

INFLUENCE OF AIR TEMPERATURE AND SOLAR RADIATION
ON SNOWMELT RIPENING AND RUNOFF

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For several years a field study has been carried out on some hydrologic effects of urbanization by the writer. The objective of the investigation was to determine the influences of the construction of a suburban community built upon agricultural land on hydrologic parameters, especially those pertaining to storm sewer design and water quality characteristics. The community is Kanata, which is situated twelve miles west of Ottawa, Ontario, Canada and has been under construction for the past nine years. The area presently developed or planned to be developed is 2,200 acres and is drained by four small streams, the drainage area of the largest being 1,100 acres.

The region in 1964 was agricultural with the present community site having a population of 14. Its present population is approximately 5,000, and the plans of the developer is to have an ultimate population of 65,000 people.

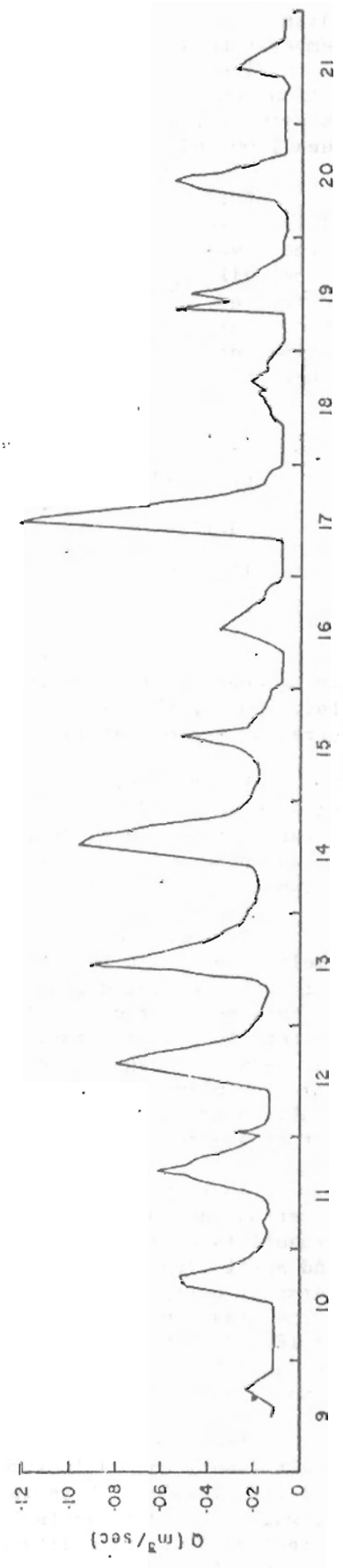
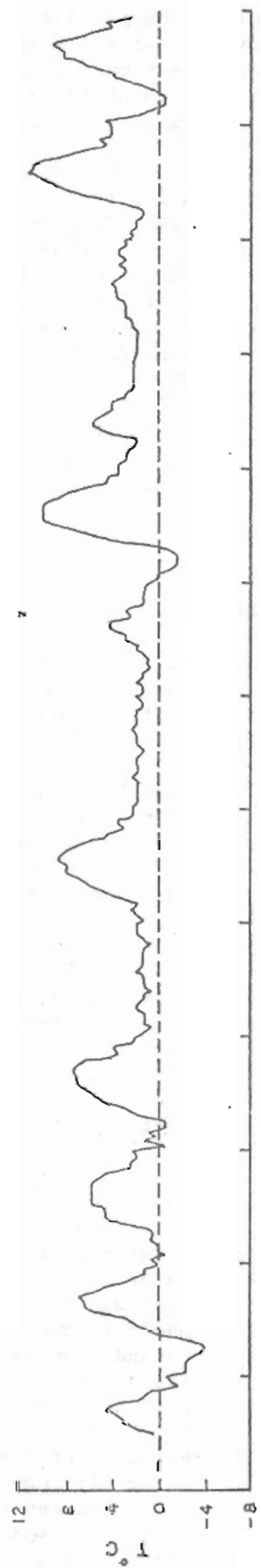
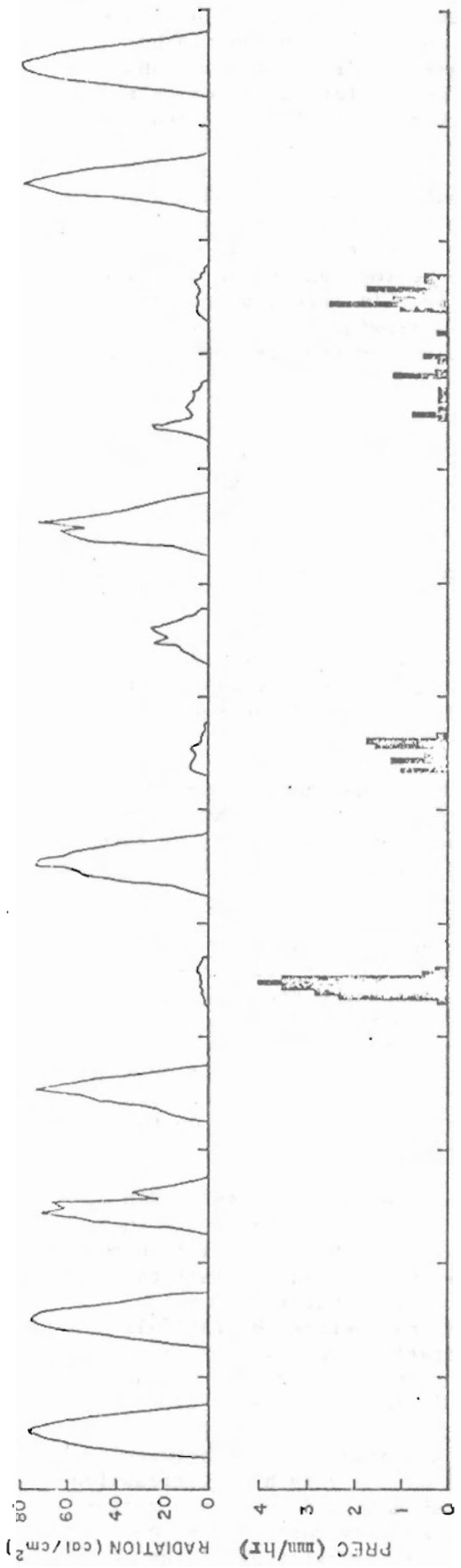
Three of the basins have been instrumented for several years with Parshall Flumes, which were built as temporary structures because of the uncertainty of the location of future highways in the area. Some of these roads are now built, and the route location of the others have been finalized. The flumes proved to be unsatisfactory for flow measurements during spring runoff because of frost heave and winter damages to the structures. There were replaced with permanent sharp-crested weirs during the summer and fall of 1972.

