WHERE DOES THE TISZA GO FROM HERE?

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MEMORANDUM

To: Professors Letov, Dantzig, Raiffa **Date:** 14, March 1974

From: M. Fiering

Subject: Where Does the Tisza Go From Here?

1) Before we deal with this question in a systematic way, we must specify the client for our work. There is, first of all, IIASA and its associated members. As the Tisza model is currently structured, or even if it is substantially elaborated, it would offer little benefit to water resource specialists from the United States, Canada, Poland, Hungary, the U.K., and both German Republics. I attach a document written nearly thirteen years ago by one colleague and one of my students; its publication is only slightly more recent. The techniques proposed at that time are similar to those in the current network model of the Tisza, and in some respects the earlier work contains hydrologic and engineering richness which our current model does not. Therefore the benefits of working with our model would accrue mainly to those among us who put it together and experiment with it. These benefits are not inconsequential, but there are probably easier ways to achieve the same results. In any case, the results of our elementary model study should not be published; if important advances are incorporated so that the model offers some new methodological insights, this position can always be reversed.

Another client for our work is that set of Hungarian agencies and experts who deal with the Tisza. It is hard to argue that a model of the Tisza, however realistic and complicated, could benefit these experts if such a model deals only with those reaches of the river which lie in Hungary. The consequences of other riparian users, must be taken into account if a model limited to the Hungarian portion of the system is to represent the prototype sufficiently well. Unless the system can be cleanly excised at its boundaries with the other riparian nations, it is hard to see how Hungary could benefit. I discuss this possibility below.

The third and last client is the collection of governments which comprise the Tisza region. A major study, which would encompass the entire basin, could presumably be undertaken by the next wave of water-resources staff. Spofford and Kindler are very experienced in this area, particularly with regard to non-linear models and large-scale simulations, but they will probably not remain with IIASA long enough to complete this work. Part of the difficulty is that water quality management is a major issue in such a large study; my experience suggests that such a topic requires a long warm-up time with respect to data collection and model evaluation, so that our best intentions might go astray.

The next sections deal with strategies which might be undertaken to serve alternate clients. The last section contains several recommendations with respect to these options.

2) Assume that IIASA is the client and that we wish to enrich the model from the point of view of its decision-making formalisms. I can identify 6 classes of complication which might be tried.

a) Uncertainty could be explicitly included by following, or perhaps enlarging upon, the technique introduced by Harold Thomas and Peter Watermeyer, as explained in the attached paper. I strongly urge that all participants in the Tisza study should read the paper, after which I would be happy to participate with David Bell in organizing a session devoted to explaining any unresolved intricacies. It would be necessary to move from a network formalism to a general linear programming code. However, this should pose no hardship because I understand it is our intent to use a linear programming code in any case.

b) Navigation and recreation benefits could be added to the model, as suggested in our meeting in Hungary. It is probably not wise to include any power benefits because variable head introduces non-linearities which unduly complicate the mathematics at this point. It is not only the fact that energy bears a non-linear relationship to discharge but also the notion that over a two-month time interval the head is likely to change over a range sufficiently great to invalidate the use of the initial head (prior to adjustment for withdrawals during the two-month interval) as a suitable estimate of the head throughout the entire interval. An iterative procedure is required to converge to an intermediate head from which the average energy can be deduced; this will generally differ from the mean head.

Navigation and recreation uses can readily be introduced by manipulation of flow constraints downstream of, and within, reservoir nodes.

c) Constraints which reflect the various flow and withdrawal requirements can be subject to uncertainty by the introduction of chance constrained programming. This is particularly important with respect to consumptive withdrawals and maintenance of low flows in the channels. By systematically varying the target levels of demands, we can show how different operating rules are generated by various security levels. Moreover, it might be possible to identify abrupt changes in system response at particular levels of reliability, thereby justifying the establishment of one or another level of security.

d) It would be useful to begin systematically to identify water quality parameters for water quality standards because it is clear that in all but the most primitive resource systems the mere maintenance of flow (adequate for dilution) does not constitute pollution abatement or management. It therefore becomes necessary to formulate indices of water quality, to route the various physical pollutants through the system, and to impose standards within the basin.

e) Finally, with an eye to actually implementing the "enriched" model, it would be useful to begin to identify potential sources of conflict among the several users of the basin's water resource. This includes not only the obvious conflicts among the several nations, but also potential conflicts between the various vested interests within one region or country. It would also be useful to begin systematically to examine non-traditional alternatives for quality and for flood control. These include advanced treatment methods, bypass of treatment facilities, in-stream treatment, and major storage facilities on the Danube (upstream of the confluence with the Tisza) to provide flood storage while augmenting irrigation, I lay special stress on this exercise because it is through systematic examination of such sources of conflict that we begin to identify alternative objective functions for system design.

