INTERNATIONAL RIVER BASINS: PERVASIVE UNIDIRECTIONAL EXTERNALITIES

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ABSTRACT

The paper reviews the phenomenon of international river basins and concludes that sharing of river basins between and among countries is the rule rather than the exception for the major river systems of the world. More than 200 river basins, accounting for more than 50% of the land area of the earth, are shared by two or more nation-states, powerful and often jealous social units that dominate what is still an age of nationalism. When population densities were low there was plenty of water for all and major conflicts were avoided. With the rapid population and economic growth experienced in the past few decades conflicts over use of water are becoming more important. It is expected that in the near future these water conflicts will become much more severe.

The paper reviews the literature on attempts to analyse the conflicts and negotiate solutions. One interesting finding is that the upstream-downstream externalities are not always negative; there are many cases where upstream development of water resources leads to increased benefits to downstream users. Some rudimentary game models are examined and some tentative conclusions, based upon various game theory concepts of stability are presented. The paper ends with suggestions on how to plan Pareto-admissible outcomes for international basins.

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1. Introduction

The observations on man's use of water in this paper fit happily under the expression "transnational commons," which is a part of the title of this Conference. We will discuss the large range of possibilities for conflict and cooperation which arise when a peculiarly strong modern social form, the nation state, superimposes itself on a geographical, physical and natural pattern of intense water resource interdependency -- a river basin.

More than 200 river basins[1], accounting for more than 50% of the land area of the earth, are shared by two or more countries. The more than 280 treaties that have been signed between countries on water issues give evidence of the tensions that divided basins engender. Two thirds of these treaties have been in Europe and North America where the problems first became acute (Vlachos, 1990, and Delli Priscoli, 1990). In the rest of the world, large scale development of water resources has only become widespread during the past decades. By the development of water resources, we mean water diversion, and often storage, to serve agricultural, industrial, municipal, flood control and other uses. Water development in our time is driven by population growth and technological advances such as hydroelectric generation and modernized year-round agriculture; under this heading it is fair to visualize multi-billion dollar, often heroic national enterprises such as the Hoover and Aswan dams, and the irrigation of the North China plain. A world-wide perception of virtually global water scarcity, relative to the emerging uses and needs for water of larger populations, is historically new, and the accompanying conflicts have only begun to manifest themselves. Rapid population and economic growth in many parts of the world are severely stressing natural resources, so much so that water is beginning to have a scarcity value and an emotional intensity resembling that of petroleum.

The concern with international river basins and the need to move quickly with mechanisms to defuse conflicts before they become deeply entrenched is also part of the current interest in global environmental issues. Most of these are by nature transnational, but the stakes in transboundary water conflicts, being

[1] The United Nations (1978) lists 214 "shared" rivers; 148 flowing through two countries, 31 through three countries, and the remaining 62 flowing through four or more countries.

more tangible and closer to home, are perceived more sharply by the individual participants than the stakes in the protection of the global ozone layer. Unlike ozone, water problems also usually present a neighboring nation or people as an antagonist, which tends to intensify popular emotions, cluster water issues with other historical grievances, and favor the combative set of attitudes associated with zero-sum situations. The growth of interest in international rivers is reflected by the dedication of the entire December 1990 issue of Water International to international water conflicts.

Table 1 shows the details of the some of the major international rivers and Figure 1 shows their locations around the world. Some of the largest rivers have multiple riparians and countries within the drainage basins, like the Amazon (with 7 nations), the Nile (with 9), the Danube (with 14), the Congo (with 9), the Brahmaputra (with 4), the Ganges (with 4), the Rhine (with 8), the Niger (with 10), the Mekong (with 6), and the Zambezi (with 8).

Some major international water conflicts, however, are in the Middle East where rivers are typically much smaller, and where the region is chronically short of water. Managing the waters of the Jordan is a perennial and growing problem among Lebanon, Jordan, Syria, and Israel (Starr and Stoll, 1988). The Turkish and Syrian developments on the Euphrates are sources of friction between both of them and downstream Iraq (Tekeli, 1990). The sharing of the Nile waters between Egypt and the Sudan has proceeded in a relatively cooperative atmosphere which is now being disturbed by Ethiopia and six other upstream riparians (whose territory generates the bulk of the flow) who are now demanding access to use of the water for their own needs (Smith and Al-Rawahy, 1990, Waterbury, 1979, Haynes and Whittington, 1981, Whittington and Haynes, 1985, and Guariso and Whittington, 1987).

With World Bank assistance, India and Pakistan settled a serious conflict over the use of the Indus which was precipitated by Partition in 1947, although it took until 1960, to arrive at a satisfactory treaty between the countries (Michel, 1967, Khan, 1990, and Kirmani, 1990). India and Bangladesh have an unresolved water dispute since 1975 concerning diversions by the Farakka Barrage in India on the Ganges, and cooperative augmentation of dry season water supplies in that monsoon zone (Zaman, 1983, Abbas, 1982, Islam, 1987, and Begum, 1987). The Bangladesh floods of 1987 and 1988 reopened the question of

basin-wide management for high flows between these two countries (Rogers et al., 1989). Problems have already arisen, or are expected shortly, on the Amazon, the Niger, the Senegal (LeMarquand, 1990), and the Zambezi rivers.

Furthermore, water often crosses international boundaries underground, and problems are now arising concerning the use of the Northeastern African aquifer shared by Libya, Egypt, Chad, and the Sudan, the Northern Sahara Basin shared by Algeria, Tunisia, and Libya, the Chad aquifers shared by Chad, Niger, Sudan, Nigeria, and Cameroon, the lower reaches of the Rhine recharge aquifers shared by Denmark, the Netherlands, and Germany, and aquifers along the southern borders of the United States, shared with Mexico. Much of the discussion about international river basins gives insufficient attention to this important groundwater resource.

2. Causes of Conflict: Pervasive Unidirectional Externalities

> An externality occurs whenever an action taken by some economic unit has a direct impact upon the welfare or productivity of some other economic unit. When the medium through which the external effect or externality is transmitted is physical, that medium is a common property resource. Dorfman (1974).

LeMarquand (1977) translated this statement into " An international river is a common property resource shared among the basin states." Water used in river basins has the interesting property that both positive and negative externalities usually have their effect in only one direction, that is, downstream. An upstream country affects the volume or quality of a downstream country's water by diverting or polluting it, but the downstream country cannot do the reverse, since it has no access to the water until it has left the upstream country. Since, given enough time, water is the universal solvent and the major geomorphological transport mechanism, the externalities are caused not only by intentional water-uses but also by other natural and human activities occurring in the upstream reaches, such as intensification of agriculture or forestry. This unidirectional feature of water use means that resolution of basin conflicts through mutual control of external effects that work, reciprocally, in both directions is generally ruled out. The downstream partners must often balance the asymmetrical water relationships by the use or exchange of resources from outside the water domain, for example, economic or military power, in the upstream direction.

Table 2 gives a list of the major downstream effects of water use and non-water use in upstream reaches. Note that although rivers flow in only one direction, these upstream activities can produce externalities that have a positive as well as a negative impact on downstream users. The traditional uses are hydropower for peak and base load power production, irrigation diversions, municipal and industrial diversions, maintenance of flow for navigation or for adequate dilution of wastewater or for general ecological values, storage for flood control and recreation, and the development of groundwater. The table also lists some of the non-water uses which cause externalities. These typically involve land use changes occasioned by agriculture, forestry, animal husbandry, filling wetlands, and urban and suburban development. There are also, however, natural (i.e., not caused by humans) processes that cause downstream effects which are often mistaken for externalities. Large and small landslides, sometimes provoked by earthquakes, in fragile high mountain environments such as the Himalayas generate huge sediment loads in the rivers, bringing drainage congestion and flooding, as well as fertility, downstream. Natural deposits of salts and heavy metals contaminate ground and surface waters leaching through them. The selenium damage caused by the irrigation drainage waters reaching the Kesterton wildlife sanctuary in California and the increasing salinity of the Colorado River are examples of external effects jointly caused by man and nature.

The sediment-drainage congestion-flooding sequence is often used to call for basin-wide management of land use practices, but recent literature is equivocal about cause and effect relationships in this regard. Repetto (1987) summarizes studies from Indonesia which indicate substantial downstream damages from agriculture and forestry in the upland areas. Ives and Messerli (1990), however, claim that for the Himalayan region most of the sediment problems are of natural geological origin, not significantly affected by human land uses.

Most of the literature on externalities in river basins focuses upon description of the phenomena and its physical quantification rather than upon its economic consequences. It will be shown later in this article how effects upon navigation, flood flows, and salinity can be incorporated into economic analysis without specific knowledge of their economic costs by the use of constraints on their physical magnitudes.

3. Legal Basis for Sharing the Waters of International River Basins

Resolving water conflicts is complicated by the fact that "an international legal framework to govern the use and development of international rivers by riparian countries does not exist" (Kirmani, 1990). According to Kirmani, at least four major legal framework doctrines about sharing water in international river basins are available. The first is absolute sovereignty over waters flowing within a country. This implies that other riparian countries do not have any right to constrain a country's use of a river within its own boundaries, and is obviously preferred by the upper riparians. The second theory is that the river belongs to its riparians; it is of great interest to lower riparians since it implies as much right to the waters for downstream as for upstream users. A third approach can be categorized as optimum development of the river basin. This theory is attractive to technical water planners since it allows them to consider the basin as a single hydrological unit and plan accordingly. The fourth approach, reasonable share or equitable use, expresses respect for a riparian's sovereign right within its territory, but restricts its uses to ensure reasonable shares for the other riparians. The words describing this theory sound so reassuring and reasonable that it is the obvious choice for non-involved third parties, however, depending upon what the stakes are, it is less attractive to upstream riparians than to downstream riparians.

One other doctrine, which has had widespread application in the U.S. West, has been applied to international river basins; prior appropriation. Under this doctrine, water rights go to the first user in time; "first in time, first in right." While this doctrine is not being specifically promoted for international water law, it is embedded in most of the definitions of "equitable use," when they refer to conditioning the definition by "past utilization of the waters." It is also often explicitly used by the more advanced, more powerful countries in a basin to deny new uses to co-riparians on the ground that these will affect existing off-takes or uses.

In addition to private efforts such as those of the Institute of International Law and the International Law Association, since 1971 the United Nations, through its International Law Commission (ILC), has been attempting to establish, with little success, a set of rules pertaining to sharing of international water resources for purposes other than navigation (Hayton 1983, Cano, 1989, and Sinclair, 1987).

After years of haggling over definitions, in 1976 the members of the ILC agreed to bypass some of them, and at its 32nd meeting in 1980, the substantive issues in the regulation of international watercourses were delimited in six articles, which were provisionally adopted by the Commission. By 1984, the six article draft had grown to 41 articles categorized in six chapters. At the time of writing 27 articles have been provisionally adopted, but it is fair to say that caution in creating or recognizing obligations upon themselves is the dominant note among governments.

The Special Rapporteur's Report of the 39th session, for example, addressed the "general principles of co-operation, notification, and provision for data and information." Article 9, on the general obligation to co-operate, raised further definitional concerns: should the article be more specific? Some members suggested a revision that would define the obligation as one "to achieve optimum utilization and protection of the water course, based on equality, sovereignty and territorial integrity of the watercourse states concerned." Others disagreed, saying that a listing of specific criteria for co-operation would destroy the effect of the regulation.

Articles 11 through 21 address planned measures for international river watercourses, focusing on rules of notification and consultation procedure. Although most ILC members recognized the fact that a state has the right to internal sovereignty over its territories, including water resources, they also noted that this does not permit a state to injure another state indirectly through its internal actions. The ILC defined "wrongful harm" as injury to another party not consistent with the equitable utilization (Articles 6-10) of the watercourse.

Articles 22-25 discuss the protection and preservation of international watercourses; they stress control of ecological disruptions such as pollution and the introduction of new species. Articles 26 and 27 of the draft emphasize the need for emergency procedures, to deal with natural causes such as floods, ice-breaks, landslides, and earthquakes. The articles proposed beyond article 27 have not yet received provisional adoption due to the time constraints of the Commission. The ILC is, however, hoping to approve the first complete draft of articles by the end of 1991.

The legal situation is, however, not without some helpful developments. Review papers by Caponera (1983) and Hayton (1983) see substantial agreement on a set of important doctrinal issues. They find that the principles of 1) "prior consultation," 2) "avoidance of significant injury," 3) "equitable apportionment," 4) "non-discrimination and non-exclusion," and 5) "provision for settlement of disputes" are widely used in water disputes despite the non-existence of a "set of laws." These principles are embedded in the Helsinki Rules formulated by the International Law Association in 1966. The heart of the 37 Article Helsinki Rules is Article V, whose recommendations are listed in Table 3; they are very similar to Article 7 of the provisionally adopted ILC text.