The flume measuring the discharge of the smallest basin was not damaged and provided accurate readings during spring runoff of 1972.

The drainage area of this basin is 61 acres of relatively flat land underlain by Leda clay. In a land-use survey conducted in 1969, percentages of different uses were as follows. Grasslands: 46%, woodland: 48% and subdivisions: 6%. During last year's snowmelt period there was a large number of condominiums under construction on the basin. In August a land-use survey revealed that paved streets and buildings made up 39% of the area and the remaining 61% consisted of lawns and open fields.

The discharge from the basin was measured by an 18 in. Parshall flume. Meteorologic parameters shown in Figure 1 - precipitation, shortwave radiation and air temperature - were measured in the vicinity of the basins. The shortwave radiation was measured at the National Research Council's Laboratories 26 miles to the east, and the air temperatures were measured at Ottawa International Airport 12 miles to the southeast. Normally daily net radiation amounts are recorded; however, the net radiometer was out of order during the snowmelt period. Precipitation amounts were measured both at the Airport and a standard gauge situated within one mile of the basin outlet.

Recent hydrologic researchers (Warnock and Lim, McCann and Cogley) have noted that the snowmelt runoff from small basins sometimes follows a diurnal sinusoidal pattern. This occurred on the basin described above as may be seen from the bottom graph of Figure 1, where discharge in $m^3/sec.$ is plotted against time is shown for the period from April 9th to 21st. Before the 9th there was no flows larger than $0.0028 m^3/sec.$ and after the 22nd of April the hydrograph follows a normal recession. During the snow accumulation period from November through to April 9th, rain and snowfall totalled 37.59 cm. (14.8 in) of water equivalent. While the snowmelt runoff was occurring, 3.83 cm. (1.51 ins.) of rain-fall fell and 9.70 cm (3.82 ins.) of runoff occurred.



