APPLICATION OF CONFLICT RESOLUTION TECHNIQUES TO THE PROBLEMS OF INTERNATIONAL RIVER BASIN MANAGEMENT

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SUMMARY OF PROPOSED RESEARCH

The objective of the propsed research is to bring recent, advanced techniques of hydrologic modelling, optimization and conflict resolution, within a decision-theoretic framework to bear upon problems of international water resource management. The proposed research contains two parts: a theoretical development of analytical tools of conflict resolution and decision analysis as they apply to water resource problems, and a case study of their application to a large scale international water resource system with existing development conflicts.

The need for cooperation in the development and management of international river basins has long been recognized (Chapman, 1963, Rogers, 1969). The international basin forms an indispensable hydrologic unit when water resource developments are undertaken. It is of extreme importance to the parties involved that the consequences of such actions within the basin be fully analyzed. The difficulties in specifying the hydrologic consequences of various development plans, quantifying economic and social benefits to each country, and the criteria upon which various competing development plans would be evaluated will be investigated fully during the proposed research. The research is establishing tradeoffs between riparian countries which can then be used in resolving resource conflicts and establishing efficient joint development plans.

Our motivation arises from the knowledge that continued research will reduce the above problems, and that the proposed research will add significantly to concepts of basin wide planning on international rivers, with application in regions where the sharing of water resources occurs. Furthermore, techniques developed under this research should apply, in general, to other problems of international resource conflicts. Examples such as high seas fisheries (salmon and whale), seabed mineral resources and Antartic land use are three areas outside of water resources which, at the moment, are the subject of negotiation and conflict among nations.

The proposed research will emphasize techniques that can be effectively applied. For this reason, the case study problem is of great importance to the success of the research effort. One proposed case study for the demonstration of these techniques is an area of the Tisza River, whose basin is shared by five riparian countries. Developments are occuring within these countries (such as the construction of flood levees) which have severe and unconsidered effects upon adjoining countries. Joint development within the Tisza Basin may be possible which would result in greater aggregate benefits within the basin as a whole than individual developments provide. Further, individual planning may and does lead to conflict regarding artificial changes in the quantity and temporal distribution of the water resources. The Tisza basin presents an excellent vehicle to demonstrate that basin wide planning techniques and resource sharing could reduce such conflicts and result in greater benefits for the river basin as a whole. It is not the purpose of the case study to formulate actual planning policies, rather the case study will be of a descriptive nature for the demonstration of basin wide planning techniques as they could apply to any river basin.

RESEARCH PLAN

Theoretical developments and problem description

Water resource development of international or inter-regional river basins are rarely very efficient due to the physical nature of the river basin and to the inherently myoptic view of each political group. Each group will try to maximize his own utility irrespective of what other users are doing.

Such piecemeal development plans do not take into account the impact that developments in one region have on other adjoining regions. Furthermore, such individual development may foreclose economically efficient options either to the basin as a whole or to another riparian region.

Consider, for example, a river shared by two countries. Country A, the upstream country, decides to build a levee system rather than a flood storage reservoir for protection against floods. On economic grounds, the levee system was the dominant strategy. For country B, the downstream country, the building of the levee system by A will have an adverse impact - it will lead to larger flood peaks and additional flooding. Thus to maintain the status quo B must build flood levees. Had A built the reservoir, the impact to B would have been of a positive nature--water that would otherwise have gone downstream would have been stored. Although the increased benefit to B is difficult to evaluate without complex hydrologic models, there is a substantial possibility that this difference would more than compensate A for electing reservoirs over levees, and thus yielding a positive aggregate benefit. So, joint development of the upstream reservoir, would be to the mutual benefit of both countries. Questions of evaluating impact and benefit and criteria for sharing of costs and operating the system require extensive application of models and techniques that will be developed under this research proposal.

