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Reservoir Operatino Using Stretched Thread Rule - A Case Study

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ABSTRACT

Reservoir operation forms a very important part of planning and management of water resources development projects. A number of techniques are available for reservoir operation and the two most commonly used techniques now-a-days are linear programming & dynamic programming. Mass curve method has been used since long to estimate required storage capacity. A new idea of stretched thread rule, a variant of the mass curve method, has been in use for quite some time.

According to the stretched thread rule, if an imaginary thread is stretched between a pair of congruent inflow residual mass curves placed parallel keeping a mutual distance equal to the effective reservoir capacity, the stretched thread represents the optimized outflow residual mass curve. The outflow curve so obtained conforms to the commonly accepted reservoir operation policy of flow equalization. The stretched thread method offers a simple, computationally efficient and exact solution to the problem of derivation of reservoir operation rule curves. It has been shown that this method is superior to linear programming & dynamic programming techniques. The stretched thread rule has been applied for operation of Dharoi reservoir in Sabarmati basin in Gujarat. The results are encouraging.

INTRODUCTION

The reservoirs are one of the most important components of a water resources development project. The principal function of a reservoir is regulation of natural streamflow by storing surplus water in the rainy season and releasing the stored water in the dry season to supplement the natural riverflow. Reservoirs are the most effective means of changing temporal and spatial availability of water.

A reservoir operation policy specifies the amount of water to be released from the storage at any time depending upon the state of the reservoir, level of demands and any information about the likely inflows. A number of techniques are available to operate a reservoir, viz., standard linear operating policy, rule curves, concept of storage zoning etc. The system engineering techniques like simulation and optimization are also used to develop reservoir operation policies. Among the optimization techniques, two techniques which are most frequently used now-a-days are linear programming and dynamic programming.

THE MASS CURVE METHOD

The mass curve method is being used in many engineering disciplines since a long time as a tool for graphical integration. Rippl used the mass curve technique to determine the smallest storage capacity necessary to supply the required release without any failure through the period under consideration. This method has been described in a number of texts such as Fiering (1967) and McMahon & Mein (1978). A detailed analysis of the different aspects of mass curve technique was presented by Klemes (1979) who has also listed various developments and applications of this method to the related problems.

The basic objectives of the streamflow regulation problems which are solved using the mass curve technique are :

(a) regulation based on a firm value of target release,
(b) regulation aimed at the greatest possible equalization of flow.

The combination of low flow augmentation and flood reduction results in a tendency to flow equalization. Thus the second objective is often regarded as the basic aim of flow control to mitigate losses caused by flows which are either too low or too high. Klemes (1979) has described the stretched thread rule which was first published by Varlet in 1923. He proved that the outflow mass curve constructed using the stretched thread rule exactly conforms to the policy of flow equalization. The stretched-thread rule is described below.

THE STRETCHED THREAD RULE

The essence of the rule is illustrated in Fig. 1. The upper fig. 1(a) shows two residual inflow mass curves called primal and dual curves placed wide apart one another so that a string is spanned horizontally in between them without touching either of them. A residual mass curve is a mass curve in which the horizontal axis represents the mean river flows. From the inflow series in the reservoir, residual inflow mass curve is plotted and two such curves are placed parallel to each other congruently.

Now, if these primal and dual curves are brought close to each other, keeping the direction of horizontal axis unchanged until the distance between them equals the effective storage capacity, then the string will be pushed up and down by the curves and will attain the final shape as shown in fig. 1(b). This shape of the string is the residual outflow mass curve. Klemes proved that for flow equalization, this is the most desirable outflow mass curve. Thus given the inflow mass curve and effective storage, outflow mass curve can be obtained.

Since no discretization is employed in the above method, this method yields an accurate solution. Although this method is basically a graphical method,it can be programmed on a computer. The computational time taken to solve a policy optimization problem by this method is a fraction of the time taken by linear programming and dynamic programming methods. Moreover, the time requirement for this method decreases with the increase in storage capacity of reservoir while the dynamic programming moves towards the curse of dimensionality as the number of discrete states increases.

Two fundamental rules which should be observed while constructing outflow mass curve are:
(a) Outflow mass curve should not cross the inflow mass curve.
(b) The difference between the height of inflow and outflow mass curve should at no point exceed the effective reservoir capacity.

CASE STUDY

The stretched thread rule has been applied to the Dharoi reservoir located in the Sabarmati basin in Gujarat. The purposes of reservoir are water supply, irrigation and flood control.

The monthly inflow series from 1935 to 1951 was available and used. The primal and dual outflow mass curves have been plotted in parallel congruently and outflow mass curve has been computed using the stretched thread rule. A computer program has been developed to determine the outflow mass curve. The monthly inflow data and reservoir storage capacity are the inputs of the program. The results for a typical case are shown in Fig. 2.

