(*Paper No. 4396.*)

"Service-Reservoirs of the Melbourne Water-Supply System."

By Edgar Gowar Ritchie, M. Inst. C.E.

The estimated population supplied by the system in June, 1920, was 784,000. The average daily supply is 45,200,000 gallons, and the maximum has been 78,300,000 gallons. The water is derived from virgin mountain and forest country, free from occupation of any description, and is delivered in a natural condition of such purity that no measures for purification are necessary. It is conveyed to the service-reservoirs near the city by four independent conduits, which are so advantageously placed that the water from each conduit can be largely interchanged in the event of a breakdown. All water is delivered by gravitation. In consequence of the fact that the conduit provision is so good, the total service-reservoir accommodation of about 2 days' maximum summer demand has been found in practice to be ample for every emergency. To provide for further growth of the city, sufficient land has been purchased to permit the construction of additional reservoirs equal in total capacity to those already in use. Details of the reservoirs are given in Table I, p. 409.

In 1907 the Author was placed in charge of the Melbourne water-supply system under the control of Mr. C. E. Oliver, M. Inst. C.E., at that time Engineer-in-Chief of the Melbourne and Metropolitan Board of Works; and for the ensuing 8 years an active policy was followed of increasing the volume of water to be impounded in service-reservoirs. Since that date six reservoirs have been constructed. In reservoirs before and since 1907 four different types have been employed, namely: (1) Earth banks with a puddle core, lined with pitchers or brickwork, partly constructed in the solid ground. (2) Mass-concrete retaining-walls partly in excavation and partly above the natural surface, the excavated material forming embankments behind the retaining-wall above the natural surface. (3) Retaining-walls, serving the same purpose as type (2), but in reinforced concrete. (4) Reservoirs excavated entirely out of solid ground and lined with concrete.

TABLE I.

Locality.	Available Capacity.	Description.	Form.	Dimensions.[1]	Available Depth of Water	Date of Construction.	Cost of Construction.[2]	Cost per Million Gallons.
	Gallons.			Ft.	Ft.		£	£
Preston No. 1 . .	13,500,000	Earth bank with puddle core lined with pitchers	Rectangular	577 × 244·5	17	1864	11,000	815
Morang	3,000,000	Earth bank with puddle core lined with brickwork	"	200 × 200	12	1876	..	..
Essendon No. 1 .	1,000,000	Earth bank with puddle core lined with pitchers	Circular	150 diam.	10	1881	1,100	1,100
Caulfield . . .	10,000,000	Mass concrete[3]	Rectangular	238 × 454	15	1883	13,500	1,350
Essendon No. 2 .	4,000,000	Earth bank with puddle core lined with pitchers	"	227 × 294	15	1883	6,500	1,625
Surrey Hills No. 1.	9,000,000	Mass concrete	"	241·5 × 338·5	18	1892	12,000	1,333
Kew.	3,000,000	"	"	200 × 200	12·5	1886	6,510	2,170
Preston No. 2 . .	24,000,000	Reinforced concrete	"	476 × 516	17	1909	25,007	1,021
Heidelberg . . .	1,000,000	Mass concrete	Circular	120 diam.	19	1911	2,489	2,489
Notting Hill . .	10,000,000	"	Rectangular	415 × 272	15	1912	15,351	1,535
Preston No. 3 . .	26,300,000	"	"	516·5 × 503	17	1913	29,190	1,110
Surrey Hills No. 2.	15,000,000	"	"	369 × 411	17·5	1913	19,376	1,292
Olinda	11,000,000	Mostly excavated in solid ground and lined with concrete; partly mass concrete	"	518 × 255	16	1915	21,016	1,911

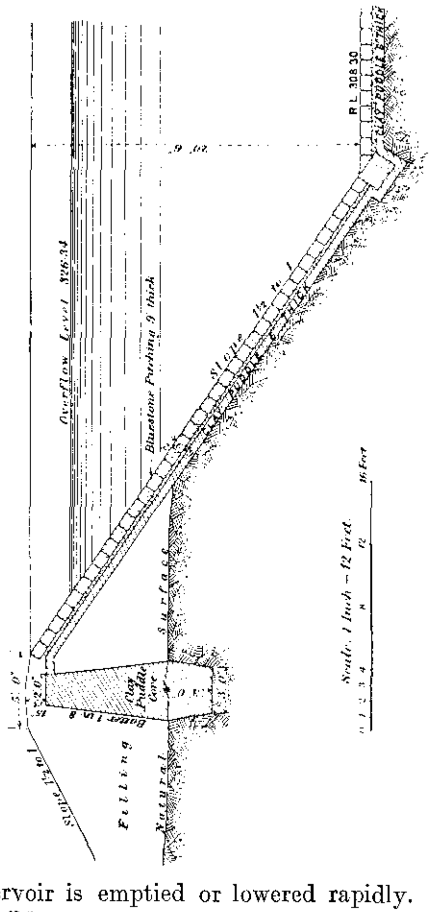
[1] The dimensions given are at top of banks of walls and indicate area occupied by actual reservoir.

