AN APPROACH TO THE TISZA BASIN STUDY

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1. Introduction

This paper outlines a possible approach that the water project may take to the Tisza study. Presented is the framework of the problem and a proposed approach to its analysis.

The Tisza basin consists of two regions--an upper basin area shared by the USSR, Romania, and Czechoslavakia, and a lower basin area shared by Hungary and Yugoslavia. Each of these areas comprise about 50% of the basin. The lower basin area in Hungary is extremely flat. Here, the Tisza has a slope of about 1:20,000 over 800 km with most of the Hungarian area being subject to extensive flooding. The soil of the lower basin is silty-clay with a low permeability. Of the water resources of the lower basin, between 95% to 98% have their origin outside of Hungary in the upper basin.

Snow melt and summer rainstorms in the upper basin are the generating process for large and extensive floods. In the basin there has been a long history of flood levee construction to try to contain these flood waters, but, as will be explained later, these levees have had only limited success.

The precipitation in the lower basin is about 450 to 550 mm per year. The evaporation during the summer has been, on the average, greater than the precipitation. Studies have shown that the ratio of evaporation to precipitation to be about 1.2 to 1.5. This leads to shortages of water for the agricultural activities and necessitates the use of supplimentary irrigation. September and October are when the shortages are most sever and Figure 1 presents an illustrative graph of the expected supply and demand.

Within this problem framework the Hungarian National Water Authority has put together a group consisting of about fifty people to study the basin. The makeup of this group is not known, but the ones that have held talks with IIASA are extremely capable water resource planners.

The models developed by the Hungarians have tended to concentrate on the operation of fairly small existing systems and not upon the investment problem. Such models are needed if the basin questions raised above are to be addressed.

2. Problem Description

This section describes in greater detail the problems faced by the Hungarians in the Tisza basin. As was pointed out in the introduction, the main issues are flood control in the spring and early summer, and shortages for irrigation in the summer and fall. From our discussions with the Hungarians the following structures may be built to alleviate the above problems:

1. flood levee system in the lower basin;
2. reservoirs for the storage of flood waters in the upper basin;
3. low land reservoirs in the lower basin;
4. ground-water development for irrigation water in the lower basin;
5. reservoirs for irrigation supply in the upper basin;
6. pump-storage reservoirs for irrigation supply in the lower basin.

For both the flood control problem and the irrigation supply problem, it is evident that the tradeoffs between investment and operation of reservoirs in the upper basin and structural development in the lower basin must be investigated. More specifically, the following issues must be incorporated into the analysis:

2.1 The linkage between the upstream reservoirs and levees and the downstream levees.

The determination of the effects of upstream reservoirs or new levees upon the downstream levees is of prime importance. In the floods of 1974 (Szamos tributary from Romania) the precipitation level was not especially high but the new levee system in Romania caused water that in the past went into storage through flooding to sweep downstream into Hungary and to produce flood levels that were 50 - 70 cm higher than those ever recorded previously. Such effects are well known, but the physical effect of new structures, either reservoirs or levees, upon downstream stages depend upon the physical characteristics of the river at hand.

To determine this effect I suggest the use of a flood routing model. An important requirement of the model is to handle both the Tisza River mainstem and the tributaries coming into the Tisza. This is necessary due to the frequent flooding caused by backwaters or by the interactions of flood waves. From our initial discussions with the Hungarians, they have repeatedly brought up this issue. Such a model exist and I have access to it in Boston, Massachusetts, USA. It solves the full continuity and momentuem equations, and it can handle the tributaries as well as structural components such as reservoirs. It is a well-developed model and I have had wide experience applying it to a number of river basins.

This model then would find certain technical transformations for potential structural systems. The inputs for the model would be releases from reservoirs or hydrographs from sub-catchments. These would have to be determined outside this model by other means--either by data or by another model of the sub-catchments starting with the rainfall.

2.2 The stochastic nature of the system

The two primary issues in this study, from the Hungarian point of view, are flood protection and supplying water for supplementary irrigation. Both of these are highly stochastic. For the purposes of this discussion let us look at each one in turn.

a) Water shortages:

From out discussions with the Hungarians it is not evident that over-year storage in the upper basin reservoirs is required to fulfill the present demands--even in dry years. This can be better estimated by looking at some data. If this is true, then it may be possible to construct an optimization model of a surface water-ground water conjunctive use. A recent paper in the literature by Maddox (WRR February, 1974) considers stochastic inflows and stochastic demands. Such a model may be adaptable to our use. There also exists a host of other papers on conjunctive groundwater models. It is important though to have a model that allows for stochastic demands since the variance in the demands can significantly affect the resulting system design.