4. Economic Basis for Sharing the Waters of International River Basins

Economists have a lot to say about the problems of allocating water in river basins (Hirshliefer, DeHaven and Milliman, 1960, and Maass et al, 1962), but they are quick to point out the limitations of their analysis in the presence of external effects. The general economic prescription to deal with externalities is to "internalize" them. The river basin itself is an ideal unit of analysis to achieve this goal: it can reasonably be assumed most externalities are captured by analyzing the river basin as a single unit. This is why the concepts of integrated river basin planning and the creation of river basin commissions to implement and plan are so popular in the economic and planning literature.

But sorting out externalities among the several nations in one basin is another matter. It is precisely because the international river basin is international that it cannot be readily planned and developed as a single unit unless all of the riparians agree. Only in a few instances has this been attempted, and a leading case, the Columbia River Basin shared between Canada and the U.S., yielded mixed results (Krutilla, 1967).

If one cannot physically internalize the externalities as between basin countries, what can one do? The economics literature is replete with proposals to tax externalities so that the individuals and groups enjoying them will factor the costs to other people into their calculations. Taxes, or fees, have been widely propounded by groups such as the Environmental Defense Fund and the World Resources Institute in the United States as a way of dealing with transboundary air pollution problems, but this approach requires

strong supra-national institutions to impose the taxes, and such institutions do not now exist to control transboundary externalities in international river basins.

Pareto Admissibility

A promising practical approach to dealing with externalities in river basin planning, called "Paretian Environmental Analysis," was formulated by Dorfman and Jacoby (Dorfman, et al., 1972). They applied Paretian analysis to upstream-downstream conflicts about the management of water quality; their example was within one country but the conflict of interest was identical to that within many international river basins. Pareto-admissibility emerges as a condition which a water resources development plan for the basin must satisfy in order to be responsive to the basin countries and to the goals of "reasonableness" and equity.

Let $NB_i(x)$ denote the net benefits accruing to country i if resource allocation plan x is adopted, and assume that each country wishes to maximize its net benefits. Then any allocation x resulting in equal net benefits for some countries and greater net benefits for other countries when compared to resource allocation y will surely be preferred by the countries as a whole over y. Expressed in terms of symbols, $NB_i(x) \geq NB_i(y)$ for all countries i implies that x is preferred over y if the inequality is strict. A resource allocation plan x is Pareto-admissible if there is no allocation plan y which is preferred over x in the sense just described.

> Formally, a Pareto-admissible allocation is any feasible allocation x such that there is no feasible allocation y making $NB_i(y) \geq NB_i(x)$ for all interest groups i with strict inequality for some i.

Dorfman and Jacoby looked for a non-coercive strategy for a river basin authority that has to persuade its members to agree on a joint solution. The commission could use the threat that if no agreement was reached then the global optimum solution ignoring jurisdictional boundaries would be implemented. The basic assumption is that the upstream polluters and the downstream users would agree upon the reasonableness of the Pareto-admissible strategy and agree to it without undue pressure. But if they were unable to agree the river basin commission would have the power to enforce the maximum net benefit plan for the basin as a whole. In the context of international river basins where the individual

countries may not wish to give up sovereignty as the global optimum solution would require them to do, but were looking for "reasonable" solutions, this approach has a lot to recommend it. However, concentrating enough power in an international or bilateral agency to impose such a choice is a very difficult political requirement, at present unlikely to be achieved.

Superfairness

Other approaches to analyzing river basin conflicts can be discussed under the general rubric of decision theory. With the increasing emphasis on "reasonable and equitable share" in the legal approaches to international river basins discussed above, it is necessary to develop operational concepts of equity and reasonableness. The economics profession has recently devoted attention to building theories of "fairness" and is relaxing its obsession with allocative efficiency. Baumol (1986) provides the most lucid description of this new concern with a book appropriately entitled Superfairness.

Superfairness rests upon the Pareto improvement criterion given above and the concept of "fair division."[2] Baumol defines superfairness as follows:

> A distribution is called (nonstrictly) superfair if each class of participants prefers its own share to the share received by another group, that is, if no participant envies the other (Baumol, 1986, p.15).

He augments this definition with a clarification of envy:

> A distribution of n commodities is said to involve envy by individual 2 of the share obtained by individual 1 if 2 would rather have the bundle of commodities received by 1 under this distribution than the bundle the distribution assigns to 2.

In generalizing the two person equal division problem to m persons Baumol focusses upon the distribution of the residue , $(y^* - y)$, among the remaining m - 1 individuals when individual i receives y, where, y^* is the total amount available to be shared. Individual i's fairness boundary for this situation is defined:

> The equal division of residue fairness boundary for i is the set of vectors (points), y, such that individual i is just indifferent between y and the amounts received by everyone of the m - 1 other individuals if the residue $(y^* - y)$ is divided equally among them so that each receives $(y^* - y)/(m - 1)$. In other words, y is on i's fairness boundary if, and only if, $U^i(y) = U^i[(y^* - y)/(m - 1)]$, where $U^i(.)$ is i's utility function.

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[2] This is the old children's game of assuring that two people will divide a cake fairly: one cuts the cake into two parts and the other chooses.

This definition is based upon the examination of two extreme cases; the first where all the residue goes to one person (the case most likely to arouse individual i's envy), and the case where the residue is split evenly among the remaining m - 1 persons (where i is least likely to envy any other person).

From the set of definitions Baumol demonstrates that if the utility functions are continuous and quasi-concave then there always exists at least one Pareto optimal solution that is superfair. So far this coincides with Dorfman's use of Paretian analysis; however, Baumol proceeds to show that a superfair distribution may nevertheless be strictly Pareto inferior to another distribution that everyone considers unfair. This may come about in a two-person case when player 1 likes what he gets at some superfair point Q less than the Pareto optimal point H, but that he likes what player 2 gets at Q even less. He does not envy individual 2 at point Q. Strategic behavior is the subject of game theory, but as a negotiating or arbitration strategy superfairness may be of use in modifying the more conventional Pareto-admissible approaches to sharing costs and benefits.[3]

Game Theory

Game theory, which deals with situations ranging from "pure" conflict to "pure" cooperation, was given an enthusiastic welcome when it first burst upon the economic scene in 1944 (Von Neumann and Morgenstern, 1944). However, it did not directly yield norms for decisions under conflict of the sort experienced in international river basins. As a result, the field has relied increasingly upon process oriented approaches such as Alternative Dispute Resolution (ADR, Delli Priscoli, 1990) or the Processes of International Negotiations (PIN, Fisher and Ury, 1981). These aim at getting the parties to arrive at a negotiated solution, making the basic assumption that there is a solution to every conflict and that it can

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[3] Dorfman suggested that comparison of Nash Equilibria and superfairness might be appropriate for these class of problems. Nash's solution is in terms of strategies not payoffs and is defined as that vector of strategies in a noncooperative game such that no one player, assuming that the others are committed to their choices, can improve his lot. Algebraically it is the vector of strategies s_i^* such that the payoff to player i, $H_i(s_i)$, is for each i,

$$H_i(s_1^*,\ldots,s_i^*,\ldots s_n^*) = \max_{s_i} H_i(s_1^*,\ldots,s_i,\ldots s_n^*).$$

This is a generalization of the minimax solution for the two-person zero-sum game.

be arrived at by judicious use of a variety of time-tested negotiating strategies (win-win, getting to yes, etc.) administered by a third party.

Despite its early lack of success, game theorists have been pursuing a variety of approaches that are potentially very useful in the case of shared international water resources. In particular, there are a series of recent papers[4] which apply some of the findings of game theory to practical problems of the allocation of benefits and costs between conflicted parties on river basins. All these approaches are based upon analysis of the core of an n-person cooperative game.

The development and analysis of coalitions is central to game theory. To analyze a coalition structure in a game, it is necessary to assess in a single numerical index the value of the game to each of the coalitions that can form. This is called the characteristic function, and is denoted v, which defines the maximum value of the game which a coalition can guarantee for itself if it forms in the playing of the game. It lists the value of the game to all possible coalitions.

In any n-person game there are potentially $2^n - 1$ coalitions. The games of interest in dividing up water in international rivers are called essential games because there is benefit to cooperation between the players. A well-defined characteristic function, v(S) must satisfy the following condition: If $S \cap T = \phi$, then $v(S \cup T) \geq v(S) + v(T)$. This super-additivity condition requires that two disjoint sets of players should not suffer by cooperating with each other. If, in addition, $v(1) + v(2) + \ldots + v(n) < v(1,2,3,\ldots n)$, the v represents an essential game in characteristic function form. In other words, the payoff to the grand coalition is always greater than the sum of individually sovereign solutions; this will always occur in the presence of externalities.

In order to arrive at a "solution" to a cooperative game some additional requirements need to be placed upon the values of the characteristic function. In particular, we can allow the members of the coalitions to make side payments to each other; although often and mistakenly disparaged by bureaucrats as "bribes," such balancing side compensations almost always play a positive role in supporting cooperation.

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[4] Young et al. (1982), Young (1985), Dinar and Yaron (1986), Tijs and Driessen (1986), Dufournaud and Harrington (1990, and 1991).

Taking such side payments to each member of the coalition into consideration leads to establishing the payoff to each member of the coalition; this is called an imputation, and should meet some logical and reasonable conditions. The three conditions that are most often set are those of feasibility, Pareto admissibility, and individual rationality. An imputation for an n-person game v in characteristic function form is a payoff vector $(p_1,...,p_n)$ which satisfies the following two conditions:

1. $p_i \geq v(i)$, for $i = 1,2, \ldots ,n$

2. $(p_1 + p_2 + \ldots p_n) = v(1,2,...,n)$

The first condition represents individual rationality and requires that any acceptable payoff vector must give no player less than what that player can obtain on his own. The second condition corresponds to Pareto-admissibility and also feasibility when the strict equality is replaced by a less than or equals to sign.

The solution concept of the core of the game rests on the idea that there are a set of imputations that leave no coalition in a position to improve the payoffs to its members. The core of an n-person game in characteristic function form v(S) is the set of imputations which are not dominated by any other imputation. A payoff vector $(p_1,...,p_n)$ belongs to the core of v(S) if, and only if:

1. $\sum_{i \in S} p_i \geq v(S)$ for all $S \subset N$

2. $\sum_{i \in N} p_i = v(N)$

Condition 1 when applied to S = (i) implies individual rationality. For any proper subset S, condition 1 states that any payoff vector in the core of a game must give no less total payoff to each coalition than the total payoff which that coalition can obtain on its own. Stated in another way, no coalition will accept a payoff vector that yields less than what that coalition can obtain on its own. In these cases condition 1 now embodies a sense of individual and group rationality. Condition 2 is Pareto-admissibility. Roughly speaking, the core of an n-person game in characteristic function form is the set of payoff vectors for which there is no coalition having both the desire and the means of effectuating a

change. The concept of the core is used as the basis to decide on the stability of different payoff vectors and, hence, coalition structures.

What should now be apparent is the pivotal role played by Pareto-admissibility in the analytic approaches that have been propounded for recommending "solutions" to the types of problems which are encountered in water allocation in international river basins.

5. Political Basis for Sharing the Waters of International River Basins

Often called the "queen of sciences," political science is rich in observation but poor in tested predictive theory. Clearly the decisions involved in international rivers are political and can only be adequately addressed in political terms. The problem is to be able to derive a basis for political recommendations and action from political science. Political imperatives contrast to the economic imperatives in three important particulars:

> 1) They concretely evaluate the desirability of a policy or an investment on the basis of its value, positive or negative, to a large number of subgroups with varying degrees of interest in the matter.
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> 2) They do not rely solely upon the simplifying quantitative economic measure of money, but are heavily influenced by non-monetizable considerations as well, and
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> 3) They are pursued separately and apart from economic objectives, with different personnel and rituals; recruitment to the political arena has a particular history and admission confers a great deal of authority.

The predictive models employed are much more diffuse and less precise than those employed by lawyers and much less quantitative than those used by economists. Political models of bureaucratic and executive politics, pork barreling, and interest groups tend to be more highly descriptive and idiosyncratic than analogous models in other sciences. The literature on coalition formation is closest to the analytic aspects of game theory mentioned above.

