this set of curves. The irregular line in Fig. 2 shows the recorded rates of rainfall for Toronto.

Mr. Wynne-Roberts developed the dotted curve, which is derived from $I = 13.2 \div (\text{minutes})^{\frac{1}{2}}$, representing the rainfall intensities as decorded by the meteorological department at Toronto, and the values given by this formula have been used. The rates given by this formula have been equalled or just exceeded at several points once or twice in 10 years. That is to say, the sewers designed for this rainfall might be working to their limit or overtaxed once every 5 years.

These are definite figures for rainfall, but it is hard to estimate the amount of run-off, as so much depends on the state of the surface on which the rain falls. In a residential district about 30% of the total area will be impermeable when fully developed. The remaining 70% of the area will, at the start of a storm, absorb a good deal of the rain, and the roughness of the lawns, etc., will hold up a film of water and act as storage tanks, delaying the progress of the water towards the sewers. Only very careful gauging of existing sewers in conjunction with short time rainfall measurements will enable us to solve the problem of run-off. For the preliminary report on York township sewers, the following coefficients of run-off were adopted:—

RAINFALL RUN-OFF COEFFICIENTS
(Impervious area taken as 30%)

Time in minutes.	Intensity of rain-fall.	Run-off from impermeable area.	Run-off from permeable area.	Total run-off as percentage of rainfall.	C.f.s. per acre.
5	5.90	80%	....	25.0	1.50
10	4.11	95%	....	28.5	1.20
15	3.40	100%	....	30.0	1.10
20	2.95	100%	5%	33.0	.98
30	2.41	100%	10%	37.0	.89
60	1.70	100%	20%	44.0	.75

Rain falling at the rate of one inch per hour, if all collected, would mean a rate of run-off from one acre of nearly one cubic foot per second. The coefficients of run-off are roughly 30% of the rainfall for the first 20 minutes. After 20 minutes, some allowance has been made for the flow from the previous area, as by this time it is probable the ground will be so soaked that the surface run-off will be considerably increased. This table of run-off coefficients gives a ready method of estimating the quantity of water to be dealt with, but in using these it is necessary to know the time of concentration for each point in the sewer.

Run-off Curve Plotted

Fig. 3 shows the coefficients of run-off adopted by the city of Cincinnati. The quantity of run-off was worked out on the principle of applying the rate of rainfall corresponding with the time of concentration at each point in the line of a trunk sewer. Thus, if the storm water took ten minutes to reach a certain point A, then the area tributary to this point in acres was multiplied by the rain-fall rate for a 10-minute storm and reduced by the percentage of impermiable area. By plotting, the results arrived at in this way for a number of sewers, the curve was obtained which gives directly the run-off to be expected from any acreage. The crosses and circles show similar results for two of the York township sewers, using the Toronto rainfall curve, which is slightly lower than that for Cincinnati. With this curve it is possible to estimate the run-off from any acreage without going into the time required for water to flow through the sewer. Thus, for fifty acres the run-off would be 60 cu. ft. per sec.

[NOTE.—Mr. Greig here showed a graphic method of working out the probable quantity of storm water in a trunk sewer. This method, suggested by Mr. Wynne-Roberts, was the subject of articles in *The Canadian Engineer* several years ago.—EDITOR.]

All the proposed sewers in the scheme have been worked out on the "rational method," taking the time of concentration into account, and their sizes fixed by the quantities arrived at in this way. When it comes down to making working drawings, it would be well to try out each trunk by the diagrammatic method.

Plans to a scale of 200 ft. to one inch were prepared, and contours drawn on them from lines of levels run on street lines. A study of the contours brought out the best lines for trunk sewers, and then the direction of flow of all laterals was indicated on each street. The watersheds being thus defined, every street intersection was given a number. The information on these plans was then transferred to a calculation sheet of the form shown in Fig. 4. It will be noticed that the data from the plan reads as follows: Street, name, from, to, distance, length (for area), width (for area), and surface elevations. From this the acres tributary to each section can be worked out, and as the length of sewer increases, the acres accumulate in Column 9.