At this point, it should be decided whether a simulation model of the supplementary irrigation sector should be performed. Right now I have no recommendation since I see both advantages and disadvantages, and I have some ideas which are not formulated enough to put down.

b) Flood protection:

Clearly, the flood protection question is different from the irrigation supply. I tend to favour a statistical analysis of the decision problem using the results of the flood routing simulation. Since the storage reservoirs are multi-purpose it will require some thought on how the flood analysis and the supply question can be handled together. This is important since for some reservoir cost and benefits to both flood control and irrigation are obtained.

One possible approach would be the following: obtain curves of efficient or optimal decisions for the flood problem. This would produce sets of reservoir capacities and levee protection levels that maximizes some utility--net benefits for example. The same think could be done for the reservoir-ground water system in supplying irrigation water. By looking at these two sets, it may be possible to choose the reservoir capacities that maximizes both systems. Or, if the problem has too many components, maybe a dynamic programming opimization of this last step can be performed.

The question of reservoir operation would be handled at the previous level. That is, for each reservoir capacity an optimal operating policy could be determined. Since the target level for floods occurs at a different time than that of supply, a conflict can be avoided.

2.3 Benefits to various users:

While conflict between flood control and irrigation can be avoided, conflicts between the uses of Hungary and those of other countries may not be. Due to the international consideration of the basin system, the models must be able to account for the benefits to each nation. Here multiple-objective analysis may be useful in displaying the tradeoffs between these users. Furthermore, models must also be able to consider other measures of system performance than economic measures (net benefits). These other measures may include system reliability due to the uncertainty in system operation.

Studies such as the Tisza have often been criticized for the lack of effort devoted to objective function formulation. Special efforts will be needed to assure that adequate effort is made in this area, and the inputs from the methodology project could be most important.

3, Data Requirements

To run or develop any model it is important to know its data requirements. The most complete model in the world will be only as useful as its data, and a much simpler model with adequate data could provide better information for decision making.

3.1 Economic data

This area will have the poorest data, if past experience is any guide. Work must be done on the demand function for water as opposed to a water requirement. The present approach taken by the Hungarians, to sepcify a water requirement through time and find the development needed to fulfill this requirement--with large losses being imposed if the supply is less than requirement.

A more correct procedure would be to determine the demand for water as a function of price. This would encourage finding optimal utilization of the water, and would tie the water sector into a macro-economic model more correctly.

Short term loss functions would still be needed, and additional work may be required to determine these. A correct procedure would be to determine the production function of the agricultural and industrial products in terms of water. Work has been done in this area for many years, but definitive results are not available. If the Tisza Basin is studied in detail, then work in this area should proceed immediately.

Other economic data should include the uses of all reservoirs--for all users sharing the reservoir, the value of the outputs such as power, and the cost functions for all the elements of the system (levees as a function of height and strength, reservoirs as a function of volume, ground-water wells as a function of capacity, pump-storage reservoirs as a function of volume and operation capacity, hydroelectric generation as a function of capacity, etc.)

3.2 Hydrologic and physical data

The hydrologic and physical data required is dependent upon the models. For the flood routing models, river cross-sections, slopes, etc. are needed as well as input hydrographs. Such data is probably available in Hungary.

If the hydrologic modelling is to start with the rainfall process, then the data will require a large effort to assemble. This is because the data exists in large quantites on paper and not on computer tapes or in some other data bank. The high data efforts probably does not warrant such modelling for the planning stages.

Any modelling of the ground-water system will require physical data such as soil permeability, soil transmissivity, etc. It is my experience that this data is often of poor quality and not readily available. The National Water Authority of Hungary has a group in ground water and they should be expected to gather the necessary information.

For reservoirs, the physical data required would be the volume-hard curves. These are usually readily available and are fairly standard information.

The data requirements should be outlined in greater detail as soon as the project begins, and the Hungarian National Water Authority should be sent a list of required data. The steps for obtaining this data should be formulated with representatives of the Water Authority at the beginning of the project. In the area of economic data, cost functions, benefit and loss functions, etc., there will have to be closer working arrangements between people at IIASA and at the NWA. This is especially true for the demand function and objective function formulations to make sure that the proper type of information is provided.