An important work on the political bases for sharing international rivers is the book by LeMarquand (1977) entitled, International Rivers: The Politics of Cooperation. The book discusses both the foreign policy and the domestic policy implications on the decisions to negotiate river basin disputes. Written in 1977, the book tends to relegate international river issues to the "middle range of objectives"

dealing with satisfying domestic social and economic demands rather than to the "core objectives" regarding a country's territorial integrity or self-preservation. By 1991 many countries would see themselves entering an era when national sovereignty is now at stake; some countries in the Middle East might claim that national survival is at stake.

LeMarquand gave the following five important foreign policy factors which influence a country's position about international rivers:

> Image. The concern for national image may be one of the most important factors in deciding how to deal with international water issues, particularly when the issues are considered in the middle range objectives. The U.S.'s decision to build a desalting plant on the Lower Colorado River may have been largely influenced by avoiding the negative image of a large and powerful country pursuing its own national interest heedless of the consequences for a poorer neighbor.
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> International Law. As discussed above international law does not provide any strong incentives to behave in any particular way. There is, however, now a widely accepted consensus on a set of principles which, depending upon how much image is important, a country may choose to abide by or not. Hence, the developing and non-binding international legal principles can be important factors in enabling countries to get involved in negotiations.
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> Linkage. The linkage of river basin settlements to other bilateral or multilateral issues is one way countries may be able to extract concessions from their neighbors. Linkage seems to be used to a certain extent in all of the major river basin negotiations discussed in the literature.
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> Reciprocity. The desire for mutual commitment and obligation can often have the most bizarre manifestations in negotiating international river basin disputes. LeMarquand cites the case of Switzerland, a land-locked country, insisting that treaties governing the protection of international watercourses against pollution be extended to cover pollution of coastal areas. This demand was, however, not irrational since it was aimed at ensuring that the Netherlands, who would benefit from Switzerland's treatment of its water discharges into the Rhine, could not dump its untreated sewage into the ocean.
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> Sovereignty. Sovereignty is the major stumbling block in the path of resolving international river disputes. Given the choice, countries would prefer independent action over international cooperation because of the general loss of sovereignty and independence and loss of control over domestic resources implied by collective or bilateral constraints.

LeMarquand cites three factors influencing domestic policy formulation which are salient with regard to international river issues:

> Bureaucratic Policy Formation. He claims that most international river issues are left to bureaucrats in the ministry dealing with foreign affairs. In turn they have to rely upon bureaucrats in the technical water and other resource ministries who often have substantive interest in a particular project, or set of projects, with interest group support. When the

foreign affairs bureaucrats then have to deal with their counterparts in the other riparian countries negotiations can drag on for years and "lowest common denominator" agreements are the most likely outcome.

Executive Policy Formation. When a president or prime minister takes an active interest in the outcome of an international river issue it is generally possible to circumvent recalcitrant bureaucrats and achieve rapid solutions. LeMarquand shows how President Escheverria of Mexico was able to press President Nixon into a rapid resolution on the salinity problems of the Lower Colorado. The current role played by President Ozal of Turkey may give his "peace pipeline" a better chance of being implemented than if it were left to the usual political channels in the Middle East.

Non-executive Policy Formation. These essentially deal with the distributive politics of the "pork barrel" and coalition building, both features much commented upon with respect to domestic U.S. water policy. Also included are the regulatory politics of environmental management which establish the ground rules under which much domestic water policy is now governed. Redistributive politics may also enter as central governments may seek to use international agreements over water as a way to regain control over regional water use for the purpose of redirecting it towards other social goals.

The most important political basis for sharing water is the "climate for agreeement." Various authors are cited by LeMarquand for insights into this aspect of the problem. The following conditions are suggested as favorable for successful international agreements concerning water:

1. Countries with the same technical perception of a problem.
2. Similar tastes for consumption of goods and services.
3. When water quality is an issue, the use of similar industrial production technologies.
4. The existence of an extensive network of transnational and transgovernment contacts between countries.
5. The participation of a small number of countries.
6. The desire of one large country to have an agreement.
7. The necessary development by one country of a good or service for its own use which may benefit other countries.

Domestic and international politics remain the most important features of international river basin development and have to be addressed in any analysis.

6. Some Case Studies

From many cases, we have chosen three real situations to illuminate these issues. They involve, respectively, two countries, three countries, and multiple countries, sharing the waters of a river basin. The basins of the Columbia, the Ganges-Brahmaputra, and the Nile have experienced substantial development,

pressure, and have given rise to international treaties governing their use. They have been widely discussed in the literature, and some form of analytical study has been performed for each.

i) The Columbia River

The background of the Columbia Treaty between Canada and the U.S. and the subsequent development of the basin was the subject of an excellent book by Krutilla (1967) and a chapter in LeMarquand's book (1977); the following comments rely heavily upon Krutilla's and LeMarquand's work. Figure 2 shows a map of the basin. After more than 20 years of planning and negotiating the Columbia River Treaty which was signed in 1961 called for Canada to provide storage of 15.5 million acre feet (19 billion cubic meters) in three dams and the U.S was given the option to build a dam in Montana that would flood 42 miles into Canada. In return for providing the storage Canada received 50% of the increased base power generation at dams downstream in the U.S. and 50% of the estimated downstream flood control benefits. When the treaty was ratified in Canada, in 1964, the Canadians sold their share of the power to the U.S. for a period of 30 years for a lump sum payment of $254 million (U.S.) and in addition received $64 million (U.S.) as its share of the flood control benefits. The treaty is to be in effect for 60 years.

Apart from their social similarity and a long history of good relations, Canada and the U.S. have the unique situation that an International Joint Commission (IJC) was established in 1909 by the Boundary Waters Treaty to deal with conflicts about transboundary rivers. There is a great advantage to having an already existing institution to turn to when a particular river problem has to be resolved. In 1959 the U.S. and Canadian governments requested the IJC to make recommendations on the principles that should be applied in determining:

a) the benefits to result from cooperative use of the storage of waters and electrical interconnection with the Columbia River System; and

b) the apportionment between the two countries of such benefits, more particularly in regard to electrical generation and flood control (Krutilla, 1967, p. 59).

Eleven months later the IJC promulgated a set of principles, the first two of which are germane to this paper. They are cited by Krutilla (1967, p. 60) as follows:

General Principle No. 1

> Cooperative development of the water resources of the Columbia River Basin, designed to provide optimum benefits to each country, requires that storage facilities and downstream power production facilities proposed by the respective countries will, to the extent that it is practicable and feasible to do so, be added in the order of the most favorable benefit-cost ratio.

General Principle No. 2

> Cooperative development of the water resources of the Columbia River Basin should result in advantages in power supply, flood control, or other benefits, or savings in costs to each country as compared with alternatives available to that country.

The application of these general principles could have led to Pareto-admissible solution if they had been strictly followed. What actually transpired is that the Canadian federal government found itself in major conflict with the provincial government of British Columbia over water resources development. This gave the province a key role in skewing the negotiations in its favor.

Krutilla (1967, p. 193 et seq.) concluded:

> It is not at all clear, in fact, that the returns to Canada and the United States combined are greater than they would have been if each country had proceeded independently (p. 193); and,
>
> ...the IJC principles appear to promise that each party to the cooperative venture will receive something that is somehow equal, the circumstances of the case in question permitted a diversion of the real gains predominantly to Canada.

The major reason why the Pareto solution was not obtained appears to be the decision, insisted upon by British Columbia, to share costs and benefits on the basis of a "grossing" rather than "netting" formula. The "netting" approach is favored by economists, utilities, and was initially favored by the two governments. Under "netting," utilities estimate the least-cost alternative of going alone and then they compare this cost with the cost of cooperative action. The difference between the cooperative case and the least-cost go-it-alone case yields the net value or savings from cooperative action. These net savings from cooperation then become the basis for the equitable sharing of the benefits between them by sharing the costs. Under the "grossing" approach each country is responsible for the costs of constructing projects in their own country and the benefits are then divided equally between them. Clearly this approach leads to a less than optimal basin-wide net benefits and an arbitrary division of the spoils.

Dufournaud (1982) presented the Canadian side of the Columbia Treaty and argues that Canada was not the major gainer. He summarizes the arguments of General A.G.L McNaughton, who negotiated the treaty for the Canadians, as follows:

> McNaughton's concerns are threefold. First, he objects to the Treaty, which, he argues, underrepresents the United States eventual gains.... He implies that Canada's gains are smaller than they could have been. Second, he objects to the requirement that the Treaty imposes upon Canada to unconditionally provide flood protection to the United States. Third, he objects to the Treaty because he believes that in the long run this will provide the United States access to Canadian resources to the detriment of Canada.

General McNaughton it should be recalled, however, was an ardent proponent of linking the Columbia to the Fraser River and diverting all of the "excess" flows away from the U.S. and into an entirely Canadian river basin. It is not clear that McNaughton could ever have achieved that particular outcome, however, the very existence of the proposal no doubt figured in the U.S.'s determination to achieve a treaty.

In presenting the Canadian side of the picture, Dufournaud analyzes the Columbia as a two-person non-zero-sum cooperative game and concludes that Krutilla's analysis does not hold up if the subsequent joint undertakings are included. He claims (p. 769) that when this is taken into consideration it "rationalizes an a priori seemingly irrational decision on the part of the United States."

The irony is however, that despite the detailed economic analyses a variety of circumstances intervened to make Krutilla's pessimistic predictions obselete. First, the rapid increase in the value of electricity as a result of the 1973 oil crisis was not predicted by anybody. Hence, the 30 year future sale of the Canadian share of the power was great bargain. Secondly, no one predicted the rate of inflation in construction costs that the Canadians had to face in order to meet their part of the bargain (the "grossing" formula came home to roost with a vengeance). Taken as whole viewed with hindsight the U.S. did remarkably well out of the treaty. It remains to be seen how the Canadians will react in 1994 when the power sale contract expires.

In a 1966 paper Krutilla showed how the Kennedy Administration's urgent desire to find something to compensate Canada for the loss of the sale of a Canadian built fighter plane to NATO in preference to a still unproduced U.S. plane, influenced Washington's decision to agree to a treaty that gave Canada an advantage. Such behavior violates one of the basic assumptions of most cooperative games; the

independence of irrelevant alternatives. On the surface it appears that real political decisions apparently pay little attention to the niceties of game theoretic formulations of decision problems. However, if the range of choice were opened up before the negotiations then the fighter plane may not have been an "irrelevant alternative." This looks like a good example of "linkage" discussed above. The strength of the "process" approaches to negotiation over formal game analysis is that they might identify such alternatives in the process of negotiation itself.

ii) The Ganges-Brahmaputra

Conflict about the development of the Ganges-Brahmaputra river system which is shared among India, Nepal, and Bangladesh, dates from the 1947 partition of India into India and Pakistan. (Figure 3 shows a map of the basin.) In the earlier period of British rule, what development there was caused little trouble because the single large nation of India was able to "internalize the externalities." With partition, however, came concern about river transport to the Indian State of Assam, which was all but cut off from the rest of India by the territory given to East Pakistan, which in 1972 became Bangladesh. Over time, however, as India began to divert increasing amounts of water for irrigation out of the Ganges system during the dry months, noticeable effects on the hydraulic regime in East Pakistan were observed. The situation was exacerbated by India's resurrection of a nineteenth century plan to maintain the ocean-going port of Calcutta by diverting large amounts (40,000 cubic feet per second out of a recorded low flow of about 70,000 cfs) of Ganges waters into the Hooghly river during the low flow months (particularly March, April, and May).

In 1975 India completed a barrage across the Ganges at Farakka, close to the Bangladesh border, which gave it that diversion capacity. Since that time there has been a great deal of tension between the two countries about sharing and augmenting the low flows. In 1977 a treaty was signed allocating a little less than two thirds of the Ganges water to Bangladesh, with the understanding that Bangladesh would cooperate on augmenting the dry season supplies by planning transfers of Brahmaputra water to the Indian Ganges via a canal across Bangladeshi territory. With little cooperation on augmentation coming from

Bangladesh, the five year treaty expired in 1982, and after several shorter extensions, lapsed entirely in 1989, leaving unilateral decisions by upstream riparian India as the mechanism for Ganges water sharing. In 1987 there was an unusually large flood in Bangladesh, and it was followed in 1988 by an even larger one of catastrophic dimensions. An estimated 10 million people were rendered homeless for up to two weeks, and the country suffered from massive transportation and social disruptions. At that time, Bangladesh newspapers, if not the government, talked about the supposed role of water developments and deforestation by the upstream riparians, Nepal and India, in intensifying the downstream floods. (Rogers et al., 1989).