The reason this is important is that we might wish to utilize this Tisza model and any subsequent simulation studies in a conjunctive mode, which has been widely used in water-resource engineering. For example, major regional studies of the Tiber River basin and of the Vega de Granada have utilized linear programming models to define optimal operation of existing or otherwise predetermined systems and have selected from these alternatives a small number of promising designs for major simulation analysis. In the Tiber study, important conflicts between water qualitiy management and power generation were identified by those interests who were charged with the responsibility of constructing system benefit functions. In some cases it is clear that these issues can be resolved by legislation, authoritarian dictate, or even compromise. But in some the issues which separate the parties are not based on perceptions of economic gain but rather on system stability, resilience and susceptibility to disastrous outcomes. For these, a new calculus is required.

In the language of game theory, the criterion function for identifying the optimal strategy can be optimistic or pessimistic; one can chose a strategy other than the classical equilibrium strategy if it were desired to minimize the probability of a poor outcome, to minimize the extent of the worst possible outcome,etc. These would lead to different mixes than those ordinarily derived from the Minimax result. It would be a useful exercise to vary the objective function not merely by assigning different weights to the outcomes but rather by prescribing the objective in quite different terms; this would have the obvious advantage of introducing into the Water Resources Project some of the ideas which Holling and the Ecology Group have developed.

f) Formulation of the problem in terms of conflicting objectives enables us to give explicit consideration to matters of quality and environmental standards. Again the Tiber River study provides a good example. In this work a set of transfer coefficients was developed for several reaches (or, in our language, arcs) of the river along which water quality was a consideration. For a given pattern of waste inflow, the transfer coefficients enable us to calculate the waste output at critical locations or nodes, where quality standards can be imposed. The calculation is linear even though the biological decay process are not. The development of this coefficient matrix is described in the Tiber River report which I have provided to members of the Water Resources Project. Professor Joseph Harrington, Harvard University, has written a computer program for providing the coefficients from sparse data on quality,and I am certain that this program could be made available or, more effectively, be run in the United States with data provided for the Tisza river system. In the Tiber study this matrix approach to water quality estimation was generalized for inclusion in the simulation of the entire basin, leading to important conclusions concerning the quality of the estuary; I could visualize that subsequent detailed models of the Tisza would require major hydraulic and sanitary calculations concerning the possibility of back-water effects and oscillatory surges at the confluence of the Tisza and the Danube. The hydraulic details of such a model might proved a useful focus for the highly specialized expertise of the member nations, while we provide the over-all supervision and administrative structure for utilizing the outputs. We are not now, no can we be reasonably be expected to be, staffed adequately to undertake this form of computation.

3) Still considering that IIASA is the client, the model can be enriched from a physical point of view.

a) We should undertake a more detailed study of the extrema, floods and droughts, whose absence was the basis of most of the objections raised by our Hungarian colleagues. This will involve two potential avenues: (i) a study of hydrograph shapes to identify peaks and troughs in the flow pattern, from which economic consequences can be deduced, or (ii) direct regression (or other functional) relationships between the magnitude and extent of the extrema and their economic consequences. We have alrealy discussed these.

b) It is essential that we undertake a major study of flood damages due to back-water flooding in the lower reaches of the Tisza. This flooding is not so much a function of excess flow in the Tisza as of oscillatory features relating to the confluence of the Tisza and Danube. The use of dummy arcs to represent conduits for excess flow during flood season, with associated economic consequences, is inadequate for this type of flooding. We should devote considerable effort to an appropriate physical mechanism for incorporating this phenomenon in the model.

