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URBAN CATCHMENT MODELS
“Brief Examination”

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Chapter 1

INTRODUCTION

It is generally accepted that the contemporary trend towards more urbanization which exists in the United States and in nearly all other nations should continue through the remainder of the century. As a consequence, urban problems associated with the hydrologic aspects of water management should become increasingly more acute. Effective disposal of storm water has become very essential. Urban stormwater management is no longer based on the interception, collection and disposal of stormwater only. Knowledge of the time distribution as well as the peak discharge of urban storm runoff has become a requirement. The Rational Formula widely used in the design of urban storm drainage systems is inadequate in this respect. A search for a more suitable method has resulted in recent years in the development of a number of mathematical models which attempt to simulate hydrologic processes on an urban catchment to predict the peak, shape, and volume of the runoff hydrograph. The mechanics of all of these processes is not completely known and some empiricism remains.

Evaluation and comparison of the merits of some of these models have been reported in the literature. However, because of the numerous variables involved in the evaluations and their subjective nature, the prospective user faces the difficulty of ascertaining the relative advantages and disadvantages of the many models proposed for urban stormwater management.

The objective of this paper is to present a survey of some of the scientific developments in urban catchment modeling during recent years which are, or could be, of value in formulating engineering decisions about urban drain age design. This is not setup as a comprehensive review. Such a report is available, and the reader is referred to Linsley (1971). As it is almost impossible to find a model which fits best in all circumstances, an attempt is made to provide guidance on the selection of models.

The models described in this paper are restricted only to those that are well documented. They consist of simple to relatively complex. Nevertheless, factors affecting evaluation and choice of models which are outlined in this paper are applicable to all other models.

Chapter 2

DEVELOPMENT OF URBAN CATCHMENT MODELS

Determination of urban stormwater runoff has been the concern of engineers for years. For most part of last century, engineers used the rule of thumb approach. A general rule of thumb was that about half of rainfall would appear as runoff from urban surface.

Following the early rule of thumb, empirical formulas became the principal mechanism for determining quantities of urban runoff. About 100 empirical formulas have been collected by Chow (1962). The most famous among these empirical formulas is the Rational Formula (or Lloyd-Davies method as it is known in United Kingdom). The Rational Formula employs the equation Q =CIA, where Q equals the peak discharge; C equals a runoff coefficient; A equals a rainfall rate in inches per hour for a selected duration equal to the time of concentration for the drainage area. Developed in late 19^{th} century, the method is still widely used today.

Recognition of the actual rainfall and runoff phenomena led to an approach termed the Hydrograph Method. This method attempts to quantify all pertinent physical phenomena from the input (rainfall) to the output (runoff). Since 1939, the City of Los Angeles and many of its satellite communities have been using a hydrograph method called the Los Angeles Hydrograph Method. The method was first reported by Hicks (1944). As a result of intensive studies, Tholin and Keifer (1959) developed a hydrograph method known as the Chicago Hydrograph Method for the City of Chicago.. The method originally involved a graphical hand computation, but was later programmed for digital computer solution by Keifer (1970). Eagleson (1962) developed unit hydrographs for sewered drainage areas and considered the degree to which their characteristics can be related to properties of the urban catchment. Sherman (1932) published the Unit Hydro-graph Theory and used it for determination of rural stormwater runoff, but it was not until thirty years later that Eagleson applied it to the determination of urban stormwater runoff.

Kaltenbach (1963) described the inlet method developed at Johns-Hopkins University for storm, sewer design.

With increasing urbanization, it became evident that most of the methods mentioned were inadequate in the design of urban stormwater drainage system. A search for a better method led to the development of a number of simulation models. These models may be classified as either continuous or non-continuous (event). In continuous, processes occur and are observed continuously. They are normally applied to systems that are operated for three, four or more years. Event models in contrast, are used for short-term operations. An event model might generate input to, and output from, a reservoir for a single storm event. The Hydrograph Method is an' early example of these models. A number of these models have water quality components.

After years of research, the British Road Research Laboratory developed an urban catchment model and termed it the Road Research Laboratory Model (RRLM). Since its publication by Watkins (1962), the method has been reported to have received widespread application in the United Kingdom. The Illinois Urban Drainage Area Simulator, described by Terstriep and Stall (1974), is an improved version of RRLM. The model does not incorporate water quality component.