4. Conclusion

It is evident from the three main planning issues presented (namely, flood control, water supply, and tradeoffs between users) that a complex system of models must be built if the issues of the Tisza Basin development are to be adequately addressed. The problem has a richness which provides fertile ground for both applied application and original research. The study, if started with a firm commitment, could be completed in about two and one-half years. I feel that the flood-levee tradeoff simulation should be started first since the model exists and results can be obtained quickly. While this work is being done, thought can be given to the structuring of the other components.

I also feel that IIASA, the Hungarian National Water Authority, and the appropriate groups in the upper basin countries must arrive at a working agreement about obtaining data. Understanding with the Hungarians is especially important since if the project is to succeed, then they must do a substantial amount of work in preparing data and in running models.

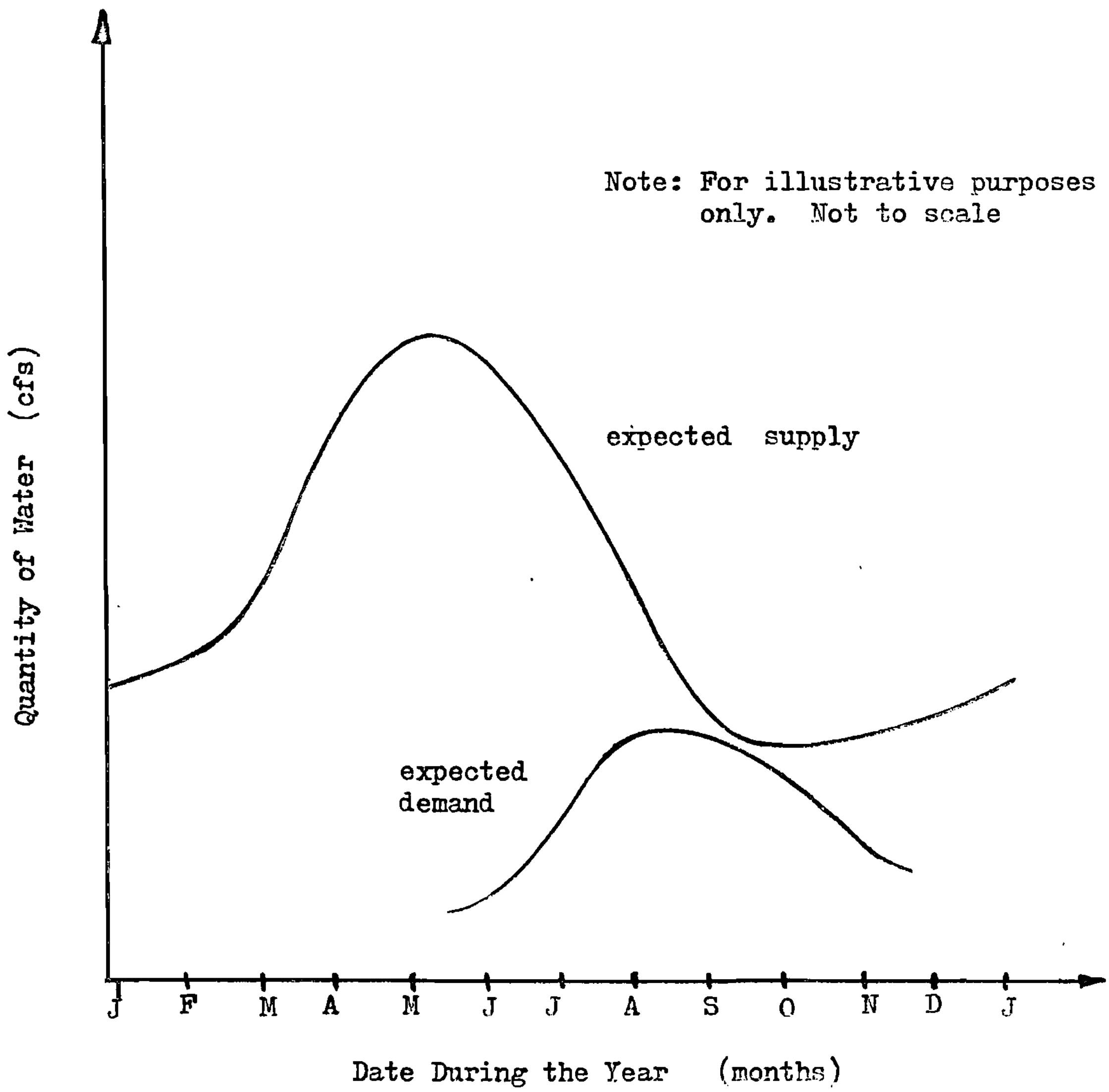

Figure 1: Expected Supply and Expected Demand throughout the Year.