c) The Hungarian experts insisted that the major physical and economic issues for day-to-day water management in the lower reaches of the Tisza turn on the relationships between topography, drainage and runoff. We should seek ways to incorporate these phenomena, if possible, in our early models because their exclusion would seriously compromise the validity of the models and the ease with which they might be implemented (even as screening exercises). The major difficulty with direct inclusion of such hydrologic and hydrodynamic issues is that they occur very slowly, over periods of months or even years, as compared to the rate of flow in a channel. That is, the time interval characteristic of the network or linear programming solutions may be incompatible with that for analyzing surface drainage; this important issue has not received adequate attention in the water resources literature, and we might be able to make a contribution here.

d) I think it unlikely that we will be able further to complicate the model without making it so cumbersome that it would no longer serve as a screening technique. If we choose to simulate the entire system, or employ some more sophisticated methodological procedure, it would be appropriate to introduce realistic economic considerations, flood routing procedures, reservoir operating policies for flood management, and other formalisms which have, to my knowledge, never adequately been squeezed into a programming formulation. This does not mean that we should no try to do so, but rather that we recognize it might be more fruitful, from the point of view of water-resource experience, to move along more certain lines. However, if the Methodology Group perceives that there is some prospect of finding more general or powerful algorithms to embrace further complication, it might be a useful parallel exercise It should be emphasized that such a decision must be taken outside the Water Resources Group because, under any circumstances, there would be little input that that group could provide to face the methodological questions.

4) If the client is limited to our Hungarian colleagues, our role would be to help abstract and represent, in convenient form, the hydrologic and hydraulic issues which intersect the Tisza system at its various national borders. That is, if a regional study is not undertaken, we would have to help develop the statistical analysis of modified flows because we cannot obtain the virgin flows in the system. The upstream storage and regulation units, operated by riparian users, would distort the virgin flows so that the system's hydrological inputs would be drawn from truncated, strongly skewed, distributions. In consultation with our colleagues, we would have to initiate a major data collection program, and presumably would have to travel widely throughout Hungary to consult with groundwater and drainage experts in order to assess the data. The resulting model, probably a simple simulation study, would be a hybrid or compromise between a mathematical programming regime and a more sophisticated simulation of the entire basin. Given the strenuous objections raised by the Hungarians to the use of a gross model for determination of daily operating procedures, we would surely have to augment any programming or network analysis by a modest simulation effort.

5) If the client is in fact the entire Tisza region, we would have to undertake everything on a different scale. For example, because the first Water Resources Research Conference recommended against an international study, we would have to present to the next Conference some evidence that we are willing and able satisfactorily to perform such a study. This would mean that it would be necessary soon to begin laying the lines for successful collaboration amongst the five countries involved. Professor Raiffa has suggested that Dr. Tokhadze should very soon undertake to contact the relevant agencies in the several countries in order to determine what forms of cooperation can be initiated. Assuming that everything goes well, it would be necessary immediately thereafter for one of us, presumably me, to travel with Tokhadze to the several agencies in order physically to examine the data

which might have been promised. Experience shows that agencies and bureaucrats are often willing to cooperate, but that when it comes to producing actual records or economic parameters, the system falls apart. All of this would have been done very quickly to be sure that I could complete it before my departure on July 1, and in time to put it on the agenda of our conferences. It should be recalled that Professor Kaczmarak told us the other day that data collection and tabulation for the Vistuala system in Poland required three years! There was no institutional opposition, there was no language problem, there was no difference in units of measurement, and there was general agreement that this was a useful study. And the data were primarily for use in a simple programming model, not the sort of detailed simulation at issue here. Nonetheless, three years were required. It is my judgement that data collection for such a Tisza study would require even more time, which may suggest that we should undertake parallel efforts: one devoted to furthering the analytical or programming models, replacing "artificial" data with real values as they become available, while at the same time launching a major data collection enterprise and formulating some of the conceptual properties of whatever (simulation) effort is to follow. Should the simulation effort ultimately fail, we will have very little to offer in terms of publication or dissemination of the analytical model; on the other hand, we will have something important to say about the feasibility, even under optimal circumstances, of constructing a model for studying a major international river basin.

6) I therefore recommend that we adopt a strategy for which the analytical models currently under construction serve a preliminary or screening function, that these models be organized so as not to generate design alternatives but rather to operate a manageably small set of pre-determined alternatives, that we consult widely with our Hungarian colleagues as to how a reasonable set should be structured, and that we think about the long-range planning process in a holistic way by encouraging Dr. Tokhadze to advise us on the institutional feasibility of such collaboration.

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