Some properties of the optimal release policy obtained using the stretched-thread method which are also confirmed by visual inspection of Fig. 2 are as follows:

(a) The optimal release at any time depends not only on past inflows but on future ones also.
(b) The optimal release directly depends on the immediate past and future flows but dependence on flows in the remote past and future is limited to the location of corner or turning points.
(c) The optimal release does not depend on the current value of storage.
(d) Difficulty in specifying the optimal release increases with the increase in reservoir capacity though in such situation, optimal release is better approximated by value of long term mean inflow.

ADVANTAGES OF THE STRETCHED THREAD RULE

The stretched thread rule demonstrates in the clearest possible way the importance of flow forecasting as well as value of historic flow record. It shows why small reservoirs need forecasts with shorter lead time and vice versa. It explains why it is not so much the inflow rates that are important for optimal operation but rather the total inflow volumes for the reservoir. It is these volumes which determine the location of corner points, which are crucial for the determination of optimum outflows.

CONCLUSIONS

Optimal operation policy for maximum flow equalization can be derived for a reservoir using stretched thread rule. The rule is very simple to use and needs no mathematical background. However, this approach has not found the popularity which it deserves The rule has been applied to a reservoir in India. The rule gives numerically precise results as against some false beliefs that the mass curve methods gives only an approximate solution. Further work is in progress regarding use of this method to determine reservoir operation policies as well as comparison of results obtained using this method with the results from other techniques.

REFERENCES

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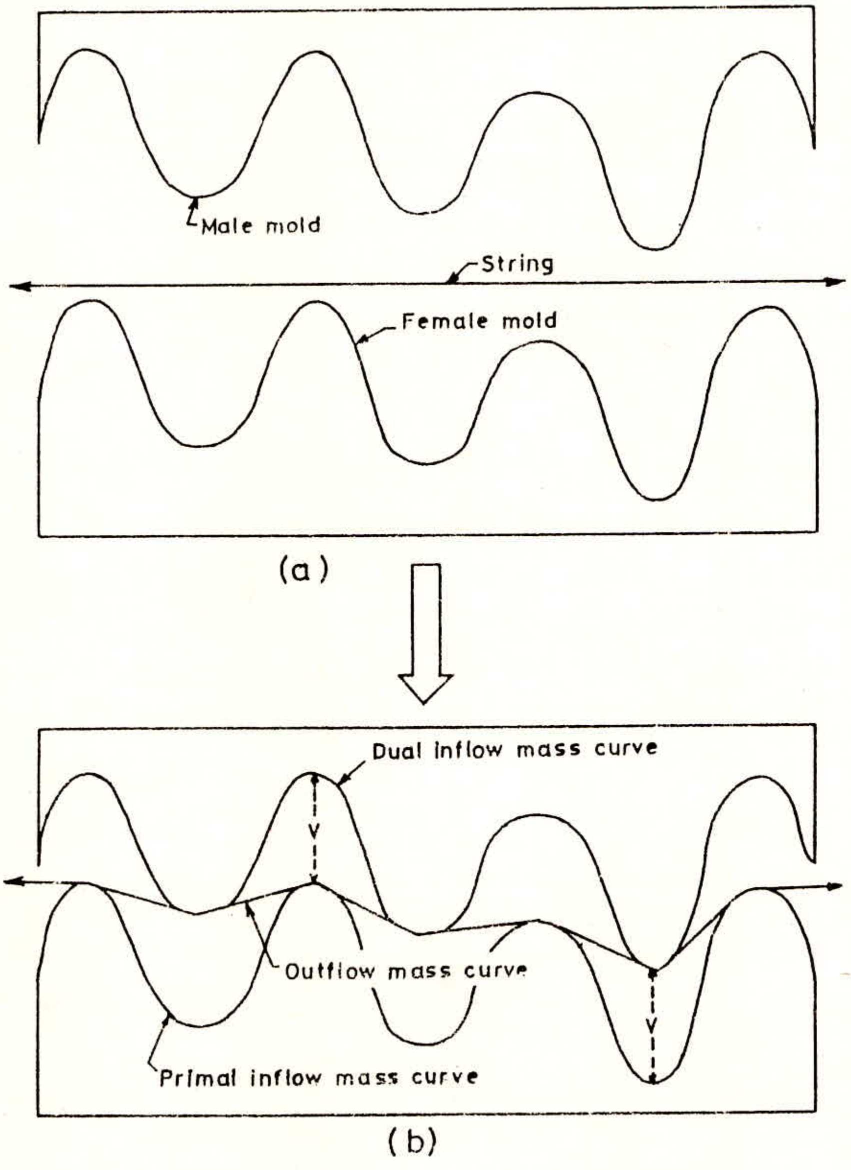