The issue of joint or separate development of the basin had been discussed in the mid-1950s by the UN Mission led by General Krug of the U.S. Army Corps of Engineers. The Krug report came out strongly in favor of basin-wide approaches. Following the 1965 war between India and Pakistan many countries urged India and Pakistan to try to identify joint development projects as a way of reducing the level of antagonism between the two countries. One such attempt was the study carried out at the Harvard Center for Population Studies under the direction of Roger Revelle. As part of this study Rogers (1969) used a two-person non-zero-sum game to look for solutions to upstream-downstream conflicts on the Ganges and Brahmaputra Rivers between India and East Pakistan. In Rogers' solution only the cases of sovereign and optimum development were strictly considered. An interesting finding of the analysis was that, under the basin optimum India did no better than she would have done under the sovereignty theory, but lower riparian Bangladesh received substantially more benefits. This would appear to bolster India's claim that the sovereignty theory is the one that she should choose. But since for Bangladesh the sovereignty strategy produces substantially lower net benefits, there would seem to be a need for some form of cooperative solution based upon "reasonable share" if not purely on riparian rights. Bangladesh, however, is currently trying to redefine the "game," at least in regard to flood control, in such a way that sovereign solutions involving large embankments will bolster its payoff. Bangladesh also seeks to broaden participation in the game by inducing Nepal to play. The existence of a third player makes the game much more interesting because of the possibility of coalition formation.

iii) The Nile

At 6,825 kms from Lake Victoria to the Mediterranean, the Nile River is the longest, and certainly one of the most studied rivers in the world. Historically recorded agricultural settlement has depended upon the river for almost 6000 years.

The basin area of just over 3 million square kilometers is split among the nine states shown in Figure 4 and estimates of the percentage of basin area, basin flow contributed, and current water use by each of the riparians are listed in Table 4. This table highlights a paradox about the water use of the Nile: the existing treaties and effectively all of the water consumption occur in the two downstream riparians who essentially make no contribution to the river flow. A standard reference on this basin is Waterbury (1979), aptly entitled, Hydropolitics of the Nile Valley. However, Waterbury's book really considers Egypt and the Sudan as the only water users on the Nile, largely ignoring the remaining seven countries, including Ethiopia, which contributes the bulk of the flow. Most of the other recent literature about water sharing on the Nile exhibits the same selective view of the basin (Smith and Al-Rawahy, 1990, Haynes and Whittington, 1981, and Whittington and Haynes, 1985).

Raj Krishna (1988), however, refreshingly summarizes the history of the Nile treaties with an eye to the basin as a whole, allowing broader concepts of equity to come into play. Table 5 is based upon Krishna's summary. The Nile appears to have developed into an extreme case of how to allocate the waters of international river basins in disregard of the Helsinki Rules or other efforts at equity. No single agreement relating to the Nile encompasses all the Basin countries, and as mentioned above, nearly all the water is used by the two countries which contribute the least water. In Sudan's defense, it is geographically the largest riparian by far and, hence, under the riparian rights theory should receive substantial amounts of water. Egypt also has substantial claims based upon having by far the largest population in the basin. "Prior appropriations," a legal doctrine popular in the western United States but in few other places, are well established going back millennia in the case of Egypt. As the most militarily powerful of the basin states, Egypt does not allow its co-riparians to overlook that fact. According to Krishna (p. 33) President Anwar Sadat said in 1980,

> We do not need permission from Ethiopia or the Soviet Union to divert our Nile water ...If Ethiopia takes any action to block our right to the Nile waters, there will be no alternative for us but to use force. Tampering with the rights of a nation to water is tampering with its life and a decision to go to war on this score is indisputable in the international community.

Guariso and Whittington (1987) have attempted to make a formal analysis of the whole Nile basin and look for Pareto-admissible solutions. Their model considered Egypt and the Sudan as a unit, since they are linked by their 1959 agreement, and their model considers Ethiopia as if it actually had the four large storage reservoirs of the U.S. Bureau of Reclamation's 1964 plan, and were operating them for hydropower. The model considers only irrigation water uses in the Sudan and Egypt, and hydropower in Ethiopia. Guariso and Whittington claim that, contrary to Egypt's belief that any works in Ethiopia on the Blue Nile would necessarily harm the downstream countries, there are potential upstream developments that could expand the amount of water available to the downstream riparians. This is mainly because the evaporation losses in the Ethiopian Highlands are much less than those at downstream reservoirs such as Aswan. They argue that Egypt and the Sudan could achieve these benefits without a cooperative agreement with Ethiopia, provided that Ethiopia could be counted upon to act in its own interest. They also claim that their model shows that the developments in Ethiopia would be particularly helpful to the Sudan. All of these claims have to be tempered, however, by ignoring substantial reductions in hydropower at Aswan in Egypt.

The striking aspect of the Guariso and Whittington study is its lack of correspondence with the perceptions of the basin riparians, and the large economic potential it asserts is available to each of them. This leads to the question whether the nations' perceptions, or the academic analysis in this case, are faulty.

7. Further Exploration of the Ganges-Brahmaputra Case

Although the practical issue of a formula to share the Spring season's low flows at Farakka has often taken over the front pages, the bilateral negotiations between India and Bangladesh have included the issue of augmenting Ganges low flows by transfers from the Brahmaputra. For this, India seeks a canal across Bangladesh to transfer Brahmaputra water from one location in India to another in India on the Ganges. Bangladeshi nationalists are determined to halt this project. At times India has set this proposal within a broader suggestion to examine very large-scale storages, hydro-electric generation, and diversions of water

in the Upper Brahmaputra basin in India (Assam). These would stabilize and support the interbasin transfer of dry season water into the Indian Ganges, but in the wet monsoon season, such works would also mitigate downstream monsoon flooding in Bangladesh which is a major problem for that nation.

At the same time, bilateral exchanges between India and Nepal concerning water have focused upon hydropower production in Nepal's mountains for the Indian market. Recent, and somewhat ephemeral, bilateral Bangladesh and Nepal discussions have focused upon flood control for Bangladesh and access to an ocean port for Nepal.

In the Ganges-Brahmaputra basin today there is a great deal of mutual distrust, and what an outsider might call a lack of clear communication between the riparians. If ever there was a situation ripe for multilateral action, this is it.

For the sake of simplicity in this paper we consider three among the many ways to analyze this problem: 1) an approach using the "reasonable and equitable" criterion for sharing the waters, 2) an approach exploiting Pareto-Admissibility, and, 3) a "game" approach using game theory. Whichever method is chosen, similar sets of information are required. For example, in order to discuss sharing benefits or costs, a method for identifying them must be established. Moreover, if the issue is of sharing the overall benefits due to cooperation, then a reliable method for identifying the optimum allocation also needs to be established. The original Rogers paper in 1969 established a data base and ways of identifying the optimum allocation of the resources. Recently, Quinn (1991) recomputed the payoff matrix for this problem and has explored the implications of "near optimality" for the originally proposed solutions. Quinn's work is the basis for computing the effects of the legal theories on the distribution of benefits and costs among India, Bangladesh, and Nepal.

Reasonable and Equitable Sharing

Article V of the Helsinki Rules lists 11 factors relevant to determining reasonable and equitable use (Article 7 of the ILC lists 6 factors). Based upon readily available data, Table 6 shows how these criteria apply for the three South Asian riparians in this basin. Using such criteria, about 70% to 85% of the total

potential benefits from basin development should go to India with the remainder roughly equally split between Nepal and Bangladesh. Such an allocation certainly should suit India and would be a reasonable position for it to maintain in international debates over the issue. The "reasonable and equitable" results, however, do not look so attractive to the other riparians. In particular, it seems to downplay Nepal's potential strategic role in the hydrology, and Bangladesh's very large population, especially in comparison with Nepal, and its strategic vulnerability with respect to India's actions.

Pareto-Admissibility

Using the Ganges-Brahmaputra basin model the global maximum is as follows:

$$\underset{x \varepsilon X}{\text{Max}} \quad [NB_1(x) + NB_2(x) + NB_3(x)]$$

where $NB_1(x)$, $NB_2(x)$, and $NB_3(x)$ are the net benefits accruing to India, Bangladesh and Nepal. This is equivalent to the Grand coalition in game theory terms. To generate Pareto-Admissible solutions we followed Dorfman and Jacoby (1972) and chose a set of arbitrary weights W and computed;

$$\underset{x \varepsilon X}{\text{Max}} \quad [W_1NB_1(x) + W_2NB_2(x) + W_3NB_3(x)]$$

where W_1, W_2, and W_3 are weights on the net benefits to each country. Eighteen cases were considered and listed in Table 7. The Pareto-Admissible frontier derived from these points for India and Bangladesh is plotted in Figure 5.

A wide range of admissible solutions are possible and, depending upon how one weighs the relative net benefits, could be used as starting points for arbitration. For example, point A weights the net benefits to each equally; the weights are 1.0 for each country. Point D, however, weights India with 1.0 and both of the others with 0.0. Similarly, point E weights Bangladesh with 1.0 and both the others with 0.0. The range of weights are shown in Table 7.

In negotiations, however, the net benefits are not the only consideration; politicians are keenly interested in the physical location of investments. Fortunately, the methodology provides detailed descriptions of the entire basin development plans for each point on the graph. For example, points A and

F which are very close to each other in terms of net benefits to each player at the Pareto frontier have one major difference; in solution F there is no surface storage project in Bangladesh whereas there is one such project in the solution at A. So while the Pareto-Admissible solution implies that India and Bangladesh should be more or less indifferent between these two points it is unlikely that the Bangladesh negotiators would accept a solution at F.

If the assumption is made that there is no pooling of the riparian countries' financial resources to create a general basin development budget, but that projects built within a country must be paid for by that country, then a different, and potentially smaller, amount of total net benefit is available. In other words, the investment decision is made autonomously with regard to the financial resources but the location and type of investment are decided on the basis of what is best for the overall basin. This may be much more realistic in many international river basin cases than pooling procedures which would bring about, for example, Bangladeshi payment for a dam in India. The autonomous investment situation is similar to the "grossing" approach insisted upon by British Columbia in the case of the Columbia River Treaty discussed above. In the case under consideration the total net benefits dropped from Rs.8,643 million per year with a distribution to India, Nepal, and Bangladesh respectively of (4922, 179, 3541) to Rs.8,380 million per year with a distribution of (4248, 23, 4108). One could apply the Pareto-admissibility methodology to this case and look for a frontier of efficient solutions, such as given in Figure 5 for the complete cooperation with the pooling of resources case. This has not been done yet, but one suspects that the range of interesting solutions will be much smaller than the case of more complete cooperation discussed above.

In order to assess the value of cooperation, both of these cases need to be compared with the situation where each country is completely autonomous. This is the case of v(1) + v(2) + v(3) from the characteristic function values; it amounts to Rs.6,961 million per year. This point is also tha Nash Equilibrium point mentioned earlier. Hence, we could argue that partial cooperation, by merely coordinating the investment decisions leads to an increase of 20% in net benefits. A full integration of the investment decision, without regard to where a facility is installed, leads to a 24% increase in benefits. Does a 4%

increase in overall net benefits justify the level of political accommodation needed to achieve the overall optimum solution?

Superfairness.

This situation seems to lead us directly to the concepts of superfairness introduced above. The difference between A and F in Bangladesh's eyes is major and is possibly occasioned by envy of the construction of reservoirs in India and not in Bangladesh. The problem is akin to the cake-cutting example with the cake now having unevenly placed icing, nuts, and raisins. "You cut I choose" is no longer a simple proposition. Moreover, with these multiple objectives it is now possible that Bangladesh will prefer a point such as G which is not Pareto-admissible, but at which Bangladesh no longer has reason to envy India.[5] From the point of view of arbitrating this type of conflict the strategic position (strategic position means physical location, economic power, and development options) of the players becomes of paramount concern. For example, it is unlikely that Bangladesh would be very successful in using such an approach in negotiations with India. Hence, the need arises for analyses which take the strategic opportunities of the parties explicitly into account.

If, however, a negotiating approach using Pareto-Admissibility is carried out, it is easy to examine each of the proposed outcomes (without any additional data generation) in terms of superfairness, especially the envy criterion.