[2] All costs given are exclusive of land-purchase.

[3] All mass-concrete reservoirs have earth backing and are built partly in solid and partly in fill.

With type (1) (shown in *Fig. 1*), the brick or pitcher lining, if impervious, prevents the water from reaching the puddle in the earth wall and maintains a uniform condition of moisture, which is essential to keep the puddle in good condition for resisting escape of water. If the lining allows water to percolate very freely, the accumulation behind the lining is liable to cause bulges and slips

Fig. 1.

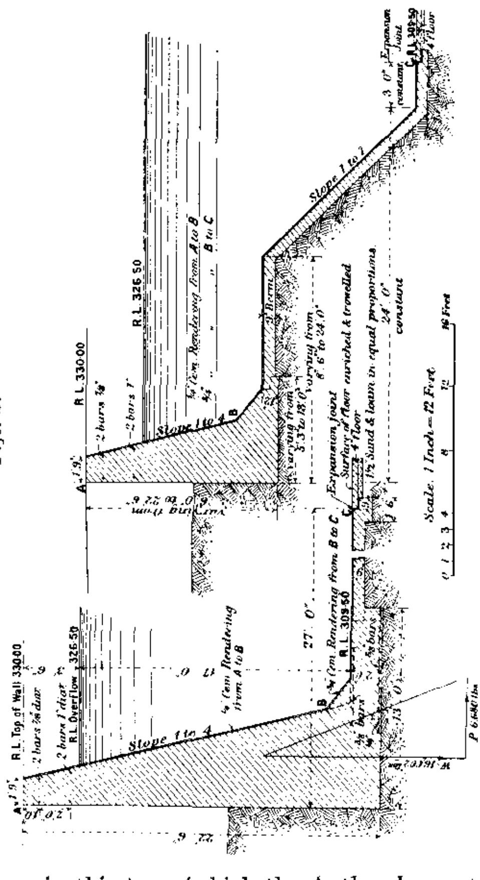


Preston No. 1.

when the reservoir is emptied or lowered rapidly. More land is required to build such a reservoir, and there is a greater area to cover, if this should become necessary.

Type (2) has been found the most satisfactory from the point of view of economy and efficiency, but the adaptation of this type as used at Preston No. 3 (*Figs. 2*), is superior to that at Kew (*Fig. 3*). In the latter the base of the retaining-walls is on a uniform level throughout, irrespective of natural surface-levels. In the former, the base follows approximately levels about 2 feet 6 inches to 3 feet below the natural surface. The change in levels is made by a step in the wall and berm. The small loss of capacity in the reservoir is fully compensated by the saving in mass concrete.

An example of type (3) is shown in *Figs. 4.* Unless there is consider-



Figs. 2.

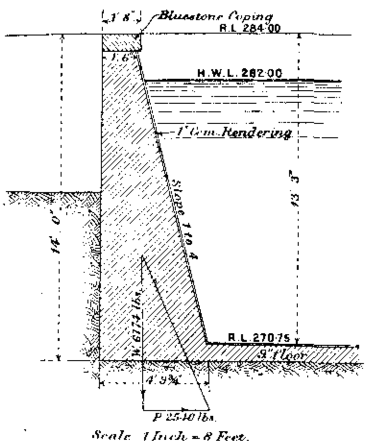
PRESTON No. 3.

able economy in this type (which the Author has not found to be the case), its use is not desirable. One disadvantage is the necessity for waiting until the concrete has obtained sufficient adhesion to the steel before the wall can be loaded with excavated material forming the bank. This delays the whole work of excavation and does not facilitate the regular and even carrying up of the earth embankment behind the retaining-wall. In the meantime, long lengths of exposed retaining-wall are left to set, and they are, in consequence, subject to more cracking than the mass type of wall, in which the earth embankment is built up gradually behind the concrete wall, while the latter is under construction, or shortly after its completion.