APRIL 1972
FIGURE 1

From the analyses of the collected data, two conclusions may be reached. One pertains to the time of daily peak of discharge, and the other to the relative influence of temperature and radiation on the volume of daily snowmelt runoff. From the graphs shown in Figure 1, it may be seen that the times of daily peaks of air temperature and radiation remain relatively constant throughout the snowmelt period for rain-free days. The shortwave radiation peaks at noon, and the air temperature reach their daily peaks between 1500 and 1700 hours.

Rain fell on three occasions during the same interval: on the 13th, when 1.80 cm. (0.71 ins.) fell, on the 15th, when 0.69 cm. (0.27 ins.) fell, and on the 18th and 19th when there was a total of 1.35 cm. (0.53 in.). From the plot of discharges, it may be seen that the daily peaks occurred earlier each day throughout the period, except on days when rain occurred. The large changes in time of peak discharge for rain-free days occurred on the day after rainfall. The results are condensed in the following table in which the peak times of air temperature, radiation and discharge are shown for the periods succeeding the three blocks of rainfall.

TABLE I

April 1972	Air Temperature	Radiation	Discharge
9-12th	1500-1700	1100-1300	1600-1800
16-17th	1500	1300-1400	1200-1300
20-21st	1500-1700	1200	1200

From the table it may be learned that there is a correspondence for the peak times between air temperature and discharge in the early portion of the snowmelt runoff period. During the latter part of the runoff period, the radiation and discharge occurred at approximately the same time.

Since there was 4.00 cm. (1.57 ins.) of rainfall during the snowmelt period in which 9.70 cm. (3.82 ins.) of discharge from snowmelt and rainfall occurred, then it may be inferred that the snowpacks became successively more ripened after each block of rainfall, which may mean that radiation starts to have a stronger influence on the time to peak of snowmelt than air temperature for ripened snowpacks.

For many years hydrologists and others used the degree day method for predicting snowmelt runoff. In the last fifteen years, the U.S. Corps of Engineers equations, considering the melting capability of each heat source, has been used more frequently; however, this method requires that a large number of meteorologic parameters and geographic characteristics of the basin be known, which they are not for most basins. More hydrologic researchers have begun to examine these equations in order to determine which parameters provide the major sources of heat to the snowpack. Recently there has been an opinion crystallize among some hydrologists that net radiation has more of an influence on the amount of snowmelt than air temperature.

In Figure 2, a plot of daily runoff volume for rain-free days from April 9th to 19th versus the summation of hourly air temperature above 0°C throughout the day is shown. The runoff is expressed in units of mm of water over the total watershed. The variables beyond April 17th were not considered because from Figure 1 it may be learned that the patterns of daily air temperature, radiation and discharge are such that it is apparent that the area contributing to snowmelt runoff is much smaller than before the rainfall of April 18th and 19th. The air temperatures and amounts of radiations were very high on these days; however, the runoff is relatively small. Figure 3 shows the runoff in the same units as before versus the summation of daily shortwave radiation in Langleys.

From these figures it may be learned that there is a linear relation between snowmelt runoff and daily summation of hourly air temperature with a very high correlation coefficient (0.98). There is a poor relation between runoff amounts and shortwave radiation, which is indicated in Figure 3, and the relation has a very low correlation coefficient of 0.02. A multiple regression analysis was carried out consisting of the daily summations of hourly temperature and shortwave radiation as the independent variables.