FIG.1–OUTFLOW MASS CURVE CONSTRUCTION BY PRIMAL AND DUAL INFLOW MASS CURVES

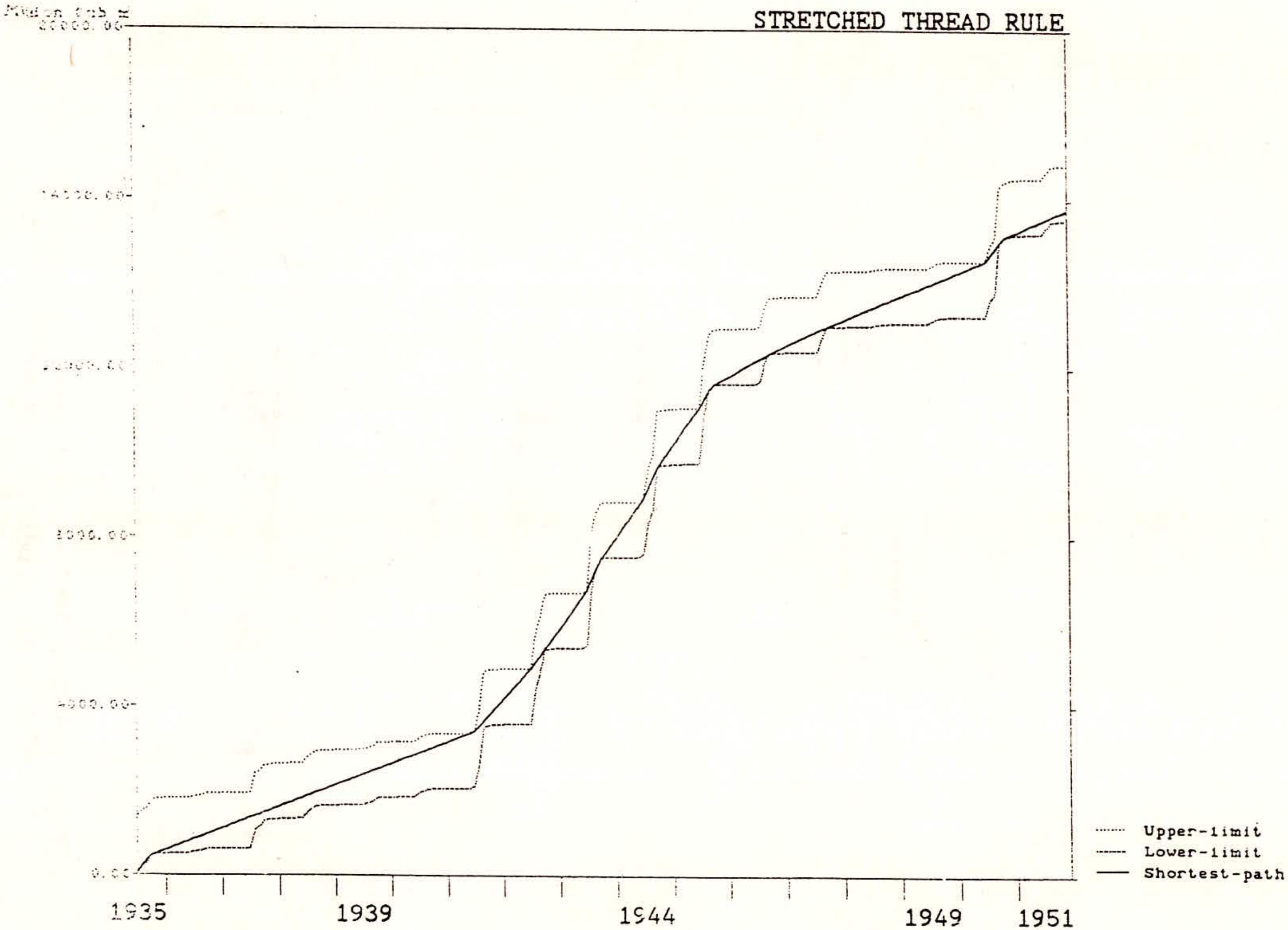

FIG. 2 OUTFLOW MASS CURVE USING STR FOR DHAROI RESERVOIR

DISCUSSION

VIJAY KUMAR : 1. The problem dealt is conservation operation and not flood management. How is this presented in this session ?

2. I have personally studied Dharoi catchment back in 1986 and the data available was up to 1984 or so. Why then 1935-51 data is used ?

3. The important point that how one rule can be used to operate this water constrained reservoir to fulfill riparian demands of Fatehwadi command and Ahmedabad city to maximum satisfaction appears to have been missed.

AUTHOR(S) : (1) The authors have nothing to say on this point.

2) We have with use data of Dharoi from 1935 to 1989 and the rule has been applied to complete data. However, for the purpose of presentation, the data of only a few years has been used.

3) We feel that rule gives the optimized outflow for the observed inflows and based on the priority, this outflow can be allotted to different demands. However, this is just a preliminary study and detailed analysis of this rule is in progress. This comment will be given due consideration in future study.