Some previous approaches

One of the approaches for planning and management of international basins is to develop the impact due to basin wide planning in the hopes of achieving basin wide efficiency. Thus Rogers (1969) used an optimization model for the lower Ganges and the Brahmaputra basins which are shared by India and Bangladesh. His optimization model was a deterministic linear programming model of the following conceptual form:

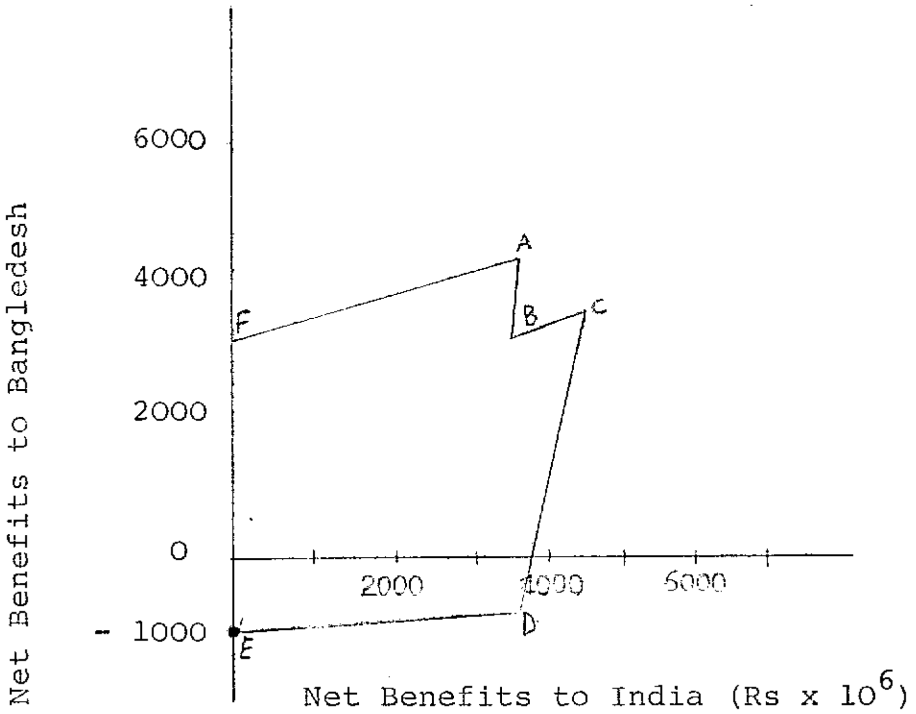
Max Net Benefits

Subject to 1) Technical Constraints
2) Policy Constraints

The policies included among others, each country making separate plans, joint plans but separate budgets, and joint development and joint budget. Figure 1 shows the geometric representation of the payoff to each country. While Roger's work demonstrated that system analysis techniques can be utilized in the study of conflicts in international basins, his analysis represents only a preliminary attempt at handling the complexity of such problems and there are two significant facets of his work that require much further development. One is the complex stochastic nature of water resource systems which is critical when the reliability of the system is important or when the countries are risk adverse to particular outcomes. The other extension is techniques for identifying an overall agreement from within the efficient set (as identified in the payoff diagram). There are a number of techniques in the literature of game theory and conflict resolution whose applicability to international river basins will be investigated.

In general, an international basin management scheme is faced with:

1) a number of regions or countries sharing the basin, each with its own multiple objectives



Development plans:

A Joint optimal development, separate budgets

B Optimal upstream plan (India,) followed by optimal downstream plan (Bangledesh)

C Optimal joint development, joint regional budget

D Optimal upstream plan, downstream does nothing

E No development

F Upstream does nothing, downstream makes optimal plan

Figure 1: Geometric representation of two-person nonzero-sum game (after Rogers, 1969)

and utility functions

2) the uncertainties in the impacts of project development with respect both to hydrologic impacts and time-stream of benefits.