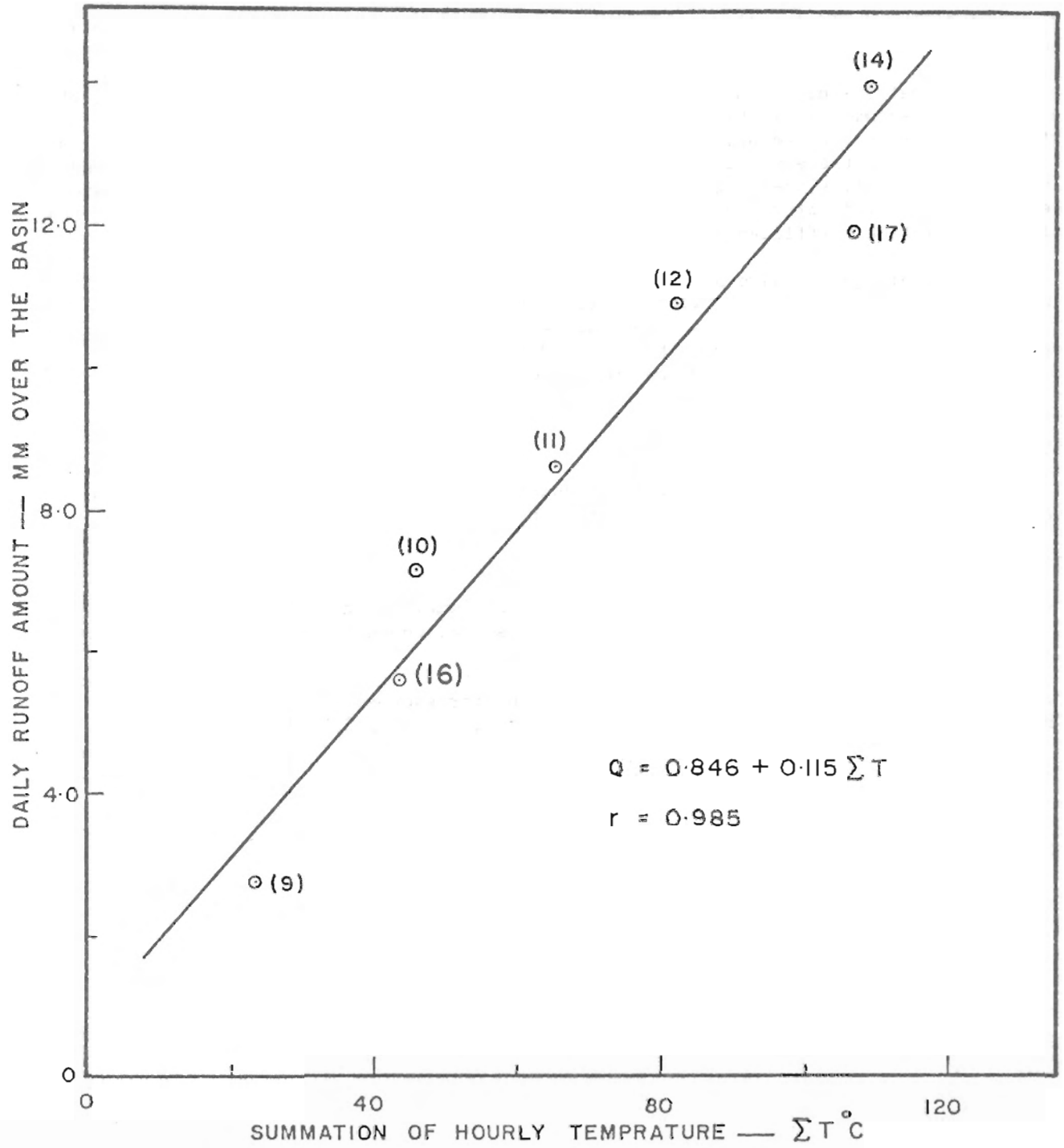


FIGURE 2

The result is:

$$RO = 0.739 + 0.00027 R + 0.115 \Sigma T$$

where RO is daily runoff in millimeters over the basin, R is radiation in Langleys and T is hourly air temperature in 0°C.

The coefficient of multiple linear correlation is 0.98, which indicates that the amount of daily snowmelts are highly dependent on combined effects of air temperature and short-wave radiation. Since only rain-free days were considered in the regression analyses, one would think that there would be a higher correlation between shortwave radiation and daily snowmelt runoff, since on these days short wave radiation would be a good indicator of net radiation. This proved not to be the case for the days considered even through the multiple correlation coefficient is relatively high.

It is planned to have a hygrothermograph and a net radiometer operating on the basin along with a stage recorder with a large time scale at the outlet weir during the spring runoff period of 1973 in order to observe more accurately the times of peak discharge, net radiation and air temperature. By doing so it is hoped that more will be learned to the influences of the two parameters on snowmelt volumes than indicated by the results cited above.