The Core

Table 8 shows the characteristic function for a three-person game involving resource allocation in the Ganges-Brahmaputra basin. An undominated imputation exists for this characteristic function if there is feasible solution to the following mathematical programming model based upon the definition of undominated imputations;

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[5] Something akin to this may have happened in some of the negotiations in the past with respect to sharing the low flows of the Ganges. It is arguable that Bangladesh's position may have had a lot to do with its unhappiness (envy) over what India was getting rather than any objective additional economic losses due to the actual share.

maximize any variable p_1, p_2, or p_3, subject to:

$p_1 \geq 4184$
$p_2 \geq 23$
$p_3 \geq 2754$
$p_1 + p_3 \geq 8265$
$p_2 + p_3 \geq 3729$
$p_1 + p_2 \geq 4409$
$p_1 + p_2 + p_3 \geq 8643$

This program is feasible and has optimal solutions (4914, 378, 3351) when p_2 is maximized, (4914, 23, 3706) when p_1 is maximized, and (4386, 23, 4234) when p_3 is maximized.

The values of the characteristic function can also be plotted to show whether the core is empty or not. Figure 6 shows the core for this game. The core is the area ABCD. All points within this boundary are feasible points and represent allocations of benefits and costs to the players that are likely to be accepted. Note that the area is quite small in relation to the total area it might have occupied. The existence of such a tight core should make the task of the negotiators easier than if the range were very large. Within this core, India always receives larger benefits than Bangladesh but only marginally so. It looks like a 50-50 split with only small amounts going to Nepal. However, the amounts going to Nepal vary considerably in percentage terms; they ranges over a factor greater than 10, from 23 to 378. Nepal's best outcome occurs at the same time as Bangladesh's worst, suggesting that Nepal should "be nice to India" on issues outside of this river problem to influence the negotiated outcome to this end of the range.

8. Conclusions

Without strong and widely accepted international law, the problems associated with the use of water resources in international river basins appear to be quite difficult to resolve unless some form of strong voluntary agreement between the parties concerned is reached. Despite the absence of such international law, however, it is not a Hobbesian jungle. In recent water use conflicts the parties have usually agreed to talk and negotiate. The existence of the various declarations and provisionally approved articles concerning the use of international river basins has indeed helped to create a body of conventions (if not customary law) that inhibit some of the worst aspects of sovereign behavior by upstream, and in some cases, downstream,

Pg. 28 not provided

institution to establish the value of coordination alone, and compare it with the value of coordination and economic integration together. The Columbia River case discussed above revealed a somewhat similar situation where the investments were paid for separately by the basin countries but sidepayments were allowed.

The derivation of Pareto-Admissible strategies for exploitation of the river basin's resources should lead naturally to the key concept that appears to be central to the current thrust of both the Helsinki Rules and the ILC recommendations; reasonable and equitable solutions. This search could be based upon the Pareto solutions discussed above and upon the imputations implied by Core Theory, by asking the following questions;

> Are there decisions (from the set of $x \epsilon X$) which a country would choose if it were acting alone that are also optimal under one of the Pareto solutions?
>
> Are there sidepayments that a country would be willing to accept to avoid choosing an independently optimal solution that would cause harm to a neighbor?
>
> Are there sets of decisions that when jointly taken will lead to an overall increase in benefits and leave no one country worse off?

Pursuing these types of questions for the Ganges-Brahmaputra river basin we found some interesting results that are not immediately apparent from examination of the river basin development from a strictly national point of view. First, we discovered that the core of the game is not empty; in other words, if a strong river basin authority existed that could allocate the costs and the benefits according to the core, there would be no incentive for coalitions to form that would block these allocations. Even in the absence of such an institution, the core could form the basic arbitration strategy of any third party approach to resolving the issues.

If it is generally the case that international river basin conflicts have a non-empty[6] core, why should it be so hard to arrive at resolutions of international river basin problems? The existence of imputations in the core implies ease in finding acceptable solutions. It might be that the difficulty arises from some other

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[6] This proposition is not proven in this paper. Chen (1975) showed that the core would always be empty for water pollution games of the type formulated by Dorfman and Jacoby no matter how many players were involved. This is a strong finding and explains the difficulty that negotiators have in arbitrating and finding agreements between upstream and downstream riparians for these class of problems. For a three-person game, however, Chen was able to show the existence of stable Bargaining Sets.

concepts of nation state sovereignty which make it difficult for nation states to negotiate on water issues. The Canadian stance on the Columbia treaty may be one good example of non-economic sovereignty issues intruding and excluding economically good Pareto solutions. Such sovereignty issues certainly are important in the Ganges-Brahmaputra basin.

The Pareto-Admissible solutions generated by using arbitrary weights on the benefits to each country could also be used to form the basis of arbitrated settlements. We discovered that there are substantial (on the order of 20% of the total) benefits to coordination alone, with only a small increment (another 5%) for full integration in the Ganges-Brahmaputra Basin. These results are based upon average flow conditions under which Nepal does not enjoy a particularly important strategic position, however, this might change markedly, if more extreme flow conditions were imposed, when large upstream storages would be required to stabilize the downstream flows.

Finally, the sets of criteria embodied in Article V of the Helsinki Rules for assessing reasonable and equitable allocation of benefits would tend to allocate too much to India and too little to Bangladesh in comparison with the more "economical" approaches outlined above. This occurs because the Article V approach does not adequately reflect the economic investment opportunities in the basin.

The sheer magnitude of the numbers of actual or potential conflicts over water use around the world, and their intensification in coming years with continuing growth of population, indicates that there is great need to develop a consistent framework and methodology to develop and sort out potential solutions for this class of problems. This paper has been a modest step in that direction.

TABLE 1
THE LARGEST INTERNATIONAL RIVERS OF THE WORLD
(Countries within the River Basins)

1. **Amazon**: Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Surinam, Venezuela. River touches Colombian border; branches to Ecuador, ex. Curaray River. Basin borders on French Guiana, Guyana, Surinam, and Venezuela.

2. **Amur**: China, Mongolia, USSR. Forms part of border between China-USSR. Breaks off into two branches, one of which goes into Mongolia.

3. **Brahmaputra**: Bangladesh, Bhutan, China, India.

4. **Columbia**: Canada, United States.

5. **Congo or Zaire**: Congo, Zaire. Forms part of this border. Tributaries run from Angola, Cameroon, Central African Republic, Zaire, and Zambia.

6. **Danube**: Albania, Austria, Bulgaria, Czechoslovakia, France, Germany, Greece, Hungary, Italy, Poland, Romania, Switzerland, USSR, Yugoslavia. Forms parts of borders between Bulgaria-Romania, Hungary-Yugoslavia.

7. **Elbe**: Czechoslovakia, Germany.

8. **Ganges**: China, Bangladesh, India, Nepal. Branches from main river stem into Nepal. Smaller River Alaknanda flows from China into Ganges at western tip.

9. **Indus**: Afghanistan, China, India, Pakistan.

10. **Mekong**: Cambodia, China, Laos, Thailand, Union of Myanmar, Vietnam. Forms parts of borders between Laos-Thailand, Laos-Union of Myanmar.

11. **Mississippi**: Canada, United States.

12. **Niger**: Algeria, Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Guinea, Mali, Niger, Nigeria. Forms part of border between Benin-Niger.

13. **Nile**: Burundi, Central African Republic, Congo, Ethiopia, Egypt, Kenya, Rwanda, Sudan, Tanzania, Uganda, Zaire.

14. **Orinoco**: Colombia, Venezuela. Forms part of Colombia-Venezuela border.

15. **Parana**: Argentina, Brazil, Paraguay. Forms part of Argentina-Paraguay border.

16. **Rhine**: Austria, France, Germany, Liechtenstein, Luxembourg, the Netherlands, Switzerland. Forms parts of borders between Austria-Liechtenstein, France-Germany, France-Switzerland.

17. **Salween**: China, Thailand, Union of Myanmar. Forms parts of borders between Thailand-Union of Myanmar, China-Union of Myanmar.

18. **Shatt-al Arab (Tigris, Euphrates, Karun)**: Iraq, Syria, Turkey.

19. **St. Lawrence**: Canada, United States.

20. **Uruguay**: Argentina, Brazil, Uruguay. Forms part of Argentina-Uruguay border. Flows from Brazil.

21. **Yukon**: Canada, United States.

22. **Zambezi**: Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zaire, Zambia, Zimbabwe. Forms parts of borders between Zambia-Zimbabwe, Namibia-Zambia.

TABLE 2
DOWNSTREAM EFFECTS OF UPSTREAM WATER USE

WATER USE	DOWNSTREAM EFFECT
Hydropower	
base load	Helps regulate river (+ve)
peak load	Creates additional peaks (-ve)
Irrigation Diversions	Removes water from system (-ve)
Flood Storage	Provides downstream flood protection (+ve)
Municipal and Industrial Diversions	Removes water from system (-ve)
Wastewater treatment	Adds pollution to river (-ve)
Navigation	Keeps water in river (+ve)
Recreation Storage	Keeps water out of the system (-ve)
Ecological Maintenance	Keeps low flows in river (+ve)
Groundwater Development	Reduces groundwater availability (-ve)
	Reduces stream flows (-ve)
INDIRECT USE	
Agriculture	Add sediment and agricultural chemicals (-ve)
Forestry	Adds sediment and chemicals, increases runoff (-ve)
Animal husbandry	Adds sediment and nutrients (-ve)
Filling wetlands	Reduces ecological capacity, increase floods (-ve)
Urban development	Induces flooding, adds pollutants (-ve)
Mineral deposits	Add chemicals to surface and groundwater (-ve)

TABLE 3

ARTICLE V OF THE HELSINKI RULES[6]

ARTICLE V: (1) What is a reasonable and equitable share within the meaning of Article IV is to be determined in the light of all the relevant factors in each particular case.

(2) Relevant factors which are to be considered include, but are not limited to:

(a) the geography of the basin, including in particular the extent of the drainage area in the territory of each basin State;
(b) the hydrology of the basin, including in particular the contribution of water by each basin state;
(c) the climate affecting the basin;
(d) the past utilization of the waters of the basin, including in particular existing utilization;
(e) the economic and social needs of each basin State;
(f) the population dependent on the waters of the basin in each basin State;
(g) the comparative costs of alternative means of satisfying the economic and social needs of each basin State;
(h) the availability of other resources;
(i) the avoidance of unnecessary waste in the utilization of waters of the basin;
(j) the practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses;
(k) the degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State.

(3) The weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable share, all relevant factors are to be considered together and a conclusion reached on the basis of the whole.

[6] Approved by the 52nd Conference of the International Law Association, Helsinki, 1966.

TABLE 4
LAND AND WATER USE IN THE NILE BASIN[1]

Country	AREA (km^2)	FLOW (% of basin)	(% from country)	WATER USE (Bcm)
Sudan	1,900,000	62.7	0	18.5
Ethiopia	368,000	12.1	86	0.0
Egypt	300,000	9.9	0	55.5
Uganda	232,000	7.7	}	
Tanzania	116,000	3.8	}	
Kenya	55,000	1.8	}14	0.0
Zaire	23,000	0.8	}	
Rwanda	21,000	0.7	}	
Burundi	14,500	0.5	}	
Total	3,030,000	100%	100%	84.00

1. Based upon Raj Krishna (1988) and Waterbury (1979).

TABLE 5
TREATY ARRANGEMENTS REGARDING THE NILE

Date	Signatories	Major provisions
1891	Italy, United Kingdom	Government of Italy undertakes not to construct on the Atbara any irrigation or other works that might sensibly modify its flow into the Nile.
1902	Ethiopia, United Kingdom	Emperor of Ethiopia promised not to construct or allow to be constructed any works across the Blue Nile, Lake Tana, or the Sobat, which would arrest the flow of their waters into the Nile except in agreement with the British Government and the Government of the Sudan.
1906 (April)	France, Italy, UK	Tripartite Agreement to protect Egypt's interests.
1906 (May)	The Congo, United Kingdom	Provided that the Independent State of the Congo would not construct, or allow to be constructed, any work on or near the Semliki or Isango rivers that would diminish the volume of water entering Lake Albert, except in agreement with the Sudanese Government.
1925	Italy, United Kingdom	Exchange of notes to protect Egypt's water rights. Granted Britain the right to build a barrage at Lake Thana.
1929	Egypt, United Kingdom	Landmark exchange of notes; called the Nile Waters Agreement. "Save with the previous agreement of the Egyptian Government, no irrigation or power works or measures are to be constructed or taken on the River Nile and its branches, or on the lakes from which it flows, so far as these are in the Sudan or in countries under British administration, which would, in such a manner as to entail any prejudice to the interests of Egypt, either reduce the quantity of water arriving in Egypt, or modify the date of its arrival, or lower its level."
1932	Egypt, United Kingdom	Jebel Awlia Compensation Agreement (about a dam in Sudan).
1947	Egypt, United kingdom	Agreement on Owen Falls Dam, Uganda, regulating the flow out of Lake Victoria.
1950	Egypt, United Kingdom	Agreement to cooperate in a meteorological and hydrological survey of Lake Victoria.
1952	Egypt, United Kingdom	A reported agreement on the Fourth Cataract Dam. The text of this agreement is apparently not available but is referred to by some authorities.
1959	Egypt, the Sudan	"Full utilization of the Nile waters." The Sudan agreed to the Aswan High Dam and the Egyptians permitted the Roseries Dam on the Blue Nile. Detailed water sharing was laid out. Financial compensation from Egypt to the Sudan. Mechanism to deal with claims by other riparians were spelled out. Permanent Joint Technical

		Committee set up.
1961	Kenya, Uganda, Tanzania	Requested the UN for technical assistance in a hydrometeorological survey of the Lake Victoria catchment.
1967	Kenya, Uganda, Tanzania,	Plan of Operation signed with the UNDP for a hydromet study of lakes Victoria, Albert, and Kyoga with the World Meteorological Organization as the executing agency. Rwanda and Burundi were added later to cover the drainage catchment in those countries.
1977	Burundi, Rwanda, Tanzania	Agreement for the Establishment of the Organization for Management and Development of the Kagera River. Uganda joined in 1981.
198?	Egypt	Egyptian Master Water Plan a joint effort between Egypt, the UNDP, and the World Bank.
1986	All riparians except Ethiopia	A UNDP Workshop for Nile Countries held in Bangkok endorsed 7 principles starting with "It is essential that the riparian countries cooperate in sharing water resources for the benefit of all on an equitable and mutually beneficial basis for the effective development of the Nile basin."
1990	Proposal stage only	Proposal to establish a Nile Basin Commission comprising all nine riparians. The proposal wishes to consider the Nile as a hydrological unit to establish the "best utilization of the waters of the Nile Basin without prejudice to severing the rights of the respective member states."