Hipel et.al. (1974) analyze water resource conflict through metagame theory. This approach is most productive if one starts with a particular development plan that is on the technically efficient frontier (pareto-optimal). The heuristic algorithm of metagame analysis takes one group and sees if they can make a unilateral improvement to another development plan. This new development plan is then studied for stability not only by the group that put forward the improvement but also for the other groups. The analysis iterates between consideration of new development plans and consideration of political acceptability until a stable solution is found (a lower bound on stability could be thought of as unilateral action). The application of this technique to some simple problems indicates that it may be a useful technique, especially in initial stages of conflict analysis, in generating discussion among groups on their respective preferences towards development plans. This occurs because the algorithm considers the utility function for each group during the stability analysis phase.

Another more rigorous approach to conflict resolution in water resources has been suggested by Suzuki and Nakayama (1974). They formulate the problem as a co-operative game in the characteristic function form to find an acceptable assignment of costs and benefits among participants. They employ the nucleolus concept of game theory after Schmeidler (1969) and apply the technique to a water resources problem in Japan. Again, they start from a Pareto-optimal solution for the whole basin and find the nucleolus of the game; that is, an acceptable division of the extra benefits due to cooperation.

The determination of efficient development plans as a starting point for bargaining is an important concept in the analysis of international water resource problems. This principle was firmly embedded within the Columbia River Treaty (see Krutilla, 1967) as General Principle No. 2 (International Joint Commission, 1959). This principle stated that cooperation in the development of the Columbia River basin must result in greater benefits to each country when compared to the potential aggregate by independent action. The main mechanism used in the Columbia River Treaty to encourage Canada to build projects beneficial to the United States was side-payments. The determination of the magnitude of side-payments is often complicated since the (certain) payments are for a future, stochastic time-stream of benefits for which each country has some utility. The Nash bargaining point (see Luce and Raiffa, 1957) is one procedure to determine the size of these payments but there is need for continued research on this topic.

Decision analysis framework

Within the framework of even a modest case study, the size of the problem may quickly expand to a level where the basic issues are hidden. To avoid this, the proposed research will embody the conflict resolution problem within a general decision analysis framework. The major benefits of using a decision analysis framework are:

1) it presents clearly the proposed developments and all of their possible impacts.
2) it often reveals secondary effects that may not be intuitive and obvious,
3) it makes the various political groups state explicitly their assumptions and their probability assessment of various occurrences,

and

4) it forms a basis of communication among groups and with outside colleagues interested in the problem.

The decision analysis framework is complementary to the planning tools of optimization models, simulation models of physical and economic systems and models for national and regional economic impact analyses. For co-operative bargaining it presents a clear framework from which mutually agreeable joint development plans can be formulated.

Proposed case study: Scope

The Tisza River basin provides an excellent case study area in which the results of the research can be applied. Due to the complex, hydrologic characteristics of the basin, many options for cooperative management exist which result in benefits of different forms: reduced cost of development, increased benefits from existing development, higher reliability of water supply, and reduced risk from floods. At present, it is envisioned that the proposed case study will concentrate on only a portion of the basin, even though it is hoped that all of the riparian countries will be interested in the study. The COMECON is currently preparing a 'Master Plan of Long Range Development or the Tisza Basin'. Due to the sensitive political nature of the problem, it is not the purpose of the proposed case study to, in any way, interfere with, or supplement any existing studies or negotiations in progress. Rather, the study would serve as a descriptive case study in which the techniques of conflict resolution are analyzed, as they could be applied to any river basin.

Proposed case study: Description

The waters of the eastern pact of the Carpathian basin are collected and conveyed to the Danube River by the Tisza River. The catchment area of the Tisza is about 157,000 km^2 and is shared by five riparian countries; the U.S.S.R., Czechoslovakia, Romania, Hungary and Yugoslavia, as shown in Figure 2. The Tiza River basin can be almost equally divided up into an upper catchment area, with elevation ranging from 200 to 2,000 meters, and a lower catchment or plain area under the 200 meter contour.

