind-Chaudron" and "Drus" methods,¹ which involve two operations; first, the boring of a "pilot" shaft about 1 metre (3 feet 3½ inches) in diameter, and secondly, the enlargement of this to the required diameter of 10 or 12 feet. They cannot, therefore, be sunk with the same rapidity, or at such a moderate cost as those described above. Two wells, sunk at L'Hôpital in France and Rothuasen in Westphalia, of 5·9 and 6·23 feet diameters respectively, cost £10 per foot of depth, nearly double the cost of the 6-foot wells herein described. A single well, for the requirements of the Southampton Works, must have been elliptical in form, with major and minor axes of at least 19 feet and 9 feet respectively, and, lined with 18-inch brickwork, according to the Author's estimate would have cost from £2,000 to £2,500; whereas the cost of the bored wells has been less than £1,700, although involving the expense of providing new and specially designed tools. The cost of the foundation work below water-level has been about £1,200, and would have been the same with either system of sinking.

¹ Minutes of Proceedings Inst. C.E. vol. xxxiv. p. 57.

The Author is indebted to Messrs. Legrand and Sutcliff for having placed the drawings of their tools at his disposal; and he desires to testify to the very liberal and complete manner in which they carried out the work. The success of the undertaking is also very largely due to the skill and ingenuity of Mr. T. W. Stone, Assoc. M. Inst. C.E., who, as Engineer in charge for the Contractors, devised and arranged the whole of the working plant.

The Paper is accompanied by three sheets of tracings from which Plate 1 has been compiled.

APPENDIX.

THE DEEP WELL ON SOUTHAMPTON COMMON.

This great work was commenced in July, 1838; it was sunk and bored to a depth of 1,317 feet by February, 1851, when operations were suspended, the yield of water then being only 130,000 gallons per day. In 1882, a further attempt to continue the boring was made, and soon reported as being impracticable, owing to the presence, in the hole, of a broken tool, left there when the work was abandoned in 1851; but the Author has no doubt that skilful well-sinkers, aided with proper appliances, would have overcome the difficulty, although undoubtedly great at such a depth.

Recent geological opinion,¹ however, is strongly against the likelihood of any large quantity of water being obtained by further sinking at this site, and the well has therefore been finally abandoned, and bricked up, after having involved the town in an expenditure of about £20,000. In sinking this well (Plate 1, Fig. 13), the strata passed through were; vegetable soil, 5 feet; sands and clays of the Bracklesham and Lower Bagshot beds, 76 feet; London Clay, 301 feet; and plastic clays and sands of the Reading beds, 85 feet. The Chalk, reached at 462 feet from the surface, was pierced to a depth of 850 feet, the last 10 feet being found very pasty and devoid of flints. The dimensions of the well and the methods of lining adopted are shown in Plate 1, Fig. 13.

The normal water-level in the well is about 40 feet from the surface, or 100 feet above Ordnance datum. The base of the Chalk is variously estimated to lie at from 20 to 50 feet below the bottom of the existing bore-hole; and it is much to be regretted that the work was abandoned without the Upper Greensand having been touched, as it would have thrown much light upon the geological formation of the district, and might perhaps have yielded a larger quantity of water than has been anticipated.

¹ "Report upon the Water-Supply of Southampton," by W. Whitaker.

WELLS AND BORINGS.

SOUTHAMPTON WATERWORKS.

PLATE I.

Fig. 1.

DISTRICT ROUND SOUTHAMPTON SHEWING WELLS.

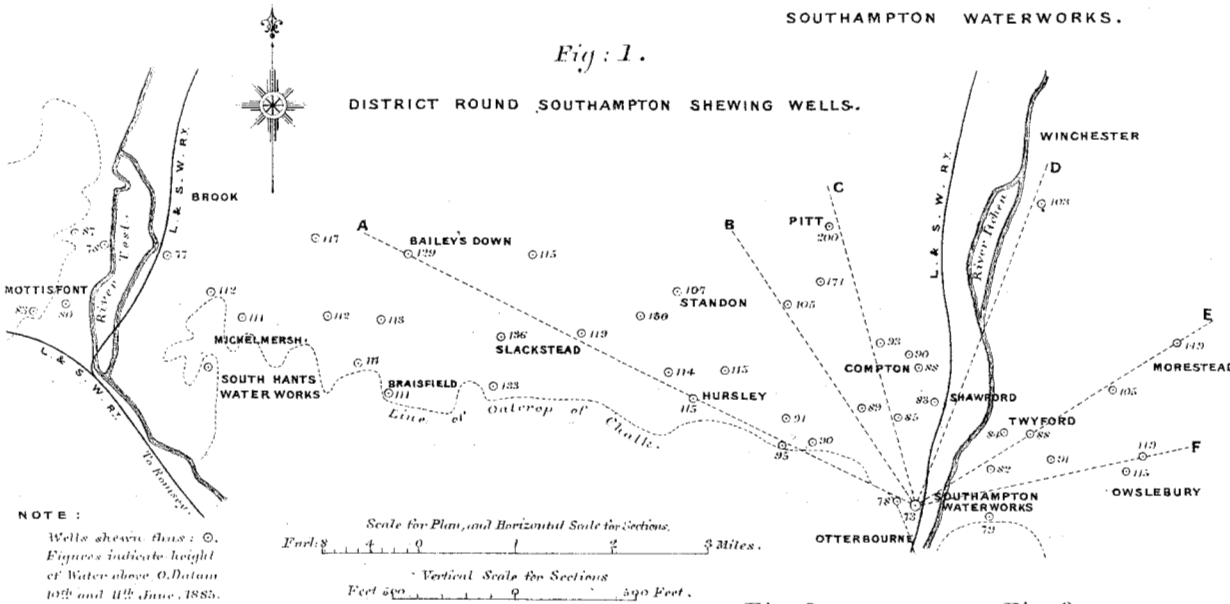


Fig. 2.

