University of Minnesota
ST. ANTHONY FALLS HYDRAULIC LABORATORY

Project Report No. 145

SIMULATION OF THE QUANTITY AND QUALITY OF FLOW IN A RIVER BASIN

by

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The work upon which this publication is based was supported in part by funds provided by the United States Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

June 1973
Minneapolis, Minnesota

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I. INTRODUCTION

Recognizing the importance of optimum use of our water resources, the Office of Water Resources Research and other governmental agencies have encouraged studies concerning quality improvement and optimum management of these resources. Because of the extremely complex nature of the problem, much more work is needed.

The study reported on herein is concerned with simulating the quantity and quality of flow in fairly large watersheds or basins. The problem was separated into two parts: (a) simulation of water quantity on a continuous synthesis basis and (b) simulation of water quality by means of a model which would interact with the quantity model.

The 16,200 square mile Minnesota River Basin, Fig. 1, was used as a study area, although the models can be adapted to other areas. The basin was subdivided into 15 sub-basins or watersheds as shown in Fig. 2. Most of the sub-basins, as well as three points on the main stem of the river, have USGS gaging stations which provide continuous records of water quantity. Figure 3 shows the National Weather Service stations used in the study to provide data on precipitation, air temperature, wind velocity, and in some cases solar radiation and dewpoint temperature. Table I lists the station numbers of these stations. The USGS has been taking water temperature and suspended sediment data at three stations in the basin since 1968. A limited amount of water temperature, BOD, DO, and other quality data is available from other sources.

Consideration was given to the development of a new water quality model, but the availability of a number of existing models suggested that these should be investigated before a new one was prepared. Possible models included the SSARR model developed by the Corps of Engineers and the National Weather Service in the Columbia Basin [1,2]*, the Stanford model [3], and several design-oriented models such as the HEC-1 program of the Hydrologic Engineering Center [8]. The first two are continuous synthesis models capable of working with one or more years of data. The HEC-1 is intended for use with one flood event, with input usually not exceeding 50 days of data. Several other models have also become

*Numbers in brackets refer to list of references on pages 33 and 34

Table I - Index of National Weather Service and Cooperative Stations for Minnesota River Basin

Station	Index	Station	Index
Alexandria	0112	Minn.-St. Paul	5435
Albert Lea	0075	Minneota	5482
Artichoke Lake	0287	Montgomery	5571
Beardsley	0541	Morris	5638
Bird Island	0783	New London	5842
Blue Earth	0852	New Ulm	5887
Bricelyn	0981	North Mankato	6007
Benson	0667	Ortonville	6224
Canby	1263	Redwood Falls	6835
Chaska	1465	St. James	7326
Dawson	2038	St. Peter	7405
Elbow Lake	2476	Springfield	7907
Fairmont	2702	Stewart	8025
Fergus Falls	2768	Tyler	8429
Gaylord	3076	Waseca	8692
Glenwood	3174	Wells	8808
Jordan	4176	Windom	9033
Lamberton	4546	Winnebago	9046
Le Center	4641	Young America	9208
Madison	4994		
Marshall	5204		
Milan	5400		

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available, although too late to be used in this study; among these are the National Weather Service API model, the TVA daily streamflow model, and a new National Weather Service model (NWSRFS5) patterned after the Stanford model.

The SSARR model was chosen for initial study under this project, but consideration was also given to HEC-1, which was being studied under a separate project. Minor modifications were made in these models, but the major problems seemed to be the fitting of various parameters in the models to each sub-basin and becoming familiar with realistic values of the parameters.

As developed in this study, a modified version of the SSARR model computes daily discharges from a continuous record of daily values of precipitation, temperature, solar radiation, and dewpoint. The model is a conceptual deterministic model and can be used with modified values of input data to test the effects of variations in parts of the system. However, stochastic methods can also be used to generate input data for studies of a wide range of input conditions.

A water quality model has also been developed to provide the basis for studies of parameters associated with water quality. The quality model is actually a combination of a stochastic input data model and a deterministic stream-reservoir system model. Stochastic analysis of available air and water temperature data taken at stations in Minnesota led to the development of a method which can be used to generate synthetic water temperature data in natural streams. The necessary regression coefficients can be determined if the drainage area and other physical parameters of the watershed are known. Either actual or synthetic air temperature data can be used to generate synthetic water temperature data at various stations in the watershed. These stochastic water temperature data are used as part of the input data for the deterministic stream-reservoir system model. The deterministic model was written for BOD and DO as well as temperature. However, due to lack of data, a stochastic input data model was developed for only one water quality parameter, daily average water temperature.

this computation it was found possible to neglect every term except the one representing the difference between the air temperature and the water temperature. A good fit was obtained when the heat transfer coefficient k_h in Eq. (1a) was set equal to 0.30.

Figure 25 shows a comparison between the water temperature at Mankato as predicted by the model and the corresponding data published by USGS. The good agreement shown here may be somewhat superficial, because the system considered in the analysis was rather short. Nevertheless, the potential value of the model in predicting the water temperature in a system for which insufficient data are available has been demonstrated.

VIII. CONCLUSIONS

This study indicates that

1. The SSARR, a deterministic model, can be fitted to Upper Midwest watersheds and provides an apparently good means of computing a continuous simulation of flow at selected locations in a 16,200 square mile basin. However, further studies of the hydrologic conditions in other years are desirable to determine optimum values of the parameters used in the model.

2. A stochastic water quality model has been fitted to various stations of the above basin, initially for water temperature, and the fitting indicates that the model provides a good simulation of water temperature in the basin for the ice-free period.

3. A deterministic water quality model has been written for the main stem of the Minnesota River basin. Preliminary results show that a good fit of the model with water temperature data is possible. Further analysis is needed to optimize the parameters, however.

5. Further studies simulating quantity and quality of flow in the Minnesota River basin for other years, and for other basins, are highly desirable.

6. The potential user of these models is referred to Refs. [1] and [2] for the quantity model. As the source deck contains about 8000 cards or statements, it was not feasible to include it in this report. A listing of the quality model (temperature) is included in Appendix A.

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