The percentage of the catchment in each country is shown in Table 1. The climate is of the typical continental character with a wide temperature range throughout the year. The average precipitation varies greatly within the basin with about 1,000 mm falling in the upper basin and 500 mm in the lower basin. The ratio of potential evaporation to precipitation, which significantly influences agricultural production, ranges from 1.2 to 1.4 in the lower basin.

Proposed case study: Development conflicts

The water management problems are more complicated in the lower part of the basin which is often subjected to severe floods in the spring from the combination of intense rainfall and melting snow and to draught conditions in the summer. Figure 3 shows the distribution of water supply and demand throughout the year in the Hungarian part of the lower basin. It is important to realize that further development of the lower basin is being hampered by the uncertainty in water supply. Due to the geological nature of the basin, groundwater reserves are negligible. Thus, increased supply can only be developed by altering the temporal distribution of the runoff through surface storage. For Hungary, such developments are not possible since

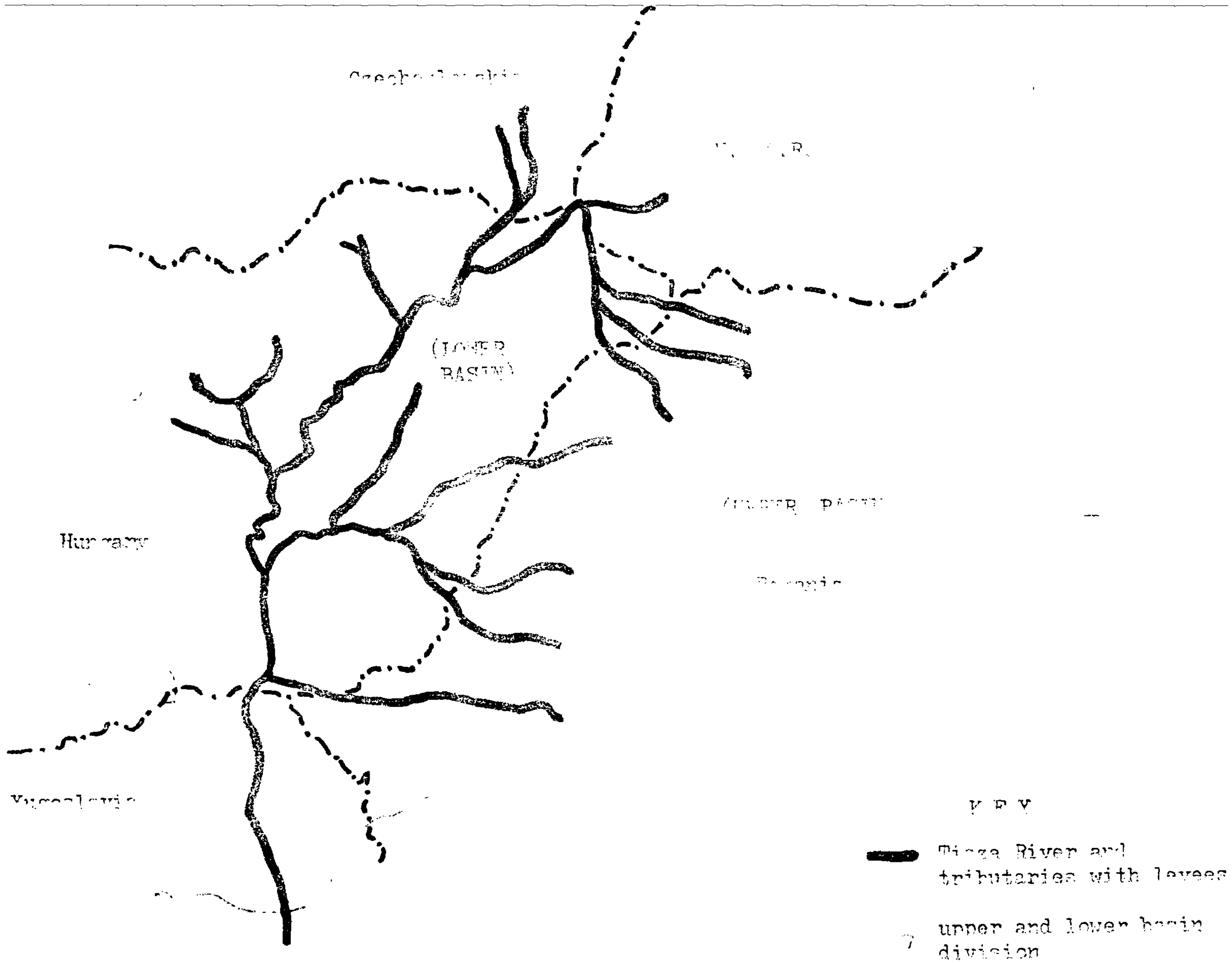


Figure 2: Tisza River Basin

Table 1.

% AREA IN UPPER AND LOWER BASIN

FOR EACH RIPARIAN COUNTRY

	% in lower Basin	% in upper Basin	% of total Basin
Hungary	97%	3%	(29.6%)
Romania	26.7%	73.3%	(46.0%)
U.S.S.R.	25%	75%	(8.1%)
Czechoslovakia	21%	76%	(9.9%)
Yugoslavia	96%	7%	(6.4%)