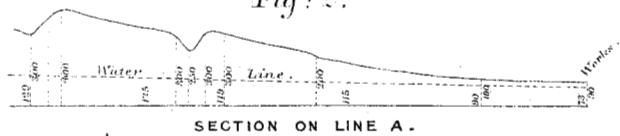


Fig. 3.

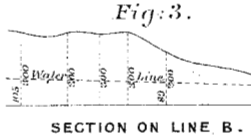


Fig. 4.

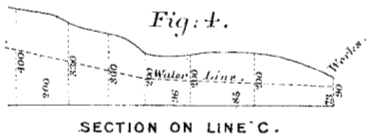


Fig. 5.

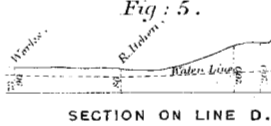


Fig. 6.

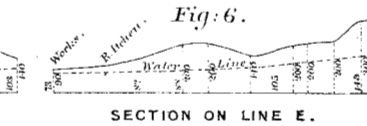
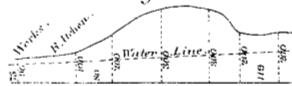


Fig. 7.

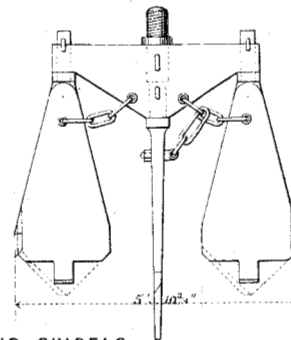


SECTIONS SHEWING WATER LINE.

Fig. 8.

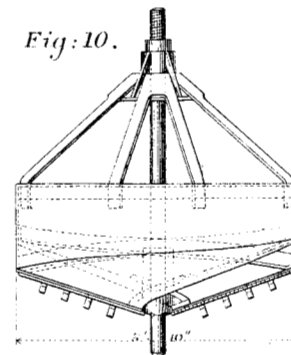


Fig. 9.



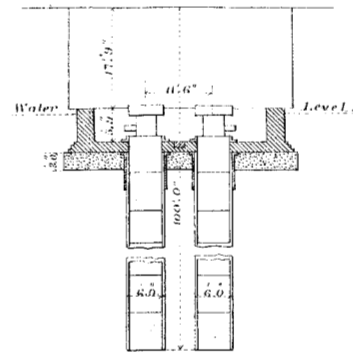
BORING CHISELS.

Fig. 10.



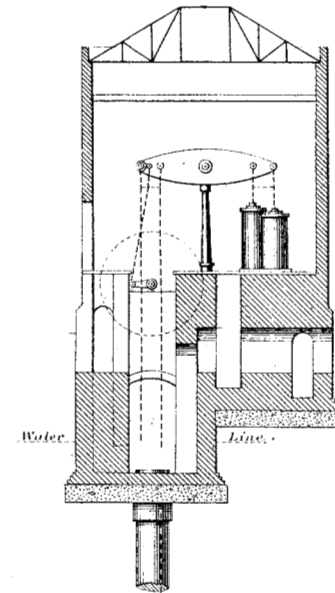
BORING MISER.

Fig. 11.



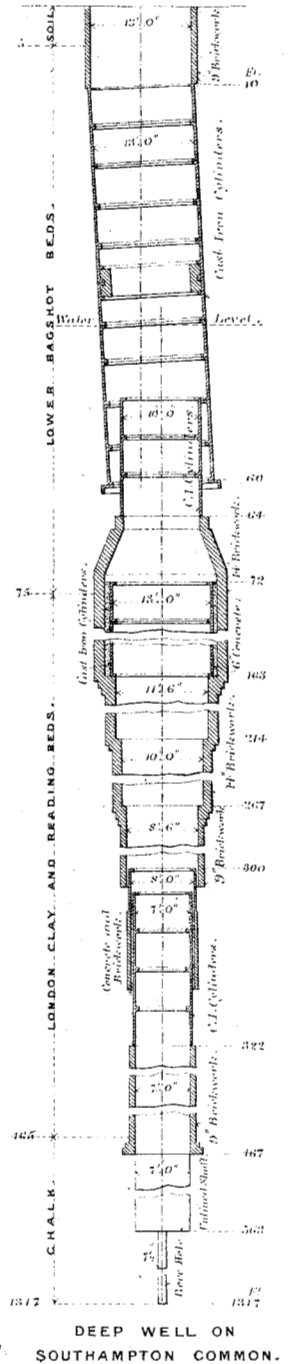
FOUNDATIONS AND WELLS.

Fig. 12.



MACHINERY AND FOUNDATIONS.

Fig. 13.



DEEP WELL ON SOUTHAMPTON COMMON.

Scale for Figs. 8, 9 & 10.

Scale for Figs. 11 & 12.

Scale for Fig. 13.

Ins. 12 9 6 3 0 3 Feet.

Feet 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 88