Dawdy and O'Donnel (1965), working for the U.S. Geological Survey, developed a rainfall-runoff event simulation model for rural catchments. A more recent version of the model published by Dawdy, Lichty and Bergman (1970) is adaptable for application to urbanized catchment. It is a semi-continuous model which excludes water quality aspect.

Harley, Perkins and Eagleson (1970) has described a model developed at the Massachusetts Institute of Technology (MIT), called MIT Model, it is one of the most complex mathematical models available. Although the model has been tested on only two very small urban catchments, the MIT has been using it on practical problems encountered in contract work. It is a non-continuous model and does not include water quality component.

The most sophisticated and significant outgrowth of the Stanford Water-shed Model was developed at Hydrocomp, Inc., and has been named the Hydrocomp Simulation Program (HSP). Published by Crawford (1971), it was

originally developed as a rural runoff simulation model. The most current version, however, includes a feature enabling it to handle urban catchments. It is a continuous model with water quality component included.

Perhaps the most comprehensive rainfall-runoff-water quality model yet developed is the Storm Water management Model (SWMM). The model was jointly prepared by Metcalf and Eddy, Inc., the University of Florida and Water Resources Engineers (1971) for the U.S. Environmental Protection Agency (EPA). The computer program for the model contains some 14,000 statements and reports describing it, ran into four large volumes. Its size alone makes it a very difficult task, for someone not familiar with the model development, to use it. The City of Chicago is using the model at the present time and they found it necessary to engage Metcalf and Eddy, Inc. solve the initial operational problems. Nevertheless, the model is widely accepted. It has enjoyed more applications and has been subjected to more verification than any other model.

Water Resources Engineers, Inc. (WRE) (1974) has modified SWMM for application to the San Francisco area. Another version of SWMM was developed by the University of Florida (1975). Termed SWMM Version II; McPherson (1975) has indicated that it is far superior to SWMM.

Under the sponsorship of the Department of Civil Engineering of the University of Cincinnati, Papadakis and Pruel (1972) developed a mathematical model called The University of Cincinnati Urban Runoff Model (UCURM). The model has been tested on urban catchments of several thousand acres in the area. Like HSP and SWMM, it has water quality component.

Designed, specifically for urban catchment runoff and quality evaluation for master *planning,* the Storage, Treatment, Overflow and Runoff Model (STORM) is eminently suited for its purpose. Documented by Roesner et al., (1974, a user's manual was prepared by The Hydrological Engineering- Center 01974) of the U.S. Army Corp of Engineers. This model can accommodate non-urban catchments, also. Not all of the models mentioned above are well documented or available. Some of those *which* have been published in various journals are briefly described in the next chapter.

Chapter 3

A BRIEF DESCRIPTION OF SOME MODELS

3:1 The Rational Formula (RF)

Developed in the late 19th century, the Rational Formula has become the most widely used method for urban storm drainage design. Persistence in the use o£ this formula can be attributed to its simplicity. The development of the method was based on 4 years of rainfall data using non-recording rain gauges and 1 year runoff data estimated from pairs of white-washed sticks.

The Rational Formula is expressed as Q = CIA, in which Q equals the peak discharge in cubic feet per second; C equals the runoff coefficient depending on the characteristic of the drainage area; It equals the Uniform rate of rainfall intensity in inches per hour for a duration equal to the time of concentration; and A equals the drainage area in acres. The time of concentration is the time required for the surface runoff from the remotest part of the drainage area to reach the point under design.

The rationale for the method lies in the concept that application of a steady, uniform rainfall intensity will cause runoff to reach its maximum rate when all parts of the watershed are contributing to the outflow at the point of design.

In applying the method, the time of concentration and runoff coefficient are first estimated. A return period, Tr, is then selected and the intensity of rain that will be equaled or exceeded on the average, once every Tr years is read from a locally derived Intensity-Duration-Frequency curve. This design storm must have a duration equal to time of concentration. The peak discharge is then determined from the Q = CIA.