TABLE 6

REASONABLE AND EQUITABLE SHARING OF INTERNATIONAL RIVERS

	LAND AREA	CULTIVB AREA	POPLN 1971	POPLN DENSITY	TOTAL RUNOFF	IRRIG POTENTIAL	HYDRO POTENTIAL	HYDRO INSTALL	LAND/ CAPITA
	MHA	MHA	10x6	per Kmx2	BCM	MHA	MW	MW	HA/CA
INDIA	109.25	73.56	244.17	223.50	897.00	20.23	29.20	2.09	0.45
BANGLADESH	15.06	9.51	70.96	471.18	153.50	4.88	0.00	0.00	0.18
NEPAL	14.08	3.98	11.29	80.18	225.50	1.20	85.00	0.41	1.25
TOTAL	138.39	87.05	326.42	235.87	1276.00	26.31	114.20	2.50	0.42

PERCENTAGE DISTRIBUTION

INDIA	78.94	84.50	74.80		70.30	76.88	25.57	83.60
BANGLADESH	10.88	10.92	21.74		12.03	18.55	0.00	0.00
NEPAL	10.17	4.57	3.46		17.67	4.57	74.43	16.40

TABLE 7

PARETO-ADMISSIBILITY FOR GANGES-BRAHMAPUTRA MODELS

NET BENEFITS FOR EACH COUNTRY (Rs./Yr)

	TOTAL BENEFIT	INDIA	NEPAL	BANGLADESH	WEIGHT ON OBJECTIVE (India Nepal Bangladesh)	
1)	8.6E+09	4.9E+09	1.8E+08	3.5E+09	(1 1 1)	
2)	7.3E+09	5.4E+09	1.8E+08	1.8E+09	(1 .1 .1)	
3)	6.6E.09	5.4E+09	0	1.2E+09	(1 0 0)	
4)	7.9E+09	2.5E+09	0	5.4E+09	(.1 .1 1)	
5)	7.9E+09	2.5E+09	0	5.4E+09	(0 0 1)	
6)	7.3E+09	5.4E+09	1.8E+08	1.8E+09	(1 .5 .1)	
7)	8.6E+09	5.0E+09	1.8E+08	3.5E+09	(1 .1 .5)	
8)	8.2E+09	5.1E+09	1.8E+08	2.8E+09	(.5 1 .1)	
9)	7.9E+09	2.5E+09	0	5.4E+09	(.1 1 .5)	
10)	7.9E+09	2.5E+09	0	5.4E+09	(.5 .1 1)	
11)	7.9E+09	2.5E+09	0	5.4E+09	(.1 .5 1)	
12)	8.3E+09	3.2E+09	1.4E+08	4.9E+09	(.1 3 .5)	
13)	8.6E+09	4.4E+09	1.6E+08	4.1E+09	(.1 .1 1)	Ind ≥ 4.4E9
14)	8.5E+09	4.0E+09	1.1E+08	4.4E+09	(.1 .1 1)	Ind ≥ 4.0E9
15)	8.4E+09	3.6E+09	0.83E+08	4.7E+09	(.1 .1 1)	Ind ≥ 3.6E9
16)	8.2E+09	3.2E+09	0.15E+08	5.0E+09	(.1 .1 1)	Ind ≥ 3.2E9
17)	8.0E+09	2.8E+09	0	5.2E+09	(.1 .1 1)	Ind ≥ 2.8E9

FIGURE 1
MAJOR INTERNATIONAL RIVER BASINS

FIGURE 2
COLUMBIA RIVER BASIN

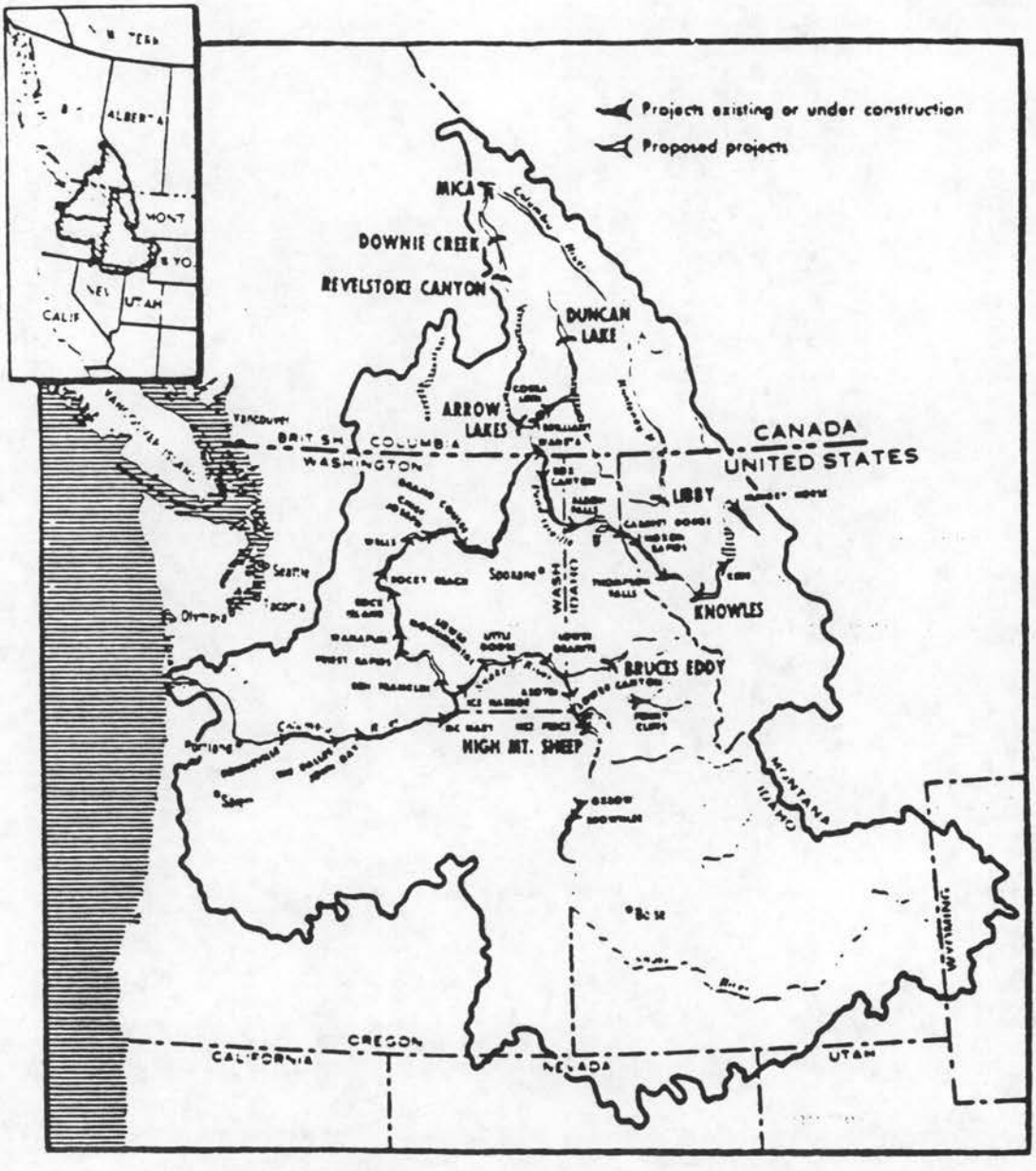


TABLE 8
CHARACTERISTIC FUNCTION OF GANGES-BRAHMAPUTRA GAME
(All values are in million 1968 Rupees per year)

v(1) =	Maximum net benefits available to India assuming that there is no development in the other parts of the basin. Solve the basin model with separate budget for India and the virgin inflows from Nepal. (Rs. 4,184 per year)
v(2) =	Maximum net benefits available to Bangladesh assuming that Nepal and India are trying to maximize their joint net benefits. Use separate budget for Bangladesh and the border flows derived from the Nepal-India coalition solution. (Rs. 2,754 per year)
v(3) =	Maximum net benefits available to Nepal. Since Nepal is everywhere upstream of India and Bangladesh solve the problem with a separate budget for Nepal and no constraints on the border flows. (Rs. 23 per year)
v(1,2) =	Maximum net benefits for a coalition of India and Bangladesh. Joint budget for these countries and the inflows from Nepal set at the level of no development in Nepal. (Rs. 8,265 per year)
v(1,3) =	Maximum net benefits for a coalition of India and Nepal. Joint budget for the two countries. No constraints on the downstream flows in Bangladesh. (Rs. 4,409 per year)
v(2,3) =	Maximum net benefits for a coalition of Nepal and Bangladesh. Joint budget for the two countries. Assume no developments in India. (Rs. 3,729)
v(1,2,3) =	Maximum net benefits to the "Grand Coalition" of the three countries. This is the "optimimum use of the basin." (Rs. 8,643)