Area of catchment 156.4 Km^2

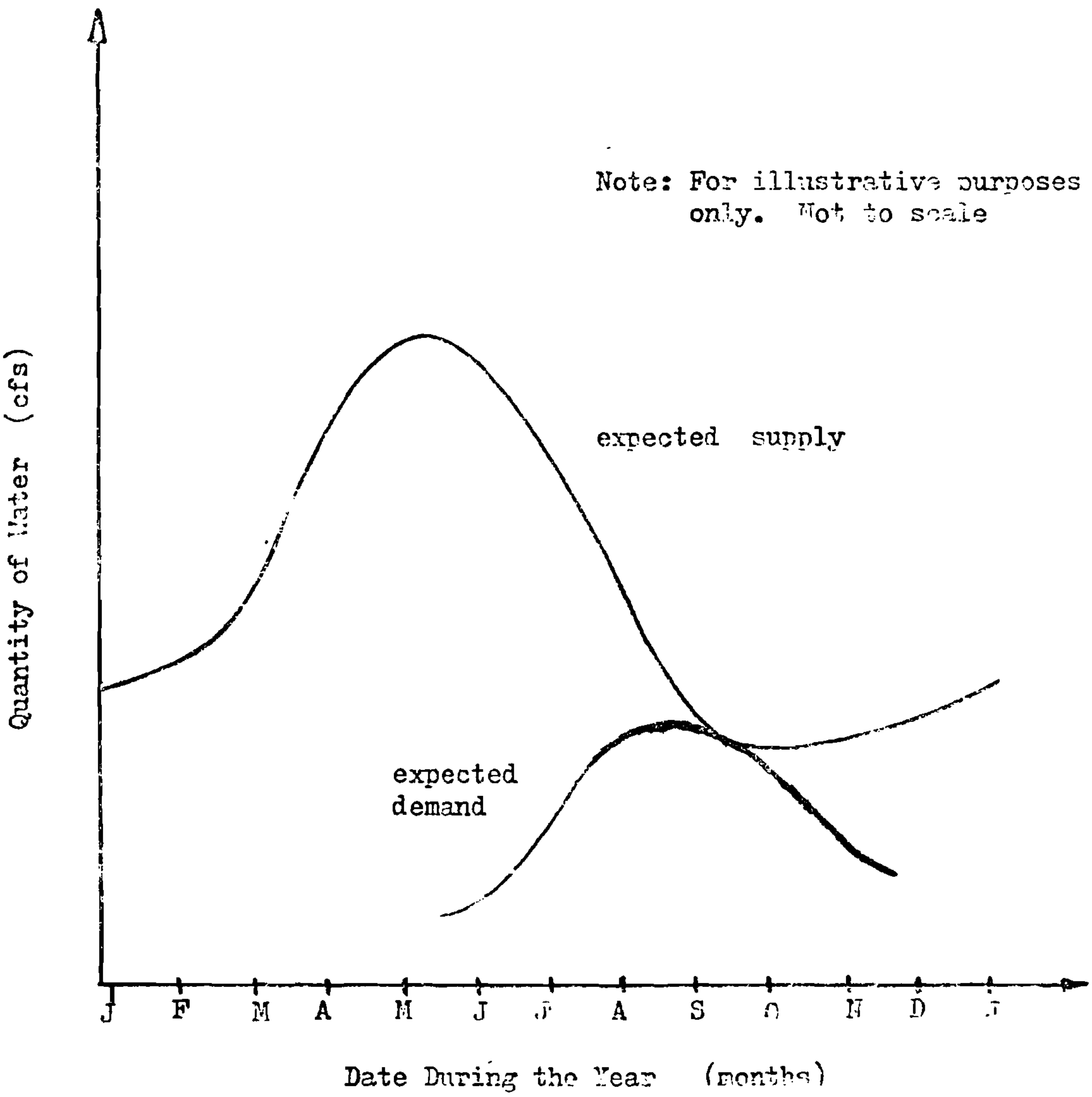


Figure 3: Expected Supply and Expected Demand throughout the Year. (Hungary)

Hungary's portion of the basin contains no reservoir sites.

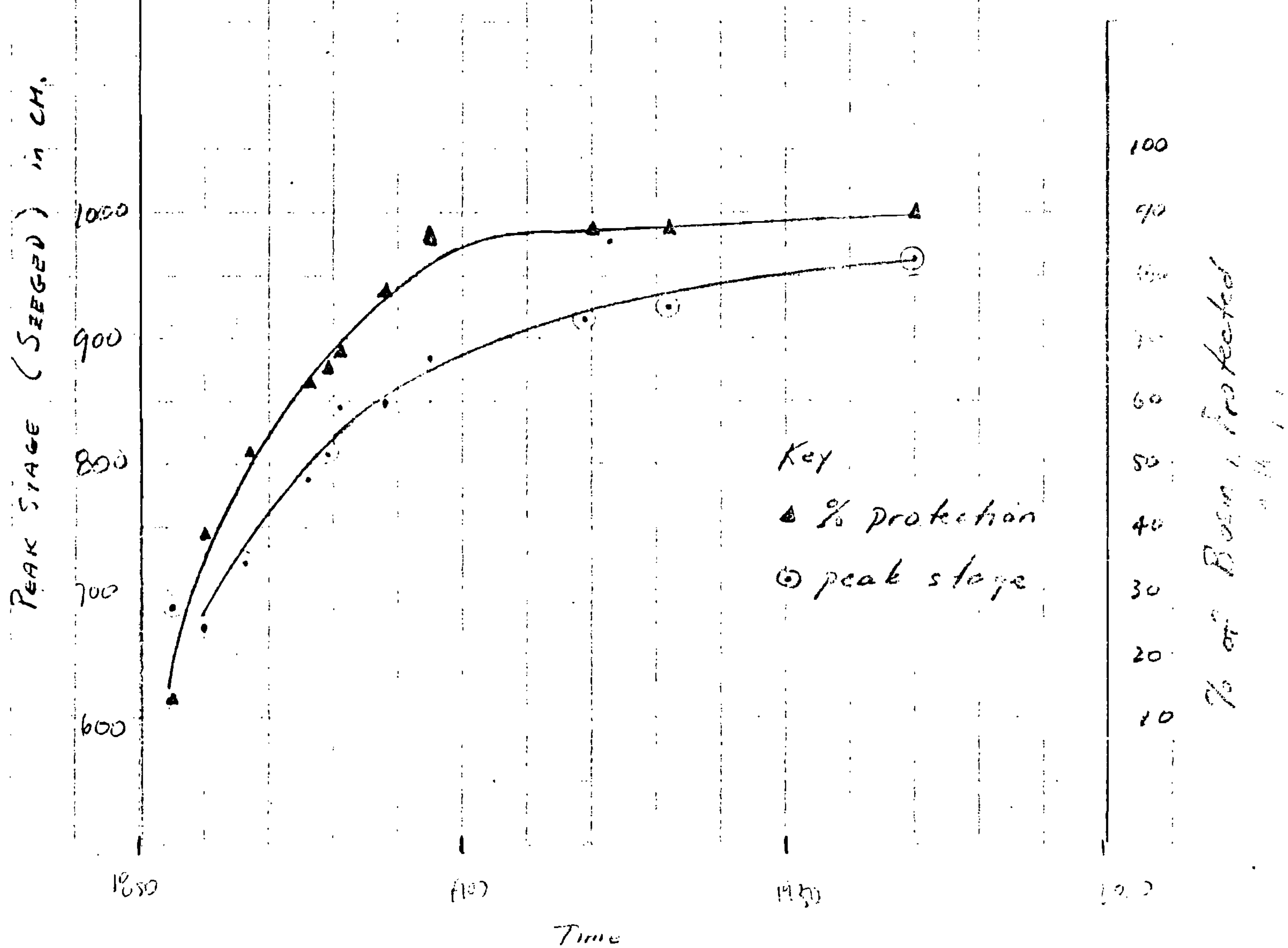
The flood problem is especially critical because their occurrence severely disrupts the economic and social patterns of the countries involved. Hungary and Romania have built and continue to build extensive levee systems. The Hungarian portion of the basin has 4,200 Km and channelization of the river has reduced the length of the Hungarian portion of the Tisza from 1,000 km. to 597 km. Owing to the complex hydrologic phenomena involved, the construction of flood levees has not reduced the peak flood levels, as can be seen in Figure 4 Continued flood levee developments are having adverse impacts on the lower reaches of the Tisza River to the point that socio-economic development may have to be curtailed. The realization that levee protection is inherently a local solution has not received the wide attention it deserves, and planning strategies based on levee construction tend to be, in the long-run, extremely inefficient.