I

The Rational Formula determines only the peak of the discharge hydrograph corresponding to the catchment time of concentration* It gives no indication of the shape of the hydrograph or of the total volume of runoff.

3:2 <u>The Chicago Hydrograph Model (CHM)</u>

Developed by Tholin and Keifer (1959), the Chicago Hydrograph Model is one of the earliest mathematical models.

Since its development, it has been used extensively for hydrologic design of the combined sewerage system for Chicago; however, its application to other areas has not followed.

The rainfall input to the model consists of a design storm pattern from local intensity-duration-frequency curves and an average chronological storm pattern or an observed rainfall event. Overland flow is computed, using Horton-type (1935) infiltration capacity curves, the estimated depth of the rainfall retained in surface depressions, and Izzard's (194-6) overland flow equation.

Various storage routing and translation procedures are used to transfer the rainfall excess from the overland flow situation and through the main pipe system. The model is not continuous; however, it contains water quality component.

A major drawback to the model is that it ignores the <u>effect of the drainage basin</u> (climate, topography, etc.) in the transformation of the storm distribution into a discharge (or volume) distribution and exceedance probability. Marsalek (1977) has pointed out the shortcomings of the Chicago Hydrograph Model.

<u>3:3 Road Research Laboratory Model (RRLM)</u>

The RRLM was developed in England by Watkins (1962). It was the result of a comprehensive research program by the Road Research Laboratory of the Department of Scientific and Industrial Research. The method which is conceptually a simple model, compared with other mathematical models, is used extensively in the United Kingdom. Terstriep and Stall (1973) applied the model to three urban catchments in the U.S.A. and reported a significant success. In Australia, Aitken (1973) has indicated that the method has been used by several drainage authorities-and consultants. The Illinois Urban Drainage Area Simulator (ILLUDAS) (1974), used by the Illinois State Water Survey is an improved version of the RRLM.

The RRLM uses storm rainfall on an urban area as input and provide the storm runoff hydrograph as output. The model can be used for continuous streamflow simulation, but tends to be used as an event model. A disturbing feature of the model is that the areas contributing to the runoff are taken to be only the impervious areas directly connected to the pipe system; hence, the estimates of peak flow rates and runoff volume are likely to be low. This has been criticized by Linsley (1970), Snyder (1970), Jones (1970), and Stall and Terstriep (1972).

In brief, the method involves the calculation of a time-area contribution diagram following standard procedures. A synthetic rainfall profile is applied to the time-area diagram to compute the inflow hydrograph which is then routed through storage in the pipe system. Five principal steps are involved in the model.

First, the total basin is divided into sub-basins, and the impervious areas that are directly connected to the storm drain system are identified. The remainder of the basin, including areas such as lawns, parks, roofs, floodways that are not connected to the storm drainage system and impervious areas that drain onto pervious areas, are all disregarded. The hydraulic characteristic, such as lengths, slopes, also, roughness of these impervious areas, are measured or estimated.

The second step is the calculation of flow velocities for all segments. These velocities are used to construct lines of equal travel time to the outlet of the basin, called isochrones. Cumulated areas between these isochrones provide a time-area diagram.

Third, any observed or specified rainfall pattern for the basin is applied to the directly connected impervious area. Rainfall losses are subtracted. The time area diagram and rainfall pattern are used to determine a translated runoff hydrograph.

In the fourth step, the hydrograph is routed through a reservoir using storage-indication method as described by Viessman, et. Al (1977), to account for the effects of storage within the basin. The fifth and final step in the RRLM is the routing of the outflow hydrograph to the output point by simplified one-step storage routing procedure. The resulting output is the total basin runoff hydrograph which results from the storm rainfall specified as input. One important feature in the RRLM is that it is readily applicable to drainage basins before urban development takes place.

Read input data

↓

Look at sub-basin

↓

Compute time-area curve

↓

Compute surface hydrograph

↓

No — Is this an initial reach? — Yes

Combined surface and channel hydrographs

↓

No — Is this a confluence? — Yes

Combine Hydrographs

↓

Select cross section for discharge storage relationship

Circular Pipe

Rectangular Pipe

Open Channel

↓

Route Hydrograph to next Input point

↓

Is there another reach?