Type (4) has only been used in special circumstances (*Fig. 5*), and there has never been any intention of adopting it generally.

Floors.—The thickness of floors has ranged from 17 inches (that is, 9-inch pitchers bedded on 2 inches of sand and 6 inches of puddle beneath) to 3 inches of concrete not rendered, but enriched on the surface by cement trowelled in. The floors have been founded, in almost every case, either on hard red marl or on clay. The substratum and surrounding ground being firm and dense, no apprehension has been felt concerning leakage, and no trouble has occurred even with the 3-inch floor. Experience has shown that the concrete floor may be considered rather as a means of keeping the water clean, and of facilitating the cleaning out of silt or other deposits, than as a medium of perfect watertightness. A 9-inch concrete floor has given results not measurably superior to a 4-inch floor, which latter has been found to be the best thickness, having due regard to economy as well as efficiency. This conclusion has particularly impressed the Author, in view of the practical impossibility of keeping the floor free from cracks through which water will pass and saturate the ground beneath. Expansion joints of tar, sand, and bitumen were used, the floors being divided into panels approximating to 100-foot squares. Notwithstanding these precautions, the covering of concrete with bags, and regular watering, cracks in the floor were found unavoidable. This applied particularly to work carried out during the summer, when it is not uncommon to have a range of temperature of 50° F. during a few hours. It was this experience which led to the discarding of the 9-inch floor in favour of the 4-inch, as being more elastic, and the latter has been found to crack less than the thicker floor. Efficiency has not been impaired,

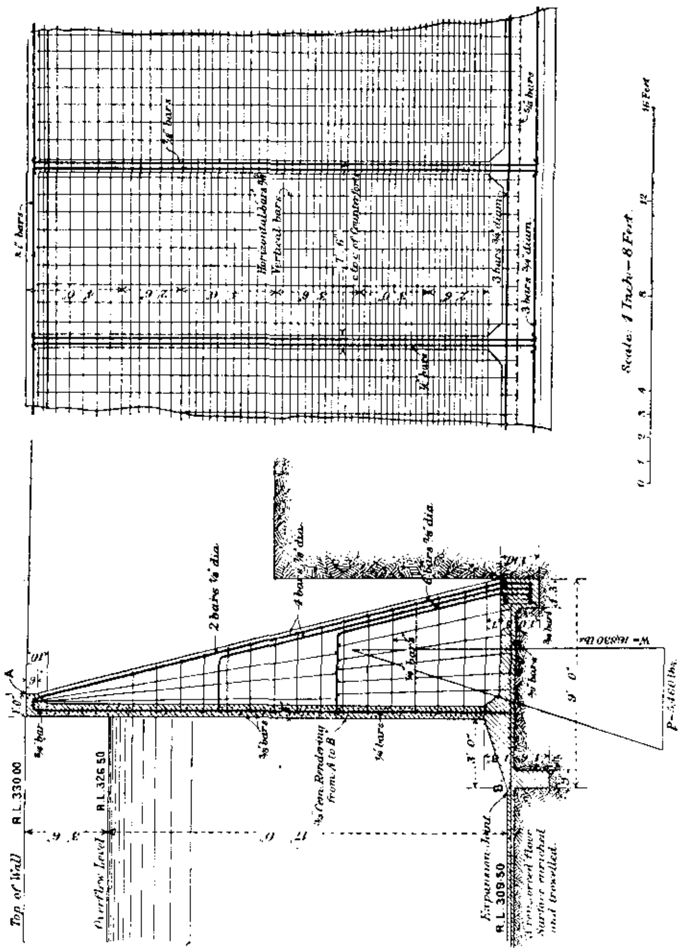
Fig. 3.



Kew.

while the saving in concrete has been considerable. In the Preston reservoirs the floor was founded on natural yellow puddled clay, and the movements caused by the swelling and contraction of this material added to the difficulty of preventing cracks. In No. 2 reservoir (*Figs. 4*) the 3-inch floor was reinforced by a

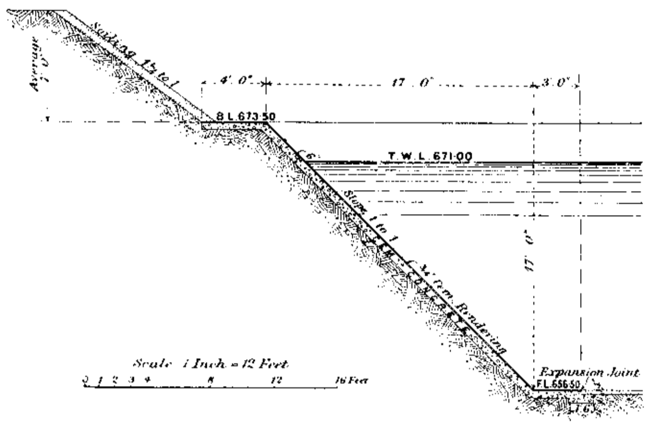
Figs. 4.



