ferent city waterworks, it may be taken for granted that it is reliable. The cost of the distributing mains in No. 1 city will therefore be about $3,840,000 and in No. 2 about $4,480,000 and additional expenditure of about $640,000. The cost of operating distribution works may be estimated at $2.50 per million gallons pumped (15) which in the first city would amount to about $11,400 and in the second about $34,200, a difference of $22,800 per annum.

After having distributed the water to the people, the city must also provide sewers to drain it away after use or misuse. The lateral sewers are, of course, designed for flows which normally will only partially fill the pipes. The trunk sewers must be calculated so as to be ample to accommodate the districts served.

Supposing that it was necessary to provide one main conduit to the outfall works, that the grade was 1 in 5,000 and that no ground water was admitted, the diameter of such a sewer to convey 12.5 million gallons per day would have to be about 54 inches and for 37.5 million gallons 82 inches, this does not take into account the hourly fluctuations, otherwise the diameter would have in each case to be larger. Accepting Cincinnati prices (16) the cost of these conduits would be:

54-in. Diameter Sewer—

Trenching 8 yds. @ $1.25	$16.00
Concrete, 1.38 yds. @ $15	20.70
Cost per foot run	$30.70

82-in. Diameter Sewer—

Trenching 11.3 yds. @ $1.25	$13.95
Concrete, 2.24 yds. @ $15	33.60
Cost per foot run	$47.55

That is, to convey three times as much sewage as would be required economically, the ratepayer would have to pay about 60 per cent. more in capital expenditure (and of course in annual taxes for interest and maintenance) on such trunk sewers. When the cost of vitrified pipe sewers are analyzed, it will be found that the extra cost for sewers laid to carry, say, 1,200 gallons per minute and 3,600 gallons per minute will be in the following ratio:

15-inch Pipe, Grade 1/600—

Vitrified pipes	$ .75
Trenching 10 feet deep	.70
Total per foot run	$1.45

24-inch Pipe, Grade 1/800—

Vitrified pipes	$2.00
Trenching 10 feet deep	.70
Total per foot run	$2.70

Extra cost 86 per cent., so that the additional cost to convey three times a given volume of sewage increases as the diameter of the sewers diminishes. The cost of sewering a city is probably about the same as to provide water mains, perhaps more, because water mains operate under pressure and sewers by gravity; the former are always full, whilst the latter are generally only partially full and consequently larger in diameter or dimensions. Many of the lateral sewers could not be reduced in size even if the water consumed was maintained at 50 gallons per capita, but many of the larger sewers could, and the saving in capital expenditure would be tangible.

(15) Wisconsin Railroad Commission Report, 1911, page 445.

(16) Report on a Plan of Sewerage, Cincinnati, 1913, page 252.

The next item of expenditure is for sewage disposal works. Whilst to some degree it is true that an extravagant use of water does not necessarily entail the construction of works to treat sewage, in proportion to the flow or volume, it nevertheless means works of a greater capacity than would be necessary in the case of economical water consumption, for tanks and pumps must be in some relation to the hourly quantity of sewage. The capacity of the pumps (if any) must be more than equal to the maximum hourly flow of sewage, with reserve pumps and power as well, in case of breakdowns or other contingencies, common to such plant. The velocity of the flow of sewage through the tanks must not for long periods exceed a critical limit. To attain this condition it is evident that tanks capable of treating 37.5 million gallons daily will be much larger than would be necessary for a discharge of one-third that volume.

Mr. George H. Wisner, in his report (17) supplies an interesting table of costs which is copied below:

Type of tank.	Nominal period of settling.	Gallons per capita.	Cost per capita.
Emscher	3 hours	200	$1.44
Dortmund	4 hours	200	.84
Straight flow	8 hours	200	.77
Straight flow	6 hours	200	.58

As Emscher or two-story tanks are now prominently before us, its estimated cost per capita will be provisionally accepted. To maintain the same velocity for 150 gallons per capita daily, the cost will be $1.44 $\times \frac{150}{200} =$ $1.08 and for 50 gallons per day $1.44 $\times \frac{50}{200} =$ $0.36.

The writer does not contend that the cost of these tanks will be in strict proportion to the flow of sewage, as there are items of expenditure which are not proportionate; still, taken as an entity, the cost will not seriously exceed the above. Mr. Clark, when discussing a plant in course of construction in Baltimore, stated that the detention period with Emscher tanks would be two hours (18)—which is the ordinary standard detention period—consequently, to maintain this detention period as closely as possible, the number or sizes of the tanks must, in the cases under present discussion, be approximately in the same ratio as to dimension and cost. But to allow for contingencies, assume that the cost would be $1.10 and 40 cents respectively per capita, then, 250,000 × $1.10 = $275,000, and 250,000 × 40 cents = $100,000, a difference of $175,000 which, at 5 per cent. interest and 2 per cent. maintenance, etc., means $12,250 per annum.

Perco filters, again, are designed to deal with about 2,000,000 gallons per acre daily. Columbus filters were designed for this rating. Mr. George W. Fuller states in his book that his practice has been to specify for average conditions a 6-foot filter at an average rate of two million gallons per acre per day (19). This would be for a sewage flow of separate sewers approximately 100 gallons per capita daily. It is contended that perco filters will deal with approximately the same quantity of organic matter per acre per day, regardless of the degree of dilution. In other words, the organic matter from a residential city will, in the aggregate, roughly amount to the same

(17) Report on Sewage Disposal, Sanitary District of Chicago, 1911.

(18) Engineering Record, July 4th, 1914.

(19) Sewage Disposal, George W. Fuller, 1912, page 697.