Print and plot output

Fig. 1 Flow diagram for the computer program of the RRL method. After John B. Stall and Michael L. Terstriep, "Storm Sewer Design - An Evaluation of the RRL Method", EPA Technology Series EPA-R2-72-068, Oct. 1972.

3:4 The University of Cincinnati Urban Runoff Model (UCURM)

The UCURM was developed by Papadakis and Pruel (1973). The model is similar to the SWMM in that it divides the drainage basin into sub-catchments with closely matched characteristics. It, however, differs in simulation techniques. A subcatchment is represented by two equivalent subcatchments - one pervious and the other impervious.

The UCURM consists of five submodels which simulate individually the processes involved, that is, infiltration, surface retention, overland flow, gutter flow, and routing through the sewer system.

The infiltration submodel uses Horton's (1935) equation to compute the infiltration capacity curve. Surface retention is related to depression storage by an equation derived by Linsley, Kohler and Paulhus (1975).
The infiltration and surface retention are subtracted from the rainfall intensity to yield the runoff. An empirical relationship between outflow depth, detention storage and detention storage at equilibrium, together with Manning's equation and the equation of continuity, provides a solution for overland flow hydrograph.

Gutter flow is computed by adding upstream and lateral inflows, and assuming inflow is equal to outflow. Routing through sewer system is accomplished by lagging the inflow hydrograph by the travel time required to reach the next inlet. Each preceding hydrograph is then added to the next junction downstream until full system is encompassed at the final outlet. This routing aspect of model has come under severe criticism from Singh (1973),as it tends to violate the very basic premise of flood routing.

Read Data

1. Rainfall intensity
2. Infiltration constant
3. Depression storage capacities

↓

Infiltration
(Horton's Equation)

↓

Depression
Storage supply

↓

Read Data

1. Slope
2. Roughness
3. Length
4. Width

↓

Overland flow

1. Detention
2. Discharge

↓

Read Data

1. Layout
2. Length

↓

Gutter flow

1. Overland input
2. Gutter input
3. Discharge (continuity)

↓ Gutters

A

A

↓

Read Data

1. Slope
2. Roughness
3. Diameter
4. Length

↓

Flow Routing

1. Gutter input
2. Average Velocity
3. Time offset
4. Add offset Hydrograph and new gutter input

Pipes ↓

Print Hydrograph

Stop

Fig. 2 UCURM Model flow chart, After C.N, Papadakis and H.C, Pruel, " University of Cincinnati, Urban Runoff Model", Proc. ASCE, J, Hyd, Div, 98 No. HY10 (Oct. 1972; 1789-1804)

The Storm Water Management Model (SWIM)

The most comprehensive urban catchment model yet developed is probably the SWMM. The model was jointly prepared by Metcalf and Eddy, Inc.; the University of Florida, and Water Resources Engineers (1971) for use by the U.S. Environmental Protection Agency (EPA). The SWMM is an event simulation model and does not keep track of long-term water budgets.

The design of the model allows the simulation of both water quantity and quality aspects associated with urban runoff and combined sewer systems. The SWMM considers a watershed as broken into a finite number of smaller units or subcatchments. Rainfall hydrographs are applied to the subcatchment. Infiltration is computed by Horton's (1935) exponential function, and subtracted from the water depth existing on the subcatchment. Overland flow is simulated by storage routing using Manning's equation and the equation of continuity, assuming that the hydraulic radius is equal to the depth of flow. Overland flow begins only when depression storage is full.

The SWMM is presently used to provide storm hydrographs for areas having lateral sewers up to 30 inches in diameter. The model is complex and requires a great amount of computer time.

Read and edit data

↓

Construct connecting matrix

↓

Overland flow

1. Rainfall
2. Infiltration
3. Detention
4. Flow (Manning's)
5. Depth (Continuity)

↓

Subcatchments

Gutter Flow

Trapezoid Hydraulic Radius	←→	1. Overland input 2. Gutter input 3. Flow (Manning's) 4. Depth (Continuity)	←→	Pipe Hydraulic radius

↓

Compute Hydrograph
Coordinate

↓

Plot Hydrograph

↓

Stop

Fig. 3 Flow chart for hydrographic computation (after Metcalf and Eddy, Inc., University of Florida, Gainesville, Florida, Water Resources Engineers. Inc., "Storm Management Model", Environmental Protection Agency, Vol 1, 1971.