PRESTON No. 2.

grid of $\frac{7}{16}$-inch diameter steel bars, spaced 4 inches apart in both longitudinal and transverse directions, and laid directly upon the clay bed. In No. 3 reservoir (*Figs. 2*) a layer of damp sand and loam, in equal proportions, was first tamped upon the clay to a thickness of $1\frac{1}{2}$ inch, and upon this prepared bed a layer of concrete 4 inches in thickness was deposited without any reinforcement. It was considered that the sand and loam mixture would insulate the concrete from the clay movements, but that it would not be sufficiently porous appreciably to rob of its cement the wet concrete placed upon it. The results were good, and the 4-inch floor without any reinforcement was found to be superior to the 3-inch steel-reinforced floor as regards freedom from cracks. No cement rendering was used on either floor. The wet concrete was screeded to a uniform surface. A 1 : 1½ mixture of cement and sand was sifted on to the wet surfaces and trowelled in, and a final dusting of neat cement was also trowelled in. This method of enriched surface-treatment of the concrete was found more satisfactory than the use of ordinary ½-inch or ¾-inch cement rendering, as well as being much cheaper. The composition of the concrete

Fig. 5.



OLINDA.

for the walls and floor was 1 : 2½ : 4. Covering of reservoirs has not so far been found necessary, but a close thicket of trees and shrubs is grown around all basin enclosures, and serves to arrest dust and other impurities which might otherwise be blown into the water.

In connection with Table II, which shows the principal items of the cost of the reservoirs, the following details of construction are of interest. Most of the excavation work was carried out by ploughs and "monkey-tail" scoops drawn by one- or two-horse teams. The excavated material in Preston No. 3 was handled principally by large scoops drawn by cable between two portable steam engines. Consolidation of banks was secured in the usual manner, either by depositing the spoil in 6-inch layers, or by traffic of scoop teams, or by rolling. Concrete was mixed, for the most part, by batch mixers. Trimming of the clay or marl reservoir-floor preparatory to concreting was carried out in fine weather. A considerable saving in the last three reservoirs constructed, both in labour and in con-

TABLE II.—PRINCIPAL ITEMS OF COST FOR RESERVOIRS CONSTRUCTED FROM 1909 TO 1915.

	Preston No. 2.	Heidelberg.	Notting Hill.	Preston No. 3.	Surrey Hills No. 2.	Olinda.
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Concrete in retaining-walls, berms, slopes . per cu. yd.	88 0	42 0	35 0	37 6	41 0	36 0
Concrete in floors . . . per cu. yd.	63 0 including steel reinforcement	42 0	33 0	40 0	40 0	41 0
Cement rendering, ¼ in. thick on mass walls . per sq. yd.			1 9	1 6	2 0	1 6
Cement rendering, ⅜ in. thick on walls or slopes, etc. . . per sq. yd.	included in concrete price for walls	2 3	2 3	2 6	2 6	2 0
Excavation and depositing spoil in banks . . . per cu. yd.	1 4	2 0	2 0	1 6	1 8½	1 9
Stripping and soiling . . per cu. yd.	1 3	2 0	2 6	2 0	1 9	1 4

The cost of cement averaged about 14*s.* 9*d.* per barrel of 4½ cubic feet on the work.

The average cost of sand was about 9*s.* per cubic yard, and of stone, metal or screenings about 8*s.* per cubic yard.

The ruling average rates of pay were :—

Navvies and concrete hands . . . 9*s.* per day of 8 hours
Plasterers . . . . 15*s.* ,, ,, ,,

crete, was effected by the use of an earth-planing machine for trimming the earth floor previous to concrete lining. This was carried on movable rail-tracks and driven by a small petrol engine.

The Author desires to acknowledge the valuable assistance received from Mr. H. A. Wood, of the designing staff of the Melbourne and Metropolitan Board of Works, and from Messrs. J. L. Nolan and H. M. Trethowan, assistant engineers, who had charge of construction work on those reservoirs built between the years 1909 and 1915.

The Paper is accompanied by one sheet of tracings, from which the Figures in the text have been prepared.