FIGURE 3
GANGES-BRAHMAPUTRA BASIN

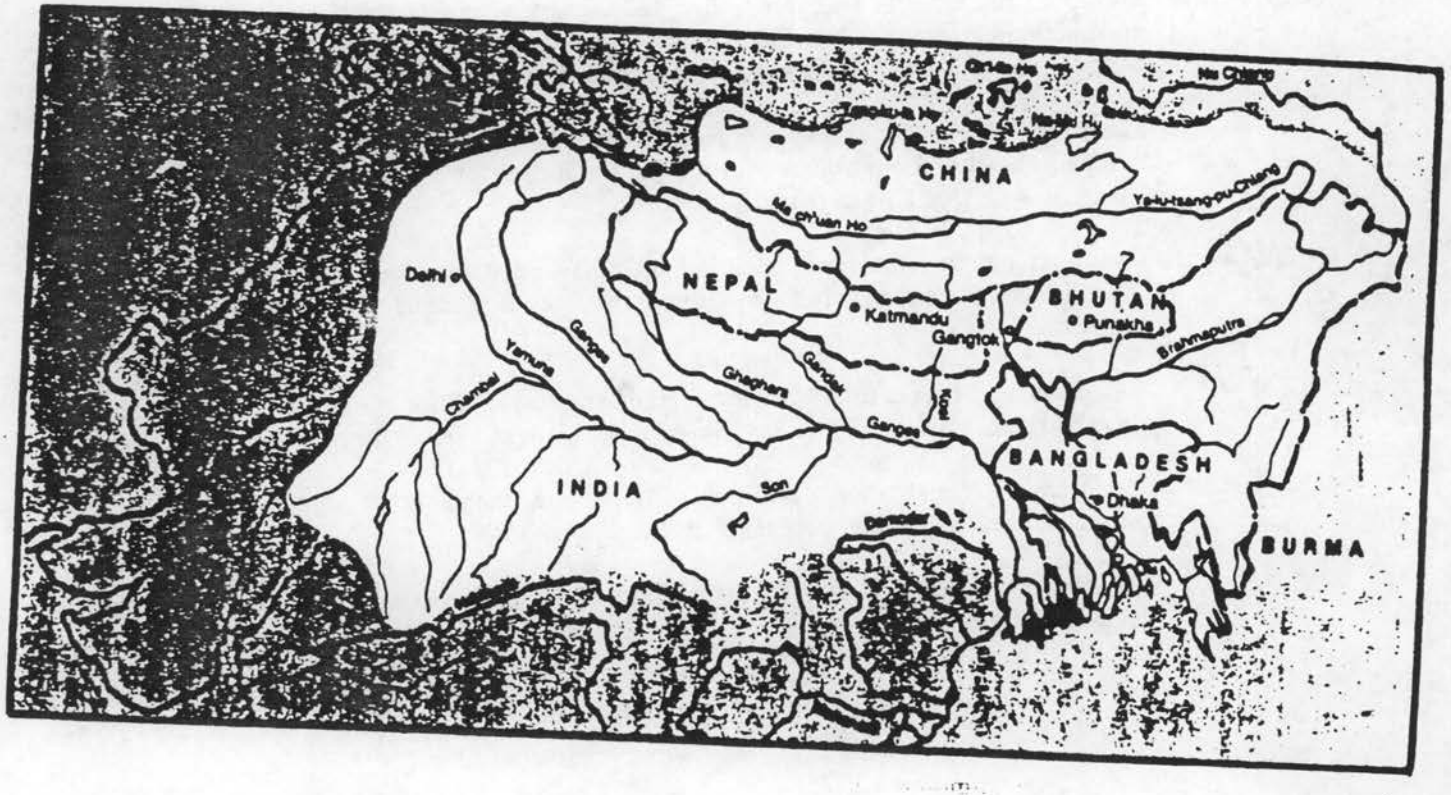


FIGURE 4
THE NILE BASIN

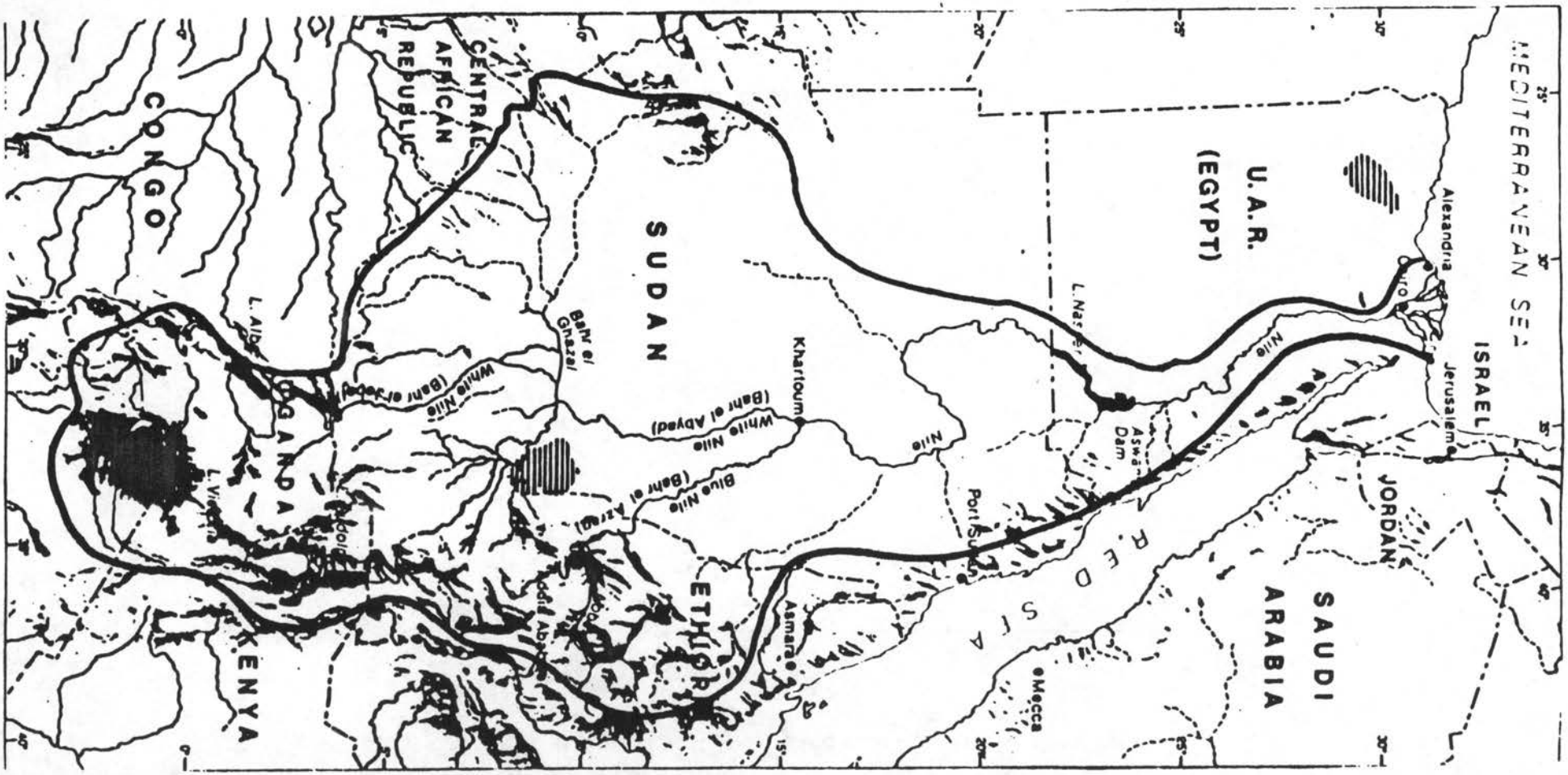


FIGURE 5
PARETO FRONTIER: INDIA AND BANGLADESH

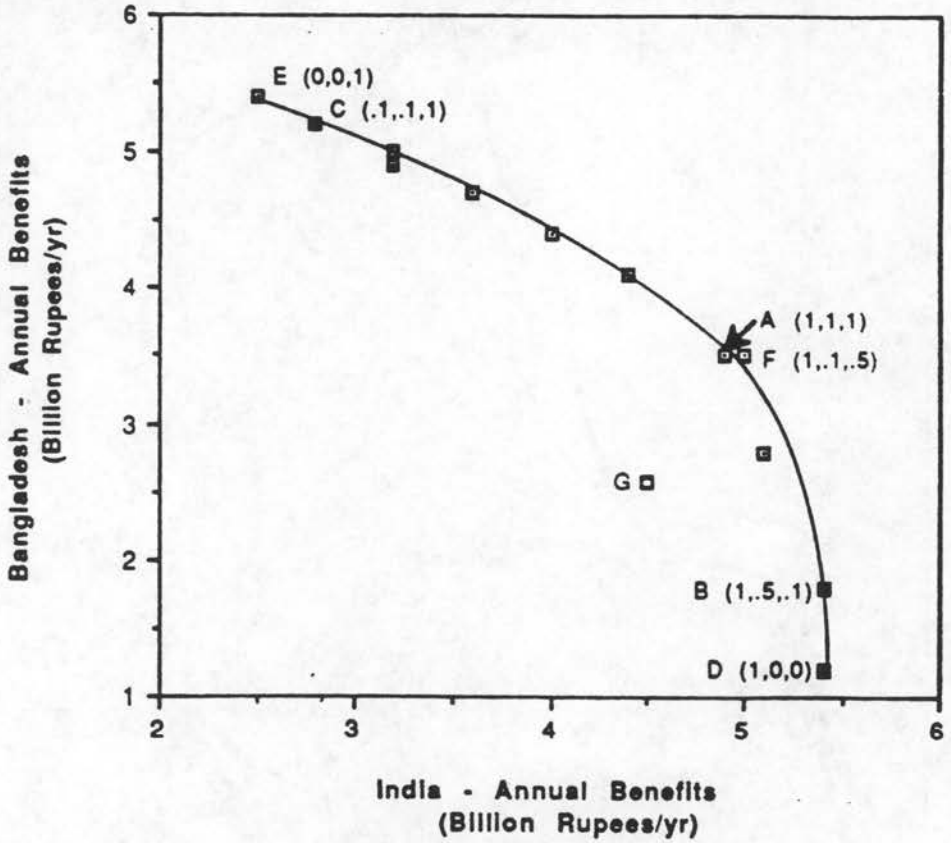
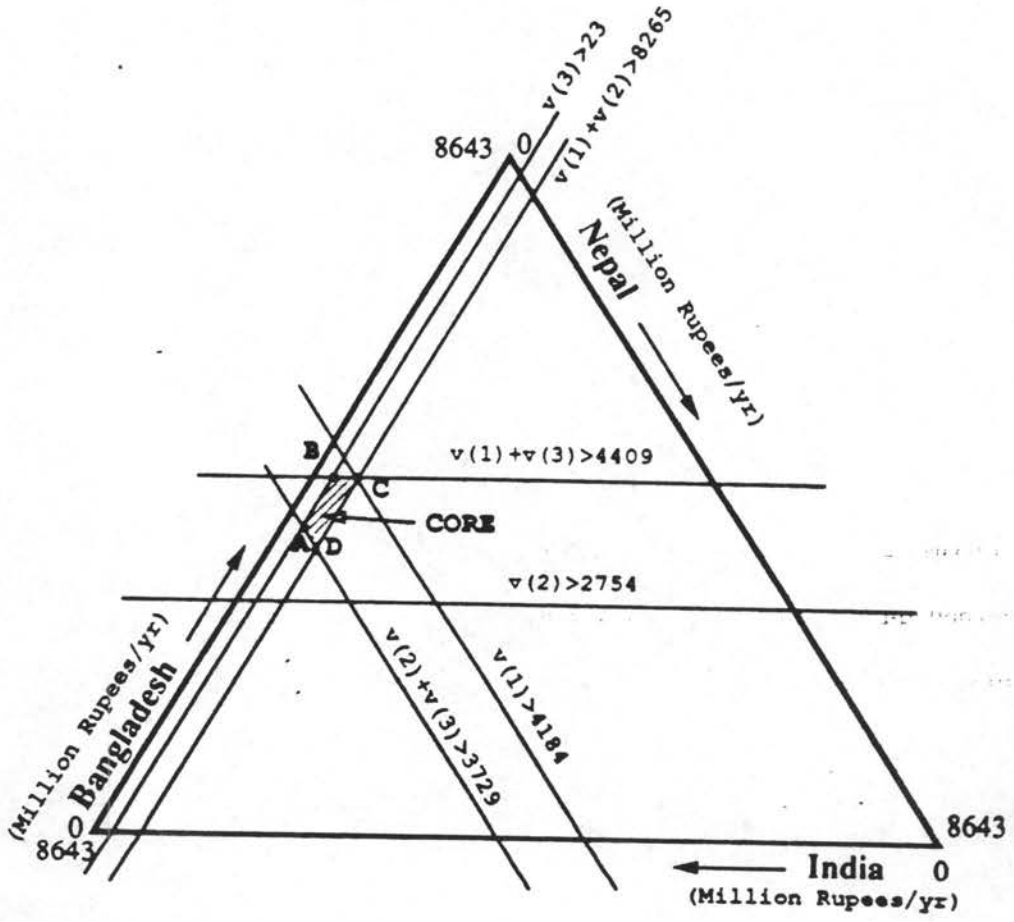


FIGURE 6
CORE FOR INDIA, BANGLADESH, AND NEPAL GAME



APPENDIX A
ARTICLES CONCERNING NON-NAVIGATION USES OF INTERNATIONAL WATERCOURSES PROVISIONALLY ADOPTED BY THE INTERNATIONAL LAW COMMISSION

The texts of the draft articles provisionally adopted so far by the Commission are reproduced below:

PART I

INTRODUCTION

Article 1 [27]

[Use of terms] [28]

Article 2

Scope of the present articles

1. The present articles apply to uses of international watercourse[s] [systems] and of their waters for purposes other than navigation and to measures of conservation related to the uses of those watercourse[s] [systems] and their waters.

2. The use of international watercourse[s] [systems] for navigation is not within the scope of the present articles except in so far as other uses affect navigation or are affected by navigation.

Article 3

Watercourse States

For the purposes of the present articles, a watercourse State is a State in whose territory part of an international watercourse [system] is situated.

Article 4

[Watercourse] [System] agreements

1. Watercourse States may enter into one or more agreements which apply and adjust the provisions of the present articles to the characteristics and uses of a particular international watercourse [system] or part thereof. Such agreements shall, for the purposes of the present articles, be called [watercourse] [system] agreements.