Chapter 4

EVALUATION and COMPARISON of MODELS

Most urban catchment models have generally been tested and evaluated by their builders. The testing has principally been conducted to make an evaluation of the predictive ability of a given model. At present, there are no generally accepted verification criteria.

Climatic conditions and catchment area characteristics under which a model is tested in no small way affect its accuracy. Stall and Terstriep (1972) noted that the RRLM is successful in Great Britain, but not in the United States, because it appears that rainfall occurs in greater amounts in the United States than in Great Britain. For similar reasons, the model is not suitable for use in most Australian cities. The Chicago Hydrograph model performs well in Chicago, but its use in other areas has not followed because the model was designed primarily for the City of Chicago. It appears that models are usually built to suit conditions of a particular area. This suggests that evaluation of a single model provides little information and that comparative evaluation is a better way of testing models. It provides the user with some basis for comparing and choosing from among various models.

Several of these comparisons of the merits of various models have been reported in the literature. They include those of Papadakis and Preul (1973); Sarma, Delleur and Rao (1973); Heep and Mein (1974); Brown, et. al. (1974); Marsalek, et.al. (1974); Brandsletter (1974); Chow and Yen (1974); and Waller, et. al. (1976). However, the results of these tests are mixed, mostly because there is no acceptable basis for multiple-objective comparison.

In the determination of peak flow, volume and shape of hydrograph, and concentrations and loading of pollutant emission, each model has its strengths, weaknesses and outright faults for a given application. Whereas, in some of these evaluations, a large number of urban catchments and storms are considered, others are based on one or two catchments and storms. There are situations in which different parameters have been used for different models, even though they should have been the same. Papadakis and Pruel (1973) tested four models, including OCURM and SWMM, by comparing observed hydrographs with hydrographs simulated by the models. They concluded that UCURM performed better than SWMM and others. An examination of their procedure reveals that different infiltration parameters were used for SWMM and UCURM even though both use the Horton (1935) equation for infiltration simulation. Thus, their conclusion is not entirely valid.

Heeps and Mein (1974) made comparative evaluation of three models. They were (1) RRLM, (2) UCURM, and (3) SWMM. All three models were applied to two urban catchments in Australia for a total of 20 storm events. Comparison of the models' performance for 4 of the 20 storms is summarized in Table 1. Heeps and Mein concluded that:

1. The degree and subdivision of the catchment has significant influence on the peak discharge predicted by each of the models. The RRLM and SWMM methods give lower peaks and the UCURM gives higher peaks for finer subdivision.

2. The SWMM was the model with best overall performance, but at the expense of large computer storage and time requirements.

3. The RRLM predicted poorly for storms in which pervious runoff was significant but performed reasonably well for many other storms.

4. A major problem with using noncontinuous models is the prediction of antecedent conditions. This problem is further aggravated by use of the Horton (1935) infiltration equation for which prediction of the parameters is virtually impossible.

5. The UCURM contains several deficiencies. The major ones are that depression storages are assigned full when the rainfall intensity falls below the infiltration capacity, and that depression storages are not depleted by infiltration. The use of instantaneous values of the rainfall intensity can cause volume errors.

Table 1 Comparisons of Model Performance

Objective Function.	Storm 1 Nov. 6, 1971 Vine Street			Storm 2 Dec. 24, 1971 Vine Street			Storm 3 Dec. 20, 1971 Yarra Lumla Creek			Storm 4 Mar. 3, 1972 Yarra Lumla Creek		
	RRLM		SWMM	RRLM	-SWMM	UCURM	RRLM	SWMM	UCURM	RRLM	SWMM	UCURM
C1	2	3	4	5	6	.7	8	9	10	11	12	13
Percentage of observed runoff volume	44	102	139	176	175	307	60	126	193	77	104	234
Percentage of observed runoff peak	91	106	189	175	207	266	45	101	139	36	47	64
Sum of squares of errors, in $10^3 ft^6/sec^2$	39	4	33	2.2	3.6	9.2	200	157	690	88	51	381
(M^6/S^2)	(31.2).	(3.2)	(26.2)	(1.8)	(2.9)	(7.4)	(161)	(126)	(554)	(71)	(41)	306
B5500 Processor time, in minutes	1.87	34.23	31.05	0.63	12.97	4.8	0.08 [a]	2.32 [a]	0.87[a]	0.11 [a]	2.95· [a]	1.28[a]