Design Sheet

The surface elevations give an indication of the gradients available. The elevations for the inverts were entered in the table as if the sewers were lying on the surface of the ground or near to it, so that at a glance it was observable how nearly the adopted grades parallelled the surface. After working through the calculations in this way, it was only necessary to take 10 ft. off all elevations to arrive at the real invert levels. It was possible by taking the data from the plans into the calculation sheets as indicated, to settle the gradients and sewer sizes without further reference to the plans or plotting of any profiles. Of course, when working drawings are got out, profiles will be used and probably many minor modifications and improvements made on the gradients.

Design Sheet for Sewers on CHISHOLM, GATWICK & DONCASTER

Reference	Street	M.H. From	M.H. To	Distance	Length for Area	Width for Area	Area (acres)	Accum. Area (acres)	Coeff. of Runoff	Q cu. ft. sec.	Fall feet	Grade 1 in	Diam. of Sewer	Velocity feet per second	Time of Start	Time in Section	Total Time (seconds)	Invert Elevation In	Invert Elevation Out	Surface Elevation	Depth of Cut	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
27	CHISHOLM	24	25	220	220	300	1.52		1.50	2.28	1.0	220	12"	3.3	300	67	367	423.96	422.96	423.3 / 422.2	Approx. 10'	
28	GATWICK	26	25	300	225	260	1.34		1.50	2.01	2.0	150	12"	4.0	300	75	375	428.36	426.36	428.9 / 426.0	10'	
	"			300	225	260	1.34	2.68	1.45	3.88	4.0	75	12"	5.8	375	52	427	426.36	422.36	426.0 / 420.2	10'	
29	CHISHOLM	25	27	260	260	300	1.79	5.39	1.40	8.40	1.0	260	20"	3.9	427	67 (Allow for change in diam.)	494	422.30	421.30	420.2 / 418.6	9	
30	DONCASTER	28	27	300	225	260	1.34		1.50	2.01	2.0	150	12"	4.0	300	75	375	428.0	426.0	426.5 / 424.0	9	
	"			300	225	260	1.34	2.68	1.45	3.88	4.0	75	12"	5.8	3.75	52	427	426.0	422.0	424.0 / 418.6	8	
31	CHISHOLM	27	29	260	260	300	1.79	10.46	1.35	14.10	2.0	130	20"	5.4	494	48	542	421.30	419.30	418.6 / 418.0	9	

FIG. 4—DESIGN SHEET FOR SEWERS IN DISTRICT NO. 1, EASTERN DIVISION, YORK TOWNSHIP

Following through the form of calculation it will be seen that from 24 to 25 the acres are 1.52, and allowing 5 minutes for water to reach the sewer in volume, the coefficient of run-off is 1.5, and the quantity 2.28, and this requires a 12-in. pipe at the adopted gradient of 1 in 220.

The "from" and "to" column show just how the areas are coming into each section. These are branch or side lines to the main trunk, as indicated by the repetition of manhole numbers. The underlined figures are those of a small trunk.

A circular slide rule prepared by R. O. Wynne-Roberts proved very useful on this work, as it gave velocity and discharge for any size and any gradient when running full or at any proportional depth.

Illustrations printed in *The Canadian Engineer* in the issues of Dec. 18th and 25th, 1919, and Jan 22nd, 1920, show the lines of sewers and laterals worked out for each particular district. The amount of work involved in fixing the grades and sizes of the many lines of sewers was considerable, but those illustrations gave the framework of a comprehensive scheme.

The report sent in was purely a preliminary one, but having built up this general scheme it is possible to try out various modifications with some idea of how they will effect the building as a whole. In a sewerage scheme comprising many drainage areas, artificial and natural watersheds contiguous to one another, it is a very intricate problem to ar-