2. Where a [watercourse] [system] agreement is concluded between two or more watercourse States, it shall define the waters to which it applies. Such an agreement may be entered into with respect to an entire international watercourse [system] or with respect to any part thereof or a particular project, programme or use, provided that the agreement does not adversely affect, to an appreciable extent, the use by one or more other watercourse States of the waters of the international watercourse [system].

3. Where a watercourse State considers that adjustment or application of the provisions of the present articles is required because of the characteristics and uses of a particular international watercourse [system], watercourse States shall consult with a view to negotiating in good faith for the purpose of concluding a [watercourse] [system] agreement or agreements.

Article 5

Parties to [watercourse] [system] agreements

1. Every watercourse State is entitled to participate in the negotiation of and to become a party to any [watercourse] [system] agreement that applies to the entire international watercourse [system], as well as to participate in any relevant consultations.

2. A watercourse State whose use of an international watercourse [system] may be affected to an appreciable extent by the implementation of a proposed [watercourse] [system] agreement that applies only to a part of the watercourse [system] or to a particular project, programme or use is entitled to participate in consultations on, and in the negotiation of, such an agreement, to the extent that its use is thereby affected, and to become a party thereto.

PART II

GENERAL PRINCIPLES

Article 6

Equitable and reasonable utilization and participation

1. Watercourse States shall in their respective territories utilise an international watercourse [system] in an equitable and reasonable manner. In particular, an international watercourse [system] shall be used and developed by watercourse States with a view to attaining optimum utilization thereof and benefits therefrom consistent with adequate protection of the international watercourse [system].

2. Watercourse States shall participate in the use, development and protection of an international watercourse [system] in an equitable and reasonable manner. Such participation includes both the right to utilise the international watercourse [system] as provided in paragraph 1 of this article and the duty to co-operate in the protection and development thereof, as provided in article ...

Article 7

Factors relevant to equitable and reasonable utilization

1. Utilization of an international watercourse [system] in an equitable and reasonable manner within the meaning of article 6 requires taking into account all relevant factors and circumstances, including:

(a) geographic, hydrographic, hydrological, climatic and other factors of a natural character;

(b) the social and economic needs of the watercourse States concerned;

(c) the effects of the use or uses of an international watercourse [system] in one watercourse State on other watercourse States;

(d) existing and potential uses of the international watercourse [system];

(e) conservation, protection, development and economy of use of the water resources of the international watercourse [system] and the costs of measures taken to that effect;

(f) the availability of alternatives, of corresponding value, to a particular planned or existing use.

2. In the application of article 6 or paragraph 1 of the present article, watercourse States concerned shall, when the need arises, enter into consultations in a spirit of co-operation.

Article 8 [29]

Obligation not to cause appreciable harm

Watercourse States shall utilise an international watercourse [system] in such a way as not to cause appreciable harm to other watercourse States.

Article 9 [30]

General obligation to co-operate

Watercourse States shall co-operate on the basis of sovereign equality, territorial integrity and mutual benefit in order to attain optimum utilization and adequate protection of an international watercourse [system].

Article 10 [31]

Regular exchange of data and information

1. Pursuant to article 9, watercourse States shall on a regular basis exchange reasonably available data and information on the condition of the watercourse [system], in particular that of a hydrological, meteorological, hydrogeological and ecological nature, as well as related forecasts.

2. If a watercourse State is requested by another watercourse State to provide data or information that is not reasonably available, it shall employ its best efforts to comply with the request but may condition its compliance upon payment by the requesting State of the reasonable costs of collecting and, where appropriate, processing such data or information.

3. Watercourse States shall employ their best efforts to collect and, where appropriate, to process data and information in a manner which facilitates its utilization by the other watercourse States to which it is communicated.

PART III

PLANNED MEASURES

Article 11

Information concerning planned measures

Watercourse States shall exchange information and consult each other on the possible effects of planned measures on the condition of the watercourse [system].

Article 12 [32]

Notification concerning planned measures with possible adverse effects

Before a watercourse State implements or permits the implementation of planned measures which may have an appreciable adverse effect upon other watercourse States, it shall provide those States with timely notification thereof. Such notification shall be accompanied by available technical data and information in order to enable the notified States to evaluate the possible effects of the planned measures.

Article 13 133/

Period for reply to notification

Unless otherwise agreed, a watercourse State providing a notification under article 12 shall allow the notified States a period of six months within which to study and evaluate the possible effects of the planned measures and to communicate their findings to it.

Article 14 134/

Obligations of the notifying State during the period for reply

During the period referred to in article 13, the notifying State shall co-operate with the notified States by providing them, on request, with any additional data and information that is available and necessary for an accurate evaluation, and shall not implement, or permit the implementation of, the planned measures without the consent of the notified States.

Article 15 135/

Reply to notification

1. The notified States shall communicate their findings to the notifying State as early as possible.

2. If a notified State finds that implementation of the planned measures would be inconsistent with the provisions of articles 6 or 8, it shall provide the notifying State within the period referred to in article 13 with a documented explanation setting forth the reasons for such finding.

Article 16 136/

Absence of reply to notification

If, within the period referred to in article 13, the notifying State receives no communication under paragraph 2 of article 15, it may, subject to its obligations under articles 6 and 8, proceed with the implementation of the planned measures, in accordance with the notification and any other data and information provided to the notified States.

Article 17 137/

Consultations and negotiations concerning planned measures

1. If a communication is made under paragraph 2 of article 15, the notifying State and the State making the communication shall enter into consultations and negotiations with a view to arriving at an equitable resolution of the situation.

2. The consultations and negotiations provided for in paragraph 1 shall be conducted on the basis that each State must in good faith pay reasonable regard to the rights and legitimate interests of the other State.

3. During the course of the consultations and negotiations, the notifying State shall, if so requested by the notified State at the time of making the communication under paragraph 2 of article 15, refrain from implementing or permitting the implementation of the planned measures for a period not exceeding six months.

Article 18 138/

Procedures in the absence of notification

1. If a watercourse State has serious reason to believe that another watercourse State is planning measures that may have an appreciable adverse effect upon it, the former State may request the latter to apply the provisions of article 12. The request shall be accompanied by a documented explanation setting forth the reasons for such belief.

2. In the event that the State planning the measures nevertheless finds that it is not under an obligation to provide a notification under article 12, it shall so inform the other State, providing a documented explanation setting forth the reasons for such finding. If this finding does not satisfy the other State, the States concerned shall, at the request of that other State, promptly enter into consultations and negotiations in the manner indicated in paragraphs 1 and 2 of article 17.

3. During the course of the consultations and negotiations, the State planning the measures shall, if so requested by the other State at the time it requests the initiation of consulations and negotiations, refrain from implementing or permitting the implementation of those measures for a period not exceeding six months.

Article 19 139/

Urgent implementation of planned measures

1. In the event that the implementation of planned measures is of the utmost urgency in order to protect public health, public safety or other equally important interests, the State planning the measures may, subject to articles 6 and 8, immediately proceed to implementation, notwithstanding the provisions of article 14 and paragraph 3 of article 17.

2. In such cases, a formal declaration of the urgency of the measures shall be communicated to the other watercourse States referred to in article 12 together with the relevant data and information.

3. The State planning the measures shall, at the request of the other States, promptly enter into consultations and negotiations with them in the manner indicated in paragraphs 1 and 2 of article 17.

Article 20 140/

Data and information vital to national defence or security

Nothing contained in articles 10 to 19 shall oblige a watercourse State to provide data or information vital to its national defence or security. Nevertheless, that State shall co-operate in good faith with the other watercourse States with a view to providing as much information as possible under the circumstances.

Article 21

Indirect procedures

In cases where there are serious obstacles to direct contacts between watercourse States, the States concerned shall proceed to any exchange of data and information, notification, communication, consultations and negotiations provided for in articles 10 to 20 through any indirect procedure accepted by them.

PART IV

PROTECTION AND PRESERVATION

Article 22

Protection and preservation of ecosystems

Watercourse States shall, individually or jointly, protect and preserve the ecosystems of international watercourse[s] [systems].

Article 23

Prevention, reduction and control of pollution

1. For the purposes of the present draft articles, "pollution of an international watercourse [system]" means any detrimental alteration in the composition or quality of the waters of an international watercourse [system] which results directly or indirectly from human conduct. */

2. Watercourse States shall, individually or jointly, prevent, reduce and control pollution of an international watercourse [system] that may cause appreciable harm to other watercourse States or to their environment, including harm to human health or safety, to the use of the waters for any beneficial purpose or to the living resources of the international watercourse [system]. Watercourse States shall take steps to harmonize their policies in this connection.

3. Watercourse States shall, at the request of any of them, consult with a view to establishing lists of substances, the introduction of which into the waters of an international watercourse [system] is to be prohibited, limited, investigated or monitored.

Article 24

Introduction of alien or new species

Watercourse States shall take all measures necessary to prevent the introduction of species, alien or new, into an international watercourse [system] which may have effects detrimental to the ecosystem of the international watercourse [system] resulting in appreciable harm to other watercourse States.

Article 25

Protection and preservation of the marine environment

Watercourse States shall, individually or jointly, take all measures with respect to an international watercourse [system] that are necessary to protect and preserve the marine environment, including estuaries, taking into account generally accepted international rules and standards.

PART V

HARMFUL CONDITIONS AND EMERGENCY SITUATIONS

Article 26

Prevention and mitigation of harmful conditions

Watercourse States shall, individually or jointly, take all appropriate measures to prevent or mitigate conditions that may be harmful to other watercourse States, whether resulting from natural causes or human conduct, such as flood or ice conditions, water-borne diseases, siltation, erosion, salt-water intrusion, drought or desertification.

Article 27

Emergency situations

1. For the purposes of the present draft article, "emergency" means a situation that causes, or poses an imminent threat of causing, serious harm to watercourse States or other States and that results suddenly from natural causes, such as floods, the breaking up of ice, landslides or earthquakes, or from human conduct as for example in the case of industrial accidents. */

2. A watercourse State shall, without delay and by the most expeditious means available, notify other potentially affected States and competent international organizations of any emergency originating within its territory.

3. A watercourse State within whose territory an emergency originates shall, in co-operation with potentially affected States and, where appropriate, competent international organizations, immediately take all practicable measures necessitated by the circumstances to prevent, mitigate and eliminate harmful effects of the emergency.

4. When necessary, watercourse States shall jointly develop contingency plans for responding to emergencies in co-operation, where appropriate, with other potentially affected States and competent international organizations.

127/ The Commission accepted a provisional working hypothesis as to what was meant by the term "international watercourse system".

The hypothesis was contained in a note which read as follows:

"A watercourse system is formed of hydrographic components such as rivers, lakes, canals, glaciers and ground water constituting by virtue of their physical relationship a unitary whole; thus, any use affecting waters in one part of the system may affect waters in another part.

An 'international watercourse system' is a watercourse system, components of which are situated in two or more States.

To the extent that parts of the waters in one State are not affected by or do not affect uses of waters in another State, they shall not be treated as being included in the international watercourse system. Thus, to the extent that the uses of the waters of the system have an effect on one another, to that extent the system is international, but only to that extent; accordingly, there is not an absolute, but a relative, international character of the watercourse."

128/ The Commission agreed at its thirty-ninth session to leave aside for the time being the question of article 1 (Use of terms) and that of the use of the term "system" and to continue its work on the basis of the provisional working hypothesis accepted by the Commission at its thirty-second (1980) session, see ibid. Thus, the word "system" appears in square brackets throughout the text.

129/ This article is based on article 9 as proposed by the previous Special Rapporteur in 1984.

130/ This article is based on article 10 as proposed by the previous Special Rapporteur in 1987.

131/ This article is based on article 15 [16] as proposed by the Special Rapporteur in 1988.

132/ This article is based on article 11 as proposed by the Special Rapporteur in 1987.

133/ This article is based on article 12 as proposed by the Special Rapporteur in 1987.

134/ Ibid.

135/ This article is based on article 13 as proposed by the Special Rapporteur in 1987.

136/ This article is based on article 14 as proposed by the Special Rapporteur in 1987.

137/ This article is based on article 13 as proposed by the Special Rapporteur in 1987.

138/ This article is based on article 14 as proposed by the Special Rapporteur in 1987.

139/ This article is based on article 15 as proposed by the Special Rapporteur in 1987.

140/ This article is based on article 15 [16] as proposed by the Sp Rapporteur in 1988.

*/ This paragraph which deals with the definition of pollution may moved up to article 1 on [Use of terms].

*/ This paragraph which deals with the definition of emergency may moved up to article 1 on [Use of terms].

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