[a] B6700 Computer

Table 2 Subjective Evaluation of Three Urban Models

	MODEL		
	RRLM	SWMM	UCURM
Effort for input data preparation	Low	Medium	High
Flexibility of Schematization	Good	Good	Fair
Accuracy of employed routing scheme	Low	Medium	Low
Model and Computer program availability	Good	Excellent	Limited
Availability of a runoff quality submodel	No	Yes	Yes
Computer time required	Low	Moderate	Moderate
Continuous refinement by the corresponding agency	No	Yes	No

Source: J. Marsalek, T.M. Dick, P,E, Wisner, and W,G, Clarke, Comparative Evaluation of Three Urban Runoff Models, Water Resources Bulletin, AWRA, 11, No, 2 (Apr, 1975) 306,328,

<u>Table3</u> Comparison of Models Simulation Procedures

(After Heeps and Mein, 1974)

Process **1**	**SWMM** **2**	**UCURM** **3**	**RRLM** **4**
Simulation	Noncontinuous	Noncontinuous	Noncontinuous
Interception	Neglects	Neglects	Neglects
Evaporation	Neglects	Neglects	Neglects
Transpiration	Neglects	Neglects	Neglects
Depression	Fills before overflow begins- part of Impervious area assigned zero depression storage depleted by infiltration	Exponential filling rate. No allowance to be depleted by infiltration on previous areas	Neglects
Infiltration	Horton equation. No time offset Satisfied by water on ground surface and rainfall	Horton equation. time offset Satisfied by rainfall only	Impermeability assumed constant (Equal to fraction of impervious area directly connected)
Overland Flow	Uniform depth of detention Storage routing using Manning Turbulent flow equation and continuity equation Quasisteady State	Profile with increasing depth Solved using an Empirical relation, continuity equation and Manning turbulent flow equation Quasisteady State	Linear time-area routing (only directly connected impervious Areas Time of entry required as input data
Gutter Flow	Uniform flow storage routing	Outflow = sum of inflows	Neglects
Inlet Pits and Junctions	Outflow = sum of inflows	Outflow = sum of inflows	Outflow = sum of inflows
Pipe Flow	Storage routing (manning equation based on the slope of energy line) Quasisteady State	No storage routing lagged using weighted average velocity Quasisteady State	Storage routing (manning equa- tion for uniform flow) lagged using full bore rage velocity Quasisteady State
Surcharge	Stores (preserves volume continuity	Neglects	Increases pipe diameter

Another comparative evaluation using the same three models mentioned above was done by Marsalek, et. al. (1974). The models were applied to 12 storms over each of three watersheds. Significant results from the evaluation are presented in Table 2. Marsalek, et. al., deduced from the results that:

1. When comparing the entire simulated and observed hydrographs using statistical measures, the agreement was found good for SWMM, good to fair in the case of RRLM, and fair in the case of UCURM.
2. Out of the three models, the SWMM simulations were marginally better than those by RRLM, and both these models were more accurate than the UCURM, with all models applied in an uncalibrated version.
3. On the whole, the three models yielded a fairly good agreement between the simulated and measured runoff events on typical urban catchments of small size.
4. The SWMM model has the most advanced routing scheme among the considered methods. The accuracy of flow routing becomes particularly important when studying larger watersheds.

In view of Canadian design practice, Maclaren, Ltd. (1975), compared four models, namely; (1) RRLM, (2) UCURM, (3) SWMM, and, (4) Unit Hydrograph method

A number of factors were considered to determine their relative performance. The results, however, did not indicate a clear-cut advantage for any model. Waller, et. al. (1976) compared RRLM and SWMM and found that both methods produced reliable results with SWMM requiring more computer time.

