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ORIGINAL ARTICLE

ANALOGY BETWEEN HYDROLOGICAL CYCLE AND QUEUEING MODEL

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Abstract:

The idea of applying queueing theory to hydrological models is not new. However literature reveals that the analogy has not been properly established. To apply queueing theory to hydrological modes first it is important to establish a proper analogy between the fundamentals, variables and concepts. The queuing situation is characterized by flow of customers arriving randomly at one or more service facilities. In the case of hydrological models, the customers are represented by water, the service time is the time it takes to move through the soil and soil act as service channel.

KEYWORDS:

Queueing model, Kendall notations, Hydrological cycle, Analogy between queueing model and hydrological cycle.

INTRODUCTION

The idea of applying queueing theory to hydrological models is not new (Arnold J. G. and Williams J. R. (1989)), however literature reveals that the analogy has not been properly established. To apply queueing theory to hydrological modes (V.Geethalakshmi and A.Lakshmanan, 2008), first it is important to establish a proper analogy between the fundamentals variables and concepts. The queuing situation is characterized by flow of customers arriving randomly at one or more service facilities. In the case of hydrological models, the customers are represented by water and the service time is the time it takes to move through the soil and over the land. Queue disciplines can also be used to describe a reservoir water budgeting system (Brad F. Gamble, et.al., (1990)).

Possible queueing disciplines that can be related to soil water movement are last-in-first-out (LIFO), first-in-first-out (FIFO), and a combination of LIFO and FIFO.

Hence an attempt is made to establish a complete analogy between Queueing model and hydrological cycle.

2. QUEUEING MODELS:

Queueing model is physical representation of a queueing system in logical and objective way. Numbers of queueing models exist in literature (Gross and Harris (1998), Andreas Willig (1999), Kainti Swarup, et.al. (2005)). Queueing or Waiting line theory is used in various real life applications (Malwina J. et.al. (2006), Li Wen LIU, Koichi and Masashi, (1989), Moez Draief, (2005).

One of important aspects of queueing theory is the representation of queueing models using Kendall notations. The general form of the notation to represent a queueing model is A/B/C/D/E, where,

A- Represents the distribution of the inter-arrival time.

B- Represents the distribution of the service time.
C- Represents the number of servers in the system,
D- Queue discipline
E- System capacity

In other words there are five components defining a queuing model completely. The most common distributions which can be associated with a queue at A or B are:

GI = general independent arrivals or service times.
M = Markovian (memoryless), negative exponential distribution.
D = deterministic arrivals or fixed length service.
Er = r-stage Erlangian.
Hk = k-stage hyperexponential.

In addition to what Kendall has used, there are few more components of a queuing model as given in fallowing table.

Table 1. Components of queuing model and Kendall options.

Sr.No.	Components of Queueing Model	Nature of Components	Kendall Options
1	Input Source/ Calling Population	Finite Infinite	Not Represented
2	Customers	Discrete Objects or Continuous flow	Not Represented
3	Arrival Pattern / Interarrival Time Distribution	Probability Distribution	A={M, GI, Ek, D, Hk}
4	Service Mechanism / Service Time Distribution	Probability Distribution	B={M, GI, Ek, D, Hk}
5	Number of Service Channels	Finite or Infinite	C = {N}, N-Set of natural numbers
6	Queue Discipline	Mapping	D ={FCFS, LCFS,GD,PRO, SSO}
7	System Capacity	Finite Infinite	E = { R^+ }, R^+ - Set of positive integers

Input source or calling population can be finite or infinite similarly customers though are discrete objects can be a mix of different sizes as in the case of vechilour traffic (Reinhart Kuhne , Panos Michalopoulos)[14], or may be continuous as in the case of hydrological models (Arnold J. G. and Williams J. R. ,1989). The option to these components has no representation in Kendall notations. In discussion to fallow we propose to not to ignore these components.

3. Hydrological Cycle: The hydrological cycle (Rick Lawford et.al., 2005) consists of the distribution and movement of water in its three phases throughout the Earth system and includes precipitation, surface and subsurface runoff, oceans, cloud cover, atmospheric water vapor, soil moisture, groundwater, and transpiration, evaportanspiration etc.

4. COMPARISON OF HYDROLOGICAL QUEUEING MODEL:

The Association of basic elements of queueing model with basic elements of hydrological cycle is represented in the following table.

Table 2. Basic Elements of Queuing Model and Hydrological Cycle.