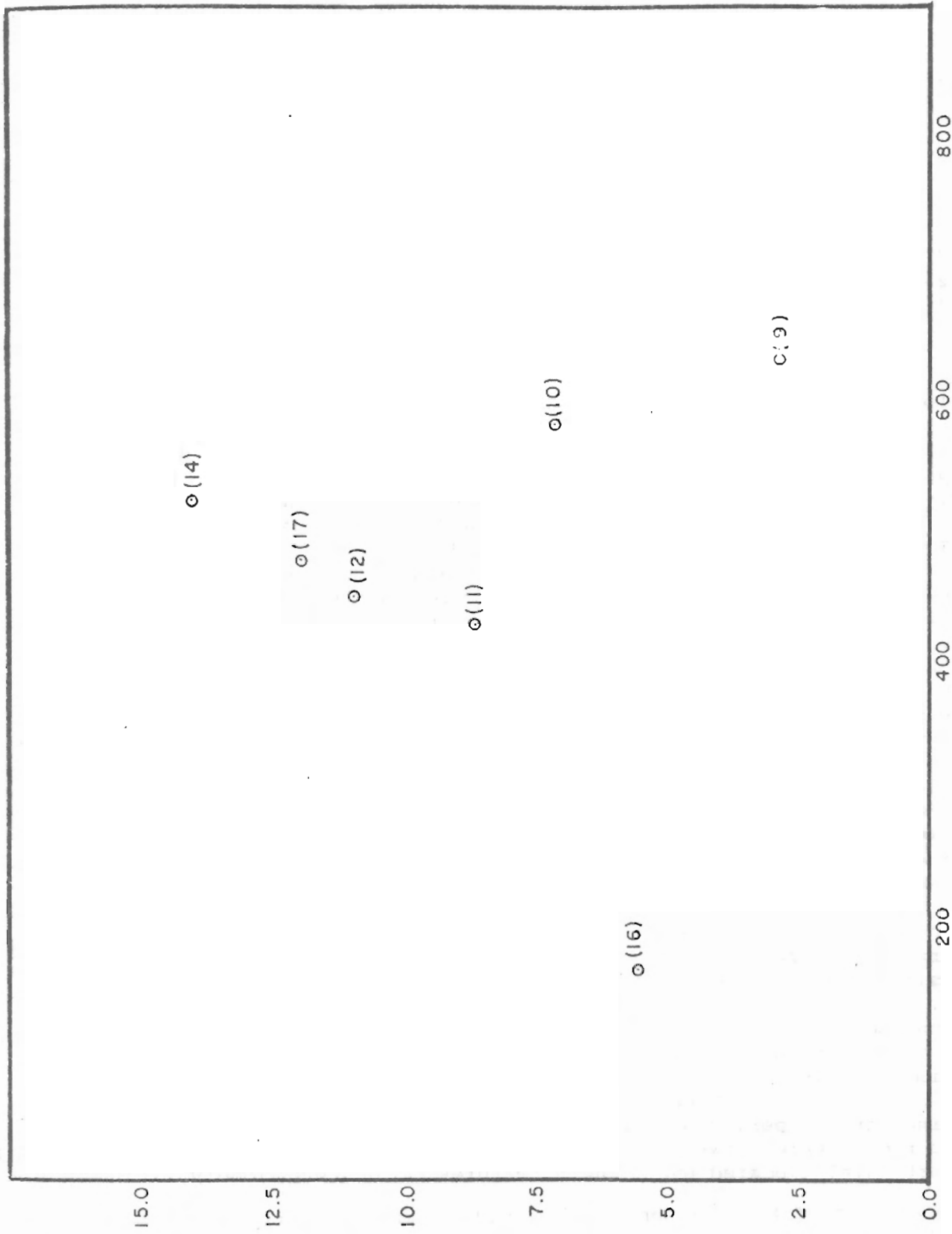
Acknowledgments

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DAILY RUNOFF AMOUNT - MM OVER THE BASIN



SUMMATION OF DAILY SHORTWAVE RADIATION - CAL/CM²

FIG. 3