Although the above comparisons of merits of various models do not answer most questions on these models, the major advantage and disadvantage of each of the models, RRLM, UCURM, and SWMM, are apparent. These are: (1) the RRLM is the simplest method among the three, but its application should be restrict ed to impervious areas because model neglects runoff from pervious areas; (2) UCURM is simpler than SWMM, but because of the nature of its structure, the* use of instantaneous values of the rainfall intensity can cause volume errors. Also, because sewer routing has been based on pure translation and no account given to the attenuation in the hydrograph shape, slightly higher peaks are estimated by the model; and, (3) the SWMM performance is good, but it is complex and requires a great deal of computer time.

Chapter 5

ACCURACY AND CHOICE OF MODELS

5.1 Accuracy of Models

Pilgrim (1975) has indicated that four levels of evaluation are necessary before a model should be applied to predict the output from a catchment. These are C1) the rational examination of the structure of the model, (2) estimation of the parameter values for the particular catchment, (3) testing the fitted model to verify its accuracy, and (4) estimation of its range of applicability. Rarely are all the four levels of evaluation applied to any model. Aitken (1975) has indicated that imperfections in the structure of catchment models may produce sysmatic errors, that is a tendency for a model to either consistently over-estimate or under-estimate flow conditions for a number of successive time periods.

A careful examination of various comparative evaluations shows clearly that only estimation of parameter values receives the most attention. This makes it difficult to answer the question, "Which of the two models is better?" For a model may be superior to another only over a certain range of applicability and not beyond.

Quantity and quality of data have great influence on model accuracy, yet, it would appear that researchers have little or no appreciation of the practical effects of data. Results from inaccurate or inadequate data used in model evaluation may be misleading. It should be recognized that the quality of output can be no better than the quality of the data used in modeling process. When Papadakis and Pruel (1973) used different infiltration capacities for UCURM and SWMM in their comparative evaluation, the results indicated that UCURM performed better than SWMM. However, other studies by Marsalek, et, al. (1974) and Heeps and Mein (1974) produced contradictory results.

The objective for which a model is used has a fundamental influence on its evaluation. A model may be "good or bad" depending on whether it is used to predict, say, peak discharge, runoff volume or hydrograph shape. Accuracy

of a model, therefore, is not of an absolute nature and it only has practical meaning relative to some objective in use of the model.

5:2 Choice of the Model

A survey of literature on model evaluation still leaves unanswered the question, “Which is the best model?” This is not surprising because there has been proliferation of urban catchment models in recent years; there has not been a corresponding effort to devise methods of objectively comparing models and, developing criteria for the best choice of model in a given situation.At present state of the art, the choice of model is purely dependent on the objective for which the model is used. It is important for the user to recognize that there is no best model in the absolute sense. This means that experience and subjective judgments are unavoidably involved in the choice of model; nevertheless, it is the factors affecting the objective which determine the model to be used. These are:

(a) Type of application involved (b) Availability and quality of data (c) Size of urban catchment

(d) Climactic and physiographic characteristics of the catchment.

(e) Level of accuracy desired.

(f) The possible need for transposing model parameters from smaller catchments to large catchments, where sufficient data for development are not available.

(g) The ability of the model to be conveniently updated on the basis of current hydrometerological conditions.

(h) The amount of time that can be spent for tuning the model.

These factors should serve as guidelines in the selection of urban catchment’s models. With respect to climatic and physiographic characteristics of the catchment, a prospective user of a model does not need to be highly discriminative in the selection of models if the catchment for which the model is selected is climatically humid. In such catchments, simple models may perform equally as well as complex, sophisticated models. For catchments in semi-arid regions, the prospective user of the model will have to be highly discriminative in the selection of the model. Determination of urban runoff hydrograph for a small impervious catchment may dictate the use of less complex model, such as RRLM. However, the application of the RRLM to long term rainfalls can give misleading results because of the neglect of runoff from pervious area. This error will be amplified in the case of a system

utilizing flood storage. If a model is to be used in simulating the quantity and quality of storm water flow from urbanized areas, then the choice reduces to SWMM, UCURM and other models with water quality aspect. A

planning urban runoff model may be used to set initial conditions for a single-event design model. The accuracy of such planning model need not be high because of high uncertainties in the input data.

