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Dear Reader,

This is the last issue of 1990 and I am pleased to say that as of 1991 *Hydrosoft* will be incorporated with *Advances in Water Resources* to provide readers with six issues a year, rather than four. I believe readers will find the increased frequency of the journal will offer greater immediacy to published work and a strengthened editorial board will also ensure, at the same time, a high quality of papers selected for publications.

Yours faithfully,

Lance Sucharov
Publishing Director

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Technical Note

Time–area diagram and peak flow estimates using rational method link–node modelling

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Time–area diagram and peak flow rate table analyses are incorporated into the *rational* method in order to better evaluate the runoff timing characteristics within the catchment. It is shown that by use of this combined analysis the rational method can better estimate peak flow rates developed by a subset of the catchment, i.e., an 'effective area'. An example is given to illustrate that algorithms can be incorporated into the rational method computer software in order to implement these time–area diagram and peak flow rate table procedures.

INTRODUCTION

The well-known *rational* method[2,3] has been widely used in estimating the peak flow (runoff) rates which are required for designing flood control systems in small urban and rural watersheds. The approximation of maximum rates of flow to be expected with some prescribed return frequency is generally sufficient for designing many flood control systems. An important parameter in the application of the rational method is the estimate of time of concentration; that is, the time for the entire catchment to contribute flow given a uniform and constant rainfall of duration equal to the time of concentration. However, in many cases, this timing parameter is inadequate for estimating peak flows. Often, a peak flow rate is obtained by considering only a subset of the total catchment, in that the smaller area has a shorter time of concentration and a corresponding higher rainfall intensity. A time–area diagram, that defines the tributary area of the watershed contributing runoff to the point of concentration as a function of time, provides for the capability of estimating this 'smaller watershed', i.e., 'an effective area'. For a watershed with multiple stream confluences, the peak flow rate table analysis guarantees the maximum peak flow rates for designing the flood control systems. As shown in this note, the algorithm needed to incorporate the time–area diagram and peak flow rate table analyses with the rational method is straightforward and can be readily integrated into any rational method model.

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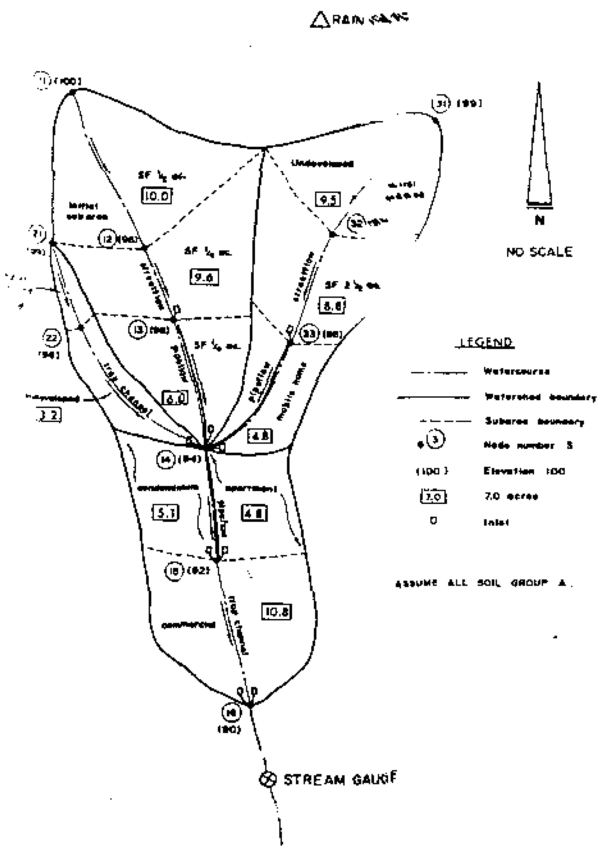
TIME–AREA DIAGRAM AND PEAK FLOW RATE TABLE ANALYSES

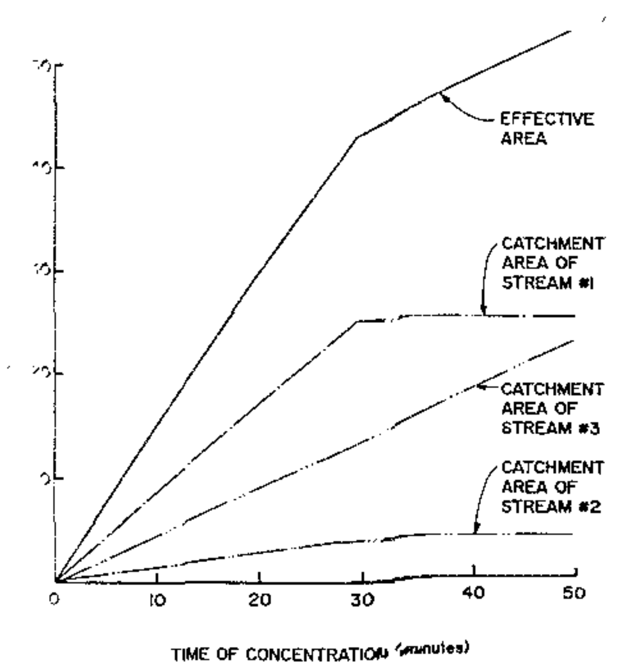
The time–area diagram can be developed by using the rational method. The following example problem demonstrates the step by step development of the time–area diagram and peak flow rate table analyses. Table 1 illustrates the watershed link–node model results at the confluence point (NODE 14) for a hypothetical watershed as shown on Fig. 1. The time–area diagrams of three confluenced streams and the time–area diagram of the three streams are shown in Fig. 2 and Table 2. The resulting confluence estimates are shown in Table 3. The maximum peak flow rate of 79.6 cfs is estimated at the confluence point corresponding to the longest time of concentration. Therefore, 100 per cent of the total watershed area is contributed at the time of 49.5 minutes. The peak flow rate of 79.6 cfs is used to estimate the pipe size between node 14 and node 15. Next, the peak flow