The problems facing development in the Tisza basin, are the necessity of controlling floods and the better utilization of the limited water resources. The limited number of local planning strategies and the numerous joint strategies makes the Tisza basin an ideal case study region for which the procedures of resource sharing can be applied.

Work Plan

The main objective of the proposed study is to demonstrate how basin wide cooperative planning techniques can lead to better utilization of international river basins and to investigate operation procedures for resource sharing and cooperative development. The proposed case study forms an integral part of the research effort as the applicability of techniques for cooperative planning to realistic situations is of prime importance.

Figure 4: Peak [illegible] and Percentage of [illegible] over the last [illegible] years



It is proposed that this research be conducted over a two year period. At the time of project initiation, it is hoped that counter-groups, from the riparian countries, interested in the study will be identified and brought together in workshop sessions in Laxenburg over the course of the project.

The workshops will have two main goals: one, to provide a focus upon the project for both IIASA staff and the counter groups; and two, to provide a means for testing alternative techniques with feedback so that techniques which appear most promising can be concentrated upon.

An initial workshop (about one week's duration) will be held four to six months into the project and will utilize some very simple hydrologic and conflict resolution models. During this initial workshop communication will be initiated among all interested groups with an attempt made at developing an awareness of the problem. The workshop will help focus and define more clearly the direction of the conflict-resolution research than is possible at this time. This "workshop approach" has already been successfully used at IIASA (Franz and Holling, 1974) in simular projects. During the course of research the simple models will be more fully developed and alternative models proposed in cooperation with the counter groups.

The project hopes to utilize the unique international character of IIASA in the formulation of the counter groups. At present the Water Resources Project has cooperative research agreements with both the Soviet Academy of Sciences, subcommittee on Water Resources, and the Hungarian Water Authority. It is felt that the research project can draw upon these research agreements in the formulation of the case study and the participation of effective counter groups.

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