Consequently, the model should be characterized by low mathematical complexity and minimum data requirements. Before any model is used, its limitations, shortcomings and drawbacks should be sorted first. Lack of knowledge may lead to incorrect conclusions from results of model application.

For a choice among various models, the advantages and disadvantages should be given serious consideration. An example below shows some of the advantages and disadvantages of the Rational Formula and RRLM.

Advantages of the RRLM:

(i) As it computes the time-area contributing diagram at each point in the catchments, it automatically takes account of any partial effects.

(ii) A hydrograph is computed at all locations in the catchment and this may be useful for the design of complex drainage structures.

(iii) It has a realistic physical basis and provides an insight into the types of models which will be developed and applied in the next decade.

Disadvantages of the RRLM:

(i) It is impractical to use RRLM without an electronic computer.

(ii) The analysis of large catchments is very cumbersome, requiring a great deal of careful data preparation and involving long computer runs which may be expensive.

(iii) It may give unsatisfactory results when used to estimate the runoff hydrograph for long period storms.

Advantages of the Rational Formula:

(i) Experience has been gained in its application over many years of use.

(ii) It is a simple concept which is readily solved without the aid of an electronic computer.

Disadvantages of the Rational Formula:

(i) It gives no indication of the shape of the hydrograph.. (ii) Its simple empiricism relates poorly to physical reality.

(iii) It gives no indication of the peak discharge for any other duration but that corresponding to the catchment time of concentration.

Similar advantages and disadvantages can be tabulated for other models. These tabulations are important tools in the selection of models. As one of the many factors involved in model selection, it would be advantageous if verification and intercomparison of models in general could be done in accordance with, at least, some generally accepted verification criteria.

Chapter 6

DISCUSSION AND CONCLUSION

Various urban catchment's models have been reviewed, SWMM is the most comprehensive and complex model among the group considered herein. It also requires a great deal of data preparation and large amount of computer time.

It is imperative that in selecting a model the intended user understands the theory, concept and assumptions upon which the model rests. This helps in the interpretation of the results from the model's application. Familiarity with a model's development is also valuable in decision making as to whether the model should be used in analysis or design mode.

Some model builders are of the opinion that increasing the complexity of models generally- improves representation of processes and the physical significance of parameters. Complex models, however, are of no use to the designer. The Rational Formula persists in dominating the urban design scene due to its simplicity. Indeed, in recent surveys in the U.K., U.S. and Canada, (Colyer (1975), McPherson (1975), Maclaren (1975) it was reported that the Rational Formula was still used in a very large majority of design offices. It should be emphasized that if urban catchment models are to be used and not kept in the files of builders and libraries, then they should be as simple as possible, commensurate with acceptable practical accuracy. In fact, improvements in the capability to provide design data within realistic limits of accuracy and cost do not require an increase in the complexity.

In the choice of model, although reliance on literature of comparative evaluation and subjective judgment should play a role, the major determining factor should, no doubt, be the objective for which the model is to be used.

It should be borne in mind that subjective separation of abstractions from total rainfall to resolve rainfall excess and other approximations render model building an art rather than a science.

There is no limit to the number of urban catchment models that can be devised. At the moment, more urban catchment models employing complex approximations are being developed. Whether these approximations constitute any improvement in the existing technique available to the designer is questionable.

It is possible to argue that the level of accuracy required for many applications does not warrant any great effort towards improving the existing technique.

Whereas, a great deal of attention has been directed towards the development of models, little emphasis has been placed on the quality of input data and the use and application of these models. Model builders tend to ignore the high uncertainties in input data. It needs to be recognized that the quality of output can be no better than the quality of the data used in the modeling process. For a model to be used effectively, the user must be taught how to use it and should be able to get expert advice as problems arise. Without this, there seems to be little advantage in the development of new and even more complex methods.

A good body of experience has been gained in model development. What needs to be done right now is to encourage practicing engineers to use existing models. Consequently, it is suggested that a larger proportion o£ the resources now allocated to urban storm management needs to be diverted to the-development of more adequate skills in the use of existing models rather than the development of new models.

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