Table 1. Watershed link–node model results at confluence point (node 14)

Stream number	Node number	Time of concentration Tc (minutes)	Tributary area A (acres)	Peak flow rate Q (cfs)
1	12	24.1	10.0	20.8
	13	26.9	19.6	38.2
	14	29.3	25.6	47.5
2	22	15.7	1.0	2.7
	14	27.9	4.2	7.7
3	32	36.4	9.5	14.4
	33	44.7	18.3	24.5
	14	49.5	23.1	29.6



1. Watershed schematic



Time–area diagram at confluence point (node 14)

…able (i.e., Table 3) proceeds downstream from node …wards the watershed outlet (node 16). Table 4 shows …dvancement of the peak flow rate table from nodes 14 … At node 15, the estimated peak flow rate of 94.5 cfs … corresponds to the time of concentration of …minutes is used to estimate the trapezoidal channel …ulics between nodes 15 and 16. …watershed outlet (node 16), the peak flow rate of 106.8 cfs which corresponded to the time of concentration of 35.5 minutes (with 87 per cent of the total area contributed) is used in designing the watershed outlet structure.

In this example problem, the maximum deviation of the estimated peak flow rates from the peak flow rate table analysis is about 15 cfs which has little impact on designing the flood control systems but illustrates the capabilities of the time–area diagram and peak flow rate table analyses. A systematic way of analyzing the watershed peak flow rate is demonstrated without re-analyzing the watershed link–node model for all the possible storm intensities corresponding to different times of concentration. For large and complex watersheds, the procedures will guarantee the maximum peak flow rates in designing flood control systems.

IMPLEMENTATION

The time–area diagram and the peak flow rate table analyses can be implemented into any rational method watershed link–node model. First, the time–area diagram can be implemented into the watershed link–node model for all the collection streams.

This can be easily accomplished by assuming the linear relationship between the time and tributary area for each stream at the confluence point. The storage spaces can be reused for other streams after the first confluence analysis is completed. The confluence analysis is implemented at each confluence point and the new peak flow rate table is developed once the confluence analysis is complete. This peak flow rate table then proceeds downstream for more watershed link–node analyses and/or confluence analyses

Table 2. Time-area diagram estimates at confluence point (node 14)

Time of concentration Tc (minutes)	Tributary area (acres) Stream # 1	Stream # 2	Stream # 3	Sum
49.5	25.6	4.2	23.1	52.9
29.3	25.6	4.2	$23.1\left(\frac{29.3}{49.5}\right)$	43.5
27.9	$25.6\left(\frac{27.9}{29.3}\right)$	4.2	$23.1\left(\frac{29.3}{49.5}\right)$	41.6

Table 3. Results of confluence analysis (node 14)

Stream number	Time of concentration Tc (minutes)	Effective area A^e (acres)	Peak flow rate Q (cfs)
1	27.9	41.6	78.5
2	29.3	43.5	79.6
3	49.5	52.9	68.6

Table 4. Advancement of peak flow rate table from nodes 14 to 16

Node number	Stream # 1 (Tc, A^e, Q)	Stream # 2 (Tc, A^e, Q)	Stream # 3 (Tc, A^e, Q)
15	(30.2, 51.5, 93.6)	(31.6, 53.4, 94.5)	(51.9, 62.8, 80.3)
16	(34.1, 62.3, 106.6)	(35.5, 64.2, 106.8)	(56.0, 73.6, 91.4)

before reaching the watershed outlet. The peak flow rate table can be stored in the memory and then updated for each link–node process and confluence analysis. This procedure ensures maximum peak flow rates for designing the flood control systems throughout the entire watershed.

The proposed model needs only additional memory storages for time–area diagram and peak flow rate table analyses. The increasing computational efforts are minimal compared to reanalyzing the watershed corresponding to all the *Tc* combinations at all the confluence points.

The time–area diagram and the peak flow rate table analyses were incorporated into the rational method computer program[1] obtaining the results of the example problem.

CONCLUSIONS

Time–area diagrams can be directly constructed from the rational method along each storm drain system. After confluencing with one or more storm drain systems, the peak flow rate table can be developed for each confluence point. Thus, the peak flow rate at each hydraulic process (e.g. street flow, pipe flow, channel flow, etc.) can be determined from the peak flow rate table analysis. The advantage of incorporating the time–area diagram and peak flow rate table analyses into the rational method is that the most critical peak flow rates may be used to develop the design peak flow rates for the flood control system without reanalyzing the watershed link–node model.

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