Sr. No.	hydrological cycle	Description	Queueing Model
1	Precipitation in the form of rainfall /Irrigations	For the measurement of rainfall various methods are used (H. M. Raghunath, (1996), pp18-22).	Arrival / Input
2	Runoff. (H. M. Raghunath, (1996),, p62)	Rainfall – (Evaporation + Transpiration+ Evapotranspiration+Infiltration) = runoff	Balking
3	Evaporation	The Dalton's law (H. M. Raghunath, 1996), p63	Balking
4	Transpiration	Transpiration Measurement Method (H. M. Raghunath, 1996), p70	Service
5	Flow of Ground Water	Flow of Ground Water is Given by Darcy's Law (1856) (H. M. Raghunath,1996), p210	Reneging
6	Ocean	Infinite Source	Source or population
7	Drainage	Drainage Density	Reneging

In general, if Sea / Water Reservoirs / Rivers will be source or calling population, rainfall or irrigation will be an arrival; the runoff, evaporation will be a balking and drainage flow, to ground water will be a reneging. Then such system can be considered as a hydrological queueing system.

To get better understanding about hydrological queueing system discussed above it is necessary to establish proper analogy between them.

5. Analogy between Queueing Model and Hydrological Queueing System:

Now that we have seen what different queueing models are and what is a hydrological queueing model, an analogy can be established. The following table maps the components of both models as closely as possible.

Table 3. Analogy Queueing Model Vs Hydrological Queueing Model

Sr.No.	Queueing Model.	Hydrological Queueing System	Nature of Components
1	Input Source/ Calling Population	Well, Lakes, Rivers, Sea	Finite Infinite
2	Customer	Water	Discrete Arrival in queueing Model Continuous Arrival in Hydrological Queueing System
3	Stochastic Arrival	Precipitation in the form Rainfall	Lognormal Distribution in case of Hydrological Queue. Poisson in queueing Model
	Deterministic Arrival	Irrigation.	Deterministic
4	Balking	Runoff, Evaporation	Customer Behavior
5	Reneging	Deep Percolation, Drainage	Customer Behavior
6	Service	Evaportanspiration, Transpiration	Probability Distribution
	Service Channels	Roots of Plants	Finite / Infinite
	Severs	Plants	Finite/ Infinite
7	Waiting Room	Soil	Finite / Infinite
	System Capacity	Water Holding Capacity of soil	Finite / Infinite
8	Entry to Queue	Infiltration	Delayed entry
9	Queue Discipline	Water picked up by roots.	Random

Now we will discuss each row in the table and argue how the analogy is logically well established.

Source or calling population: In case of hydrology the sources of water are Sea, Lake, Rivers and Wells etc. so we call them as sources or calling population.

Customers: In case of hydrology the arriving object is water therefore water is called customer.

Arrival: Water reaches to soil as a result of precipitation in the form of rainfall or irrigation then rainfall or irrigation will be is called arrival.

Balking: In case of hydrology water doesn't enter into the soil as it finds soil is fully saturated and no water may get infiltrated so that there is runoff such behavior of water as a customer is called the balking.

Reneging: In case of hydrology the water that enters into the soil and there is infiltration of water. The whole infiltrated water will not be picked up by roots of the plants so that some amount is simply drains or deep percolates as a result the amount of water which drains or deep percolates leaves hydrological queueing model without being serviced is called reneging.

Service: In hydrology queueing system water that infiltrated into the soil depends upon the soil condition which is assumed as service channel and what time spent by water for infiltration is called service time. If the soil under consideration has plats then they consume a required amount of water for the growth. The transpiration or evaportanspiration by plants is the service and roots of the plants are servers.

Waiting Room and system capacity: In case of hydrology water which infiltrated is accumulated by soil prior to evaportanspiration and transpiration so soil will act as waiting room or waiting space. The water holding capacity of soil is analogs to system capacity as in case of classical queueing models.

Queue discipline: In this case of hydrological queueing model queue discipline will mean the arrangement by which water is either there is transpiration or evaportanspiration by plants called queue discipline.

Entry to Queue: Customer joining the queue does not have any resistance in case of queueing models. Where as in case of hydrological queueing model, after saturation of water into the soil there is no more infiltration so that entry of water into the soil is denied which causes resistance to the entry.

6. CONCLUSIONS:

We have established a reasonably satisfactory analogy between a continuous hydrological models a discrete queueing system. The terminologies, the phenomenon, parameters in either case have been shown map 1-1 so that analogy is complete.

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